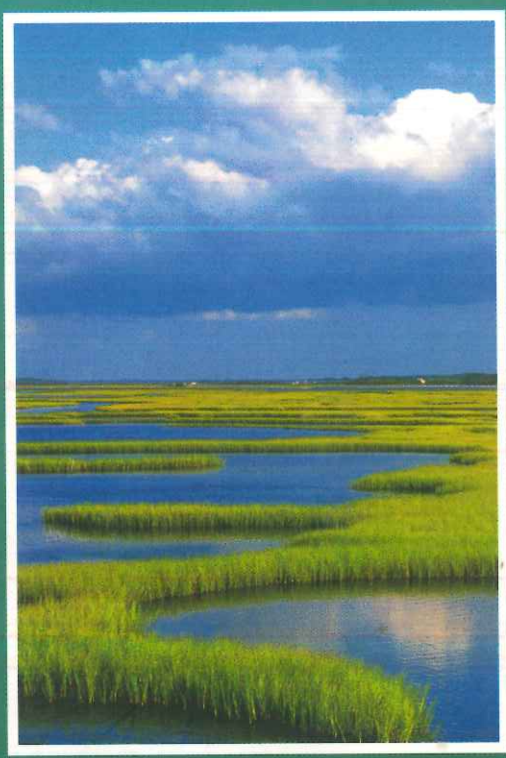
Reconciling Environment and Economics : Executive Summaries of EERC Projects



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Reconciling Environment and Economics : Executive Summaries of EERC Projects

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PREFACE

Jyoti K. Parikh

The Environmental Economics Research Committee (EERC) was constituted to build nation-wide capacity in environmental economics research under the Ministry of Environment and Forests implemented, World Bank aided "India: Environmental Management Capacity Building (EMCaB) Technical Assistance" Project.

When we began, we needed innovative approaches. As there were no readymade environmental economists we had to invest in capacity building. EERC provided a new opportunity to those who wished to branch out into this area. Those who were already working in the area of environment such as pollution, solid waste, land-use and natural resources such as forests and biodiversity, benefited by incorporating economics to make their research more relevant for policy guidance. On the other hand, some economists diversified their interests to address the environmental externalities of economic development. After scrutinizing nearly 320 projects that were submitted, 61 projects were funded. A vast number of areas are covered which can be seen in the table of contents.

"Reconciling Environment and Economics: Executive summaries of EERC projects" presents executive summaries of 51 selected projects. The summaries cover the objectives, methods used, analysis, results and policy recommendations. Considerable efforts were put in for capacity building by giving continuous feedbacks. During project execution, inputs from EERC members, national experts and international reviewers helped to refine the outputs and monitor the progress to ensure quality. More than 20 project review workshops improved the understanding, led to capacity building and synergy.

The projects contain case studies rooted in India with data and coefficients based on Indian situations. Some of them would be useful in teaching environmental economics and some in solving problems or managing conflicts, as they relate to local conditions and real life. The methods, approaches, databases and results may be of interest to not only academics in India but also elsewhere. Many of these projects are helpful for decision-making and of interest to relevant ministries, administrators, non-government organizations, local communities and stakeholders.

On behalf of the EERC and the project investigators, I acknowledge the help of a large number of national and international experts who reviewed the projects whose names appear in the annexure. In addition, I thank Paul Appasamy, Dilip Biswas, Sudarshan Iyengar and S C Pathak for reviewing some of the summaries. It was a formidable task to obtain these summaries from 51 projects spread across the country and across many disciplines and to edit a number of draft versions to ensure some uniform level. Despite the best efforts, some errors may have remained. The full text is also available from our website and a CD.

I thank Seema Roy and Y N Rao for their support to bring this publication out. I thank Ministry of Environment and Forests, Madras School of Economics and the World Bank for their cooperation.

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National and International Policy Issues

WETLANDS

AND

BIODIVERSITY

Valuation of Bhitarkanika Mangrove Ecosystem

Ruchi Badola and S.A. Hussain *Wildlife Institute of India, Dehra Dun*

Introduction

The Bhitarkanika mangrove conservation area (BCA) comprises of Bhitarkanika National Park and Wildlife Sanctuary and parts of Gahirmatha Marine Sanctuary. It covers an area of 1006.5 km^2 of which around 4.8% area has mangrove cover. This deltaic, estuarine-mangrove wetland system harbours the highest diversity of Indian mangrove flora, the largest known rookery of the olive ridley sea-turtles in the world, among the last three remaining wild populations of salt-water crocodiles in India, the largest known population of king cobra, one of the largest heronry along the east coast of India and one of the highest concentrations of migratory waterfowls - both ducks and waders. The loss of mangrove in Bhitarkanika is mainly due to human encroachment, reclamation of land for agriculture and unsustainable resource use practices such as aquaculture activities. Around 336 villages with a total population of 1.5 lakh in the adjoining areas depend for fuel, fodder and other non-timber forest produce on the Bhitarkanika mangrove ecosystem. Recent developmental activities such as the construction of jetties and roads and the proposed development of a major port at Dhamra threaten the existence of this ecosystem. The declaration of the mangrove forests of Bhitarkanika as a Protected Area has affected the local people as they have lost access to their life support systems. The unsustainable resource use by the locals is a major threat to continued existence of the mangroves as well, resulting in conflict between the forest department and the local population.

This study attempts to fill the information gap by exploring the varied functions and uses of the mangroves. It endeavours to assist planners and PA managers to make informed decisions on the management of the Bhitarkanika mangrove ecosystem.

Objectives

The major objectives of this study are to:

- Enumerate ecological functions and key productive uses of the BCA.
- Estimate the usage values and ecological services provided by BCA.
- Quantify the extent of the local community's dependency on Bhitarkanika and identify marginalized stakeholders.
- Examine the local community's attitude towards present and proposed management alternatives.
- Derive a predictive model to assess the impact of sea level rise on the Bhitarkanika mangrove ecosystem.
- Recommendation for management of the area.

Vegetation Structure

The Bhitarkanika mangrove ecosystem was characterized in terms of vegetation structure to relate it with the major ecological functions performed by this ecosystem. The vegetation map at the landscape level was prepared to identify distinct habitat types by using Indian Remote Sensing Satellite (IRS-1D), LISS – III data of November 2000. The vegetation of BCA was divided into 9 major vegetation communities - Salt Marsh/Wet marshland, Palm/Tamarix Swamp, Brackish Water Mixed Forests, Salt Water Mixed Forests, Mangrove Forest, Mangrove Scrub, Village Woodlot/Agriculture and Agriculture/Habitation/Prawn culture/Barren areas and mangrove and non mangrove mixed. For the micro level assessment the Bhitarkanika National Park was stratified into distinct blocks. Stratified random sampling was employed to collect the field data on mangrove plant species composition and tree species diversity.

A total of 64 species of plants were recorded from Bhitarkanika Mangrove Protected Area, which included 28 true mangroves, 4 mangrove associates and 32 others. The mean canopy cover of Bhitarkanika mangroves was found to be 33.25% of the total area while the mean ground grass cover in the meadows of Bhitarkanika was established at 47%. Grasses were the main contributors to the ground cover. Tree density was 1376.93 per hectare. Sapling density was 83.33 per hectare while seedling density was found to be 45.79 per hectare. The total tree basal area (m^2 per hectare) was 220.26. Tree, seedling and sapling diversity varied within the mangrove area. The Bhitarknika mangroves differ considerably from other Indian mangroves because of their dominant trees: *Sonneratia apetala* and several *Avicennia* species. In addition *Myriostachya wightiana* a species of grass is very common here.

Ecological Services

The information on ecological functions and the key productive uses of mangrove ecosystems were collected from existing literature, as well as from discussions with the park management and staff, field biologists, scientists, commercial fishermen and local people. These were also partly identified during the door-to-door socioeconomic/attitude survey. Four parameters - nutrient retention, land accretion, storm abatement, and fish and shellfish production - were selected for valuation.

Nutrient Retention

By applying the market price method, the monetary value of major nutrients present in mangrove and non-mangrove soil was compared. The NPK (Nitrate, Phosphate and Potassium) in one ha of mangrove and non-mangrove soil was estimated. The total value of nutrients is given in Table 1.

Fish and Shellfish Production

To estimate the contribution made by Bhitarkanika mangrove ecosystems to fish production, data from another ongoing project of the Wildlife Institute of India, Dehra Dun, titled "Experimental Trawling Along the Orissa Coast to Estimate the Mortality of Sea Turtles," was extensively used. The market price method was used to value the offshore fishery. We found a significant difference in the total catch/hr between mangrove and non-mangrove area. The Gahirmatha coast (with mangrove) has considerably high fish yield (123 kg/hr) as compared to the Paradip coast (without mangrove) where the yield is 17 kg/hr. Hence, earnings per hour are also considerably higher in Gahirmatha, amounting to Rs.1784 per hour, while in Paradip only Rs. 104 is earned per hour. Data from secondary sources indicates higher species richness from Dhamra – a fish landing site closer to the mangroves.

Data on inshore fish productivity was collected between March and June 2002 from six creeks originating from the main Bhitarkanika River, which has rich mangrove vegetation cover. The estimated value of the catch per hour for inshore fishery was Rs. 90 for 3.77 kg of fish.

To verify the role of mangroves as nursery ground for fish and shellfish, a circular drag net was used. Prawn and fish seedling catch per hour was calculated. Fifteen species were caught, of which three were commercially

Table 1. Estimated value for total nutrients available in the mangrove area

Nutrients	Amount of nutrient in mangrove (kg/ha) (1)	Amount of nutrient in non-mangrove (kg/ha) (2)	Amount of extra nutrient in mangrove (kg/ha) (3)=(1)-(2)	Total Area under Mangrove Forest (4)	Amount of extra nutrient in total Mangrove area (kg/ha) (5)=(3x4)	Market Value (Rs./kg) (6)	Estimated value for total extra nutrients in total mangrove area (Rs.) (7)
Available N	2907	2057.67	849.33		12315285	10	123152850
Available P_2O_5	28.11	20.08	8.03	14500 ha	116435	15.43	1796592
Available K_2O	1564.55	1222.46	342.09		4960305	7.09	35168562
Total value of N+P+K							160 million

exploited. The catch (kg/hr) was 65 for White prawn, 6 for Tiger prawn and 15 for Mud crab, while earnings (Rs./hr) from these species were Rs. 7 to 33, Rs. 2 to 3.5 and Rs. 3 to 6 respectively.

Storm Protection

Damage cost avoided approach was used to evaluate the storm protection function of the Bhitarkanika mangrove ecosystem. Actual figures on damage avoided due to presence of mangroves were estimated using information from the super cyclone of 1999. Three villages, namely Bankual, Bandhamal and Singidi were identified to represent three situations viz: Mangrove areas with dykes, Non-mangrove areas with dykes, Non-mangrove areas without dykes. All the three selected villages were equidistant from the seashore. The two villages outside mangrove covers were located close to each other, but both were far from the forest in order to eliminate the effect of mangroves. A door to door survey was conducted and a 100 percent sampling of the households was done to assess the socio-economic status of the villages, the actual damage to houses, livestock, fisheries, trees and other assets owned by the people and the rate, level and duration of flooding. Information was gathered by focused public interviews about the direction of the entry of water and probable reasons for flooding.

The mean household size in the three villages was 4.5 to 8.2. The overall human density in the study villages ranged between 260-340 persons/ km^2. The literacy level was highest for Singidi and lowest for Bankual. In Singidi and Bankual majority of the people (70%) were engaged in agriculture, where as in Bandhamal around 61% were labourers. Most of the houses (94%) were made of mud and thatch. The damage to houses was measured on a '0' to '19' scale, where 19 is maximum damage. The maximum damage to the houses was 10.44 $\pm$ 0.848 for Bandhamal. The least damage took place in Bankual, amounting to 5.34 $\pm$ 0.578. Majority of the houses in Bandhamal, the villages protected by dyke but without mangrove cover, were flooded while the least flooding took place in Bankual, the village protected by mangrove cover. The highest level of flooding in the fields occurred in Singidi, a village situated outside the mangrove area and not protected by dyke, followed by Bandhamal and then by Bankual. The agricultural production was highest in Bankual in 1999 with a value of 6 $\pm$ 0.376 qtl./acre and the lowest was in Bandhamal with 1.4 $\pm$ 0.956 qtl./acre. The highest damage to fish seedlings was in Singidi where Rs. 311 $\pm$ 144.975 worth of the seedlings released were washed away and it was the least in Bankual (Rs. 70 $\pm$ 32.198). The maximum number of livestock casualties occurred in Bandhamal, followed by Bankual and Singidi. The loss incurred per household was found to be greatest in Bandhamal Rs. 6918.63 $\pm$ 1136.201 per household followed by Singidi and Bankual.

Significant difference were found among the variables used to assess the contribution of mangroves in avoiding damage from cyclones and floods for mangrove and non-mangrove areas. No reports of breaches in the dyke located around the forest area indicate the protection provided by mangroves to the dykes, although this is not conclusive as further data authentication is required. However, in areas far from the forest several breaches in the dyke were reported. This resulted in higher level and longer duration of flooding at Bandhamal. The object of this study therefore, is to highlight the importance of mangroves as an effective barrier to storms, surpassing man-made structure such as the dyke in this case.

Land Accretion

Mangroves trap sediments and accelerate land formation on the coast, initially as islands or mudflats. Subsequently due to succession, these newly created landforms develop into tidal swamps with mangrove species. The Bhitarkanika mangrove ecosystems have significantly contributed to the formation of mudflats and islands along the coast and in the associated riverine ecosystems. Newly created landmasses were identified from Survey of India toposheets and remotely sensed using IRS-1D, LISS – III data of November 2000. A total of 4.68 km^2 of land formation has occurred within the Bhitarkanika mangrove area in a time span of

111 years from 1889 to 2000. The market value method was used to estimate the contribution of the Bhitarkanika mangrove ecosystem in land accretion. The value of 468 ha of land at the current market price is Rs. 46 million. The cost of reclaiming land should have been used to estimate the value of this function. Since cost of reclamation was not available for the study area, a conservative estimate of the value of this function has been given by stating it as the current price of land in the area.

Among the four parameters valued, the nutrient retention function was Rs. 16450 /acre/ year, quite high as compared to the valuation results of other studies. The fish and shell fish production valuation was done at three levels and the estimated value for offshore fishery, inshore fishery and fish seedling was determined by using the market value method, which amounted to Rs. 1785/hr, Rs. 90/hr and Rs. 1/hr respectively. The storm abatement function was valued using the damage cost avoided method. In the village with mangrove cover, the damage cost avoided was estimated to be Rs. 5465/ household. The value of land accretion function was estimated to be Rs. 46 million over a period of 111 years.

Socio-economics of local people and their dependence on BCA

The data on socio-economic and dependency aspects was collected in three stages. The first stage involved a rapid assessment of the 403 villages located in the impact zone of Bhitarkanika Wildlife Sanctuary. Information on 35 parameters concerning socio-economic status, location and distribution of villages with respect to the forest and the villagers' dependency on forests for fuel wood, timber, fodder etc., was collected. In the second stage, hierarchical cluster analysis was carried out to identify relatively homogeneous groups of villages. A sample size of 35 villages was identified and the villages were then randomly selected from the clusters in proportion to the size of each cluster. In the selected villages from 10% of the housing units, data regarding the socio-economic set up, dependency on mangrove ecosystems and attitude of the people towards conservation were gathered. In the sampled villages the family size obtained was found to be a little over 8 individuals per household. Overall literacy rate was 69.19% (male 79.82 % and female 59.12%). Majority of the people were involved in the primary sector i.e. agriculture. The percentage of skilled labour was low (4.01). The primary occupation of 6-9% of the people was fishing, 2.2% of people were involved in NTFP collection. Mean months of employment were 6.25 $\pm$ 0.212. The average income per household per annum was Rs. 22976.3 $\pm$ 1791.486. Agricultural income was Rs. 2039.7 $\pm$ 297.076. Mean cattle holding per household was 2.3 $\pm$ 0.184.

The results reveal a high degree of resource use by villagers despite the protected status of the Bhitarkanika mangroves. Wood from the Bhitarkanika mangroves is being used, particularly by the communities in the periphery of the forest for firewood. An overall 14.2 percent of the needs of each of the household was being met by the forests with a mean consumption of 3.1259 $\pm$ 0.3216 qtl./annum in the sample villages. The highest consumption was noticed in the villages located within 1.5 km. from BNP (5.8 $\pm$ 0.533 qtl./annum). The highest fish extraction (1.25 $\pm$ 0.391 qtl.) was observed for the villages located in the peripheral areas of the mangroves and the least (0.60 $\pm$ 0.495) for those farthest from it. Thus, highest consumption of Non Timber Forest Products (NTFP) was seen for villages in the adjoining areas of forest while the villages situated more than 3 km away from the forest did not use this resource.

- Around 90% of the local people in the area are aware that Bhitarkanika forests have protected status and that it is a declared Wildlife Sanctuary.
- 84% of people feel that they have a responsibility towards conservation of flora and fauna and 92.9% are in favour of an ecodevelopment programme for the area. 43% of people are willing to cooperate with the forest department in this regard. Only 18.3% of people feel there has been a violation of their rights with the park's declaration.
- 52% of the respondents felt that the local community should take initiative in the ecodevelopment programme and

consequently be involved or at least informed of the management decision.

- Very few people (0.7%) are in favor of cutting down the forests and 76.9 % of the people have said more mangrove plantations should be carried out.
- 80% of the people living close to the forest seemed to be more willing to cooperate with forest department in the conservation of flora and fauna, as compared with those living away from it.
- Majority of the respondents (87.7%) favored the Dhamra port extension.
- Very few respondents (8.6%) favoured aquaculture practice.
- In case, free access to forest resources was stopped, 30.6% respondents said they would buy alternatives available in the market, while 10% opted for stealing the produce from the forest. Only a few respondents (2.6%) opted for growing fodder and a very small percentage (0.4%) were willing to reduce the number of livestock.

The findings point out that the local people appreciate the contribution of Bhitarkanika mangroves to their lives and livelihoods. A high percentage of people (88.6%) recognize the contribution of mangroves in cyclone and flood mitigation. The people have even recognized functions such as biodiversity conservation and ground water recharge.

Sea Level Rise and BCA

A predictive model to assess the extent of impact of sea level rise on Bhitarkanika has been developed. Data was generated from different maps in the form of point information of elevation. After this, the digital elevation model was interpolated. The map was depicted with two levels of inundation (a) 0-1 m, which indicates the predicted sea level rise of 1 m and (b) 1-2 m of sea level rise. The local coastal process and wave patterns were not considered at present due to lack of reliable information that can be extrapolated on a large scale.

The land between 0-1 meter elevations has 73.2 to 63.9 percent estimated probability of inundation by 2200. The possible area of inundation at three levels i.e. 0-1, 1-2 and 0-2 m rise are 194.77 km^2 (6.5%), 253.71 km^2 (8.5%) and 448.48 km^2 (15%) of BCA respectively. Though this seems small and relatively insignificant, it will ultimately adversely affect the vegetation of the entire Bhitarkanika Conservation Area.

The estimated goods and services provided by the Bhitarkanika Mangrove Ecosystem is significantly high when compared to other land uses in the area such as aquaculture, paddy cultivation and development options. Moreover, the ecosystem services provided by the natural systems cannot be substituted by man-made capital. Despite this, the Bhitarkanika mangroves are facing threats of extinction due to anthropogenic and developmental pressures. There is a high degree of resource extraction by the locals due to limited availability of livelihood options such as paddy cultivation and fishing. Land use changes coupled with developmental activities all around the area threaten the ecological integrity of the Bhitarkanika Mangrove Ecosystem.

Recommendations

The Bhitarkanika area has had a strong protection policy since 1951. In 1975, the Government of India declared 670 km^2 of the area as a Wildlife Sanctuary under the Indian Wildlife Protection Act, 1972. A core area of 145 km^2 was upgraded to a National Park status in 1988. In 1997, 1435 km^2 area was declared as Gahirmatha Marine Sanctuary, with a core area of 725.5 km^2. Despite this , at a higher spatial scale there is ample evidence to suggest that in the area market faliure, informatioin faliure and intervention faliure are occurring because of inability of the government to implement the Wildlife Protection Act effectively; and lack of inter-sectoral coordination.

Between 1951-61 there was an unprecedented increase in the population of the area due to resettlement of refugees from Bangladesh. Between 1994-95 the Revenue

Department legalized a large number of illegal settlements within the Sanctuary area, with little regard to Wildlife and Forest Conservation Acts. Similarly, despite the protected status of the Bhitarkanika area and the existence of a strong Maritime Act (1982) of the Government of Orissa and Orissa Marine Fishing Regulation Act (1982) and Rules (1983), unabated development has been taking place in the area such as the construction of port and defense structures and inshore fisheries using mechanized vessels. This is the result of information failure on part of the fisheries, waterways, defense and other government departments. In the absence of valuation studies the forest department is unable to articulate the importance of this ecosystem against the developmental activities, that though promise higher economic returns are unsustainable.

All these factors are together exerting pressure on the Bhitarkanika Mangrove Ecosystem. Integrated Conservation and Development Plan for the area is needed to manage the area.

Legal Protection

MoEF recently declared Bhitarkanika as a Ramsar site and its wise use would imply careful planning, management, regulation or even prohibition of certain activities. This can be made possible through proper consultation and an agreement with the stakeholders, which would also garner more support for its conservation. The existing positive attitude of people towards conservation need to be creatively channelized for sustainable development of the area. The following policy initiatives are suggested for long-term conservation of BCA.

Stakeholder Participation

Resource extraction from the PA is not permitted under the current law (Wildlife Protection Act, 1972). However, the 336 villages located inside the Sanctuary have no option but to use the resources from the PA. The use in this case is de facto, which is usually indiscriminate. It is crucial to address the dependence of the local communities on the PA resources. We suggest that:

- The National Park i.e., the core zone be maintained as a sanctum sanctorum and all resource use therein stopped.
- The livelihood needs of the people (living within 1.5 km of forest boundary) on the PA, be met from the buffer zone. The buffer zone in this case is a Wildlife Sanctuary where resource extraction is not permitted. Controlled resource extraction in this zone be permitted, in such a way that it does not affect the ecological balance. This will also develop stakes of the local people in the conservation of the area.
- The status of the buffer zone be changed to other categories of Protected Areas as proposed under the amended Wildlife Protection Act.
- Subsistence fishing in rivers like Dhamra, Brahamani, Baitarani, Hansua and Pathsala be legalized. This is unlikely to have a major impact on the ecological balance as long as the nursery grounds of the fishes i.e. the small creeks- Thanpati, Ganjeikhia, Jalahar, Suajore, Gokhani and main Bhitarkanika River remain undisturbed.
- Alternative fuel to the local people needs to be provided to reduce their dependence on the BCA. It is imperative to develop better supply and distribution mechanisms. Since the income levels of people in this area are relatively high, it can result in a shift to more efficient alternate fuel.
- For the poor, the Sanctuary still remains the source of wood biomass. Mangrove plantation should also be taken up extensively in and around forest blocks, which are under tremendous pressure and are already degraded due to excessive lopping (e.g. Mahisamunda, Ragdapatia and Kalibhanjdia forest blocks).

Employment Generation

- The villages located within 0-1.5 km distance from forests have higher numbers of unemployed population. For these villages income-generating programmes are needed to counter high unemployment. Programmes that have been successfully initiated in few villages by the forest department and local NGOs should be extended to more villages.

- Pisiculture and apiculture can be introduced as these have tremendous scope in the region. Most of the villages have sufficient number of ponds to sustain fish population and have basic equipment and knowledge to carry out such programmes.

- Local communities can be involved in tourism (as guides) in the area. This will provide employment opportunities for the local population. It should be made mandatory for visitors to have a trained tourist guide with them, which will not only facilitate these visitors but will also help in monitoring the activities of the visitors.

- The entry fee to the park should be increased to generate revenue for the forest department. Funds generated should be used to set up ecodevelopment / village development funds as is being done by the states of West Bengal, Madhya Pradesh and Rajasthan.

- Overnight stay facilities for tourists should be developed at other sites beside Dangmal, and measures taken for up-gradation of existing forest guesthouses at Ekakula and Habalikhati so as to distribute the tourism pressure.

- Villagers can be encouraged to build ethnic huts at places like Khola and Gupti to facilitate boarding arrangements for tourists and provide the villagers with an alternate income source. Existing nature trails inside Bhitarkanika forest block and the heronry at Bagagahana should be properly maintained.

Infrastructure

- Maintenance of existing roads and bridges should be done so as to improve transportation facilities for locals and tourists. Boat transportation in the inner creeks should be regulated to reduce disturbance to birds and crocodiles. Though people support construction of Dhamra Port, its building will have detrimental impact on the Bhitarkanika National Park. Increased movement of boats due to construction of the port will be detrimental to the nesting sites of turtles, and the social impact will hamper the integrity of the entire ecosystem.

- Small sluice gates should be made at strategic locations on the dyke so that storm water drains out quickly after extreme disasters like cyclones.

Conflict minimization

Although prawn farming is banned in the sanctuary area, a number of illegal prawn farms (Gheries) continue to exist. The forest department frequently demolishes these farms, resulting in a conflict of interests between the local people and the forest department. Awareness programs should be run along with the demolition of Gheries to educate the people about the negative impact of aquaculture on agricultural production.

Trawling too is prohibited within a 5 km range from the shoreline. In spite of this, illegal fishing by mechanized trawlers continues, causing large-scale mortality of sea turtles. Restriction on mechanized fishing in the coastal zone should be imposed with the help of the Coast Guard and Fishery Departments. The number of field staff presently employed is inadequate to patrol the BNP and efforts must be made to attract employment of qualified professionals in the area. Cooperation of the local villagers is crucial to check the smuggling of timber and wildlife articles. Sufficient number of enforcement staff with VHF sets and transport facility should be deployed at all entry points at Dangmal, Khola, Gupti and Chandabali.

Awareness Creation

A large section of the population, particularly those living in and around Bhitarkanika in remote areas are uneducated. In order to reach out to and educate them, visual literacy programmes should be implemented using the skills and expertise of local NGOs.

Conservation of Gir Eco-System: Assessment of Benefits and Costs under Alternative Management Systems

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The context

The policy discourse on Protected Area (PA)-management has come a long way from purely conservationist strategies to participatory approaches. In between these two there is a wide range of options that combine different elements of resource sharing, market regulation and privatization. Ideally, the PA-management strategy should pick and choose from these broad strands of approaches to suit the location specific situations, especially with respect to important parameters such as: economic and ecological services flowing from the ecosystem; size and status of the system; extent of people's dependence and conflicts; scope for revenue generation from eco-tourism; and availability of financial resources for PA-management. The experience from a large number of developing economies suggest that none of the pre-conceived, 'blue-print' solutions may work across different PAs, though it might have worked in the situations of wilderness without much human activities around. This implies that the analysis of the cost of bio-diversity loss and the development of appropriate institutions and incentives should primarily be local exercise. The choice of PA-management approach therefore, has to be in tune with the location specific situation - ecological, socio-economic-political and financial. Also, the choice is time specific; it may undergo changes along with the different stages of PA-management. Exploring options and evolving new approaches therefore, are important aspects of policy formulation on PAs.

Gir Protected Area (PA) represents one of the successful cases of design and implementation of a management plan. This has been achieved through effective protection and habitat development practices. As a result, it has succeeded in reviving wildlife population, especially the Asiatic Lion, which is fairly close to its 'optimum size'. The next stage therefore, is to evolve sustainable strategies for regeneration and conservation of vegetation and biodiversity. Given a large number of local stakeholders, sharing of the regenerated resources might help both conservation as well as people's participation in PA-management.

The analysis is to be carried out in light of the important postulations emerging from the above description of the ecology, people and the management approach adopted for the PA. These postulations are:

- Given the large size of human population in the periphery, there is an inherent trade-off between conservation and livelihood requirements of the people. However, the trade-off could possibly be resolved by taking into consideration the carrying capacity of the area to support the Asiatic Lion, for which the PA is primarily designated. It is estimated that Gir PA can support 300 lions, the maximum population of lions that had ever existed in Gir.
- Maldharis are a part of the Gir ecology; hence the carrying capacity should also be defined in terms of human as well as livestock population of this community within and in the periphery of Gir.
- Conservation efforts over the past two-and-half decades have improved the wildlife habitat, especially by enhancing vegetation (or restocking) in the core area and effective punitive measures. This however, has left a large part of the pastures within (and also outside) the sanctuary in degraded condition.
- While the protection measures have resulted in reducing poaching of wildlife, illegal grazing continues, though on a significantly lower scale than before.

- Nevertheless, continued degradation of pastures is a combined effect of: (a) illegal grazing; (b) climatic conditions (i.e. frequent droughts); and (c) inadequate measures for regeneration.

- Intrusion of wildlife on crop fields in the peripheral region has increased mainly due to degraded conditions of forests especially during droughts.

- The problems of water and shelter (i.e. vegetation) within the PA could be mitigated by proper measures for soil-water conservation within the PA. This in turn, might also help promoting sustainable use of water for agriculture in the lower reaches of the watersheds.

- Regeneration of vegetation within the PA could help reduce the pressure from outside provided (a) pastures in the periphery are developed; and (b) management of fodder supply is streamlined.

- Development of pastures both within and outside the PA requires substantial resources - financial (i.e. land, water, manure, etc.), natural and institutional. Given the budgetary support, these aspects so far, have received a lower priority despite the recognition of their critical importance.

Given this backdrop the present study tried to examine the status of Gir ecology, people's dependence, and alternative approaches that might be more relevant for the next phase of management in the PA. Valuation of economic and environmental services has special relevance in this process.

Objectives:

The main objectives of the study are:

- Identification as well as valuation of economic and ecological services from the PA.

- Assessment of people's dependence on the PA across different categories of households-farmers with and without irrigation, landless, and traditional herder communities. Also, estimation of cost under alternative management practices, especially for regeneration of pastures, wastelands, and reserve/protected forests.

- Drawing implications for a management strategy that incorporates people's stakes while ensuring ecological sustainability of the PA.

The above analysis will help contributing to certain long-term objectives such as:

- Getting a clearer understanding of the interface between development of the core and the peripheral regions, which may lead to evolving a sustainable strategy for PA-management; and

- Identifying effective mechanisms for protection and also sharing of resources through development of markets, institutions and community participation.

Methodology and Approaches for Valuation

The study has been based on data collected from both secondary as well as primary sources. The assessment of the value of economic and ecological services (benefits) has been done by using the estimates of various indicators - intensity and diversity of vegetation across different areas within the PA, availability of irrigation, farm yard manure (FYM) and other non timber forest produce (NTFP), conservation of soil-nutrients, carbon sink function and wildlife diversity, etc. from the various studies on the Gir-PA and/or other comparable situations in India. The estimates of costs are based mainly on the norms used in the official management plan. However, these sets of secondary information have been supplemented by primary data collected from: (i) a complete house listing in 8 revenue villages; (ii) a detailed survey of 162 households in four revenue villages; (iii) meetings with key informants, which included group discussions on the status of common property resources in 29 villages; (iv) a series of focus group meetings with various stakeholders viz; people, members of the eco-development committees and functionaries of the forest department; and (v) informal discussions with policy makers.

The four villages where the detailed survey of sample households has been undertaken were selected from the West and the East divisions within the PA – two in each division. Of these, one village is on the border i.e. within the periphery of 2 kms., and the other at a distance of 2-7 kms. from the PA-boundary. After completing the house-listing exercise in the four (out of the 8) revenue villages selected for detailed study, a sample of households was selected from five categories viz; large farmers with irrigation (LI); small farmers with irrigation (SI); farmers without irrigation (UI); landless (LL); and traditional herder communities (LH). The sample households were selected by adopting a stratified random sampling procedure.

The basic purpose of the primary survey was to ascertain (a) dependence on the PA households across different categories; (b) people's perceptions about the relative importance of non-use values; and (c) preferences about alternative land-use, and their implications for alternative management systems. Together, the secondary and primary data provided a comprehensive picture of the ecological status, prevailing management practices, and implications on alternative systems for regeneration and conservation of the Gir-PA in a sustainable manner. It is expected that the analysis would provide inputs for further fine-tuning of the issues and policy alternatives for management of Gir and therefore, would be a useful addition to the rich set of existing literature on various aspects of the ecology.

Given the specific context of Gir, a wide menu of valuation methods, and feasibility of data collection, the present exercise will attempt assessment of various benefits and costs as listed in Chart 1.

Chart 1.

Benefits from Environmental and Economic Services			Cost of Conservation		
Direct Benefits	Loss of Potential Benefits	Benefits Under Alternative Management Plan	Direct Cost	Opportunity Cost	Replacement Cost
Actual Use as well as Non use Values	Untapped potential of Use as well as Non use Values due to Incomplete Conservation Efforts	For Alternative Systems of Land Use, Incentives and Institutional structures	Actual according to the Management plan for Mitigation of Forest Degradation	Under Alternative Land Use For Ensuring Practices	Effective Conservation through Alternative Management Plan

Major Findings:

People's Dependence on the PA

- Local stakeholders consist of a human population of 3-5,000 and livestock population of about 14,000 within the PA. The periphery, consisting of 99 revenue villages has an estimated population of about 1,80,000 persons and 95,000 livestock.

- People within the PA have rights for grazing their livestock, and depend entirely on the PA for their livelihood. The total economic benefits accruing to the Maldharis within the PA amount to Rs. 1,035 lakh per year or Rs. 2.87 lakh per household per year. Against this, the major cost incurred by the Maldharis is in terms of loss of livestock, which is estimated to be Rs. 112 lakh per year, besides the difficulties arising due to lack of basic amenities like education, roads and electricity. While the present size of livestock inside the PA is well within the carrying capacity of about 22,000, there are other costs due to human settlements within the PA. These are infiltration of outside animals, faulty grazing practices, damaging the regeneration process, selling of FYMs outside the PA, extraction of fuel wood for commercial purpose, and offering less productive livestock as easy prey, and thereby distorting the genetic characteristics of lions.

- More than 50 percent of the households in peripheral villages access fodder from the PA. Similarly, a large proportion (i.e. about 80%) of the households obtain fuel wood from the PA - directly or indirectly from the markets. These constitute about 74 percent of the total requirements for fuel wood in the peripheral region.

- There are no systematic estimates on fodder production or its requirement in the peripheral villages. Ascertaining the actual extraction of fodder by the people is difficult because it is illegal. However, assuming an average fodder yield at the national level, i.e. 3000 kgs/hectare, the surplus fodder (after meeting requirements of the livestock and herbivores within the PA) can support about 21,000 adult milch cattle in the periphery. Another 19,000 can be supported by the crop-residue. This still leaves a large number of adult milch cattle, plus other small livestock, which need to be supported through regeneration of pastures within the periphery of the PA.

- Since landless as well as small farmers without irrigation can hardly afford to keep milch animals, they tend to depend mainly on agriculture of the largefarmers with irrigation, and also on collection of MTFP + fuel wood from the PA. Nevertheless, increased irrigation leads to depletion of ground water resources at the expense of soil-moisture and availability of water inside the PA. Reducing the use of irrigation for growing water-intensive crops may result in stagnating/declining demand for labour on farms. But this could be compensated by increased availability of fodder and MTFP from pastures, possibly by applying irrigation within and outside the PA.

- Enhancing the livestock base among landless/small farmers without irrigation, thus needs to be preceded by a realistic assessment of livestock population in the periphery and carrying capacity of the PA. The reported livestock population of about 95,000 in 1991 appears to be an over estimation. With an average of 2-2.5 livestock per household, the total population among approximately 30,000 households in the periphery may work out to be around 60-75,000. The recent droughts in the late 90s might have further reduced the number closer to the lower end of the range i.e. around 55-60,000. A realistic estimate of livestock in the peripheral villages is therefore, quite crucial for assessing the requirement as well as pressure on the PA.

- Against the various economic services, people in the periphery have to face several difficulties, especially when protecting the crops and livestock from wildlife. While the actual incidence of crop damage is not very significant, the efforts and the risk involved in protection is fairly high.

- A large proportion of people recognize the present level of dependence on the PA as non-sustainable. While they consider conservation as necessary, they don't endorse the present system of protection and restrictions, which in their opinion, leads to corruption and over-exploitation of the PA-resources.

- People's expectations from PA-management are availability of fodder through a regular supply system, limited grazing rights, fuel collection, and employment in PA-management activities. Settlement of the issues pertaining to land acquisition are also an important concern, absence of which leads to non-cooperation among a large number of villages that have lost a part of the community pastures or private land to the PA.

Benefits and Costs of PA-Conservation

The total value from various economic services from the PA is estimated to be Rs. 477 million, of which about 20 percent is comprised of the various direct use-values like fodder, fuel wood, irrigation, etc. The estimated fodder value is based on the national average of Rs. 3000 kgs/hectare for the Indian forest. Since there are no systematic estimates of the production of a large number of (MTFPs) available from the PA, we used the national average to estimate the market values. We tried to keep a downward bias for estimating the benefits, so that they do not become unrealistic vis-à-vis the estimated cost of investment, necessary for regeneration of the PA.

Valuation of Non-Use Benefits

More than direct as well as indirect use-values, non-use benefits have special relevance in the context of a protected area. These include benefits like existence value, rarity and aesthetic value, option value, cultural value and ecological value. Assessing the monetary value of these benefits however, is difficult. Alternatively, what we have attempted here is obtaining stakeholders' perceptions about the relative importance of some of these non-use benefits in comparison with the benefits of direct as well as indirect use, the value of which we have already estimated. This will provide some kind of an indirect assessment of the non-use value of the resources within the PA.

We have tried to assess the value of non-use benefits by obtaining a relative ranking of various functions/services provided by the PA. The exercise is based on the perceptions obtained from a sample of 162 households in four villages in the periphery of Gir. The relative score is highest for fodder as well as fuel, closely followed by vegetation and biodiversity. The next group contains the other environmental services like rainfall, wildlife and soil conservation. Benefits like NTFPs, timber and income-employment were among those, which are perceived to be relatively less important from the viewpoint of the perceived benefits from conservation of the PA.

We also tried to capture the relative importance of the five major attributes of the Gir-PA by obtaining people's perceptions about the desirability of conservation of the PA. This was obtained by asking the respondents to rank the five major attributes, which can be broadly classified as Watershed Functions, Rarity of Lion, Bequest value, religious-aesthetic value and consumptive value (grazing + fodder). Apart from consumptive use, people in the peripheral villages attach significant importance to the religious-aesthetic aspects of the PA, which is closely followed by watershed services, rarity and bequest value. It may be noted that the religious aspect has a close link with the overall ambience of the forest ecology and its aesthetic value. It is clearly believed that the religious spots may also lose their importance if the forest/ vegetation get deteriorated.

Cost of PA-Management

Budgetary Allocation and Expenditure

The estimated budget for the period (1995-2000) is Rs.598 million, of which Rs.187 million (45%) is contributed by the GEF-supported Eco-Development Project (EDP). The average budget for the year is estimated to be Rs.119 million. The proportion of the budgetary resources allocated for measures that have direct bearing on regeneration of the PA is about 52.4 percent of the total budget, including the Eco-Development Project. Compared to this, a significantly large proportion of the budget is allocated for infrastructure and recurrent expenditure. Moreover, the budgetary allocation for regeneration measures noted above also has some components that may not have a direct impact on regeneration. For instance, the amount spent on tourism, socio-economic and village eco-development could be spent in a manner that may not directly improve vegetation and other ecological aspects with the PA. A similar pattern is also observed in the actual expenditure for Gir region, which also includes Barda Sanctuary. In fact, if one looks at the component of soil-water conservation (SWC), it is fairly low i.e. < 4 percent.

It is possible that the PA-region is also receiving benefits from other on-going schemes like Watershed Development from the Ministry of Agriculture and Rural Development. A large proportion of expenditure on Integrated Forestry Management could yield better results if the SWC-component is also properly integrated with it. The important point is that of 'appropriate' allocation of resources, especially when funds are limited.

The Eco-Development Project constitutes a major proportion (31.45 %) of the total expenditure. If the major part of expenditure under the Eco-Development Project is on development/support to the household's immediate requirements like land leveling, deepening of bore wells, purchase of agricultural employment/inputs, or obtaining alternative sources of fuel and building material, as it appears to be true in a large number of cases, regeneration of vidis and degraded forests may once again take a back seat in the total expenditure on the PA. The management team often finds it difficult to obtain permission for regeneration of village pastures from eco-development funds. Encroachment of the pastures and illegal grazing in the degraded forest in the peripheral villages is another important issue that constrained utilization of funds for some major activities like fodder development/nutrient enrichment programmes in the region.

Overall, a comparison of monetary benefits and costs suggests that the former is significantly higher than the average budgetary allocation for the PA management plan. Even if we compare the value of direct use benefits, the estimates are fairly higher than the actual expenditure. A summary of the major benefits and costs has been summarized in chart 2.

Chart 2

Summary of Benefits and Costs (Rs. Lakh at 1995-96 Prices)

Value of Benefits		Value of Costs	
Details	**Value**	**Details**	**Value**
Direct Use	9669	Average Budget for Management per year	1191
Indirect Use	37883	Crop Damage	419
Opportunity Cost	39524	Loss of livestock	143
Loss of Crops to replace the fodder	2592		
Potential loss of fodder	1170		
Soil Loss	9793		

Impact on Environment:

The substantial gap between direct economic benefits and the cost of PA management seems to have led to inadequacy and/or slower pace of regeneration measures. This, along with climatic factors and human interference, as large as 34 per cent of the area is categorized as degraded or highly degraded. Obviously, this would lead to environmental costs that need to be checked as early as possible. For instance, the Gir region is presently classified under 'high' degree of soil erosion. Based on this categorization, we have tried to estimate soil loss from the Gir PA. The estimated loss amounts to Rs. 979 million per year. Mitigating this loss may trigger a chain of positive impacts such as: improved soil-productivity, better vegetative cover, increased availability of fodder and fuel, increased income from crops and livestock, and above all, better rainfall and thereby reduced risk of drought which is of prime importance to the people in the peripheral region. The task is to check soil erosion and regenerate degraded land within and outside the PA.

The reported low vegetation density within the PA may also affect the carbon-sink function of the ecology. We have tried to estimate this by using the estimated densities of teak and miscellaneous trees. The total c-stock in the Gir eco-system is estimated to be 6.58 Tg. There is significant scope to improve this ecological function by improving the status of vegetation within and outside the PA.

While soil-water conservation is considered to be the basic treatment for changing the scenarios of environmental as well as economic services, major constraints are faced by the PA management in terms of financial resources.

Alternative Approaches for PA Management

The Forest Department of the Government of Gujarat has already worked out the second phase of the management plan, envisaging a special focus on regeneration of pastures, and also a significant expansion of the home range in order to sustain a population of 500 lions. This of course, is a detailed plan for resource management, people's livelihood and implementation strategy. Given the need for regeneration of vegetation within and outside the PA, and the critical role of soil-moisture and water thereof, we have tried to explore alternative land and water use planning for the region.

Since SWC is a resource intensive activity with a long gestation period of about 7-10 years, the initial investment has to be funded by external resources. Convincing fund-givers / sponsors (national or international) would require a realistic assessment of the impact of resource regeneration, and sharing a part of the regenerated resources with the local stakeholders, so as to mitigate the future loss in terms of continued pressure and degradation within the PA. Lessons from the Eco-Development Project in Gir and other PA sites should get integrated into the fresh planning. Some of the important suggestions for the next phase of the PA management have been highlighted as follows:

Components	Costs	Benefits
SWC to be given a top priority	Average cost Rs.15-20000/ ha, including the cost of water harvesting structures	Triggers a chain of improvement in terms of: Availability of soil-moisture Improved vegetation in PA Providing fodder+fuel through regulated operations Reduced illegal extraction and grazing Saving of the value of soil-loss Employment generation
Regenerating vidis within PA through additional inputs to be used as incentives to reduce irrigation and grazing	Average cost of Rs.10,000/ ha (including seedling, water, manure, labour)	Replenishing groundwater Reallocating water to CPLRs and vidis Reduced damage due to illegal grazing within PA
Regeneration of CPLRs in periphery	Fodder + plantation Rs. 35,000/Ha	Better employment + income to small farmers +landless Reduced dependence for fodder, fuel-wood, illegal felling Reduced risk of fire
Institutional arrangement for collection of fodder, fuel and NTFP	Involving a professional developmental agency to arrange supply and distribution at a reasonable price	Saving of cost of drought relief programmes Reduced impact of droughts Reduced pressure on PA Reduce conflicts with FD-staff and better cooperation Improved quality of livestock Reduced pressure of grazing Preventing entry of outside animals
Mobilisation of Funds	Loan from national govts. Grant from environmental groups and donor agencies Credit support to people	Evolving a mix of incentives through Increased availability of resources, cost-sharing, and subsidies rather than subsidies and compensation alone

Recommendations

- While regeneration of vegetation should primarily look into the requirements of the wildlife in the area, it should, at least for the next 10-15 years, also provide a stable supply of fodder, fuel, and NTFP through a regulated management system adopting the 'cut and carry' method. Improved vegetation and habitat management should thus, ensure that incidence of attack on crops and wildlife is reduced. A professional agency might be involved to help organize the supply system. At present, the allocation for soil-water conservation accounts for only 3.85 percent of the total budget. This needs to be increased significantly.
- Soil-water conservation measures should take a lead in the process of regeneration of the ecology. This should be done by adopting the ridge-to-valley approach, covering the entire area of the major watersheds in the region. This is critical for reducing the frequency as well as impact of droughts. In turn, it should also result in improving the soil-moisture profile, and promoting a more sustainable use of ground water resources in the periphery.
- While the management plan has already envisaged development of irrigated fodder plot in the periphery, its actual implementation is found to be difficult. The experience of the Eco-Development Project is also not so encouraging with respect to regeneration of Common Property Land Resources (CPLR) in the peripheral villages. Hence, development of pastures within and outside the PA should be undertaken as an integrated activity with people's participation and reciprocal commitment for protection. The next phase of the Eco-Development Project, focusing mainly on community pastures and other resources should therefore be closely interlinked with the plan for regeneration of pastures within the PA.
- Given the high cost of an effective resettlement package, the present approach of relocation of the Maldharis within the PA boundary appears reasonable. Nevertheless, the Maldharis within the PA should be made to adhere to the norms of a 'sustainable' size of livestock and replenishment of FYM for

regeneration of the PA. Against this, some basic amenities like housing, schools, electricity, drinking water, and health services should be provided to the households, which should shift close to the PA boundary. For the Maldharis who have already shifted outside the PA, a comprehensive plan for their effective rehabilitation on various land-based activities should be worked out. This is essential not only for checking further deterioration of their livelihood base, but also for mitigating the problem of 'illegal' re-entry of human as well as livestock population into the PA.

- A large number of visitors coming to the PA for pilgrimages could be reoriented towards eco-tourism by involving environmentally conscious leaders / organizations for sustainable development in the region. This could also help strengthening the institutional base in the region.
- The management plan needs to be strengthened by filling up some of the crucial information gaps. These include assessment of vegetation and changes over time; carrying capacity in terms of wildlife as well as livestock; dependence of human and livestock population within and outside the PA; size and status of CPLRs in the periphery of the PA; and interface between regeneration of vegetation and habitat management. These are some of the crucial aspects on which information is not readily available in the public domain. It is pertinent to recognize that filling this information gap is an essential pre-condition for designing a management plan for the PA. This is particularly important at this stage of the PA management, when the initial objective of conservation of wildlife is more or less achieved, and the task ahead is to strengthen the process of ecological regeneration.

Given the large area of the PA and also in light of the perspective plan for a still larger home range for its core wildlife specie, i.e. the lion, it is essential that the next stage of the PA management is much more interactive and inclusive of the people in the region. The above suggestions should thus, be appreciated in the context of the long-term goal of a sustainable management of the Gir PA.

Economics of Protected Areas : A Case Study of Pench National Park

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Introduction

The establishment and management of Protected Areas (PA) has been one of the most important ways of ensuring conservation of the world's natural resources and biodiversity to meet the needs of the present as well as future generations. The modern concept of conservation is a combination of three principles - to plan resource use on the basis of accurate inventory; take protective measures to ensure that resources do not get exhausted, and consider stakeholders perceptions. The present study was undertaken to focus on issues associated with Pench National Park (PNP), such as the dependence of local stakeholders on PNP, status of biodiversity, tourism and fishing, and estimation of cost-benefits to the local community.

Importance of Pench National Park

Most nations consider it desirable to protect outstanding examples of their natural heritage, and acknowledge that this is a contribution to the worldwide effort to protect living resources and conserve biological diversity. The Pench National Park contributes significantly to such tangible and intangible benefits to mankind. The study of Pench National Park is important as the general physiognomy and floristic of the tiger reserve are indicative of the two types of forests – Southern Tropical Dry Deciduous Teak and Southern Tropical Mixed Deciduous Teak. PNP is very rich in its faunal representation and most of the wild animals prevalent in the area, have taken shelter here . It is also equally rich in the floral diversity. PNP serves as a living repository of various economical, medicinal, aromatic, ornamental plant species. It has such potential values so as to perceive the real worth of this beautiful treasure house of nature, which must be protected as a part of our national heritage. The importance of this study is based on an attempt to highlight the ecological, faunal, floral, conservational, employment generation, educational and research value of PNP.

Objectives

The main objectives of the study are to:

- Identify the stakeholders of PNP.
- Estimate the dependence of the local population in and around the National Park for biomass consumption, and examine the impact of human intervention on the biodiversity status of the PA.
- Identify and estimate the benefits and costs of PNP.
- Suggest short term as well as long-term policy measures for management of PAs and conservation of natural resources for sustainable economic development.

Study Area

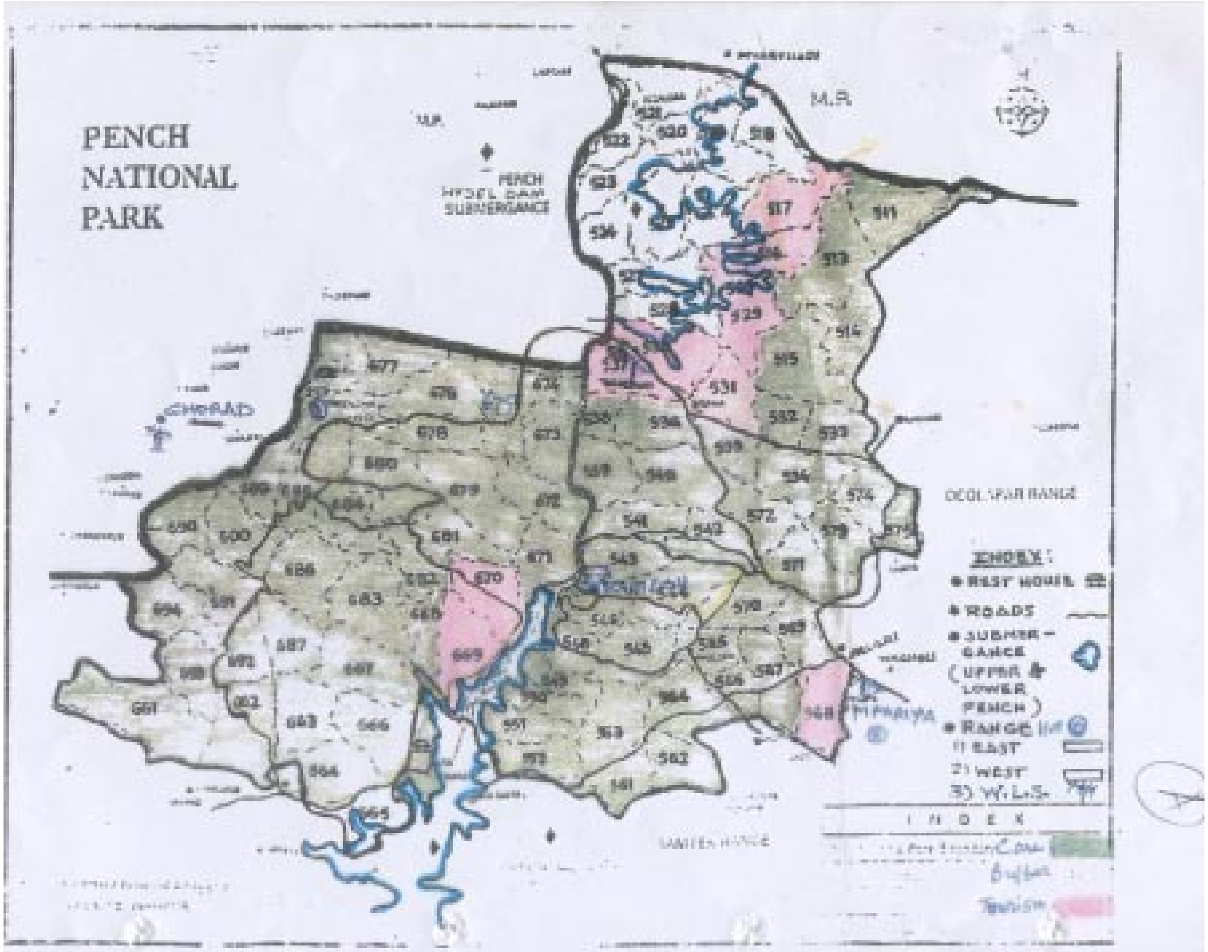
Pench in Maharashtra was declared the 25th Tiger Project in 1999. It is a magnificent forest and boasts a healthy population of predators and prey. In 1975, it was formally declared a protected area known as 'Pench National Park'. After years of protection and conservation, it was included in the Network of Project Tiger.

The Pench Tiger Reserve (with National Park Status of 257.26 sq. km.) derived its name from the river Pench that flows through the reserve in a north-south direction. It is about 67 km from Nagpur by road on the Nagpur-Jabalpur National Highway.

Methodology

Data was collected by using both primary and secondary sources at two levels:

- Village level
- Forest level



The methods adopted to estimate resource dependency of local communities in and around the PA involved the following steps: (1) questionnaire survey; (2) personal observations; (3) monitoring of entry points at village boundary; and (4) monitoring of selected households.

A combination of both census and sample methods were used to collect relevant information. A complete census of 42 households was undertaken to examine their dependence on the forests of PNP. The parameters for explaining dependence were identified to facilitate econometric analysis of the data by using the technique of multiple regression analysis.

A 33 percent sample of surrounding villages within 10 kms of the PNP boundary were drawn by stratification of villages in three distance zones, i.e. 1 to 3 kms, 3 to 5 kms, and 5 to 10 kms. The total area under the eleven sample villages is 2,077.17 hectares with 895 households. A 10 percent random sample of households from each village were drawn for detail investigations. The status of biodiversity was studied by taking the internationally accepted method, i.e. IFRI for taking a sample of plots in the core zone, tourism zone and other zones in proximity to the villages. With the help of this method, the impact of human intervention on the status of biodiversity was examined. The demand for tourism was estimated by using travel cost method. The log linear model was used to quantify the dependence of locals on fishing in PNP.

Main Findings of the Study

An attempt has been made to identify the main parameters of dependence. Income from forest and forest related activities has been estimated to assess the degree of dependence on PNP for the village Fulzari, lying within the

PA as well as for the villages surrounding PNP within a radius of 10 km of PNP. Resource use pattern of tribal communities has also been examined to quantify their dependence on PNP for fuel and fodder.

Dependence of Fulzari Village

Occupational distribution of the population of Fulzari village shows agriculture as the main source of livelihood. Almost 43 percent of the population is engaged in cultivation. However, agriculture contributes only 16.87 percent to the annual average income of the village. Low productivity of land and small size of land holdings are the main factors for disproportionately small income originating from agriculture. This has been a major factor in enhancing their dependence on the forest of PNP as a source of livelihood. Landless population constitutes almost 48 percent of the total population. Landless villagers find only a meagre source of income either as agricultural labourers or as forest labourers. Working as agricultural labourers supports only 12.5 percent of their income, whereas income from forest labour offers them employment opportunities, and thereby generates only 5 percent of the total income. For quantification of income from agriculture, shadow prices have been used. Self-consumption and non-marketability of agricultural produce has compelled researchers to use this technique for estimating income from agriculture.

The resource use pattern of the village community in Fulzari also shows heavy dependence on forests for fuel and fodder. Almost 32.7 percent of the imputed value of the household income comes from fuel wood. In the absence of any other source of fuel, the dependence on forests is almost total.

The dependence of the livestock population on forests is also equally high The imputed value of fodder for grazing is estimated at Rs.1,738.00 per household annually, constituting 54 percent of the total income of the households in Fulzari. Agricultural waste contributes only marginally in meeting the requirements of fodder to the livestock population of the village.

The resource use pattern of households in Fulzari shows the importance of the Non Timber Forest Products (NTFPs) in contributing a major source of livelihood to the tribal communities in the village. The prominent NTFPs found in the forest of PNP, and collected by the villagers are Charoli, Amla, Gum, Bamboo, Tendu leaves, Mahua flowers, etc. Household surveys show that 44.22 percent of the annual average income of the village households is derived from NTFPs. In spite of legal restrictions on the collection of NTFPs, this dependence on the forests is quite high. Almost one-third of an average household's income is earned through collection of NTFPs. Dependence of the village community on timber for construction of houses has also been found to be significant. The imputed value of timber for construction of houses for the village is estimated at Rs. 10 lakh at current prices.

Dependence of Sample Villages on PNP

A sample of households from three distance categories within 10 kms of the PNP boundary i.e. 1 to 3 kms, 3 to 5 kms and 5 to 10 kms - show equally high dependence of village communities on the forest. Distribution of households according to different occupations show that in 80 percent of the villages, the proportion of the households working as cultivators is more than 70 percent. The proportion of households working as agricultural and forest labourers is also equally high, and constitutes 80 percent of the households in Wagholi village, followed by Ghatpendhari village.

The dependence of village communities as reflected in income derived from forest related activities, shows heavy dependence on the forests of PNP. In villages like Kolitmara, Khapa, Tuyapar, Ghoti Dahoda and Kadbikheda, more than 50 percent of the annual income of the household is obtained from forest related activities. Only three villages have other sources of income like fishing, hunting and government service.

Income from non-forest sources like agriculture, self-employment, and dairy, have contributed around 40-50 percent of the income of the households, with wide variations for different distance categories of villages. The common feature of all the sample villages, where dependence on agriculture as a source of livelihood was found to be high, has been to relieve the pressure on the forests to some extent.

The estimate of dependence of local communities for fuel-wood consumption shows per capita consumption of fuel-wood at Rs.704 annually. The dependence of livestock population on the forests also shows equally high values. The total annual consumption of grass for the sample households is reported at 3,35,720 bundles of grass. The estimates based on local market rates shows monetary value of dependence at Rs.0.34 million. These are gross underestimates, as these villages are prohibited from extracting forest resources from PNP.

Three variables, fishing, income from agriculture plus agriculture labour, and collection of firewood, explain more than 87 percent of the dependence of Fulzari households on the PNP

Table 1: Regression Results for Fulzari

Dependent Variable: p1

Independent Variable	Estimate	t-value	p-value
Constant	97.940	26.274	0.000
Firewood2	7.061	2.22	0.033
Fishing	—0.00341	—11.442	0.000
P2*	—0.899	—13.366	0.000

$R^2 = 0.873$

* P2 = income from agriculture and agriculture labour

Fishing, income from agriculture plus agriculture labour (p2), and firewood2 are the variables that have significant impact on household's dependence on PNP. Out of these variables, p2 and fishing have a negative impact, whereas firewood2 has a positive impact.

The regression results for the sample households of the combined sample (Fulzari + Other Villages within 10 kms) are presented in the following table:

Table 2: Regression Results

Dependent Variable: p1

	Combined Sample		
Independent Variable	Estimate	t-value	p-value
Constant	36.198	9.579	0.000
NTFP	0.001489	4.478	0.000
Hunting	0.002137	2.369	0.019
Fishing	—0.00134	—2.182	0.031

$R^2 = 0.216$

All the four exogenous variables together explain a 21.6 percent variation in the dependence of the households of villages in PNP.

In the case of these households, the exogenous variable NTFP seems to be playing a very important role in determining the dependence on PNP.

Biodiversity Status

The study describes the biodiversity status of PNP by providing a checklist of the fauna and flora in PNP. A sample of plots from the core zone, tourism zone and other zones with high probability of human intervention has been drawn to test the impact of human intervention on the vegetation structure and status. The study shows that Pench biodiversity is negatively affected by tourism, but not necessarily due to grazing and construction and other extraction by the people living close to the Park boundary. Because of the proximity of revenue forests, the locals fulfil their basic needs from there. They utilize natural resources only for small timber, fuel, and for other non timber forest products like fruits, leaves, gum, medicinal plants, grass for thatch, etc.

The study also attempts quantification of some major tree species for the sample plot of 250 m x 400 m, by calculating market value of these tree species. Separate quantification of timber and fire wood value is attempted for Tendu, Dhawada, Salai, Moie, Bija, Haldu, Kalam, Shiwan and Saja. The estimated timber value amounts to Rs.4.52 lakh, and the fire wood value is Rs.32,000, resulting in a total timber and fire wood value of Rs.4.84 lakh for the plot. An inventory of medicinal plants in PNP and their medicinal use have also been attempted to show their use in curing various diseases and their valuable potential contribution in the preparation of life saving drugs.

Tourism

The tourism aspect of the study focuses on the role of the protected area as a source of recreational benefits. The Travel Cost Method was used to estimate demand for tourism. The visitors to Pench have been divided into three tourism zones i.e. Nagpur, M.P and Mumbai. Various functional forms like linear, log linear, etc, were estimated to find the best fit. The endogenous variable used in the model is the total number of visits from Zone I to Site m. Exogenous variables are population of zones, mean income of zones, entrance fee, characteristics of zones, travel cost from zones (TC) to substitute site, entry fee in substitute site, and quality characteristics of wildlife viewing available at substitute site.

The constant term that captures the joint effect of the factors exogenous to tourism in PNP has a statistically significant positive effect. This implies that the prevailing environment and infrastructure in PNP are not conducive for tourism. However, the positive signs of the constant terms for the entire three samples indicate that there is scope for tourism development. Tourism, so far, has not posed any threat to the environmental aspects of PNP.

Fishing

The role of fishing in PNP, and the dependence of local communities on fishing for their livelihood is also an important issue of the study. The estimated growth rate of fishing is 5.9 percent. The value of R^2= 0.07.

The estimated growth rate indicates that in spite of sufficient stocking of fishes and fingerlings, the harvesting is very low. This further implies that it is not at all a threat to the water bodies or environment.

Cost Benefit Analysis of PNP

Quantification of the various benefits and costs of PNP at cross section data set has been attempted. The benefits from forests, in the form of income from NTFP, grazing of livestock, environmental benefits - oxygen, soil conservation, etc., income from tourism or benefits from recreation in PNP, biodiversity benefits, etc. have been quantified as far as possible. The incidental benefits from water supply, irrigation and power supply have also been estimated.

Direct as well as indirect cost of PNP has been estimated. The cost of maintaining PNP, establishment cost, opportunity cost of labour in PNP, cost of resettlement, crops damaged by wild animals, have been measured to focus the cost of PNP.

Table 3: Estimates of Cost & Benefits

A) Estimates of Costs

Sr. No.	Items	Estimate of Cost (Rs. in Lakh)
1.	Resettlement (Fulzari)	179.47
2.	Land Development	81.40
3.	Crop Damage (Fulzari + 11 Villages)	4.30
4.	Opportunity cost of labour time spent in NTFP (Fulzari + 11 Villages)	10.79
5.	Environmental loss (Construction and submergence)	3.31
	ESTIMATE OF TOTAL COST	279.27

B) Estimates of Benefits

Items	Income from (Rs. in Lakh).	
	Fulzari	11 Villages
1. NTFP Collection	2.31	7.08
2. Hunting	0.27	0.01
3. Fishing	1.10	0.32
4. Forest Labour	0.26	5.14
Total	**3.94**	**12.55**

Recommendations

Based on the findings of the study, the following policy recommendations are suggested:

Economic Upliftment of Target Groups in and around PNP:

The small and marginal farmers, as well as landless tribal population constitute the target group for provision of income / employment opportunities. Their dependence has roots in poverty and lack of employment opportunities in non-forest based economic activities. Low agricultural productivity appears to be a major factor for their low livelihood status. Economic development plans for these target groups need to be directed towards improving productivity in agriculture or providing them with alternate sources of livelihood. These groups may be provided technical, financial, logistical support to improve yield from land, or training facilities in agro-based industry.

Providing Local Communities in and around PNP with Alternate Source of Fuel:

The major threat to conservation of valuable natural resources arises from lack of alternate source of fuel like LPG, Kerosene, Gobar gas, solar cookers, etc. The lack of purchasing power to use LPG, Kerosene or solar cookers may be one of the major reasons for heavy dependence on PNP for fuel wood. The Forest Department's schemes of providing Gobar gas to the locals seem to have created only a marginal impact on the villages in and around PNP. The huge ownership of livestock population will certainly work as an asset to extend the services of Gobar gas to most of the households.

Establishment of Herbal Research Institute:

The cultivation of medicinal plants in the agricultural fields owned by the local population may be popularised by emphasising their value in curing and preventing life-threatening diseases. The establishment of an Herbal Research Institute may help the local people to transmit their traditional knowledge of medicinal plants, which is on the verge of extinction in the absence of intergenerational transmission. Special institutions may be created to preserve this knowledge if family institutions no longer serve this purpose.

Involvement of Local Communities in the Management of PNP:

The observations based on the sample of biodiversity plots have shown no adverse impact on regenerative potential of vegetation due to human intervention. This indicates the awareness of tribal communities in ensuring sustainable use of forest resources. No conservation strategies will succeed in India unless the biomass requirements of the locals are harmoniously integrated with conservation of resources. For sustainable development of PNP and conservation of natural resources, a management plan embracing the goal of conservation without adversely affecting the livelihood of the local communities needs to be evolved on priority basis. The present emphasis on exclusive management of PNP needs to be changed by inviting participation of locals in various conservation activities. In designing the management plan of PNP, collaborative participation of academicians, research scholars, social workers, and most importantly, the stakeholders of PNP should be facilitated. Workshops may be organised to initiate participation of this cross section of the population in the formulation of management plans of PNP. The management plans should focus on:

- **Awareness Creation:** Strengthening of the interpretation centre at Sillari, Construction of auditorium, audio-visual aids, publicity material, etc.
- **Capacity Building and Research:** Training provided to staff, research and monitoring for scientific management, research on floristic and faunistic forest wealth, regeneration survey of PNP, establishing links with governmental and Non-government organisations / institutions
- **Management:** Use of funds collected through the entry fee, beautification of Ambakhori, conversion of Ranidoh Forest Rest House to Ranidoh Research Centre, environmental education for sustainable development, creation of new water holes, etc.

Eco-Tourism Plan

The eco-tourism plan should focus on the following objectives of tourism:

- Picnic sites
- Education and Research
- Religious tourism

An attractive package should be created for tourists, which may include audio-video publicity, educating tourists, organisation of nature camps, imparting training to local people, etc. Facilities to be made available to the tourists should include machan rest houses , transport facilities, development of picnic spots, children's park, etc.

With the implementation of these suggestions, tourism activities are likely to create demands of different forms. Some of the avenues can be – repairs of various vehicles, boating and fishing etc. Two types of visit plans for tourists can be arranged during:

- Summer or leave-shedding period
- Lush green (spring) period

The development of agro-eco tourism development plan will be useful for the local people, particularly the tribals, whose livelihood is highly dependent on agriculture. The plan should aim at improving the material life of the local people. It should involve educating farmers, local communities, government officials, NGOs, as well as industry tourists.

Promotion of eco-tourism is one of the main goals of National Parks and Tiger Projects. The occupational structure of locals in PNP is highly skewed in favour of cultivators, which necessitates promotion of economic activities conducive to the development of agro-eco-tourism. The age structure of the population with a predominance of youth may be a blessing in disguise for the development of tourism related activities. Failure to provide employment opportunities to these youngsters may impose a high social cost of resettlement.

If the above policy recommendations are translated into policy decisions, Pench National Park will be a “paradise” of flora and fauna” and a model Tiger Project for the region.

Economic Analysis of Biodiversity Conservation: A Case Study of Tropical Forests in the Western Ghats

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Introduction

Tropical forests cover 14 percent of the earth's land surface (8 mil.sq.km). They are rich in biodiversity. Half of all vertebrates, 60 percent of known plant species, and possibly 90 percent of the world's total species are found in tropical forests. The Western Ghats of India spread over five states of South and Western India (i.e. Kerala, Karnataka, Tamil Nadu, Maharashtra and Goa), is one of the eighteen biodiversity hotspots listed in the world. The Nilgiri Biosphere Reserve is located in this region. It is a treasure house of several known and unknown flora and fauna, including several endangered species such as the Lion-tailed macaque, Nilgiri Thar, Nilgiri Langur, Malabar Civet, Malabar giant squirrel and Asiatic Elephant among others. Due to demographic and economic pressures, market failures and inappropriate policies, the biodiversity of the region is under various stages of degradation and therefore, needs to be conserved through appropriate policies and adequate measures.

Objectives

The objectives of the study are to:

- Assess the benefits of biodiversity conservation as against alternate land use options of forests.
- Assess the socio-economic and institutional factors inhibiting or promoting biodiversity conservation, and people's perceptions and attitudes towards biodiversity conservation and wildlife protection.
- Estimate the Willingness to Pay or Willingness to Accept compensation for participatory biodiversity conservation.
- Assess the institutional alternatives and mechanisms for conserving biodiversity without retarding growth.

Data and Methodology

The study is based on both secondary as well as primary data collection. Secondary data was gathered to provide basic information on the biodiversity of the Western Ghats and of the study regions. Analyses of the changes in land use pattern, human and livestock pressure on land and forest resources over time in the selected districts are also carried out so as to serve as a backdrop to the in-depth study based on primary investigation.

For the present study a cluster of tribal villages/hamlets in Mysore district were selected, which are in the vicinity of the Nagarhole Wildlife Sanctuary which has witnessed considerable tribal unrest due to the establishment of the sanctuary, covered under the World Bank aided Ecodevelopment project. These included a coffee-growing village in Kodagu district of Karnataka and two farming villages in Uttar Kannada district having close interaction between agriculture, livestock and forests. These villages were selected purposively, after consultations with forest department and village officials.

The data for the in-depth study has been collected through a sample survey of households/respondents. Data has been collected on the following:

- Socio-economic data of sample households, covering demographic particulars, operational holdings, income, etc..
- Cropping pattern.
- Cost and returns from crop production and other allied activities such as livestock rearing and forest-based activities.
- Extent of dependence on forest resources (land, timber and NTFPs) and value of forest products extracted.

- On-farm consumption and marketing of forest products.
- Respondents' perceptions and attitudes towards biodiversity conservation.
- Respondents' Willingness to Pay (WTP) or Willingness to Accept (WTA) compensation for forest conservation / protecting wildlife species (e.g. elephants).

The survey covers 303 households/ respondents from the selected villages to elicit information about the extent of their dependence on forests for various socio-economic activities, their production activities and income, on-farm consumption and marketing of forest products and also to elicit their value preferences for diverse forest products and services.

Sampling Design

A two-stage sampling design was followed to conduct the in-depth study. Maldari village in Virajpet taluk of Kodagu district, which is close to a reserve forest, where coffee growing is predominant, and where man-animal conflicts are conspicuous, was selected. This village has a mix of coffee plantations of different size groups including some managed by large companies. Households in this village were listed and selected on stratified random sampling based on land holding categories and other criteria such as coffee growing, etc.

In or near the Nagarhole sanctuary, due to the small size of tribal villages or hamlets (some having just 10 or 15 households), a cluster of tribal villages or hamlets were selected in order to have a reasonable sample size. Eight tribal villages or hamlets, viz., Nagapura, Dammankatte, Sungattkatte, Kaimara, Nannachi, Kolangeri, Ganakoor and Majjighalli were selected for an in-depth survey. Of these, Nagapura is a rehabilitated village outside the sanctuary, whereas Dammankatte is a non-rehabilitated village near the periphery of the sanctuary. The remaining six tribal villages or hamlets are located within the sanctuary. All the households within the selected cluster of villages were surveyed. A total of 100 households were covered out of 250 households in this cluster of tribal villages.

In the case of Uttara Kannada again due to the small size of villages and the requirement of a reasonable sample size, a cluster of two agricultural villages, viz., Kegdal and Badakanasirada in Haliyal taluk of Uttar Kannada district were selected for our sample survey. Of them, Kegdal is within the Dandeli wildlife sanctuary and Badakanasirada is outside the sanctuary. All the households in these two villages were surveyed for an in-depth study. This included 32 households from Kegdal village and 48 households from Badakanasirada village, making a total of 80 households from this region.

Thus, in all, the study covered about 303 households from these villages or cluster of villages located in Kodagu, Mysore and Uttar Kannada districts.

Analytical Techniques Used

While collecting data the following analytical techniques were used:

- Cost benefit appraisal, contingent valuation method (discrete choice methods), logit or probit models, descriptive cum tabular statistics, and averages and proportions.
- Survey method and Contingent Valuation Method (CVM) to estimate the use and non-use values of the tropical forests.
- The dichotomous method or discrete choice method, which seeks simple "yes" or "no" replies to an offered bid, was used for the contingent valuation method (CVM) study. The discrete choice method is preferred over other methods (e.g. open ended methods) since it would be easier for villagers to understand and respond to the question. Also households could respond keeping some budget constraint in view i.e. the upper bound on bids could be controlled. This method also minimises any incentive to strategically over-state or understate WTP. Dichotomous choice methods require the use of parametric (typically logit or probit) probability models relating yes or no responses to offer amounts, the computation of an expected mean, and relating the WTP or WTA response to relevant socio-economic and other variables.

Major Findings

The following are the major findings of the study:

- An analysis of land use and crop pattern changes in the selected regions between 1960-61 to 1996-97 reveals that the net area sown and total cropped area as a proportion of the reporting area has risen for Karnataka and selected districts and Taluks in Kodagu, Mysore and Uttar Kannada. This increase in net area sown has largely come due to reductions in area of other land use categories such as permanent pastures and grazing lands, land under miscellaneous tree crops, cultivable wastes, etc. Total forest cover in the country and Karnataka seems to have increased slightly over the time period under review. Across districts it is seen that while Kodagu and Uttar Kannada report a marginal decline in their forest cover in recent decades, Mysore district interestingly records a marginal rise in the forest cover. This however, doesn't tell us anything about the forest and biodiversity in these three districts, which are degraded in many parts due to encroachments and other human interventions. An analysis of crop patterns and changes over the same time period, reveals that the relative share of crops like rice and banana which are highly prone to attacks from wildlife like elephants and wild boar have declined in the selected areas, which may be a coping strategy by farmers to reduce losses arising from damage to these crops by wildlife. Area under coffee cultivation has increased rapidly in Kodagu district and Virajpet Taluk in particular.

- The population pressure on forests and other natural resources are increasing over time. This trend is more conspicuous in Karnataka and the three districts under review.

- The livestock pressure measured in standardised animal units per hectare of forest and other natural resource has increased from 1961 to 1990 in Karnataka as compared to all-India figures/trends. Among the three districts, Mysore reported relatively greater pressure per hectare of forest area as compared to Kodagu and Uttar Kannada districts. However, a rising trend in livestock pressure per hectare of forest area is seen in Uttar Kannada over the last three decades.

- The opportunity cost of biodiversity conservation in terms of the foregone coffee benefits among the sample farmers in Maldari in terms of net present value (NPV) would be about Rs.1,94,900 per acre at 8 percent discount rate, and Rs.1,38,500 per acre at 10 percent discount rate, assuming a time horizon of 50 years. When the external costs of coffee production such as damage due to wildlife and preventive costs are also added, the NPV declines to Rs.1,88,500 per acre at 8 percent discount rate, and Rs.1,33,300 at 10 percent discount rate. Across land holding groups these benefits in terms of NPVs are positive and significant for all strata of holdings. Sensitivity analysis revealed that even if the expected benefits from coffee were to decrease by 20 percent and costs rise by a similar proportion, the benefits from coffee would still be positive and significant (IRRs range between 19.5 to 20 percent). Out of the total external costs incurred by coffee growers, 57 percent is due to damage caused by wildlife. The average damage cost due to wildlife attack was estimated at Rs.331.2 per acre, and the cost of preventive measures at Rs.196.5 per acre.

- The foregone benefit due to biodiversity conservation from Non-Timber Forest Products (NTFP) in terms of Present Value among sample Nagarhole tribals was estimated at Rs.67,123 at 8 percent discount rate, and over Rs.57,076 at 10 percent discount rate, assuming a time horizon of 25 years.

- The foregone benefit of biodiversity conservation in terms of paddy and cotton production among the sample farmers in Uttar Kannada in terms of NPV was estimated at over 29,400 per acre at 8 percent discount rate for paddy (excluding external costs), and Rs.23,400 (including external cost), assuming a time horizon of 25 years. For cotton, the NPV was Rs.56,801 per acre at 8 percent discount rate. The external costs of agriculture due to damages from wildlife were estimated at Rs.566 per acre.

- The foregone grazing benefits of biodiversity conservation among the sample farmers in Uttar Kannada in terms of Present Values was estimated at Rs.19,481 per standardised animal unit at 8 percent discount rate, and Rs.16,566 per standardised animal unit at 10 percent discount rate assuming a time horizon of 25 years. Aggregating over the animal units owned by the sample farmers this worked out to about Rs.6.43 million (at 8 percent discount rate), and Rs.5.47 million (at 10 percent discount rate) for the same time horizon.

- As regards attitudes towards biodiversity conservation and wildlife protection, majority of the sample households had a positive attitude. Regarding biodiversity conservation, the sample farmers in Kodagu felt that biodiversity should be conserved due to its value for future generations, its ecosystem functions, and use value for developing new products. The Nagarhole tribals emphasised its livelihood functions, importance for future generations, aesthetic and recreation values as well as its ritual and cultural values. The sample farmers in Uttar Kannada emphasised its ecological functions and livelihood aspects for biodiversity conservation.

- Elephants, which are a keystone species, and are vulnerable in the study area, were the focus of the study. Sample farmers in Kodagu, Nagarhole and Uttar Kannada emphasised the existence value of elephants, their beauty and use value for domestic work.

- A CVM study revealed that sample farmers in Kodagu were willing to spend 25.8 human days on an average per household per year for participatory elephant conservation, which amounted to over Rs.6,003 per household per annum in terms of the opportunity cost of income foregone.

- A logit function which related the “yes” or “no” responses to Willingness to Pay for Participatory Elephant Conservation in Maldari, Kodagu district, to a number of variables revealed that land ownership, age settlers and a dummy variable for decentralised government institutions were the significant variables influencing the yes or no responses of the sample farmers.

- In Nagarhole and Uttar Kannada, Willingness to Accept (WTA) Compensation was found to be more relevant. A probit function of Nagarhole respondents which related the “yes” or “No” responses to WTA to selected variables revealed that age, sex and income were the important variables influencing the “yes” or “no” responses. Nagarhole tribals, who report more income from work in neighbouring coffee estates, are reluctant to move out of the sanctuary due to uncertainty about their future, especially if relocated far from the coffee estates. Older people and women are also less likely to prefer to move out of the sanctuary. Those not willing to accept the rehabilitation package to relocate outside the Nagarhole sanctuary cited difficulty and uncertainty in coping with new surroundings, protests from community leaders, etc., as major reasons.

- A majority (96%) of the sample farmers in Uttar Kannada were willing to participate in participatory conservation. On an average, the villagers were ready to spare 85 hours in a year for activities related to elephant conservation. In terms of the opportunity cost of time of foregone labour benefits, this was estimated at Rs.585 per household in a year (assuming a wage rate of Rs.7 per hour).

Economic Valuation of Ecological Functions and Benefits: A Case Study of Wetland Ecosystems along the Yamuna River Corridors of Delhi Region

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Introduction

Wetlands are one of the most threatened ecosystems in the world. Whether they are mangroves, paddy fields or lakes, they are disappearing or are getting degraded owing to the process of urbanization, industrial and agricultural activities, and other formal and informal encroachments from various economic agents. At the formal decision-making level too, contribution of wetland ecosystems is ignored due to their public good/ Common property nature. Wetland ecosystems provide innumerable tangible and intangible benefits to society, but somehow they remain away from the domain of the market force. Thus, these benefits are left as "external" to the management decision makers of this natural resource, which keep getting depleted and degraded over time. Perhaps the most threatened riverine ecosystem in India is the 25 kilometer stretch of the River Yamuna, extending from Wazirabad to Okhla. It faces anthropogenic pressures on the riparian habitat, particularly in the floodplain areas. The ecological services performed by the wetlands in the river corridor region provide immense benefits to human society. The floodplains of the Yamuna River have continuously been confronted by the encroachments and conversions of land for various commercial purposes, threatening the very existence of this wetland. If the economic valuation is done for the wetland of the Yamuna River, a conservation strategy can be developed in a convincing manner with adequate justification for investable funds for the purpose. The question before policy makers and planners is whether this habitat needs to be conserved to maintain ecological functions, or used for alternative purposes. To address this issue, it is imperative that the wetland ecosystems be identified and delineated and their ecological functions quantified in a way that is suitable for economic analysis.

Objectives

The objectives of the study are to :

- Delineation of the floodplain areas and their ecological functions e.g. water recharge, nutrient retention, habitat to biodiversity, recreation and other biological productivity.
- Identification of crucial flora and fauna sustained by these floodplain wetlands.
- Estimation of economic values of ecological functions of floodplain wetlands.
- Estimation of total economic value of these floodplain areas in terms of user and non-user benefits.
- Providing rationale for conservation and sustainable use of the wetlands of Yamuna floodplains.
- Contributing towards the policy formulation for planning of Delhi in a more comprehensive and sustainable framework.

Study Area

For identification, delineation, mapping, and valuation of wetlands, the study area was divided into three sectors:

Wazirabad to I.S.B.T.	= Wazirabad Sector
I.S.B.T. to I.T.O.	= I.T.O. Sector
I.T.O. to Okhla	= Okhla Sector

Exact location and size of the different wetland ecosystems were mapped using Geographic Positioning System (GPS) during the field surveys where the GPS coordinates of a particular type of wetland were recorded. These geographic coordinates were then used to show the distribution of different wetland types on the toposheet of the study area.

Floodplains

Floodplains are the areas between man-made embankments and the levee of the river channel. These areas are inundated with water during floods. Floodplains are used for a variety of purposes, which include dry season agriculture and temporary makeshift human settlements, natural vegetation of the floodplains is today restricted to small pockets near the Wazirabad barrage. These pockets harbour pure strands of *S.munja*. The local people use a major portion of the floodplains for practicing dry season agriculture.

Seasonal Pools

Seasonal pools are present predominantly on the western banks of River Yamuna. These pools are formed due to the filling up of water after floods in the low-lying areas of the river corridor region. Seasonal pools are spread in both Wazirabad and I.T.O. sectors. These pools dry up during the late winter and summer seasons, and human settlements come up in their place. The seasonal pools abound with a large number of commercially important fish species. Local people fish in these waters for about 4-5 months every year. Water present in the seasonal pools also recharges the ground water of the neighbouring areas in a gradual and sustained manner.

Marshy Areas

Marshy areas are spread from Chilla regulator to Okhla barrage. *Typha angustata* is the dominant plant species present in the marshy areas. Fragmentation and destruction of marshy areas have taken place due to the construction of the Noida toll bridge and other civic structures. Marshy areas present on the banks of the Yamuna River provide nesting and feeding grounds for many migrating waterfowl species. Thus, marshy areas are of prime importance with respect to their potential to act as waterfowl habitat.

The extent of these wetland types were mapped out by field surveys of the respective areas. The area of various wetland types is given below:

Types of Wetland Ecosystem: Area in Ha

Floodplain	3100
Marshy Area	110
Seasonal Pools	40
Total Area of Wetlands:	3250

This floodplain area is shrinking due to the rapid urbanization of Delhi. In this way, valuable ecological functions and their corresponding benefits are irrevocably lost. The major hurdle in the process of an efficient decision regarding sustainable use of these natural resources is generally due to the lack of a monetary value of these functions so that it can be incorporated into extended cost-benefit analysis of the conversion of these areas.

Methodology and Data

Since the identification of the area of floodplains in the Yamuna Basin is a complex issue, we primarily depended upon the data generated through the primary experiments and observations. Scientists of our investigating team, especially ecologists and hydrologists, have gathered information pertaining to ecosystem functions of floodplains through physical mapping and laboratory-based experiments. The data gathered was further verified through ground-truthing and consultation with the scientists working in this area at institutes like the Indian Agricultural Research Institute and the Central Ground Water Board.

Various methods followed for evaluating the functions and benefits accruing to the stakeholders have been provided in Table 1 and the findings are summarized in Table 2.

Table 1: Estimation Methods of Different Ecological Functions of Yamuna Floodplain

S. No.	Ecological Functions	Benefits	Beneficiaries	Valuation Methods
1.	**Water Recharge**	i) Low-cost irrigation cultivation	Farmers in floodplains	Production Function Approach
		ii) Potential source of water supply	Households in Delhi	Alternate cost of water supply
2.	**Nutrient Retention (N P)**	i) Fertility of soil	Farmers in floodplains	Replacement Cost Approach
3.	**Biological Productivity** I) Fish Breeding and Fish Fry	i) Fisheries Production	Local people & Government Departments	Market Value
	II) Sustenance to the Grass ecosystem	i) Fodder production	Local people	Indirect Substitution Method
		ii) Thatching Grass Production	Local people	Market Value
4.	**Habitat to Wildlife and Cleaning of the surrounding water**	i) Recreation, Existence and Bequest Values	Local and general people in the region	Contingent Valuation Method (CVM)

Table 2: Annual Economic Estimation of Selected Ecological Functions of the Floodplain

S. No.	Ecological Functions	Value (in Rs. Lakhs) Min.	Max.	Mean	Remarks
1.	Water Recharge Benefits to Agriculture	535943	535943	535943	• Production function for six major crops have been estimated from the cross section survey of farmers in the floodplains • Only water input has been allowed to be used optimally. • Cost of pumping of water has been linked with the fuel cost (variable cost only).
2.	Water Recharge Benefits to the households of Delhi Region	511	609	560	• Alternate cost of water has been estimated for different sources of supply. • The cost of supply includes raw water cost, transportation cost and treatment cost. Distribution cost has been excluded. • For calculation purpose, only that water, which reaches the aquifer in the study area, has been considered.
3.		1.66	3.44	2.55	• The cost in procuring the equivalent amount of N, P & K through the chemical fertilizers (Urea, DAP and Muriat or Potash) has been treated as the nutrient retention benefits. • Maximum and minimum values of nutrients are according to the availability of nutrients along with the amount of sediments in the flooding season.
4.	Biological Productivity i) Fishery	377.28	503.04	440.16	• Two prices (composite) i.e. contract and market gives the lower and higher estimate.
	ii) Fodder	5.57	342.43	174.00	• Current market price of fodder gives the higher value, while opportunity cost of labour to collect the equivalent quantity of fodder gives the lower range of value.
	iii) Thatching Grass	4.82	6.02	5.42	• Primarily two types of grasses namely *S.Munja* and *T.aungustata*, which are in great demand for Mats and Roof purposes.
	iv) Others (production of Cucurbits etc.)	19.20	19.20	19.20	• Here, the production of Watermelon, Sweetmelon etc. have been accounted.
		213.00	277.74	245.37	Under Contingent Valuation Method (CVM), through the dichotomous choice questionnaire has been used to derive the value for use, bequest and existence values. Choice of model (linear and log-linear) gives the range of values.

Preservation vs. Development of Land Uses in the Floodplain Area

The study shows that the benefits of preservation of land under floodplain as they exist currently, far exceed the benefits of conversion of the same land for other uses e.g. township development, industrial activity, etc. The benefit-cost analysis performed on the preservation of land versus conversion of the floodplain area sufficiently justifies the preservation argument.

Since these floodplains are part of the metropolitan area of Delhi, there is a constant pressure on this area for conversion for different developmental activities like construction, industrial township and thermal power stations, etc. Also, a major part of the floodplains area has been encroached upon by illegal slum dwellers. The developmental benefits of the floodplains are slightly problematic, as far as their estimation is concerned. Since the developmental activities are heterogeneous and involve substantial cost on which reliable information is not available, computation of developmental benefits became difficult. One good approximation of developmental benefits could be the price of the land paid by the development agency like Delhi Development Authority (DDA). This one-time price paid by the DDA may be treated as the discounted value (Capitalized Value) of all the development benefits accruing over a period of time extending to infinity.

The B/C ratio varies from 6.91 to 1.15 at 2 percent and 12 percent rates of discount respectively. Such a favourable ratio eminently justifies the conservation arguments on the basis of efficiency criteria. Moreover, a few ecosystem functions, e.g. bioremediation and recharge of distant aquifers, remain unaccounted and unpriced in this study due to time and resource constraints. In any case, this exercise provides a rationale for preservation of this floodplain. This also suggests that any activity like channelization of the river, which impairs the health of floodplain ecosystems, should be avoided.

Recommendations

- The annual flow value of ecological functions of the floodplains of the Yamuna River is quite substantial. This value is much higher than the return or alternate uses i.e. for housing and industrial activities.
- The value of habitat and recreational element of the floodplain is also very significant. Since the area of the floodplain has considerably reduced due to the rapid urbanization of Delhi, the relative value of these areas will increase exponentially as Delhi continues to expand at the present rate. Therefore, keeping alive this productive ecosystem is crucial for the city planners and the public.
- The loss of ecological functions provided by floodplain inflict a heavy cost on society in terms of its tangible and intangible benefits. Among all the values, the value of water recharge function is highest. Since the urban ecosystem of Delhi is water scarce, the conservation of the floodplain becomes a prerequisite.
- As recharged water into the aquifer from Yamuna floodplain area is of very high quality, maintenance and preservation of this wetland will substantially save the treatment cost of water, which the city of Delhi would have to meet otherwise.
- Since the floodplain provides habitat to a large number of bird species in the Okhla Bird Sanctuary, and the Willingness To Pay (WTP) for preservation of biodiversity is quite high, floodplain preservation needs added attention. Water is already a scarce commodity and in coming years, it is going to be more scarce and precious. Any human activity impairing the water recharge function of the floodplain ecosystem will create problems not only for the present but future generations as well.
- The River Yamuna should be allowed to flow as a river in Delhi. This would be possible only when a minimum level of water is allowed in the river round the year. The volume of water, which is diverted at Wazirabad barrage, should be determined keeping this fact in view.

Economic Valuation of Bhoj Wetland for Sustainable Use

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Introduction

The Bhoj wetland, located in the heart of Bhopal city, is a prime example of a wetland ecosystem vulnerable to degradation due to multiple uses by a rapidly increasing urban population. The various benefits that accrue to multiple stakeholders from this wetland are either under priced or not priced at all. The existing management strategy of the wetland does not value these various environmental services.

Objectives

The objectives of the study are to:

- Value various wetland benefits / resources so that planners and policy makers can make appropriate allocation of wetland uses and services.
- Develop a socially acceptable, environmentally sound and economically feasible strategy for Bhoj wetland management.

Study Area

The Bhoj Wetland comprises of two lakes: the Upper Lake and the Lower Lake. In 1988 the Ministry of Environment & Forests (MoEF) of the Government of India declared the Upper and the Lower Lake to be a Wetland of National Importance. Bhoj Wetland is among the 16 wetlands in India to be included in the National Lake Conservation Plan (NCLP). In 2002, MoEF declared it as an internationally important wetland by including it in the Ramsar Convention list. The present Upper Lake is the highly diminished remains of a large lake constructed by Raja Bhoj in the 11th century. Its catchment area measures 361 km^2 and it has a water-spread area of 31 km^2. The Lower Lake also known as the Chota Talab or Small Lake is situated towards the east end of the Upper Lake and is almost fully surrounded by built-up areas. It has a small catchment area of 9.60 km^2 and a water spread area of 1.29 km^2. The Lower Lake receives its inflow in the form of seepage from the Upper Lake in addition to the drainage coming from 8 nallahs or drains. The water level is maintained at a constant point by regular outflow through a waste weir at Pul-Pukhta into Patra Nallah.

Multiple Uses of the Bhoj Wetland

The Bhoj Wetland provides:

- Drinking Water: Nearly half the city's drinking water supply comes from the Upper Lake, which provides 64.4 million litres of water per day. This is the most important use of the wetland, directly impacting the welfare of the citizens of Bhopal.
- Employment: The Wetland directly and indirectly provides employment to various communities like fishermen, washermen, boatmen, vendors and others. Approximately 300 families are engaged in fishing and trapa (water chestnut) cultivation while about 100 washermen make their living from the Wetland. There are approximately 50 boatmen whose livelihood depends on the Bhoj Wetland.
- Microclimate Stability: The microclimate of Bhopal is quite moderate as compared to the surrounding areas. According to its geographical location, the city should actually have an extreme type of climate. The Wetland's moderating effect on temperature however, results in cool land breeze during the evenings which make the environment of the city enjoyable, even during the peak of summer. Vegetative cover adds to this effect.

- Recreation Opportunities: The Wetland offers recreational activities to the people of Bhopal such as boating and other water sports, as well as scenic views.

Threats to the Wetland

The Bhoj Wetland faces major threats from siltation, solid waste pollutants, sewage, pollutants resulting from washing clothes, trapa cultivation, encroachment, increasing population, weeds and eutrophication, boating, agricultural waste, idol and tadjia immersion, and hospital waste on account of excessive use by large numbers of stakeholders.

Methodology

The study first identified the various stakeholders of the Bhoj Wetland through a pilot survey. Following this, a stakeholders' workshop was conducted to identify the management issues of the Bhoj Wetland. The stakeholders' workshop used the 'Sticky Cloth and Paper' method to facilitate discussion. The multiple stakeholders were identified as the entire population of Bhopal city, washermen, boatmen, water chestnut or trapa cultivators, fishermen, NGOs, various line departments, and corporators of different wards, among others.

Stakeholders of the Bhoj Wetland

- **Entire Population of Bhopal city** – for drinking water and recreation
- **Lake front property owners** - for aesthetic beauty
- **Washermen** - for washing clothes in the lake
- **Fishermen** - for fishing activities
- **Trapa cultivators** - for cultivating trapa
- **Water supply agencies** - for water purification and distribution
- **Bhopal Municipal Corporation** - for management of the Lake
- **Department of Housing & Environment, Govt. of Madhya Pradesh** - for decision making processes
- **Madhya Pradesh Tourism Development Corporation (MPTDC)** - for tourism development on the lake
- **Vendors** - for secondary benefits

Three major issues, viz. sewage and waste disposal, fishing and washing activities and recreational activities were recommended to be addressed for sustainable management of the wetland. This was followed by development of an ecosystem model using STELLA software based on water quality parameters. Various simulation runs were carried out by changing the parametric values. The results of the modelling exercise were used for scenario building to administer the valuation techniques such as Contingent Valuation Method (CVM) and Hedonic Pricing by conducting a sample survey of all the wards of the Bhopal City.

Results

Ecosystem Modelling of the Bhoj Wetland Using Water Quality Parameters

The main objective of the Ecosystem Modeling of the Bhoj Wetland was to understand its physical characteristics to enable stakeholders to have a better understanding of the resource which is to be valued.

An ecosystem model using the water quality parameters was developed to study the current status of the lake, followed by changes in these parameters over the last few years. The model was also used to project the status of the Upper and Lower Lakes in the future, based on past data and information from the restoration activities currently being carried out. A base scenario was developed and then by changing the value of various parameters, simulation runs were carried out.

The basic ecological parameters brought under the purview of the conceptual model for the Bhoj Wetland are sewage and proliferation of weeds. The other water quality related parameters like Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), pH, Total Hardness, Total Alkalinity, phosphate, Turbidity, Total Dissolved Solids (TDS) and Bacterial Count are correlated with these variables and with each other. Their dynamics in the lake's ecosystem is studied. Data from seven out of 32 Quality Monitoring Stations were used for water quality parameters representing different kinds of pressures on the Upper and Lower Lake.

An advanced ecological model was developed using a system's dynamics software package STELLA. A model was developed representing the base scenario and simulation runs were carried using data of 1991-92 and 1999. The scenarios so obtained actually represent the health of the lake ecosystem and stress the need to value the impact of the changing health of the lake on an economic system. They further throw light on prioritization of future policy interventions, which shall be required if the lake is to be sustainably managed.

Economic Valuation of Wetland Benefits

The scenarios so obtained through ecosystem modeling exercise were represented through various visual presentations and figures. These graphs were then converted into picture cards for easier explanation of status of the lake to the respondents in the survey. Having attempted the ecosystem modeling and knowing the extent of degradation and threats, valuation was undertaken so as to cover the extent of monetary benefits or losses to various stakeholders where benefits are directly or indirectly marketed. As the benefits as well as the users are multiple, a spectrum of valuation techniques have been used to capture the economic value of various uses.

The valuation exercise included: calculating the benefits of supplying drinking water to the city; the value of benefits accruing to various people whose livelihoods depended on the wetland; the value of preventive measures that people used to avoid water borne diseases, and the willingness of the people of Bhopal to pay for enjoying better recreational facilities from the Bhoj Wetland. In addition to this, the effect of the presence of the Upper Lake on the value of property prices was also studied and estimated.

Valuation of Recreation

To estimate the recreational value of the Bhoj Wetland, all 66 wards of the city covering 1500 households were surveyed, as this value accrues to all the residents of Bhopal. The technique of CVM was employed to obtain the willingness to pay by people (WTP) for improved recreational facilities at the Bhoj Wetland. The CVM was administered through a questionnaire-based survey with an initial open ended, followed by closed ended bidding model. The questionnaire comprised of attitudinal questions and scenario building. Two types of payment vehicles were proposed - one in the form of a voluntary payment to the body that would undertake the management of the Bhoj Wetland in the future; and the second, a compulsory tax imposed on the people of the city, the collections of which would go to this maintenance society.

The following were expressed by the people in terms of the WTP in terms of the voluntary payment and tax (Table 1). The values so obtained were then extrapolated for the entire city to estimate the value of the lake in terms of recreation (Table 2).

Table 1. Mean and median willingness to pay voluntarily (FINVOL) and in the form of tax (FINTAX)

	FINVOL	FINTAX
Mean	537.85	219.17
Median	241.00	29.50

Table 2: Estimated WTP For Entire City

Median FINVOL per household per annum = Rs 241/-	Total Number of households in City = 2,01,116	Total Voluntary WTP per annum = Rs 48.4 million
Median FINTAX per household per annum = Rs 29.50/-		Total WTP as tax per annum = Rs 5.9 million

Valuation of Property Prices

This valuation exercise attempted to calculate the proportion by which the closeness to the Upper Lake affects property prices. For this exercise, people's attitudes and the importance they give to particular factors while buying a piece of property, were studied. In the second step property prices in particular areas of the city were obtained, and these areas were then ranked against parameters of neighborhood, proximity to markets, ease of access, environment, housing density and presence and absence of the lake. A regression model was created for this equation and from that, the effect of the presence of the lake on property prices was gauged. The analysis found that the price of a site near the lakes, similar in all other respects to a site away from the lakes, would be nearly 50 percent higher.

Comparative analysis of Various Values

Various other values generated incomes to stakeholders from activities like fish production, boating, Trapa cultivation, washing of clothes, and secondary selling activities, among others. Then the values were measured in terms of cost incurred by the population for treatment of water borne diseases, as well as the cost of getting high-quality water. Agencies incurred supply costs to purify and distribute water. The values so estimated using various valuation techniques are summarized in Table 3.

Table 3: Estimation of Economic Values of the Bhoj Wetland (Annual 1999-2000)

Uses / Impacts	Stakeholders	Valuation Techniques	Value (in Rs.)
A. Drinking Water	Water supplying agencies	Supply Cost	9,54,13,962
B. Fish Production	Fishermen	Market Price of Existing Production	80,00,000
C. Boating	Boatmen	Income Estimation	24,37,880
D. *Trapa* cultivation	*Trapa* (water chest nut) Cultivators	Market Price of Existing Production	50,00,000
E. Washing of clothes	Washermen	Income Estimation	36,00,000
F. Secondary Activities			
Maize cob selling	Maize Cobb sellers	Income Estimation	1,44,000
Sugar cane juice selling	Sugarcane juice sellers	Income Estimation	2,73,600
Snacks &cold drink stalls	Individual owners	Income Estimation	2,06,400
Horse rides	Individual owners	Income Estimation	7,92,000
MPTDC	MPTDC		
a. Cafeteria		Revenue Generation	18,00,000
b. Boating		Revenue Generation	6,74,635
G. Water borne Diseases	Population using lake's water	Cost of Illness	12,00,254
H. Quality water	Population using lake's water	Purification Costs	1,24,35,876
I. Recreation	Entire population of the city	CVM (i) As Voluntary Payment (ii) As Compulsory tax	 4,84,68,956 59,32,922
J. Increase in property prices	Lake front property owners	Hedonic pricing	50% higher property prices

Conclusion

It is evident from the Table 3 that the drinking water, recreation and property attributes command high values from the lake, whereas other income based values are important to specific sections of the people. All the values so estimated have not been aggregated, as some stakeholders use the lake for multiple values and such overlapping could not be avoided. Other important values like biodiversity and microclimatic effects have not been estimated due to lack of availability of data. The undertaken exercise however, does give a good insight of the multiple values that have not been considered to the extent possible in the current management activities.

Further, even if one is able to collect the revenue through what people were willing to pay in the from of voluntary payment to the society (Rs. 4,84,68,956 per annum), or in the from of tax to the government (Rs. 59,32,922/- per annum), the amount so collected would be much more than the existent estimated cost of maintenance of various subprojects of the Bhoj Wetland agency (Rs. 80,70,00/- per annum), if the collected revenue is from voluntary payment and reasonably collects 74% of the amount through taxes. With this, it is hoped that the authorities would keep the following recommendations in mind while implementing the current work and also before taking up fresh activities in the Wetland.

Technical Recommendations

The following suggestions are proposed to effectively implement the restoration sub-projects:

a. ***Preventive measures:*** Floating fountains have been put up in the Lower Lake at huge costs without completing the garland drain project, responsible for stopping sewage from entering the Lower Lake. As a result, on the one hand, sewage continues to flow unabated into the Lower Lake, while the floating fountains are supposed to aerate the Lake. The effect of the fountains is thus negated, and cannot be observed unless the flow of sewage is stopped.

b. ***Problems with the road:*** The Retghat–Lalghati Road has been constructed on the left bank of the Upper Lake, and is supposed to act as barrier to prevent encroachment. However, sewage through neighbouring colonies continues to flow underneath.

Policy Related recommendations

The critical need today is to recognize the inter-linkages and benefits that could be obtained if the Wetland is managed in an 'integrated manner' and is 'sustainably used'. It is a challenging task and requires action at many levels as well as delicate integrity of diversity of issues and management institutions. Such an approach must begin with involving all stakeholders in the Wetland in the form of a local area institution. This would be helpful in eliciting their views for the use and future management of the Bhoj Wetland. The Institution so formed could frame an action plan to cover all ecological, economic, social and institutional issues. To cover the above issues, the following set of policy recommendation is proposed:

- People's Participation
- Effective co-ordination
- Transparency in the System
- Setting up of a Bhoj Wetland Management Committee
- Economic Valuation
- Setting up of a Management Fund
- Cost Benefit Analysis
- Promotion of Eco-tourism
- Development of View Points
- Prioritisation of Activities Using Simulation Runs of the Proposed Ecological Model.

Integrated Management of Water Resources of Lake Nainital and its Watershed: An Environmental Economics Approach

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Introduction

It is widely recognised that water resources are greatly influenced – both qualitatively and quantitatively – by their catchment (watershed or drainage basin). Though the impacts of water pollution have been discussed from the viewpoint of environmental economics in several studies, the impacts of catchment-based activities have received little attention.

This project takes an integrated approach to understanding the problems of availability of water resources and aims at bringing an environmental economics perspective into water resources management by evaluating the resources of both the Lake and its watershed. Since the dependence of the lake on its watershed is emphasised, the lake condition is analysed both in relation to human activities in the watershed as well as in-lake activities. The study explores the hypothesis that if catchment-based degradation factors are not taken care of, the cost of conservation of the lake ecosystem would increase multi-fold.

Lake Nainital along with its watershed in Uttranchal was selected for the present study in view of its importance for at least two major ecosystem services: (i) as the major water source for the township of Nainital, and (ii) high recreational value for tourists. Since tourism is the principal economic activity in Nainital, the presence of the Lake becomes life supporting for the local population. Besides, it is a lake where the lake and its watershed are intimately connected.

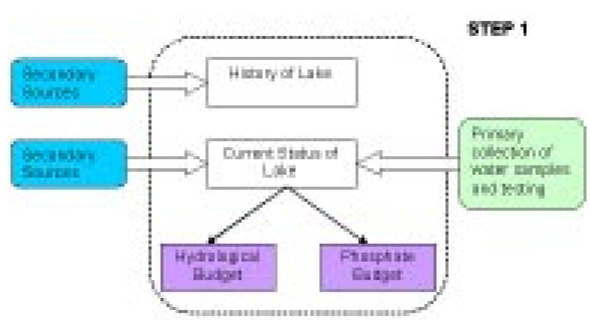
Objectives

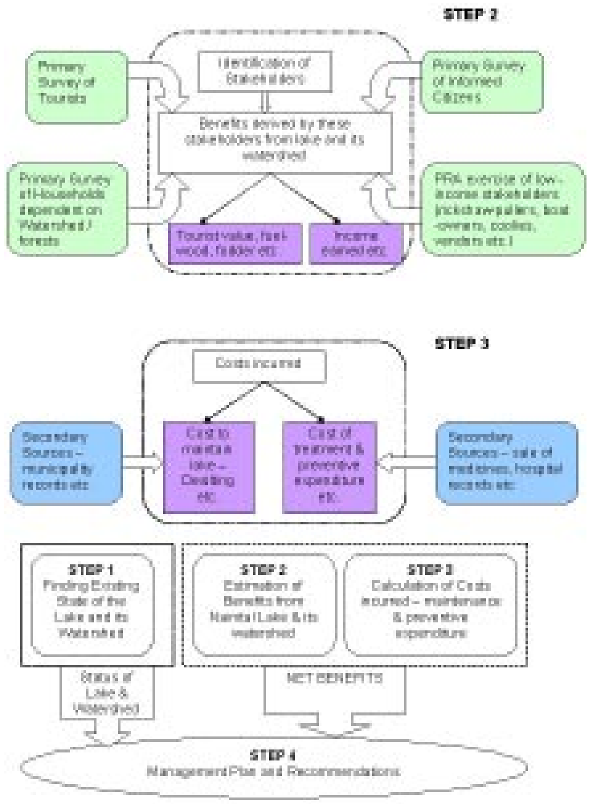
The specific objectives of the projects are to:

- Estimate costs and benefits of resource use of Lake Nainital and the lake watershed as well.
- Estimate cost of water quality degradation in Lake Nainital and its relationship with anthropogenic activities in the watershed.
- Develop a resource management policy for Lake Nainital and its watershed.

In order to meet the objectives of the study, both primary and secondary data was collected. The lake water quality was ascertained using secondary data as well as testing of samples at different points in the lake. On the other hand, the pollutant load to the lake was found from the water samples taken from the inflows and outflows to the lake. The primary survey involved interviewing tourists, households dependent on the watershed especially forests, and informed citizens of Nainital town. Besides these, a PRA (Participatory Rural Appraisal) exercise was carried out on a number of low-income stakeholders – boatmen, horsemen, coolies, rickshaw-pullers, vendors, etc. – entirely dependent on the Lake and its watershed for their livelihood. The entire exercise of meeting the three objectives was carried out in the following four stages / steps (Figure 1).

Fig. 1: Different Steps followed to fulfil Project Objectives





Organisation of the Work

The work is organised in seven core parts. Part 1 gives in brief the historical sketch of Lake Nainital and its watershed, the current status of the lake and how the status has changed in the past and what are the factors contributing to these changes. Part 2 identifies the stakeholders and the possible values they derive from the lake. Though different stakeholders are benefiting from a unique ecology of the lake, the whole is much greater than the individual sum. The clear indication of this synergy effect is the tourism activity in Nainital. The tourists visit Nainital for the whole and not for an isolate and individual attribute. What values do they give, or in other words, how much they are willing to contribute to preserve the ecology of the lake forms Part 3. A revealed preference method, i.e., the Travel Cost Method, has been employed to calculate the tourist values.

It is generally argued that stakeholders are narrow in their viewpoint. The profession shapes their views / perceptions. For instance, a boatman would be more concerned with the well-being of the lake health; horsemen might wish to concentrate on peaks; tourists visiting Nainital will be more interested in the features around the lake and in the peaks, etc. Most of them would disregard, or are unaware of the services of the Lake and its watershed. It is the informed or aware citizens, who would value a natural resource for its totality not for an individual aspect. Part 4 is an attempt to look into how the informed citizens of Nainital perceive valuation exercises as such and which aspect of the Lake and its watershed they view as the most important for humankind and to the system.

The questionnaire method adopted in Parts 3 and 4 concentrates on responses from individuals. However, it is argued sometimes that they remain passive contributors. Therefore, in order to complement the questionnaire method, Participatory Rural Appraisal (PRA) exercise was carried out, which seeks the opinion of different stakeholders. Part 5 gives in brief the PRA technique and the results obtained therein from the exercise. Part 6 calculates the direct benefit in the form of fuel wood and fodder as obtained from the forests followed by summarising the benefits derived from the Lake and its watershed. Part 6 also gives the costs of maintenance or cost incurred by individuals to prevent any illness (i.e., preventive expenditure). The analysis shows that the Lake and its watershed provide innumerable tangible (and intangible) benefits to the local economy. The continuation of these benefits in the future requires proper maintenance and management of the Lake and its watershed. The last part is devoted to the management aspects and incorporates both technological and institutional components of management.

Study Area

Ecology of the Lake and its Watershed

Discovered first in 1841, Nainital (29°24' N latitude and 79°29' E longitude at 1,938 m above sea level) is one of the major hill resorts of North India. It supports a resident population of about 40,000 (with a floating population of nearly 7,000 during tourist season) and attracts 3-4 lakh tourists annually within a small area of 11-12 km^2.

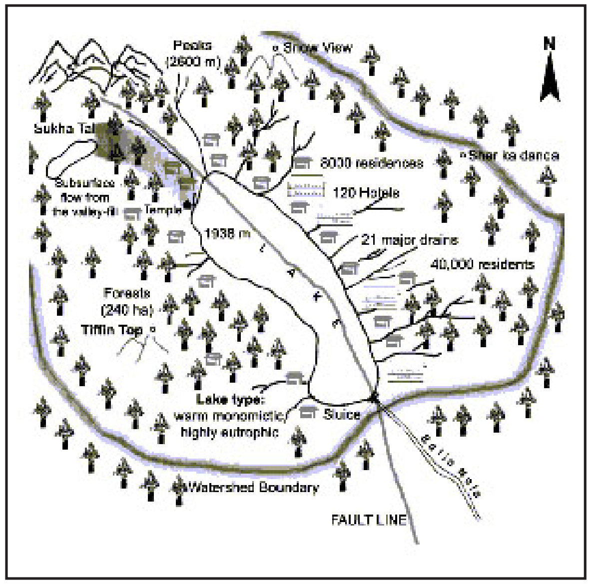
Of this, about 5 km^2 area that forms the watershed of the lake is densely populated. The climate is temperate monsoon type, with annual rainfall generally ranging between 200-250 cm. Geologically, Nainital is extremely complex and fragile, characterised by landslide scars and fans, and debris cover, mostly associated with the Nainital Fault that separates the lake and watershed into two roughly equal parts (Fig. 2). Already seven major landslides have occurred during the last century.

The lake receives water from its catchment through 21 major drains, springs, runoff and subsurface inflows (Fig. 2). The hydrological budget of the lake shows that most of the water in the lake owes its origin to the watershed in the form of surface flow (25%) and subsurface inflow (42.8%). Direct precipitation accounts for only 15 percent of the total annual inflow. However, much of the water that enters the lake is affected by organic and heavy metal pollution. For example, the biochemical oxygen demand (BOD) of the drains range between 60-74 mg/l and bacterial population is up to 1,218 colony forming (coliform) units/ml. The concentration of lead in the lake water often exceeds the permissible level, vehicles and excessive use of lead containing paints particularly on tin roofs being the major sources.

The valley-fill in the catchment is the major source of subsurface water to the lake (accounting for over 40% of total inflow) and is used directly for drinking water supply. The forest cover (mainly oak and cypress) is still substantial, accounting for about 48 percent of the catchment area and providing habitat for nearly 700 plant species and about 200 species of birds.

The lake is small with the following morphometrics: maximum length of 1,423 m, breadth 253-423 m, maximum depth 27.3 m, surface area 48 ha and volume at maximum level 8.58 million m^3. The lake volume is gradually declining due to sedimentation caused by landslides, erosion and illegal dumping of construction waste in drains and on slopes. The young and rising mountains with immature topography are highly vulnerable to destabilising forces. Life expectancy of the lake is estimated to be less than 500 years.

Fig. 2: A sketch of Nainital Lake and its catchment



The lake is warm monomictic with fairly stable summer time thermal stratification and highly eutrophic with almost opaque water (Secchi disk transparency generally less than a meter).

Stakeholders and Benefits they derive from the Lake and its Watershed

As the study has three objectives, to fulfil them it is essential to find out what are the stakeholders in the Lake and its watershed and what benefits they are deriving from the lake and its watershed.

Conceptually, the total value of a system/ resource is the sum of use values – direct, indirect and option - and non-use values. Direct use values can either be consumptive or non-consumptive. In Lake Nainital and its watershed, taking water from the lake for drinking or other purpose is clearly a consumptive use, whereas boating in the lake is an example of non-consumptive value. Lake Nainital and its watershed provides a plethora of consumptive and non-consumptive values, besides having non-use values in terms of existence, culture, bequest, intrinsic, religious and heritage value. The study identifies a number of stakeholders in Nainital Lake and its watershed and the benefits they derive (Table 1).

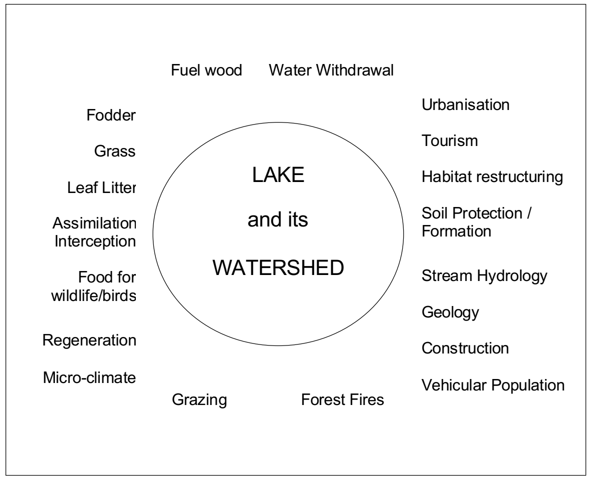
Table 1: Stakeholders in Nainital Lake and its Watershed with Benefits / Values derived

No.	Stakeholders	Benefit or Value Stakeholders Deriving from	Type of Value
1	Local Population	Income generated by hotel and tourism industries	Non-consumptive use value
2	Tourists	Derive services of recreation, education and tourism	Non-consumptive use value
3	Boatman	Lake through income generated from tourism	Non-consumptive use value
4	Horseman	Hills / peaks through income generated from tourism	Non-consumptive use value
5	Rickshaw -pullers, Taxi-owners etc.	Income generated from tourism	Non-consumptive use value
6	Vendors, Shop owners, Petty Traders	Income generated from tourism	Non-consumptive use value
7	Population of Nainital Town	Lake as the source of drinking & other water supply	Consumptive use value
8	Local Municipality	Revenue from the Toll charged from tourists & saving in water-treatment plant costs because of natural cleansing property of lake & its watershed	Non-consumptive use value
9	Lake Management Authority	Responsible for the maintenance of the ecological health of the lake & its watershed such that the economic benefits continue	Non-consumptive use value
10	Low-income group	Income / saving in expenditure through collection of fuel wood, fodder etc.	Consumptive use value
11	Scientists and Ecologists	By putting a premium on the existence value of the lake and its watershed such that research activity continues	Non-consumptive non-use value
12	Non-users	Value the existence of lake & its watershed	Non-consumptive Non-use value

Note: Many of the stakeholders like petty vendors, rickshaw-pullers, horse-owners etc. are not the local inhabitants; they migrate during the tourist season. Hence are given separately.

Thus a large number of stakeholders depend on the Lake and its watershed for a number of goods and services. It is quite ironic that some of these are, in fact the cause of anthropogenic pressure also. Figure 3 gives a simplified summary of anthropogenic pressures on Lake Nainital and its watershed.

Fig. 3: A summary of Anthropogenic Pressure on the Lake and its Watershed



Impact of Anthropogenic Pressure - Problem of Eutrophication

One of the implications of this anthropogenic pressure is that the lake has become eutrophic (i.e., with excess phosphate), and this has adversely affected its recreational and aesthetic values. The population of game fish has declined dramatically, and the lake is no longer used for recreational fishing and swimming. Seasonal oxygen depletion and consequent fish mortality, release of toxins and algal blooms, have become quite common in the lake.

The study has attempted to compute a phosphate (PO_4) budget for the lake using hydrological data of NIH, Roorkee and concentration of PO_4 in various inflows and outflows measured from the samples taken at various places. The budget indicates that the lake has approached the condition of irreversible eutrophication, as of the total annual inflow of 643.3 kg, nearly 25 percent i.e., 159 is retained in the lake. The phosphate budget points out that the steady state phosphate level cannot be reduced drastically by taking measures that control only the phosphorus input to the lake. The hypolimnion (up to 15 m thick) remains anoxic for much of the year; consequently the phosphorus of the sediment gets readily soluble and recycled. Restoration that involves the treatment of the sediment, which accumulates P at the rate of about 114 kg/yr and the anoxic hypolimnion, is necessary to revive the lake to a healthy condition. Removal of phosphorus from detergents and treatment of the watershed (better network of sewer lines and afforestation) are some of the measures required.

Impact of Anthropogenic Pressure - Cost of unsafe drinking water

Another consequence of the anthropogenic pressure is the quality of water of the Lake, which in turn is used by the local population for drinking after some minimal treatment. Though the Jal Sansthan (Water Board) claims that the quality of drinking water supplied is safe, peoples' behaviour connotes differently, as they spend a substantial amount of money to make it safe. The cost of unsafe water includes the cost of buying bottled water, use of water purifying devices and the treatment of waterborne diseases, which are rapidly increasing. This amounts to about Rs.6 million annually, of which about 60 percent is spent on medical expenses alone. Decline in human resource capital and loss of working hours could not be calculated, as that requires an in-depth socio-economic survey of the local people.

Benefits and Economic Valuation

As given in Table 1, the Lake and its watershed bestows a number of consumptive as well as non-consumptive uses for a large number of stakeholders. Besides these, the Lake and watershed provides a number of goods and services, which have no substitute. Some of these services are:

- Lower cost of water treatment because of filtration while passing though forests and valley fills.
- Direct water supply without treatment from Sukhatal valley-fill and various springs.
- Increased turnover of lake water flushing.
- Increased hill-slope protection by the forests.
- Reduced cost of silt removal due to the forest cover.
- Carbon sequestration by the forests.
- Support to activities like bird watching and the trade of photography.

Estimating value of the Lake and its Watershed from Tourism – use of Travel Cost Method

In order to estimate the value of the Lake and its watershed from tourism, a revealed preference indirect proxy method – the travel cost method – is employed. Assigning a proper value to the Lake and its watershed from tourism is also a sine quo non from the policy-makers point of view if they aim at restricting / curtailing catchment-based anthropogenic activity in the watershed.

When the preferences are expressed on a market, it is easy to estimate the demand for a good or a service, provided the market price is not the distorted one. However, as seen above, most of the natural resources and the functions they perform have no market value. For such cases having no market, two alternate approaches are usually adopted. In one approach known as the stated preference method, a hypothetical market situation is created and individuals are asked their willingness to preserve the natural resource. The second approach, known as revealed preference method, uses the behaviour of the individuals to approximate the price of a natural resource.

To estimate the recreational value of Lake Nainital in the present study, a revealed preference method i.e., the travel cost method (TCM) is used. In the method, the expenditure incurred on visiting Lake Nainital is treated as a revelation of a tourist's preference for the (environmental) services provided by it. The variations in travel costs and visitation rate are used to estimate a demand curve. The area under the demand curve (i.e., the consumer surplus) measures the willingness to pay (WTP) of consumers for the environmental goods and services. The basic premise is to use the cost of travel as surrogate for the WTP for using the Nainital site. Besides actual transportation costs, the travel costs may also include tariffs paid at hotels and the opportunity cost of travel time spent on the journey, as a proxy for asset value of the recreation site.

Before moving further, it needs to be stressed that these non-consumptive direct use values are lower estimates of the total social benefits of the lake and its watershed. This is because the total economic value (TEV) of the natural resource requires estimation of both use and non-use values (refer to Table 1). Incidentally, in the present study the focus is only on the use value.

Zonal Travel Cost Method

In the TCM also, there exist two approaches to estimate the demand function – the Zonal Travel Cost Method (ZTCM) and the Individual Travel Cost Method (ITCM). In the ZTCM, the unit of analysis is the Zone. Under this method, visitors are divided into different zones of origin. A visitation rate is then calculated for each zone given by the number of visits to the Lake per year from a zone to the total population of the zone i.e., the rate of participation per capita. On the other hand, the dependent variable in the ITCM is the number of trips per period made to a site by each individual. Practically, ITCM works best when individuals take a highly variable number of trips in the period to the site e.g., a park or zoo in the city. However, when recreation sites are greater than 2-3 hours driving time distance from their homes, multiple visits to a site by an individual become less common. Under the situation, the ZTCM is better.

In the case of Nainital though, visitors are predominantly from the North Zone (nearly 75%), but in general they have to travel more than 3-4 hours to reach Nainital. This implies that multiple visits to Nainital by an individual are not possible and the utility of ITCM is highly restricted. This is also substantiated by our data on 273 surveyed visitors. More than 55 percent of visitors were visiting Nainital for the first time. Of the 122 visitors that had visited Nainital earlier, only 18percent had multiple visits during the year, while the remaining 82 percent had visited Nainital two or more years ago.

There is a basic difference between other studies and the present study - the earlier studies have used a larger definition of a zone, where concentric circles have been used to form zones. The underlying assumption is that the costs to travel will be the same within the circle. This assumption is valid mainly in the case of developed countries. But for a country like India, where available infrastructure is highly skewed, such a definition would not work. The discussion with the tourists and the local people revealed that some of the places in Uttranchal though are one-fourth the distance vis-à-vis Delhi or Meerut, but the time taken may be much more than coming from Delhi or Meerut, and sometimes even more expensive to reach. This motivated us to consider each district as one zone and do a Zonal analysis.

While constructing the variables, three major issues arose – (a) how to account costs for the persons who have come by car, but could not elicit precisely how much they had spent on travel; (b) how to value housewives time; and (c) how to assign value to the travel time (i.e., the opportunity cost of travel time). These issues were effectively tackled in the study.

The consumer surplus arrived at by the use of ZTCM from tourism suggests that the WTP to preserve Lake Nainital and its watershed varies from Rs.4.3 million to Rs.5.27 million, depending on the functional form used. However, when travel cost consists of local cost also, the consumer surplus increases to Rs.5.60 million (for the linear model) to Rs.6.55 million (for the semi-log model). Since the lake and its watershed are spread over an area of 14.32 km^2, the recreation value per unit hectare comes out between Rs.3,022 to Rs.4,260. The values obtained are an underestimate of the total value that the people are willing to pay to preserve the Lake, as the method captures only the use-value, and that too is under represented. This is because the sampling did not consider foreigners, people on package tours and children.

Informed Citizens Views

Analysis of the responses of the informed citizens of Nainital indicates that the valuation exercise is a step towards conservation of resources and can contribute significantly to the planning for the study of watershed in other areas. The more educated and environmentally aware residents have given great importance to the existence value of the lake and pointed out that soil, water quality, streams and springs are the major benefits to humans from the watershed. A majority of such citizens are willing to pay about Rs.1,000 annually for its conservation.

Stakeholders' Perceptions

Issues of environment and development warrant integration, not only of ecological and economic factors but also social ones. The results of PRA techniques were based on nine stakeholder groups. These include boatmen, horsemen, coolies, rickshaw-puller, vendors, tourists, professionals, hoteliers and citizens. We treated it as a complementary tool to the questionnaire survey to look into the perceptions of different stakeholders. The difference in perception across different stakeholder groups clearly indicates that to achieve participatory management, they are to be effectively included in the development of any management plan. For example, while a number of stakeholder groups appear to be lake-centred, horsemen were mainly interested in peaks and view-sites, adding new dimensions to tourist interest and attractions based on nature.

Nearly Rs.400 million is primarily generated through tourism, of which about 17 percent is distributed across the poorer stakeholders groups numbering over 1,600 individuals comprising rickshaw-pullers, horsemen, boatmen, coolies and vendors. The average income of poor stakeholders as calculated by PRA during summer tourism season is as follows: rickshaw puller – Rs.6,750; horseman – Rs.31,500; boatman – Rs.36,000; vendors Rs.18,000; and coolies – Rs.13,500. When considered in relation to the lake area, the density of money flow is about Rs.10.5 million/ hectare annually, which is enormous given the fact that this is only a fraction of the total economy of more than Rs.420 million (a crude estimate) based on tourism (Table 2).

Table 2: Summary of Annual Benefits and Costs to different Stakeholders

Benefits/ Costs	Beneficiary/ Losers	Valuation Technique	Benefits (Rs.x10^6)	Costs (Rs.x10^6)
Primary Benefits#				
Direct	Income from Forests Use	Market Price of Existing Products (fuel wood & fodder)	1.8	
	Drinking Water Supply	Cost of alternate scheme	NA	
Indirect	Recreation Benefits	TCM	4.3– 6.6	
	Non-use Values		NA	
	Cost saved due to lower erosion from the forested watershed than from non-forested watershed	As Removal cost of Silt from the shallow parts of the lake	0.2	
Secondary Benefits$				
Direct	Total earnings of poor stakeholders like Rickshaw-pullers, horsemen, boatmen, vendors, coolies	Income Estimation	56.6	
	Hoteliers Earnings	Income Estimation	315.4	
	Taxi Earnings	Income Estimation	27.0	
	Municipality – Luxury Tax from Hotels	Revenue Generation	6.0	
	Municipality – Revenue from Vehicles Toll Tax Passes	Revenue Generation	0.4	
	Municipality – Revenue from Vehicles (Toll Tax)²	Revenue Generation	3.2	
Costs	Purification Cost – cost of filtering, boiling, bottled water etc.	Purification Costs		2.4
	Cost of treatment for water-borne diseases	Cost of Illness		3.6
	Cost of construction of public toilets^	Cost of Prevention of Nutrients Inputs		13.3
	Desilting of Lake~			0.5
	Cost of maintenance of Sewer system			0.9
	Total		**423.6**	**20.7**

The approximate value of economy generated annually due to the Lake and its watershed comes to about Rs.50 million per hectare. It is quite apparent from the above table that most of the benefits are lake-centred, and the continuity of these benefits from the Lake would necessitate that it would not get degraded. In fact, generation of such a huge amount has heavy environmental costs on the eco-geologically fragile watershed. As a consequence of this, the restoration of the Lake is quite expected and justified.

Limitation of Travel Cost Method

The travel cost method we used to estimate the value of Lake Nainital and its watershed relates to several ecosystem services such as filtration and storage of water by the Sukhatal valley-fill, and concomitant influence on the lake level, pollution abatement, recreational values, and direct drinking water supply. However, their specific contributions go unestimated in this method. It is always difficult to estimate the entire valuation of non-consumptive components, and this applies also to the present lakescape. For example, we could not find the impact of decline in the Lake's aesthetic and recreational values on tourism. Also, it was not possible to address the specific questions such as how the ban of fishing and swimming affected tourism and attraction of Nainital as a living place.

Our study however, makes it abundantly clear that we must give appropriate weight to the "natural capital stock" (lake, forests and others) that produces various ecosystem services in the decision-making process. The health of natural capital stock heavily depends on ecosystem connections, and interactions between ecosystems and connected abiotic components, such as rocks and valley-fills, which store water and subsequently release it to the lake and forests.

Economic Valuation and Management

According to Constanza and others, if ecosystem services were actually paid for, keeping their contributions to the economy, the price system would be very different from what we have. Our study has also shown that the ecosystem services of Nainital Lake and its watershed have considerable value. The estimates we have arrived at should be incorporated into the regional accounting to have a more sustainable development, and a future that does not drastically suffer on account of ecosystem degradation.

The ecological observations indicate that the Lake is highly eutrophic, approaching an irreversible stage, and thus warrants restoration. Measures such as reduction in input of nutrients and maintenance of a healthy watershed are desired, as they have meaning even when the Lake is revived and the steady state P-level is drastically reduced. The restoration cost can be justified, considering the values of ecosystem services over a long horizon. In recent years, some minor restoration activities such as desilting of shallow parts of the Lake and construction and maintenance of drainage network have been taken up, involving an expenditure of Rs.3.9 lakhs annually. These activities have resulted in a minor improvement in the lake condition.

According to the recent estimates by CMPNL (Comprehensive Master Plan for Nainital Lake, 2002) approximately Rs.188 million would be required to bring about restoration of Lake Nainital. The major expenses are likely to be: (i) conversion of the Lake from the present hyper-eutrophic state to oligotrophic state through in-lake restoration works (siphoning-off the lake bottom, controlled aeration of deeper water, dredging of banks and introduction of ecologically appropriate fishes) would amount to Rs.81.7 million; and (ii) watershed treatment to prevent inputs of nutrients and pollutants (construction of additional sewer lines and community toilets, improvement of sanitation infrastructure, and activities such as plantation, bioengineering, and landslide treatment), which would amount to Rs.106.3 million. This one-time cost of Rs.188 million is justified keeping in view that the total economic activity generated through tourism is approximately about Rs.500 million/year.

Furthermore, while undertaking a specific project in the watershed, the benefits accruing should be weighed against the loss it may cause to ecosystem service and tourism value. For example, the construction of a car park in Sukhatal valley-fill may damage its capacity to provide filtered and clean subsurface water to the Lake, resulting in its rapid deterioration. This in turn, is likely to reduce its tourism value.

The study finds that the Lake warrants ecological restoration on a priority basis, and that is a difficult task given the geological sensitivities and insensitivities of administrators and decision makers (so far no Indian lake has been restored). Still, the study has come up with some policy recommendations – the adherence to which would lead to restoration of the Lake.

Recommendations

- At present the responsibilities of managing the lakescape is distributed across numerous departments in a fragmented manner. An integrated unit of development that focuses on the Lake and its watershed and their interconnections is required. In other words, the entire lakescape should be treated as the unit of management. Problems of the Lake as an ecosystem, rather than water as goods should be addressed. While addressing the problems of the Lake, both in-lake, and lake and watershed connections should be given due weightage. For example, we need to conserve Sukhatal valley-fill so that its services that are important for the Lake continue to flow, such as, water filtration, dilution of lake pollutants, and maintenance of lake-water level.

- A restoration work that addresses the issues of irreversible eutrophication is required. It is good that action is being taken to stop phosphorus input to the lake, but it may be insufficient to make the lake oligotrophic. This may warrant a complete documentation of P-budget and its recycling from the lake sediment, and treatment of the P-rich lake sediment. For removing P-rich sediment, information would be required on sediment chemistry, the area and thickness of the sediment that can be removed safely (from the standpoint of geological fragility and stability), periodicity of P-recycling from the sediment and cost involved. Other measures include siphoning-off anoxic hypolimnion water and deep aeration. For all these operations, the Ministry of Environment and Forests (MoEF), India has agreed to provide finances. However, maintenance costs would be required. Measures required to check input of P and other nutrients to the Lake include (i) ban on the use of P-containing detergents, (ii) connection of all bathrooms, toilets and kitchen to sewer lines, and (iii) provision of more public toilets.

- People's participation should be promoted at all levels: constituting bodies, decisions making, sharing responsibilities, and awareness programs, education, etc. Our PRA exercise showed that the participatory management should be stakeholder-based. There is a need to constitute an institution with due representation of all stakeholders (e.g. horsemen, boatmen, hawkers, hoteliers, tourists from different zones, traders), with the government as a facilitator. It would be an NGO or a cooperative of stakeholders. The scientists of Kumaun University would need to play a crucial role in monitoring and providing inputs relating to science and technology.

- A master plan keeping in view the carrying capacity should be the starting point of management.

- Arrangements should be made for pedestrians to promote safe walking along all motor roads. This would reduce traffic and air pollution.

- Both the zonal travel cost method and surveys undertaken to procure citizens perceptions indicate that direct payment for the lakescape conservation is possible. It could be in the form of a "green tax" for lake conservation, to be utilised under the supervision of stakeholders cooperative/NGO. Developing a conservation fund in such a way would also give the message that the lakescape is a precious resource to be managed sustainably.

- Forest cover should be maintained and forests should be well-stocked as they play a significant role in the control of soil erosion, retention of water and its release in the form of springs.

- The ban on tree cutting should continue for urban areas, even when it is lifted for the region.

Thus, to conclude, the study made an attempt to estimate the value of Lake Nainital and its watershed. The economic estimates we arrived at though did not consider all the ecosystem services; yet, they were reflected to some extent. The project has also attempted to integrate ecological economics and social perspectives by considering a variety of stakeholders while analysing various geological components.

Environmental Conservation and Valuation of East Kolkata Wetlands

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Introduction

Kolkata is a city of 14 million inhabitants in West Bengal. A wetland area of $78km^2$ marks the eastern fringes of this city. Over the past 100 years, this area has developed into a very sophisticated waste treatment, nutrient capturing and recycling system. The wetlands take all the sewage and wastewater from Kolkata through drainage channels and canals. The wastewater is used for fish cultivation and irrigation of vegetable plots, having been cleansed by the natural action of a large mass of plant matter and sunlight in ponds of no more than three meters in depth. The wetlands also take the solid waste of Kolkata. After scavenging, the residue is spread on land and supports three crops of vegetables each year. The entire recycling and recovery system provides direct employment to over 70,000 people and has no fossil fuel energy requirements. This tradition is now endangered. These wetlands are today under threat of encroachment, and perhaps extinction - mainly because of the pressures exerted by the ever-expanding metropolis, Kolkata.

Kolkata is uniquely privileged to have a built-in tradition of using urban waste in fisheries and agriculture, and thereby employing a remarkable natural system to help meet three basic problems faced by megacities - shortage of food, shortage of employment opportunities and shortage of funds to treat the waste. Instead of using stagnant water pool effluents in fisheries as a conventional alternative, here, fisheries are using an indigenous technique of sequencing sewage ingress[1] to become more efficient, effective, economically viable and environment friendly.

The present study is an attempt to bring out an ordered assimilation of various environmental issues and disorders relating to these East Kolkata Wetlands (EKW). A concomitant attempt is made to arrive at an economic valuation of the goods and services generated by these wetlands. The study is based partly on empirical data and partly on expert opinion survey.

Objectives

The broad objectives of the study were to:

- Identify economic activities associated with EKW.
- Estimate direct or indirect income and employment generated.
- Examine and weigh the arguments and justifications, if any, to divert the growth process of EKW towards rapid urbanization.
- Ascertain the nature and extent of damage likely to be caused to the ecosystem by the urban expansion.

Site

The study was primarily based on the area of Waste Recycling Region (WRR) defined by the Government of West Bengal. The area consisted of 32 moujas[2] from four police stations of three districts. Out of total area of 10,685 hectares, the study area covered 4,093 hectares. This included six moujas adjoining Rajarhat Police station, which was not included in the official map. The study covered 30 percent of the total wetland area. Out of the total listed households, 10 percent of households were canvassed.

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[1] *Technical term for Paracitology. It means systematic use of sewage effluent*
[2] *Mouja is an administrative unit consisting of two or three villages*
[3] *it includes among others increased number of crimes like murder, extortion, rape, dacoity, etc.*
[4] *Garbage farming is cultivation of green vegetables with the help of organic manure out of solid waste*

Methodology

Three different surveys were conducted. The major thrust was on 443 households staying within the EKW zone. The other two were directed to wetland experts and non-stakeholder citizens of Kolkata. In the household survey, direct questions were posed. The survey on experts was based on Delphi technique. The third study was basically opinion survey regarding general awareness of the citizens. For the household survey, a stratified random sampling method was followed. For the expert opinion survey, a Delphi panel was formed consisting of 46 members from 15 disciplines. To understand people's perception about the wetlands, an attempt was made to find out the association between willingness to pay (WTP) for preserving the wetlands and any of the factors like consumption, income, fishing land, agricultural land, fish production and agricultural production. The association of willingness to pay was found to correspond with consumption, income, holding size of agricultural land, agricultural production and fish production.

With a view to capturing cumulative variance, a stepwise multiple regression was attempted. From the OLS regression results, it was found that fishing land and agricultural production were statistically significant at five percent level with WTP. It was thus observed that people engaged in two crucial activities, pisciculture and agriculture were very keen to protect the wetlands.

Finally, an opportunity cost had been attempted on 1,500 hectares of wetland that was converted during the past ten years. A popular financial and partial equilibrium approach was followed. Due to the dearth of relevant data on the benefits from the alternative use of wetlands, we restricted our cost-benefit results only on the estimation of potential losses of 57,000 quintals of paddy alone among other crops, and a money value of Rs.338 million including fish production.

Results

In EKW, with the continuous conversion of agricultural land to non- agricultural use, the phenomenon had also been reflected in the occupational patterns. The average occupational holding of agricultural land was found to be 0.46 hectare, and for fishing ponds, 0.35 hectare. The produced crops of wetland agriculture are many. Apart from two types of paddy and vegetables, pulses, maize, sugarcane and oilseeds like mustard are grown there. Productivity of paddy was found to be 48.71 quintals per hectare, and for sewage fed fish it was 31 quintals per hectare.

Household data of the survey explained the fact that poverty was, on an average, 24 percent in EKW. Lorenz curves for four police stations (viz. Tiljala, Rajarhat, Bhangar and Sonarpur) showed gross inequality. Distribution of the population under poverty was found to be uneven among police stations. The largest number of poor had been found in Bhangar followed by Tiljala, Sonarpur and Rajarhat. The expenditure of the households was also found highly skewed in favor of consumption of food. Average annual household income of the EKW area was found Rs.32,395.

It was observed from the present study that EKW supports 1 lakh direct stakeholders and 5.1 thousand hectares of cultivation. It provides annual direct employment to a population of approximately 70,000, produces 1.28 lakh quintals of paddy, 69,000 quintals of fish and 7.3 lakh quintals of vegetables. It also generates gross revenues of Rs.266.75 million and net returns of Rs.79.64 million a year.

Many of the observations raised by the panel members in the expert opinion survey were as expected. For example, waste recycling and resource recovery system received the highest priority. This led to better hygiene in the city as well as wise use of the wetlands. The present area of EKW is less than one third of what it was during the 1950s.

People living in the wetland area were found to be concerned about the existence of the resource and expressed their WTP for the preservation of EKW. But inhabitants, being less ecologically educated than experts, had far less clear and distinct priorities when identifying environmental problems, from the point of view of their importance. Hence, the opinion expressed by non-stakeholder city dwellers differed on many counts from that of stakeholders and experts.

While a majority of the experts were of opinion that the wetlands would affect the sewage system of the city and reduce agricultural and fish production, only 50 percent of the non-expert citizens were also of the same opinion.

The average willingness to pay of the stakeholders was found to be Rs.143 per year, whereas on the part of non-stakeholder citizens the amounts ranged from Rs.60 to Rs.1,200 per year for the existence value of EKW.

The wetland ecosystem of Kolkata is a delicate, complex and under studied area, which requires immediate attention for the survival of the city. The study confirmed most of the common apprehensions on the vectors of threat operating on EKW. Further research would undoubtedly identify more numbers of specific threats.

Recommendations

- Changes in hydrological regimes, thereby affecting ecological balances and functions.
- Inundation of periphery, causes loss of property and life.
- Loss of agricultural and fish production and diversity lead to unemployment.
- Rise in urban pollution and social unrest[3] .

From the producers' point of view, fishing activities are going to be less profitable due to various reasons, mostly related to labor and poaching. While the total area of sewage fed fisheries is declining at a rapid rate, the population in the adjacent villages is increasing. The poaching problem is due to rising unemployment. To face the situation, the following measures may be taken:

- Conversion of bheries (large fishing pond with shallow water) for other uses is to be stopped.
- Strict legislation on the wetland is urgently needed. The existing Fisheries Acts are welcome measures to this end, but these are not sufficient to protect the water bodies.
- Middle scale bheries are becoming unprofitable if considered in terms of opportunity cost of real estate use. Hence, ecological benefits are to be recognized with sufficient importance.
- Adequate amount of sewage-laden water is to be ensured. The fisheries frequently complain that they do not get sufficient amount of sewage water after the management of storm water flow and dry weather flow channels were handed over to the Irrigation and Waterways department from the Kolkata Municipal Corporation (KMC). Rational distribution of sewage water requires careful handling by a sensitive organization. There is scope to widen the command area of sewage fed fisheries.
- Due to poaching, conservation of wetlands faces risk and induces the owners to sell off their ponds or turn them into arable land. A concerted effort of the government, political parties and owners may lead to some solutions.
- Vegetable growers hardly get remunerative prices due to poor storage facilities. Better storage systems and faster transportation to far off markets of the country may give a boost to the garbage[4] farmers of this region, especially during winter.
- The paddy growers of the region do not get institutional credit from any agricultural bank in the area. This is a serious problem for the poor farmers. In spite of getting the advantage of both irrigation and organic manure, lack of institutional credit increases the production cost.

The popular belief that sewage fed fisheries are effectively solving the problem of sewage treatment is far from the truth today. After the development of Salt Lake City and the virtual non-functioning of the Bantala treatment plant, the problem of treating sewage has become acute. Moreover, underground sewer systems also failed to expand beyond the KMC's limit. Naturally, the waste enters the surface canals. Not only siltation, but also human interventions like unauthorized settlements along the canals have almost jeopardized the drainage system. To solve the problem, the followings were recommended:

- Existing canals are to be cleared through regular dredging.
- Canal sides are to be kept free from settlements.
- A sewage treatment tax can be introduced for financing the cost of canal development.
- Carrying capacity of EKW should be ascertained and additional avenues have to be found for waste.

Further recommendations are:

- The EKW was declared a Ramsar site by Ramsar International in November 2002, but the state government continues to work with a three-tier system comprising core, buffer 1 and buffer 2. This system must be scrapped.
- It is recommended that the wetland together with the surrounding agricultural land be declared as a No Development Zone (NDZ). The tract containing existing built up areas should be a Regulated Development Zone (RDZ). A buffer should be created in the shape of a green belt with variable width between the NDZ and RDZ.
- The proposed new township should have its own drainage outlets with treatment plants. Untreated waste should not be permitted to pass through the wetland core zone.
- Kolkata must have a long run action plan with canals. Canals like Bagjola, Krishnapur, Beleghata, Bhangarkata and Tolly's Nala should be brought under an organization like the Canal Development Authority. An apex body with sufficient financial and executive power should control the functioning of this Authority.
- Alternative transportation could be arranged using Kolkata's canals. If beautified and properly managed, these canals might attract tourists.

Degradation of Water Bodies and Wetlands in West Bengal: Interaction with Economic Development

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Introduction

The interaction between a wetland ecosystem and the economy has contrasting effects, both in terms of benefits as well as degradation. Wetland ecosystems, both inland and coastal, support a large biodiversity (flora and fauna). Besides, wetlands yield various products, which give substantial economic returns. To reap these benefits, different types of anthropogenic activities are performed in and around wetlands. As a consequence, water quality deteriorates and the habitat is disturbed. Moreover, to derive greater short term, often private benefits, wetlands are often converted to other uses. These conversions not only distort the food chain of the wetland ecosystem, but also deprive the beneficiaries who were users of the wetlands in their non-converted state. The present research is devoted to the analysis of these situations in the wetlands of West Bengal, India.

Objectives

The objectives of the present study are to:

- Find out the usage pattern of the wetlands in selected regions of West Bengal, both coastal and inland areas.
- Identify and select techniques to estimate the direct and indirect economic costs and benefits from all direct uses of these wetlands.
- Study the impact of economic activities on the degradation of the wetlands.
- Suggest policy changes for the sustainable management of wetlands.

Site

Ten inland wetlands were selected in Bardhaman district, which are natural water bodies, and three of them are seasonally drained. Villages and agricultural farmlands surround almost all the surveyed wetlands. Major economic activities in and around the wetlands are fishing, irrigation, jute retting and collection of fodder. Nine coastal wetlands were selected from Medinipur district, consisting of aquaculture ponds, saltpans and fish landing centers.

Methodology

To understand the current situation of the wetlands and the benefits derived by the households, a field survey was conducted where 10 percent of the households were randomly selected for a detailed questionnaire survey. Care was taken to include all segments of the stakeholders. Benefits derived from the wetlands were calculated in monetary units using the market price method and surrogate price techniques. In the present study, biodiversity loss is represented by reduced sighting of types of birds and aquatic animals, and non-availability of certain types of fish within a particular wetland in the survey period. The level of dissolved oxygen (DO) represents the deterioration of water quality. The deviation of actual value of DO from the standard level of 7 mg/l is considered to be the degradation of water quality of the wetlands.

Results

Inland (non-coastal) Wetlands

All the anthropogenic activities viz., fish catching, irrigation, jute retting etc., generate economic benefits to the surrounding households (Table 1). These benefits impinge upon the wetlands status, and the consequent degradation of the wetlands manifests in deterioration of water quality and biodiversity loss. The anthropogenic activities have adversely affected the ecological balance for most of the wetlands, and biodiversity has declined remarkably as compared to the biodiversity present in the wetland ecosystem in its natural form. It is evident from the analysis of data that the loss in biodiversity is higher in wetlands that are drained off seasonally as compared to other wetlands.

Table 1: Benefits Derived from Different Wetlands ('000 Rs / year)

S. No.	Wetland name	Fishing	Irrigation	Jute retting	Total
1	Haruabhanga	160	160	0	320
2	Kalobaur	144	70	20	234
3	Lakshmipur	112	60	0	172
4	Chakkobla	180	70	0	250
5	Barokobla	300	40	0	340
6	Bara Beel	600	350	0	950
7	Jalanga	200	350	0	550
8	Srikhanda*	125.5	0	50	175.5
9	Bater Beel*	500	0	75	575
10	Padma Beel*	10	0	12	22
	Mean	**233.15**	**110**	**15.7**	**358.85**

* Seasonally drained

The linkages between degradation and benefits derived through anthropogenic activities are presented by estimating some functional relationships. As more and more benefits are derived from these wetlands, the loss in biodiversity increases. Similarly, the level of dissolved oxygen falls as irrigation activities intensify, while the opposite phenomenon is observed for fishing activities.

The benefits derived from these wetlands in their natural state play an important role in determining the fate of the wetlands. In spite of these benefits, a part of the wetlands were converted to other forms. Field survey reveals that the extent of conversion of the wetland, on one hand, was higher in cases where the wetland ecosystem yielded comparatively low direct benefit in its natural state. The types of conversion, on the other hand, have been influenced by the value of expected benefit from the desired conversion. For inland wetlands, that part of the wetland area that has been temporarily or permanently converted to other apparently more productive uses is considered to be the loss of wetland area. In most of the cases, converted wetland areas have been devoted to agricultural operation (92%). Other types of conversion are aquaculture ponds (6.5%), horticulture and reclaimed land for construction . These conversions have a direct impact on the wetland ecosystem and degrade them.

A comparison of benefits from wetlands in their natural form and that from their converted form explain the crucial economic forces that result in further conversions. In this study, the comparison has been captured through the benefit-cost ratios. In this cost-benefit analysis, benefit foregone collectively by the losers (due to conversion) is defined as the social cost and benefits accrued collectively by the direct beneficiaries (after conversion) is defined as the social benefit. The ratio is high for seasonally converted wetlands.

The external factors like Government and Non-Government organisations, and also interest of the stakeholders influence the conservation of wetlands. Had the benefits and costs from all aspects of degradation been incorporated in the cost, the benefit-cost ratio would have declined to a smaller value, which in turn could exert a negative influence on conversion. The degradation should have forced the government to take necessary steps to restrict anthropogenic activities that are performed in and around wetlands. Although the policy makers may well have been aware of the degradation of wetlands through conversion, they are not concerned about the degradation of non-converted wetlands due to their indiscriminate uses. For example, the government has emphasized in the West Bengal Town and Country Planning and Development Act, 1979, that no permission for filling of tanks, ponds, water bodies, marshy land, etc. will be given if it is considered necessary for being used as (a) public water body, (b) maintaining drainage facility, (c) fire fighting purposes, (d) environmental and ecological reasons, (e) pisciculture purposes, etc. These policies are either overlooked or ignored.

Coastal Wetlands

The district of Medinipore was selected to study the benefits from, and degradation of coastal wetlands. Nine converted coastal wetlands were selected in this district. Coastal wetlands are continuously transformed from one state to another to derive more and more benefits from them. It was observed that higher benefits from one type induce the others to convert wetlands generating lesser benefits to that particular form.

Economic benefits have been calculated for each form of the converted coastal wetlands (Table 2). Among the aquaculture ponds, this is least for traditional practices and highest for prawn culture. So there is a natural tendency on the part of the stakeholders to shift from traditional fishing and salt production to the higher valued option of prawn culture. But the practice of prawn culture in most cases did not last. Even in some cases, the continuous conversion processes ultimately led to wetlands that could not be used. These deserted wetlands neither generate any economic benefits, nor can they be converted back to their original state. Thus the basic idea of economic development has not been fulfilled. Moreover, degradation of valuable natural resources has occurred. As a result an asset for the society is lost forever, posing a burden on future generations.

Table 2: Benefits Obtained from Different Types of Manmade Coastal Wetlands in Medinipur District

Converted Wetlands	Total Surveyed Area (ha.)	Benefits per Hectare (Rs.)	Standard Deviation
Traditional Aquaculture	279	5625	354
Mixed Aquaculture	215	13750	707
Prawn Culture	4.4	175000	42427
Salt Pan	600	9625	495
Infrastructure Development for Marine Fishing	36	694600	72238

The Environment Protection Act,. 1986 [No. 29 of 1986J) and its amendment in March 1992 led to the declaration of Coastal stretches as Coastal Regulation Zones [CRZ] and to a regulation of activities in the CRZ. In spite of all these governmental policies, the major part of the area under study has been converted for economic purposes. This has adversely affected the ecology of the Digha-Contai coastal stretch. For example, with the introduction of aquaculture including prawn culture, salt production and other developmental activities in and around the coastal region, the biodiversity has reduced substantially. It is also found that biodiversity loss is maximum in case of infrastructure development for marine fishing as compared to other activities. (Here, biodiversity loss implies reduced sighting of birds and aquatic animals, and non-availability of certain types of fishes in a particular wetland in the survey period.) In this region, water quality measured in terms of DO varies with types of activities being carried out. It has been found from the water analysis that the damage of the water quality is least if the economic activity is aquaculture. That the loss of biodiversity in traditional aquaculture practices is least also supports this finding.

Policy Recommendations

In spite of all these regulations and proceedings of the Court in other cases, it has been found that saltpans are being converted to prawn culture ponds in Digha-Contai coastal stretch for better economic gain. Along with it, a reverse trend has also been observed in a few cases of conversion from prawn culture to aquaculture ponds during the period 1995-2000. On the other hand, the infrastructure development for marine fishing in this coastal region is an activity that generates short-term benefits surpassing those from all the available alternatives. It is interesting to note that the benefits of all sorts of aquaculture practices can be well availed of from marine fishing, even if it is run alone. But from the perspective of biotic diversity, infrastructure development for marine fishing has the most disastrous effect. Next to it is prawn culture. However, the area-wise extent of damage is lower in the case of infrastructure development, as a larger area has to be converted to get the equivalent monetary benefit from prawn culture or commercial aquaculture.

Again, prawn culture requires collection of seedlings of prawn from seawater that affects offshore marine fishing within a few kilometers from the shoreline. This process disturbs the marine biological chain as the undesired species are thrown away by the collectors. The method of prawn seed collection has, to a large extent, inflicted irreparable damage on faunal lives of Digha-Contai coastal area of Medinipur district. The activity of prawn culture also did not sustain itself, and defunct prawn cultivation ponds left behind non-reusable, non-productive wetlands. So the activity of prawn culture is ruinous as it depletes marine resources on one hand, and causes ecological imbalance on the other.

If conversion should be permitted to a limited extent, then infrastructure development for marine fishing seems to be the best alternative among all types of conversion made on coastal wetland. However, care should be taken that it should not intensify marine fishing so much, that it might aggravate the problem of over-exploitation of marine resources. As far as employment opportunities and economic returns are concerned, this developmental activity to facilitate marine fishing is considered to be sustainable in nature. Also, this coastal development is in accordance with the Environmental Protection Act. Once an infrastructure for marine fishing is set up, it is expected that investments will be channellised in favour of marine fishery rather than for further conversion of coastal, wetlands. This will eventually preserve a larger area of coastal wetlands. For the saltpans it can be said that their product is unique in this state. Moreover, a saltpan generates fishery income mainly to the people working there, during the lean seasons. This income is generated from the naturally grown sea fish that enter the ponds through in-flowing seawater. This provides a two-fold benefit: salt production and aquaculture. Also from both the environmental and ecological perspectives saltpans do not produce hazards as great as compared to others. Thus the saltpan in this region should be allowed to continue their operation, at least from the developmental point of view. Furthermore, any conversion from the sustainable state like saltpan to undesired state like prawn culture should be strictly restricted.

- A comprehensive policy should be framed for preservation and better maintenance of existing wetlands.
- If all the anthropogenic activities cannot be curbed due to economic pressure, only those activities should be encouraged which cause the least damage.
- The maximum sustainable level (such as maximum sustainable yield in the case of fishery) of those activities should be determined.
- Over fishing in wetlands should be stopped, water lifting for irrigation purposes should be restricted to a pre-determined level for the sustenance of existing species habitat, and seasonal draining should not be encouraged.
- The beneficiaries who suffer from such actions may be compensated by alternative employment opportunities like animal husbandry, multiple cropping and food for work programmes.

To conclude, conversion of wetlands cannot be stopped totally due to developmental pressures. But some physical components may restrict the long-term functioning of some of these converted wetlands. Hence, conversion should be made from a rational and realistic standpoint so that “better and more efficient utilization of the converted wetlands can be carried out which is sustainable in nature and eco-friendly”.

COMMON PROPERLY RESOURCES AND FORESTS

Common Property Resources Agricultural Development Strategies and the Poor in West Bengal

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Introduction

This study examines the impact of agrarian development strategies on the use of rural common property resources (CPRs) by the poor in West Bengal. Governments in developing countries usually aim at rapid agricultural development combined with upliftment of the poor. However, the relation between agricultural development and the conservation of CPRs is often ignored. Agrarian Development adversely affects the supply of CPRs on which the poor largely depend. On the other hand, better income and employment opportunities that follow from development may also reduce the dependence of the poor on CPRs, thereby preventing the overexploitation of such resources. Thus, while some of the poor may benefit from development efforts like redistribution of land, public irrigation, input subsidies, creation of employment or income generating assets, others have to fall back on a reduced supply of CPRs.

Ignoring the relationship between the private property resources (PPR) and CPR based processes leads to policies that are unsustainable in the long run. Subsidizing irrigation in areas with a low water table or providing cattle through Integrated Rural Development Programmes (IRDP) in areas where pastures are scarce are common examples. Thus, a study of the impact of agricultural development strategies on the use of CPRs is essential to promote a balanced development of CPR and PPR based activities for the improvement of the condition of the poor in the state.

Objectives

This study focuses on three types of CPRs

- Forests
- Pastures
- Water bodies

The impact of agrarian development strategies is examined in selected areas of West Bengal, such as:

- Land reforms
- Irrigation and promotion of modern agrarian techniques
- Anti poverty programmes – on the interaction between the CPR and PPR based processes, the supply of CPRs, the demand for CPRs, and welfare and economic inequality

Methodology

Valuation of CPR-Based Items

CPRs are usually freely accessible so prices do not exist. Thus, we need alternative methods to value them, such as:

- Imputed Market Values: Value of (cheapest) equivalent market based items. This applies to food, fuel and fodder
- Time Spent In Collection: Value of Time that could be spent in other use (work, leisure)
- Carrying Capacity: Maximum population that a CPR stock can sustain

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[1] Gross Primary productivity is the rate at which radiant energy is utilized by the photosynthetic activity of producers to form organic substances of high potential energy from inorganic sources. Primary production is the amount of organic carbon produced and primary productivity is therefore the rate of production i.e. amount per unit time. Net primary productivity is the amount of organic matter stored after expenditure in terms of maintenance. Secondary productivity is finally the ultimate amount of organic matter produced at the consumer level (in this case measured in the form of fish productivity) of the system under study.

Supply Of CPRs

We choose as our indicator of CPR supply:

= Av value of collection per hr (V) x Av Time Spent in collection per adult (L^{O}_{CPR})

L^{O}_{CPR} varies across households and is related to CPR Demand, while V is approximately constant for a village, and may be used as an indicator of CPR supply. This indicator takes 'quality' into account, since the average collection per hour in a village is lower if either total forest area (quantity) or quality of the forest is poor.

Demands For CPRs

We take the ***time spent per adult in collecting CPRs***, L^{O}_{CPR}, as the indicator of CPR demand. This is like the ***travel cost method*** of valuing of recreational sites such as parks. We ***do not value this time at the prevailing wage rate*** as people engage in collection only when they are unemployed. The choice is not between employment and collection, but between collection and leisure or household activities.

We first use ***OLS regressions*** with L^{O}_{CPR} as the dependent, and family size and per capita income as independent variables. Next, since income and employment depend on family and area characteristics and policy benefits, we estimate the ***reduced form OLS equation***; with the latter as independent variables.

Policies are often based on household characteristics, income and area specifics. For example, the low income and low landowning households are beneficiaries of land reforms and anti-poverty programmes. Hence, ***recipients of policy benefits may have higher CPR demand, as most are poor.*** To avoid this problem we use ***the method of 2-Stage least squares***, where family composition, income, land owned and area features are included as predetermined variables.

Common Property Resources, Inequality and the Gini Coefficient:

Agricultural development policy simultaneously degrades the supply of CPRs and increases non-CPR income, leading to a reduction of CPR demand. Thus, we find two kinds of effects on rural inequality if the CPR income is taken into account:

- ***Higher inequality in the high policy implementation areas*** as only some receive policy benefits while others fall back on a reduced supply of CPRs
- Second, the poor generally depend more on CPR income, so that ***if CPR income is included, the degree of inequality appears to be lower***

To examine these factors, we calculate the GINI coefficients of income with and without the CPR income included for all villages in the area. We calculate ***Gini coefficients for the entire village and not only for the poor*** since considering only the poor gives an incomplete picture of the impact of agricultural policies.

Agricultural Policy Indicators

We adopt two types of indicators of agrarian development for this study:

- ***General indicators***: These items indicate the overall level of agrarian development or progress in a region such as indicators of productivity like yield per unit area, ***cropping intensity***, ***wages*** per Labour Day.
- ***Indicators of specific agrarian strategies***: These include:
  - **Land Reforms:** Percentage of landless who received land and percentage of tenants who recorded their tenancy and crop share received by tenants
  - **Technological Reforms:** Irrigation ratio, multiple cropping, fertilizer and HYV use, agricultural investment, etc. that encroaches upon or degrades CPR stocks
  - **Rural Development Programmes:** Proportion of the poor benefited by rural employment (e.g. JRY) or self-employment (e.g. IRDP) schemes like subsidies for cattle, making of saleable items from forest products, etc.

The Survey

The data is from the districts of Birbhum and Burdwan in West Bengal. **First**, we did a

preliminary survey of 60 villages in Ausgram I and II and Raina Community Development (C.D.) blocks of Barddhaman and Bolpur, Ilambazar, Labpur and Rajnagar C.D. blocks of Birbhum. Information was obtained from block, district and panchayat officials, NGOs, district and block level maps and reports.

Then 18 villages were selected in the **second stage** – six for each type of CPR, i.e., land, forest and water out of which, two were to focus on each type of agrarian strategy, (land reforms, technology and anti-poverty programmes). Of these, one each represents ‘high’ and ‘low’ implementation. Villages representing ‘high’ land reform implementation have high proportion of recorded leases, crop shares and land redistribution beneficiaries. Those representing ‘low’ technology policies have poor public irrigation, levels of institutional credit disbursals, etc. These were covered with a *Detailed Village Level Report* dealing with (a) village natural resource and CPR flows (b) access to these flows and (c) their use and management.

Then we distributed a *Preliminary Household Questionnaire* in all the households in each village. It related to agricultural and non-agricultural occupations, income and assets, and classified households into: (I) non-poor, (ii) poor beneficiaries of agrarian policies, and (iii) poor non-beneficiaries. **Finally**, 30 households were selected from each village according to the proportion of the groups in the population and covered by a *Detailed Household Questionnaire*.

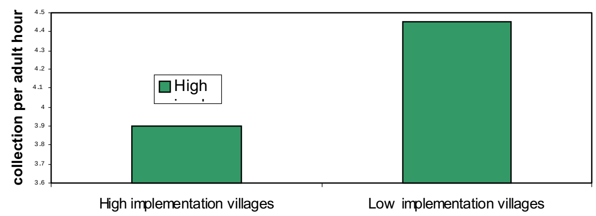
Data Analysis and Results

The Supply of CPRs

The supply of CPRs is common to all households in a village. Since we have detailed data for 18 villages, we study the impact of policies on the average levels of supply.

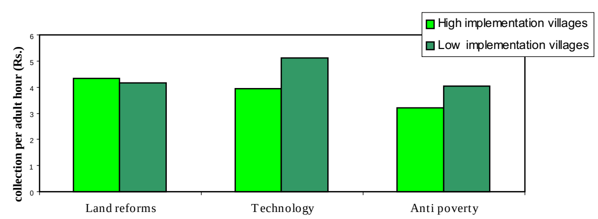
Result 1: *Average. collection per hour in the high implementation villages is lower than in the low implementation villages & this difference is significant at 1% level.*

Chart 1: Effect of Policy Implementation on Average CPR supply



It is important here to conduct the same test separately for the 3 policy areas

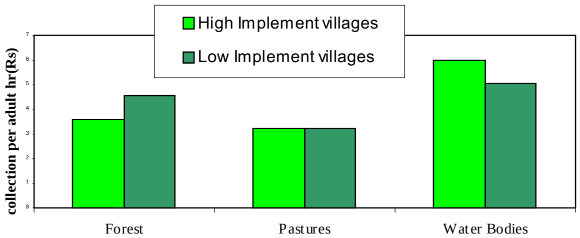
Chart 2: Effect of Specific Policies on Average CPR supply by policy



Result 2*: Average collection per hour is significantly higher* (at 1% level) *in the ‘low implementation’ regions for Technology and Anti-poverty policy areas*; but *lower (not statistically significant) in the’ land reform areas*.

Thus, while technology and anti-poverty policies deplete CPRs, land reforms do not. To probe this, we examined the impact of land reforms on average collection per hour in all 3 types of CPR areas: forests, pastures and water bodies.

Chart 3: Impact of Land Reform on CPR Supply by area type



Result 2A: *Average collection per hour in high land reform villages is lower for forestand pasture areas* (significant at 1% level), *but higher in water-body areas.*

The Demand for CPRs

We estimated the OLS regression, which sets household demand for CPRs - hours devoted to collection per adult (PRADHRCP) - as a function of adults in the family (FAMADL), per capita income (PERCAPINC), days spent in agricultural work (LABDAYS) and of household size (HOUSENO), percentage of children (PCTCHIL), of women among adults (PCTFEMAD) and area dummies (FOREST, PASTURE).

Result 3. *Collection time per adult decreases with income, labour days and family size and increases with female and children. It is higher in forests and pastures compared to water bodies.*

Table 1: General Determinants of Hrs spent on Collection per Adult (PRADHRCP)

Model	1.OLS	2OLS		3.OLS
CONST	247.940**	79.802**	23.091	(.753)
	(8.470)	(2.798)		
PRCPINC	-774**	-.487	-.576	(-.1788)
	(-2.171)	(-1.485)		
LABDAYS	.702**	1.510**	1.159**	(4.202)
	(7.196)	(4.081)		
FAMADL	-25.122**	x	x	
	(-3.482)			
HOUSENO	x	-11.162**	-9.320**	(-1.924)
		(-2.238)		
PCTCHIL	x	2.798**	2.484**	(5.107)
		(5.586)		
PCTFEMAD	x	3.355**	2.859**	(7.208)
		(8.306)		
FOREST	x	x	151.900**	(6.581)
PASTURE	x	x	58.901*	(2.575)
R^2	0.188	0.305	0.358	
Adj R^2	0.183	0.299	0.350	
F	41.322	46.967	42.355	
SIG F	.000	.000	.000	

X – variable not included in equation
* Significant at 5% level; ** significant at 1% level
Sample size = 420 households collecting out of 540 sample households

Next, we carried out OLS regression of the following variables on PRADHRCP:

- VESTPERC – land received through redistribution – and REGDTEN – tenancy registration dummy for land reforms
- Benefits under IRDP and JRY as indicators of anti-poverty programmes,
- CRINT – cropping intensity and COSTINT – cultivation costs per unit gross cropped area as indicators of technology policy.

A problem is that ***the recipients IRDP, JRY or vested lands are selected, based on their household, income and area characteristics***. We therefore, estimate a 2SLS regression with PRADHRCP as the dependent variable and the above factors as Predetermined Variables and the policy variables as endogenous.

Result 4: *Collection time per adult is significantly* (*in the statistical sense*) *lower for beneficiaries of land reforms and technology policies. However, this cannot be confirmed for policies aimed at the poor - like IRDP, JRY and land redistribution.*

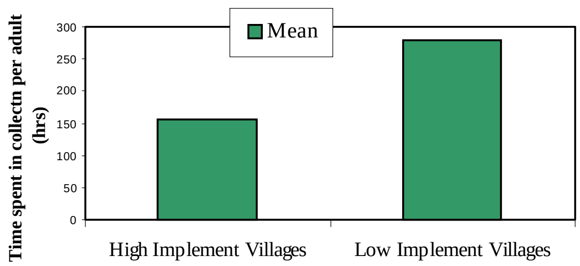
Table 2: Impact of Policy on Hours spent on Collection per Adult (PRADHRCP)

Model	4. OLS	5.OLS	6. OLS	7.2SLS
CONST	226.856	117.064	23.464	373.88
	(7.179)	(2.450)	(.483)	(2.300)
REGDTEN	-49.390	-60.355*	-40.093	-7.556
	(-1.508)	(-2.028)	(-1.338)	(-.142)
VESTPERC	.547	398.613	325.493	303.540
	(1.449)	(1.497)	(1.915)	(.076)
COSTINT	-30.145**	-21.175*	-6.354	-136.428**
	(-3.383)	(-2.158)	(-.661)	(-3.144)
CRINT	-18.894	9.183	19.794	21.300
	(-.987)	(.609)	(1.365)	(.910)
IRDPBEN	23.221*	6.387	6.856	-15.369
	(1.753)	(.488)	(.554)	(-.820)
JRYPRCP	2.280**	1.557*	1.585*	-.490
	(3.377)	(2.240)	(2.385)	(-.077)
OWNPRCAP	-64.003**	-43.356	-41.807	
	(-2.655)	(-1.684)	(-1.687)	X
NAGPCINC	-1.389	-.660	-1.216	
	(-1.260)	(-.553)	(-1.067)	X
LEASEPERC	X	125.285**	143.036**	
		(3.682)	(6.197)	X
HOUSENO	X	-11.682 **	-9.923**	
		(-2.626)	(-2.355)	X
PCTCHIL	X	3.142**	2.541**	
		(5.928)	(5.140)	X
PCTFEMAD	X	2.039**	1.818 **	
		(4.272)	(4.007)	X
FOREST	X	92.863**		X
		(3.668)		
PASTURE	X	66.401**		
		(2.5088)		X
R^2	0.202	0.386	0.458	0.288
AdjR2	0.185	0.363	0.434	0.265
F	11.671	16.966	19.384	12.651
SigF	.000	.000	.000	0.000

* Significant at 5% level; ** significant at 1% level, sample size = 420

Next, we compared the time devoted to collection in areas of high and low implementation of anti-poverty programmes to check whether these have an impact on demand for CPRs in the area beyond the effect on beneficiary households.

Chart 5: Impact of Policy Implementation on CPR demand in Anti Poverty Program Areas

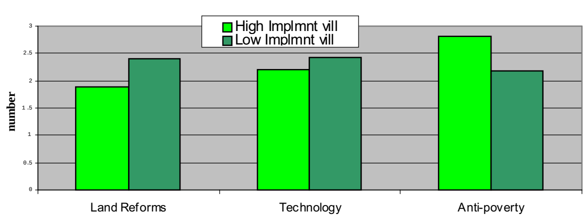


Result 4A: *Average time spent per adult is significantly lower* (at 1% level) *in areas selected for good implementation of anti-poverty programmes compared to the areas where implementation was poor.*

Interaction of PPRs and CPRS - Grazing

Time spent on grazing is not an adequate indicator of the demand for grazing. While cattle ownership is an indicator of 'demand for grazing', the reduction in feed cost per cattle from grazing is an indicator of the grazing resources in the relevant area.

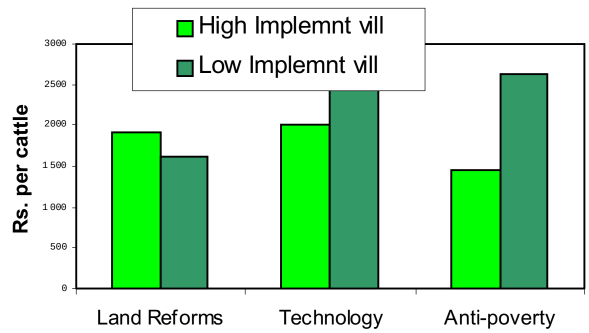
Chart 7: Impact of Specific Policies on average cattle ownership



Thus, average number of cattle per household is higher in low policy implementation villages than in high implementation ones, except for areas selected to study the impact of anti-poverty programmes. Since these frequently subsidize purchase of cattle, number of cattle is comparatively higher in high policy implementation areas.

The 'supply' of CPR grazing resources is estimated by the value from grazing per cattle. This indicates the extent to which grazing substitutes for purchased feed and depends on the quantity and quality of the fallows utilized as grazing land.

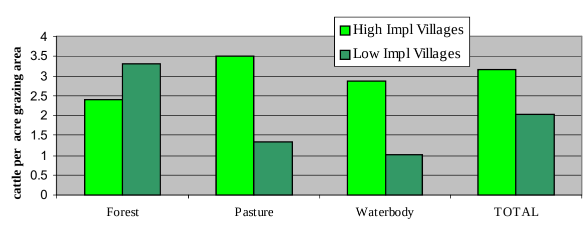
Chart 8: Impact of Specific Policies on average income from grazing per cattle



Result 5: *The income from grazing per cattle is higher in the low implementation villages compared to the high implementation ones, except for land reforms, where the difference – in the reverse direction – appears to be statistically insignificant*.

Since implementation of anti-poverty programs like IRDP lead to higher cattle per household, the greater pressure on grazing land is likely to reduce the income from grazing per cattle. For technology policy where 'high implementation' areas have lower cattle per household, the likely reason for lower income from grazing per cattle is the decrease of grazing land as reflected in the higher cattle per unit grazing area.

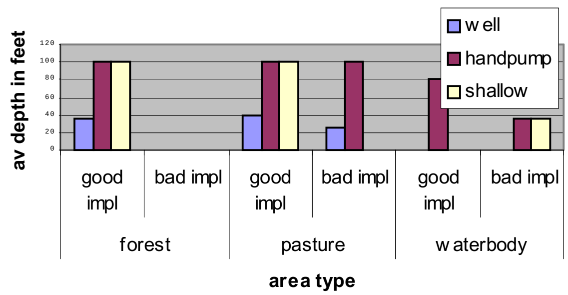
Chart 9: Impact of technology policies on grazing intensity by Area Type



Use of Common Property Water

Domestic and farm use of water are difficult to link with agricultural policies. For example, overexploitation of groundwater raises tube well depth, both in the 'high' and 'low' technology villages that draw from the same underground aquifer. We may include wells and hand pumps, but the depth to which these are sunk may not indicate the required depth. With these in mind, we present the water table data for the technology policy areas to show that intensive cultivation lowers the water table.

Chart 10: Impact of Technology Policy on the water table



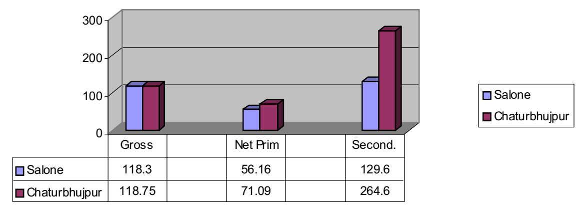
Carrying Capacity Analysis

We also used carrying capacity analysis to analyze the impact of technology policy on two ponds in water body areas - Salone and Chaturbhujpur. Although gross primary productivity values are equal in ponds, net primary productivity and hence estimated fish productivity is greater in pond II (Chaturbhujpur) in the low technology policy implementation area. [1]

Agricultural Policy, CPRs and Inequality

The poor depend more on CPRs than the wealthy. Thus, including CPR income may decrease the estimate of rural inequalities. Agricultural policies benefit a section of the population but constrain others to fall back on a reduced supply of CPRs. Thus, while mean incomes in the area may rise, inequality of income (as characterized by GINI coefficients) including the CPR resources in the village is likely to increase.

Chart 11: Carrying Capacity Analysis of Impact of Technology Policy on Surface Water Resource Productivity



Result 6: *High implementation of Agricultural Development Policies:*

- *Raises mean per capita income - with and without CPRs - except for land reforms*
- *Raises inequality except in the case of anti poverty programs*

Summary of the Main Results

- Land Reforms reduce the demand for CPRs without significantly affecting CPR supply and are unlikely to cause a major damage to CPRs. Grazing income does not decline in the 'high' implementation areas. However, land reform lowers income - except in forests - and raises inequality except in water body areas.
- Technology Policies reduce both the demand for and the supply of CPRs and also perennial and seasonal fallows so that grazing income is reduced. The long-run impact depends on

Table 3. Impact of Policies on Mean Income and Income Inequality (Gini Coefficients)

Area	poly impln	Land reforms				Technology				Anti-poverty			
		PCpINC w/o cpr		PCpINC with cpr		PCpINC w/o cpr		PCpINC with cpr		PCpINC w/o cpr		PCpINC with cpr	
		mean	gini	mean	gini	mean	gini	mean	gini	mean	gini	Mean	gini
Forest	low high	6693.161 9303.133	0.406 0.596	7867.28 10663.6	0.353 0.512	3243.7 5428.38	0.327 0.538	4718.69 7546.56	0.273 0.415	1892.6 3042.36	0.324 0.298	4037.89 4989.103	0.235 0.244
Pasture	low high	3769.303 2603.114	0.347 0.434	4762.59 4060.57	0.295 0.339	5389.88 7882.42	0.526 0.385	9135.2 6938.93	0.447 0.314	4940.45 7342.81	0.439 0.4	6208.809 7711.421	0.372 0.383
Watbd	low high	6195.371 4261.002	0.255 0.315	6718.21 5584.39	0.268 0.454	3697.54 6709.95	0.312 0.422	5608.12 7586.51	0.238 0.394	2979.2 6514.85	0.461 0.36	4729.776 7304.099	0.405 0.284

which effect is stronger. Average Income and inequality rises due to policy implementation.

- Anti-poverty programmes raise the demand for CPRs while degrading supply, and are most likely to degrade CPRs. Thus, IRDP programmes lead to higher cattle ownership causing greater pressure on land, and lower the income from grazing. However, these programmes raise income and reduce rural inequality.

Policy Recommendations

If we look at specific agricultural policies, the recommendations are as follows:

- **Land Reforms:** Policies in this regard were formulated and implemented before 1980s - and there is little scope for further reform in our study area
- **Technology and Irrigation Policies:** Sustainable agricultural policies preserve agricultural income and employment - particularly of the poor - without degrading CPRs. These include: (a) ***Study of the natural resources*** in each area; (b) ***Choice of appropriate crops through expert help and information*** and removing the incentive distortions underlying public support prices; (c) Increasing the use of organic manure and pesticides by ***lowering subsidies on chemical fertilizers*** along with subsidizing the production and consumption of organic manures and ***promoting awareness of organically produced crops***; (d) Optimizing use of water to preserve the water table through ***grant of community rights to ground and even specific uses of surface water*** combined with ***participatory management methods for appropriate allocation and enforcement of these rights***.
- **Anti Poverty Programmes:** The administrators of these programmes must consider their impact of on CPR demand and supply. While programmes like IRDP are vital for the upliftment of the poor, promoting purchase of cattle in an area with low pastures may not be the appropriate way to do it. The need is: (a) ***Setting up participatory Joint Rural Resource Management Committees*** that take an integrated approach towards the private and common property resources in an area; (b) Selection self employment and rural works ***schemes that are locally sustainable*** and alleviate poverty; (c) ***Coordinate the functioning of CPR management schemes*** (such as JFM committees) ***with Rural Development Programmes*** for developing and maintaining pastures, watersheds and promoting social forestry.

CPR Institutions in West Bengal: An Analysis of Environment Economy Interface

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Introduction

Some natural resources are Common Property Resources (CPRs). The characterising features of these resources are:

- Consumption reduces total stock of the resources.
- It is difficult to apply the exclusion principle that prevents people from using the CPRs.

Such resources are important for both production and consumption of rural households, employment and the social security system. Finally, in many cases resource users have themselves established rules to exclude outsiders and control resource use. The creation of such common property resource institutions has ensured sustainability of such resources.

Objectives

The objectives of the project are to:

- Analyse the process of evolution of CPR institutions as a response to resource degradation.

Collective action is necessary to create new CPR regimes or modify existing ones. We sought to examine the factors that were relevant in this process - either encouraging collective action, or hindering such attempts.

This would enable us to demarcate areas where meaningful policy intervention can help enhance the indigenous capacity to manage the environment.

Hypothesis

Our project is focused on the process of creation of CPR institutions and its changes in response to changes within and outside the community. Our hypotheses thus are related to the creation and evolution of CPR institutions.

Our central hypothesis was that the awareness of the problem of resource degradation would generate processes leading to collective action and the emergence of sustainable communal management systems. This means that we interpret the emergence of CPR institutions as a collective response to the degradation of the environmental resource base. This collective action is manifested through the supply of appropriate institutions.

The process of evolution of CPR institutions was linked to several factors. Our sub-hypotheses were related to these factors. i.e. in identifying the factors affecting collective action and the direction of causality.

- The resource appropriators perceive that the resource is being degraded and this can lead to disaster.
- The resource appropriators acknowledge their role in creating this crisis, i.e. they acknowledge that outcomes are jointly produced and can be avoided by changes in their existing behaviour; Pro-social norms arrest the process of degradation when activated.
- Economic cost of cooperation is low.
- Social and economic conditions of agents are more or less uniform and recurrently shared (i.e. agents have mutually consistent expectations).
- The expected flow of net benefit is an important determinant of the institutional form of the property regime.
- Another determinant of the institutional form of the CPR regime is the physical characteristics of the resource in question.
- The feedbacks to resource conserving behaviour are positive.

- Situational factors like a temporary fall in income may lead to defection
- Such defection will be tolerated up to certain limits without punishment. However, the contingent fulfilment of the threat will have to be credible

Methodology

The study used an empirical approach. Four CPR institutions were examined in detail, and another CPR regime cursorily.

Since the study relates to the historical development of institutions, it relied on primary data. This data was collected based on field surveys undertaken in five areas.

The survey method consisted of interviewing community members using a structured questionnaire. In view of the historical nature of the information required, non-conventional techniques like group discussions were also employed.

Sample Size

Rather than choosing the sampling method, we attempted to interview all members (census enumeration). However, some members were not available during our survey. In such cases, we simply interviewed the available population.

A group discussion was undertaken with about 8-10 members at a time in each of the three villages. In the case of the co-operative, participants of the group discussion were chosen randomly with replacement .

To factor out the view of a particular individual being repeated, we identified participants repeatedly joining such discussions.

Surveys were undertaken in the following areas: Belemath (210 respondents) in the district of Burdwan (forest resource), Matha (75 respondents) in the district of Purulia (forest resource), Hazamdihi (96 respondents) in the district of Bankura (water body), and two fishermen's co- operatives in Bon Hooghly (37 respondents) and Charcharia in Kolkata (water body). Resource-dependence of the community at different locations are indicated in the following tables:

Table 1: Dependence of Income from CPRs in Belemath

Income Class	Past	Present
0-10000	35.39	29.73
10001-20000	37.64	29.20
20001-30000	19.96	16.96
30001-40000	14.16	12.98
40001-50000	31.21	20.36
50001-60000	3.06	2.97
60001-70000	0	0
70001-80000	0	0
80001-90000	5.27	5.15
90000>	0	0
Village Average	**31.69**	**25.33**

Table 2: Item-wise Dependence on CPR in Belemath

Classes	Items	Village Average	
		Past	Present
Consumption	Housing Materials	1.30	0.76
	Roof	0.42	0.27
Energy	Leaves	13.54	11.19
	Branches	1.15	0.80
Intermediate	Shal Leaves	4.87	2.68
	Mattress	1.23	1.03

Table 3: Dependence of Income from CPRs in Matha

Income Class	1995	2000
0-10000	113.35	52.39
10001-20000	67.90	42.76
20001-30000	49.07	38.58
30001-40000	101.28	32.99
40001-50000	13.03	12.22
50001-60000	3.21	3.11
60001-70000	0.00	0.00
70001-80000	0.00	0.00
80001-90000	4.57	4.37
90000>	10.53	10.53
Village Average	65.37	38.51

Table 4: Item-wise Dependence on CPRs in Matha

Income	Consumption		Energy		Intermediate	
Class	Housing Materials	Roof	Leaves	Branches Leaves	Shall	Mattress
0-10000	2,00	0,00	0,00	35,32	60,13	0,00
10001-20000	0,00	0,58	1,89	28,87	27,26	0,77
20001-30000	0,22	0,13	0,26	20,03	7,90	1,24
30001-40000	0,00	47,40	20,33	16,95	5,20	0,00
40001-50000	0,00	0,77	0,00	3,24	4,66	0,00
50001-60000	0,03	0,00	0,00	3,19	0,00	0,00
60001-70000	0,00	0,00	0,00	0,00	0,00	0,00
70001-80000	0,00	0,00	0,00	0,00	0,00	0,00
80001-90000	0,06	0,00	0,00	4,51	0,00	0,00
90000>	0,00	0,00	0,00	0,00	0,00	0,00
Total	**0.53**	**4.73**	**2.95**	**24.12**	**21.03**	**0.69**

Table 5: Direct and Indirect Benefits to Members in Bon Hooghly

Year	Personnel Cost (inclg. Bonus)	Indirect Benefits	Total Benefits	Percentage Share of Indirect Benefits in Total Benefits
1990-1	536873	4997	541870	0.92
1991-2	349498	17557	367055	4.78
1992-3	623688	18911	642599	2.94
1993-4	659120	63820	722940	8.83
1994-5	696018	32322	728340	4.44
1995-6	639238	35803	675041	5.30
1996-7	752585	52811	805396	6.56
1997-8	738878	38969	777847	5.01
1998-9	682532	36493	719025	5.08
1999-0	682532	150315	832847	18.05

Table 6: Relative Importance of Income from Co-operative in Bon Hooghly

Income Class	Number of Individuals	% Share of Wages from Co-op in Total Income earned by the individual	% Share of Wages from Co-op to Family Income
1000-1250	3	100	94.80
1251-1500	8	100	94.73
1501-2000	10	81.30	69.63
2001-2500	5	76.19	55.68
2501-3000	4	74.11	45.77
3001-3500	3	61.25	39.00
3501 and above	4	63.90	18.10

Table 7: Pond Use by Different Income Groups (%) in Hazamdihi

Income /uses	Pujas /Jatras	Family Work	Irrigation	Fish at cheap rate	No benefit	All benefits
Less than 10000	33.33	40	20	13.33	20	13.33
10001-20000	28.13	50	21.88	25	6.25	6.25
20001-30000	18.75	75	37.5	37.5	6.25	0
30001-50000	33.3	50	83.33	58.33	0	0
50001-80000	58.33	50	50	16.67	0	16.67
More than 80000	57.14	71.43	71.43	28.57	0	14.29
Total	**34.04**	**54.26**	**39.36**	**28.72**	**6.38**	**7.44**

The sites were partly selected to enable the researchers to make comparisons across resources, and between management systems for the same resource. In the case of forests, a co-produced management regime viz - Forest Protection Committees were studied. Both the survey sites were similar with regard to their socio-economic backgrounds. Both were poor villages, with low levels of literacy. The main occupation was agriculture. Dependence on forests was high in both cases. The only difference was that the population in Matha was tribal, while that in Belemath was mixed. These two studies formed an interesting contrast as - despite their similarities - the performance of the regimes was different in these villages: in Matha, it was a failure, while in Belemath it was a success.

The other three sites studied were similar with regard to the resource. However, while the regimes in Charcharia and Bon Hooghly were formal fishermen's co-operatives, in Hazamdihi a multi-use water body was informally managed by the village. The cases of the formal co-operatives are also important in view of their location - both were situated in an urban belt, within the Kolkata Metropolitan Area. Hazamdihi in contrast, is in the poor under-developed district of Bankura.

Analysis

The data so collected was integrated using the Oakerson framework. The conclusions from our empirical study were then contrasted with the results of game theoretic models.

Results

Our central hypothesis is not validated by our survey. The emergence of CPR regimes do not seem to be related to the onset of the resource degradation problem. In Matha, degradation did not evoke any response from the community. (Table 8) Although the water bodies were being managed with varying degrees of success, in none of these cases were the resource threatened.

Table 8: Grass-root Indicators of Resource Development

(Number of Respondents in Matha)

Indicators	Increased	Decreased	Unchanged	Uncertain
Number of trees	0	54	20	1
Forest area	0	28	46	1
Time taken to go to forest	19	10	44	2
Time taken to collect leaves	24	5	34	12
Level of Income	4	27	28	16
Income variance	9	3	17	46

Our central hypothesis had been divided into several components. We analysed the validity of each of these sub-hypotheses below:

- The emergence of CPR institutions is not always linked to degradation issues, making our first sub-hypothesis invalid. This will affect the other sub-hypotheses that were linked sequentially to each other.
- Outcomes (like resource degradation) need not always be jointly produced. Further, interdependence may manifest across generations - especially in the case of forests. However, some amount of reciprocity is needed to foster co-operation.
- Attempts to free ride are present in all the case studies (Table 9) in the absence of normative or institutional constraints.

Table 9: Incidence of Defection of Villagers in Matha

Activities	No of Respondents (%)
Village average of people breaking rules	33.80
Village average of people who are not caught	7.97
Village average of people who are punished	0.32
Village average of people who are pardoned	0.07
Village average of people who are freed by manipulation	0.00

- Low economic costs of co-operation were significant in explaining the success in Bon Hooghly, Charcharia and Hazamdihi. In the case of Belemath, the reduction in income due to co-operation was low. In the case of Matha, the high costs of co-operation appeared to significantly inhibit co-operation.
- Homogeneity of agents remains a contested factor in explaining collective action. This is in line with the conclusions of recent works on this area.
- The surplus from the resource has determined the *choice* of the regime in each case - though it has not affected its efficiency.
- The physical feature of the resource is an important factor explaining the range of possible forms of regimes.
- Feedback, either in the form of visible restoration of the resource or in the form of stable income flows, is an important factor contributing to the success of the regimes in Belemath, Bon Hooghly, Charcharia and Hazamdihi.
- Despite the success of these regimes, we found that transgressions of the rules were also present. Such violations were mainly due to a temporary fall in income. A seasonal pattern of defection was observed in both Belemath and Matha (Table 10).

Table 10: Incidence of Defection in Belemath

Activities	Average (per month)
Village average of people breaking rules	20.42
Village average of people who are not caught	12.16
Village average of people who are punished	1.97
Village average of people who are pardoned	1.40
Village average of people who are freed by manipulation	4.88

- The community did not normally take any action and tolerated such violations. However, reputation was used to judge whether such behaviours were temporary or a manifestation of deviant behaviour.Sanctioning was applied only in the case of the latter.

Game Theoretic Structure

Collective action problems come in diverse forms, and there is no unique best solution to all of them. The nature of the problem and its solution method, thus needs to be approached from the perspective of the type of game played. However, we have observed that a unique type of game may be unable to capture the nature of the problem in its entirety, and hence we experimented with several proximate game structures.

Baland and Platteau (1996), discuss interesting hybrid cases of payoff structures where players with a payoff structure characteristic of the Assurance Game (AG) interact with players with a payoff structure characteristic of the Prisoners Dilemma (PD) or Chicken Game (CG). In particular, when the group size is small and when PD players coexist with AG players, it may be in the interests of the former to conceal their free rider type by cooperating till the last (few) stages of the game. Clearly, situations, which can arise/ evolve in field settings and contextual factors operating there are of a much wider variety than what the tragedy of commons implies. Depending on the characteristics of the resources concerned as well as various features of user groups - their social and historical background, size, their time preference and the importance of their subsistence constraints, their exit possibilities, quality of community leadership, presence of third party catalytic agents, existence of other areas of social interactions, etc. - problems of resource exploitation may or may not be appropriately described as PD games. Such problems of resource management thus, may well lead to AG or CG situations, or a mixture of different payoff structures, or may assume the characteristics of embedded games. Moreover, the type of game itself may undergo change over time.

This is the perspective that we adopt here. This perspective emphasises human encounters in a CPR setting involving problems of trust, mutual vulnerability, group identity, homogeneity of group members, leadership, and co-ordination among group members. Co-operation in general but not always, works better in small groups with similar resource needs and close interactions, shared norms acting as focal points and coordinating mutual expectations, and patterns of reciprocity. In such communities, monitoring is easier, ‘common knowledge’ assumption of models of strategic decisions is likely to be more valid, incentive dilution is less of a problem, chances of pre-play communication and learning about one another’s intended plans of action are better, and social sanctions are easier to implement through reputation mechanisms and multiplex relationships of face-to-face communities. Bankura, Burdwan, Bon Hooghly and Charcharia are the cases in point. The absence of many of such traits exemplify Purulia.

Migration and outside opportunities leading to mobility possibilities work against cooperation and sustainable resource use. Contact with outsiders and exit options reduce effectiveness of social norms, and prolonged repetition of the game also becomes more uncertain, raising incentives for short-run opportunism. Sometimes, as in the case of Purulia (Matha), owing to the survival constraint and contact and proximity of the market, the discount rate of future incomes of the resource users seems to be infinitely high, and free riding behaviour (mining the forest) appears as a natural weapon in the mutual struggle for sheer subsistence. With receding regular opportunities for income and employment, the poor tend to make up for the loss of income by exploiting CPRs more intensely with ever-increasing risk of degradation of the underlying resource base. Local level management is much more problematic when, as attested by the Purulia experience, a market develops for resource (forest) products, thus giving rise to over-harvesting for sale by the community members themselves.

Awareness of ecological stress leading to collective preventive actions is likely to develop more quickly in those societies in which a sense of loss and scarcity or dispossession prevails. Moreover, it emerges more easily with respect to localised and visible resources than with respect to resources having opposite characteristics. In our field studies, Burdwan, Bon Hooghly and Charcharia appear to belong to the first group, while Purulia, with dispersed villages to the second. We have seen from our field experience that quite often success of collective action in many cases is additionally associated with effective leadership. Good leaders (from within the community or as a catalytic third party) perform several critical functions: to help people become aware of the resource condition and the nature and extent of confronting them; to convince them that their long-term interest lies in concerted action; to set before others the good example; to mobilise a sufficient number of them to ensure coordinated efforts; in generating AG environment; and in the designing and enforcing of rules and sanction mechanisms. Experiences of Burdwan, Bon Hooghly and Charcharia show that collective action probably performs better when it is led by committed and literate persons who have been exposed to a wider world.

Policy Implications

Our theories and experiences based on the case studies show that in many situations, though not always, co-ordination and leadership problems play a dominant role. When poor people overexploit local natural resources even when they are aware of the ecological impact of their actions, it is often because they face acute subsistence constraints, which leads them to discount streams of future benefits heavily. They generally need externally provided economic incentives to be induced to conserve their resources. An external catalytic role by the state via local level institutions can play a significant role here. Even a political party, as we have seen, can act as a catalytic agent. Trust and co-ordination can be created under the impulse of catalytic agents who often come from outside the community. All these imply that in many situations, state intervention could be reshaped to institutionalise collaboration between state administration and local resource users. The precise mode of such partnership will, of course, depend on the specific contextual factors.

Joint Forest Management and its Impact on the Forest Fringe Economy: A Case Study of a Dry and Arid Region of West Bengal

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Introduction

The term 'Joint Forest Management' (JFM) refers to a program of co-management of the forests by the forest department and forest dependent communities in India. The basic component of this program has been the formation of Forest Protection Committees (FPCs), which comprise villagers as well as government representatives, including a forest department official. The West Bengal Forest Department has been a pioneer in this field, and presently 4,90,582 hectares of protected forests and 74,045 hectares of reserved forests (including Wildlife Sanctuaries and Tiger Reserves) in the state are managed by 3,431 FPCs and 87 Eco-Development Committees (EDCs) respectively. After more than a decade of existence, the time is ripe for assessing the effectiveness of FPCs/EDCs in managing forest resources.

Study Areas

Our study is based on the collection of extensive primary data from three districts - Medinipur and Bankura (representing the plains of South Bengal and FPCs as the local institutions); and Jalpaiguri (representing the protected forests of Madarihat with FPCs as local institutions and Jaldapara Wildlife Sanctuary with EDCs as local institutions), although the quantitative analysis uses data solely from South Bengal.

Objectives

Our objectives are to:

- Measure the pecuniary (income from felling and the consumption and sale of non-timber forest produce) and non-pecuniary benefits accruing to the forest dependent communities through JFM
- Critically examine the performance of JFM as an institution by determining the relationship between the state of the forest on the one hand, and socio-economic variables as well as variables representing the functioning of the FPCs on the other
- Identify, using a game theoretic structure, the issues and problems related to the prevailing benefit sharing pattern, incentive structure and institutional functioning governing JFM, and suggest suitable policy alternatives

Methodology

The Data

The field survey was done in the year 2000. Appropriate statistical techniques were used to select a representative sample of 62 FPCs/EDCs (20 %of the total number). Of these, 58 are located in South Bengal and 4 in North Bengal. The statistical analysis was conducted for the South Bengal FPCs – as such, 1,016 households (20 %0of all the households in each of the 58 FPCs). The basic unit for most of our analyses is the FPC - in other words, we have ultimately reduced all the data to the level of the FPC. However, this data was *collected* from the following five sources.

- The condition (density and diversity) of the forest was ascertained using sampling techniques
- Some of the socio-economic data was at the level of the villages under the FPC, such as the ratio of the forest area (under the aegis of each FPC) to the number of households and the ethnic composition ('general' caste to scheduled caste to tribal)

- Socio-economic data was collected at the household level
- Information was obtained at the level of the FPC - largely regarding its operation
- We met different strata of forest officials - the Chief Conservator of Forests, Divisional Forest Officers, Range Officers, Beat Officers and Forest Guards to understand the attitude and functioning of the forest department at various levels

Benefits Obtained by the Forest Fringe Populations

We considered only the local populations that have a direct connection with the forests. The benefits then, are in the form of:

- Non timber forest produce (NTFP) consumed/ used directly by the collector
- NTFP collected for sale after or before processing
- The 25 percent share of timber and intermediate biomass sale by the forest department
- Benefits from the illegal felling and sale of timber
- Other intangible benefits

The first three benefits have been evaluated for each household and FPC, using standard valuation techniques. It may be noted that the illegal nature of felling and sale of timber prevents us from evaluating it. Moreover, it is certainly a benefit, albeit dubious, that the forest provides, but it would not be a benefit in a scenario where protection is the norm. Finally, for other intangible benefits we used a contingent valuation by asking the respondents what they would be willing to pay for the 'existence' of the forest, quite apart from the tangible benefits they get.

The average yearly benefits are Rs.10,366 per household (Rs.2,073 per person). We see that fuel and fodder account for the major part of benefits, followed (not closely) by 'NTFP for sale', and then food. The other NTFP categories yield insignificant benefits. Also, felling benefits are very low. The amounts recorded as "willingness to pay " are also meagre.

Relationship between the State of the Forest and FPCs

The relationship between the state of the forest and socio-economic as well as FPC-operation variables was looked into.

The variables are listed below:

The state of the forest	S	Dependent Variable
Educational level	E	
NTFP income per household	NI	
Non-forest income per household	NFI	Socio-Economic Vars.
Tribal share	T	
Forest to household ratio	FHR	
Age of the FPC	AG	
Internal conflicts index	IC	
Other conflicts index	OC	
Meeting index	M	
Guarding per unit area	G	Operational Variables
Alienation ratio	AR	
Register maintenance	RM	
Executive Committee form. mode	EF	
Representative EC	REP	

IC, OC and M have the following definitions:

$$IC = \frac{\text{Cumulative years of intra-FPC problems}}{\text{Total no. of intra-FPC problems x FPC age}} \text{ x Satisfaction Index,}$$

Where, 'Satisfaction Index' is an index reflecting the satisfaction FPC members have with the internal operation of the FPC, and

$$OC = \frac{\text{Cumulative years of 'Other' problems}}{\text{Total no. of 'other' problems x FPC age}} \text{x Trust Index,}$$

Where, 'Trust Index' is an index reflecting the degree to which the FPC is able to co-ordinate with the forest department. Also,

$$M = \frac{(MY + MB)}{2} \text{ X ATT where}$$

MY = Meetings in the preceding year

MB = Meetings in the presence of the Beat Officer (in the preceding year), and

ATT = Percentage attendance, on average.

'Alienation ratio' refers to the number of households that are totally alienated (from the operation of the FPC) as a ratio of total households. The last three variables are dummies. RM refers to whether the FPC maintains a register, EF refers to whether the executive committee is democratically formed every year , and REP refers to whether the executive committee is representative in terms of caste. The other variables should be (largely) self-explanatory.

We have conducted correlation (ordinary and rank) analyses of the variables; these correlations give some indication of the regression results that follow. Regressions are carried out with 'S' (state of the forest) as the dependant variable, and the following independent variables:

(a) the socio-economic variables

(b) the operational variables

(c) all variables

(d) NI and all operational variables, but keeping out IC and M

(e) other random combinations.

The best fit is given by the equation:

$$S = 2.128 + .26\,NI - .504IC + .21\,M$$
$$(2.48) \qquad (-4.95) \qquad (2.01)$$
$$(\text{Adj. R-square}: \ .43 \qquad F: \ 15.3)$$

with a satisfactory goodness of fit as indicated by the t-values, R-square and F. Hence, the three factors critically influencing S are the Internal Conflicts index, NTFP Incomes and the Meetings index.

We have grouped the variables according to criteria such as the age of the FPC, level of satisfaction with the operation of the FPC, percent of tribals, and so on, and obtained the average S for each group. We have used 11 criteria. The results gave us greater insight into the working of the FPC.

Game Theoretic Point of View

We have looked at the problem in a game theoretic framework, formulated the present structure of the game (forest department versus the villagers at one level and amongst the villagers at another) and identified the benefits and costs of defection (in other words, using the forest resources in an unsustainable fashion) by a villager. We have then looked at (A) how the structure of the game may be altered and (B) how to reduce the benefits and enhance the costs of defection so that the villagers do not defect but rather participate in protecting the forests.

Results and Conclusions

Our conclusions are based on both the data analysis as well as an in-depth and qualitative evaluation of FPC operations. Some of the points that emerge are

- The collection of non-timber forest produce (NTFP) is certainly an incentive for forest preservation but the villagers do not feel that it is 'provided' by the forest department.
- The most publicised incentive, the 25 percent felling returns, is virtually absent.
- The amounts the villagers are "willing to pay" for the mere existence of the forest may be small but definitely not zero.
- The socio-economic variables such as education and income (from sources other than NTFP) are not important in determining the state of the forest.
- FPCs do operate; only 6 out of the 62 FPCs covered do not operate at all.
- The operational factors are in fact more important determining factors, even compared to NTFP collection.
- The " internal conflict " factor is most important - in other words, if there are too many unresolved problems, it has a negative impact on the state of the forest.
- Informal rather than formal guarding is effective.
- The current relationship of the FPC with the forest department is not so clearly important; indicating that the role of the forest department, which is at best tepid, has to change.
- The importance of operational variables such as register maintenance is not absent but not very great.

- Caste representation in the Executive Committee is not always necessary or may even be counter-productive - the EC should be chosen with effectiveness in mind.
- The best FPCs have been formed in the intermediate years - the early 1990s.
- For North Bengal, the elimination of sawmills, a more careful micro planning of the village economy around the reserved forests and the formalisation of the rights of the villagers are seen to be critical.
- Exclusive reservation of the forests does not appear to be feasible, as they are the only sources of fuel and fodder and as poverty forces the people to resort to illegal felling.

The Game-theoretic Analysis throws up the following points:

- It is necessary to bring clarity to the structure of the 'game' of forest preservation/ exploitation.
- Payoffs for protecting the forests should be high and regular.
- The elimination of alienation (of women and certain other groups from FPC operation) is crucial because if *some* defect, others follow.
- The role of the forest department should be recast for effective management.

Policy Recommendations

The following is an action plan for the centre, the state and the local institution (FPC/EC).

The Centre

- The ministry of environment and forests should review and restructure the responsibilities (and hence, specific duties) of the state forest department, keeping in mind the fact that the department should be a facilitator rather than a key player in forest preservation.
- It should recognise FPCs/EDCs as legal bodies and should clarify their functions and their rights (e.g. the share of felling returns)
- It should also provide the scientific input required to determine the basic rules for sustainable extraction.

The State

- The main function of the state forest department would be to implement the centre's guidelines after incorporating local features.
- It should individually determine the modus operandi for NTFP extraction and timber felling cycles for each FPC, for which, it should take professional help from scientists and NGOs.
- It should then instruct and supervise the activities of the FPCs/EDCs/villagers to ensure that
    - The basic rules are adhered to
    - The flow of benefits is regular
    - There is an equal sharing of rights and responsibilities.
    - Women are as involved as the men
    - Illegal felling is prevented through vigilance, social sanction (for minor defections), legal action and the elimination of channels for timber sale.
    - FPCs/EDCs hold regular meetings, and that the meetings are well attended, interactive and democratic.
    - There is no lacunae in terms of the dissemination of information – both scientific and organisational.
- The department should *convince* the villagers that it is critical to protect and regenerate forest resources by showing them that the benefits, including the less obvious ones, are very significant.
- Political interference is a crucial factor at the local level – ways and means of bypassing such intrusions have to be explored.

- The state forest department should also explore ways in which social sanction can become a major disincentive for potential offenders.
- Another aspect that has not been sufficiently or competently developed at the state level is the sale of processed NTFP. Several departments have to be involved if the collection, processing and marketing of NTFP that have a commercial potential can substantially benefit the locals.
- The state forest department has to deal with the issue of whether EDCs should be allowed to collect some NTFP, and if they cannot, what kinds of benefits can be provided to them.

FPC/EDC

- The FPC/EDC has to organise itself better – and that it would do if it were convinced that there would be major positive returns from forest protection.
- Whilst it may consider regularising some of the formal aspects of functioning (such as maintaining records, organising frequent meetings), it must, at the same time, ensure that some of the informal mechanisms (such as mutual vigilance, forms of social sanction) are in force.
- The FPC must certainly ensure that women are totally involved, that not a single household is left out, and that benefits are fairly distributed.
- It also has to take a major initiative in the area of commercial NTFP by organising its processing and taking part in its marketing.

Ecological-Economic Analysis of Grassland Systems: Resource Dynamics and Management Challenges – Kachchh District (Gujarat)

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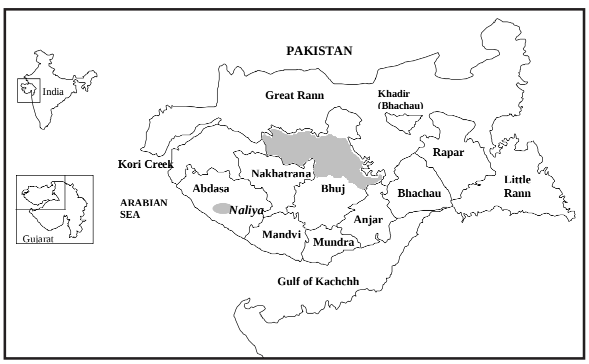
Introduction

About 1,400 km^2 of the grasslands in Gujarat are administered by the State Forest Department and are known as vidis. Of the total vidis in the state, a large proportion (92%) is distributed in the semi-arid and arid regions of Saurashtra and Kachchh. About 44 percent of these are in the Kachchh district. Other than these vidis, there are also large grassland tracts that are open for free-grazing. A significantly large population of pastoral and agro-pastoral communities in these arid/semi-arid regions sustain their livelihoods based on free-grazing livestock. Most of the grasslands of Kachchh are in the Banni and the Naliya regions (Fig. 1). The grasslands are severely degraded through a combination of intensive grazing, changes in institutional arrangements, nature of property rights, illegal encroachments and invasion by the exotic woody species, *Prosopis juliflora*,[1] a mesquite native to South America. The area with the potential for grass cover in Banni is about 1,610 km^2, of which 80percent is at present invaded by the mesquite, leaving only about 350 km^2 with grass cover. Naliya represents a contiguous grassland tract of nearly 160 km^2.

Fig. 1: Location of Study Areas in Kachchh District



Banni & Naliya Grasslands

Banni represents the case where grassland resources are crucial to the pastoral economy, while Naliya is a case where the biodiversity values are very high. Endangered wild animals like the Chinkara (Indian Gazelle) and Wolf extensively use Naliya, which is also one of the rare breeding areas for the three globally endangered species of bustards – Great Indian Bustard, Lesser Florican and the Houbara Bustard. The property and resource management regimes are in striking contrast in these two regions. The pastoral system dominates Banni, while agriculture is the mainstay of the rural economy in Naliya. Banni is also characterised by the absence of agriculture and non-existence of individual or collective village property rights. Most of the Naliya grasslands are government owned, and much of the village pastures or *gauchars* are also part of the grassland system.

Objectives

The major objectives of the study are to:

- Examine the dynamic links between the economic variables and grassland resources in a system dynamics framework
- Disaggregate income sources and distribution in the context of different kinds of resources

[1] It is also known by the synonym Prosopis chilensis
[2] Adult Cattle Unit (ACU): Numbers of different types of livestock are converted into a uniform number – ACU, based on the biomass requirement, which is determined on the basis of body weight of animal. The conversion units are: One Adult Cattle = One ACU; One buffalo = 1.4 ACU; One sheep or goat = 0.25 ACU, One Camel = 1.4 ACU.

- Understand the implications of various resource management scenarios on the economic returns and ecological conditions

Methodology

The study focuses on the grassland resource dynamics within an ecological economics perspective. Disaggregating income derived from the different sources and their association with the grassland resources is critical to establish the economic significance of these grasslands, especially in the context of arid and semi-arid tracts where pastoralism/ agro-pastoralism is still an important component of the rural economy. The overall goal of this study is to explore the possibilities for better management of grasslands as an ecological entity, and to study the economic ramifications of various options.

Sampling & Data Analysis

The ecological information was gathered from samples at every kilometre interval (146 sample points in Banni and 28 in Naliya). Several Focused Group Discussions, meetings with village elders and informal group discussions were also held to gather information. The random sample data covers approximately 20 percent of the population in the two study regions. The surveys covered 387 households from 13 out of 51 villages of Banni and 174 households from 9 villages of Naliya. However, for the analysis of data on various aspects, only those sub-samples (datasheets) were considered, which had complete information and were relevant to the theme. In the case of Banni, for example, only a sub-sample of 251 out of 387 had complete responses to the income related parameters, and migration related data was analysed with a sub-sample of 130 families. The relevant sample size is mentioned while describing the results through tables or graphs.

The statistical methods employed include minimum variance hierarchical clustering, various descriptive statistics, regression analysis – linear, non-linear and logit, analysis of means and decomposition analysis of incomes and inequalities. The inequality measure, CV2, was separated into weighted contribution from the components for the decomposition of inequality. Satellite remote sensing data was used to get a synoptic view of natural resources and to estimate the invasion of grassland by woody cover.

Modelling Resource Dynamics and Economic Returns

We have attempted to understand the dynamics of the ecological and economic linkages by a system dynamic modelling approach. The major steps in this effort are:

- Constructing an ecological model to capture the basics of ecological dynamics that is realistic enough to contain the 'core' ecological or resource degradation problem
- Using the ecological dynamics model to provide the constraints for the renewable resources – grass and wood that are determinants of income in the economic model
- Computer simulations to arrive at inferences on different modes of resource management and policy, based on appropriate choice of parameter values and constraints

Results

Banni Grassland

The available livestock census data for Banni region shows that the livestock numbers, which were about 35,000 in 1957, reached a peak of nearly 49,400 in 1982 and fell to about 30,000 in 1997. The lowest figure recorded in the census is about 25,000 in the 1977 census. The dominant occupation is of livestock rearing (65.4% of total families), followed by wage labour, most of which appears to be linked to illegal wood-charcoal making from the woody species. About 69 percent of those who possess cattle earned supplementary income from charcoal making, while the buffalo owning herders have almost exclusive dependence on livestock based economic activity. Among the major drought coping strategy is the reliance on scarcity relief programs (43.7%). Also, 53.5 percent of households sent their livestock to cattle camps run during drought periods. The tendency to migrate increases with herd size, and smaller herds are less likely to migrate.

- ***Income Decomposition***

The income sources in Banni can be split into livestock and non-livestock based incomes. Agriculture is non-existent due to the absence of the right to own land and the intrinsic difficulties for sustaining agriculture. The existence of a large pool of woody biomass has created a new non-livestock based income (NLBI) opportunity, albeit illegal under the current policy environment, which was almost non-existent till about 1960. The livestock based income (LBI) includes milk-based income, MBI (milk & milk products) and the proceeds from the sale of animals, wool and dung. The miscellaneous category represents all other incomes such as salaries, wages, handicrafts and other sources, such as transfers and trade. The *Prosopis juliflora* based income is disaggregated into returns from wood charcoal and that from non-timber produce (NTFP) such as honey and gum.

Mean annual gross income per household is about Rs.57,000 from livestock, while that NLBI is nearly Rs.23,500. Total extrapolated gross income per year in Banni works out to be about Rs.170 million (Table 1). The extrapolation is carried out by applying the proportion of households deriving incomes from the different sources would conform to the pattern that has emerged from this study. The largest share is from LBI (70.3%) with milk sales alone accounting for 63.6 percent. The share of woody resource based income is 16.3 percent, while sources other than those based on grass and wood account for 13.4 percent.

Table 1: Income from Major Sources in Banni

Source	Households*	Mean GAHI (Rs.)	Extrapolated# (Million Rs.)
Livestock	210	57,150	119
Non-Livestock (i.e., all others)	217	23,550	51
All sources	251	68,175	170

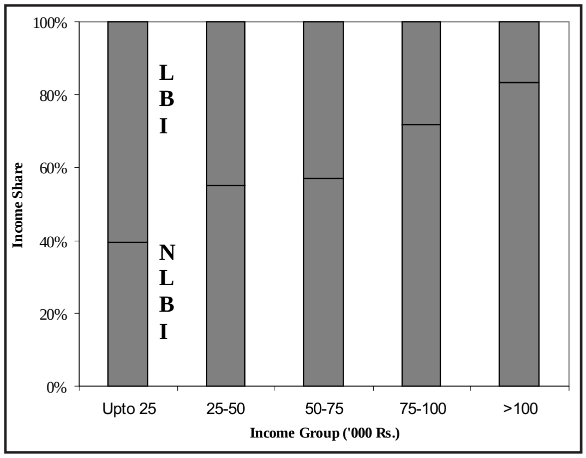
* There are, in general, multiple income streams for each household, and therefore the values in the column do not add up to those given as the total

Extrapolation to nearly 2,500 households (census 1991), based on the assumption that the proportion of households depending on the different resources conforms to the pattern reported here. The extrapolated income = *(total households of census data)**(proportion of households by source)*(mean GAHI by source).

Resource Dependency

The income distribution is highly skewed with 20 percent of families in the low-income group (0 to Rs. 25,000/yr) and 16 percent in the high-income group (above Rs. 1 lakh/year). The share from LBI is more in the richer households, while poorer families have heavy reliance on NLBI, derived mostly from Prosopis juliflora (Fig. 2).

Fig. 2: Income Share from LBI and NLBI



The inequality was much lower in the non-herder category than among herders, where there are very large differences (Table 2). Although a large part of the inequality within non-herders comes from woody resource, the disparity tends to get evened out by the income from other sources. The woody resource based income has only a negligible role in altering the overall inequality, which is determined by the dominant share of LBI in the total income. A buffalo herder is able to generate about 74 percent more net income than a cattle herder. It is also seen that there is significant dependence of the poorer herders and those without livestock on the woody resource, despite the illegal nature of this commercial activity. The analysis shows that the higher the non-livestock-based income, the less is the probability of a household to migrate.

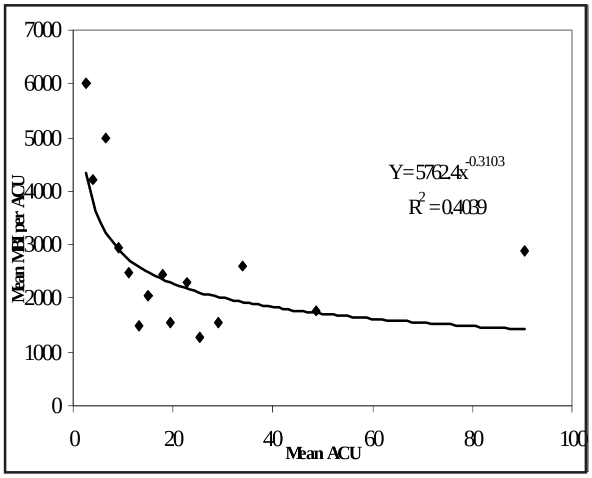
Table 2: Income Inequality- Herders vs. Non-herders

Parameters	Herders	Non-Herders	All Families
Mean GAHI (Rs.)	76,731	24,261	68,175
Gini Coefficient	0.44	0.35	0.46
CV^2	1.13	0.39	1.28

Returns per Animal and Open Access Resource

In order to analyse the pattern of LBI per Adult Cattle Unit[1] (ACU), we grouped the buffalo herds into various size classes, and then computed different parameters of income and herd size. The milk-based income (MBI) per animal turns out to be a slowly declining function of herd size (Fig. 3) that follows a power law function ($Y = a*X^b$, where the constants, a>0; -1<b<0) and the total return X*Y will naturally increase with herd size. In other words,

Fig. 3: Relationship of herd Size and MBI in Buffalo Group



the utility per animal declined with the addition of one animal, if the asset value of an additional animal is not considered. Regression analysis also showed that the mean livestock maintenance cost per ACU also followed a similar power law function, declining with increasing herd size. The net return per unit maintenance cost obtained from these two is a slowly declining power law function, falling very slowly with herd size. The nature of this function implies that a strategy to maximise returns from grassland resources would be for each herder to go for larger herd size, which will yield greater incomes, even though the return per animal may decline with herd size. This is consistent with conditions of open access involving zero costs. It may also be noted that owning a larger herd amounts to possessing greater wealth as well as larger productive assets. A strategy to extract the maximum of freely available grass resource and the drive to increase assets will in combination give rise to a functional relationship that is revealed by the data. The declining power law function for MBI per animal naturally raises the question of the economy of scale in such an economy. As a corollary, it may also be inferred that the conventional economy of scale do not appear to be valid if we consider only a single output such as milk. However, if all the benefits are fully accounted for, the apparent diseconomy of scale may disappear.

- ***Dynamic Model of Resources Economics***

The resource dynamics were modelled using a system dynamics approach with three state variables:

- Livestock expressed in ACU
- The grazing potential or the maximum cattle that the rangeland can support
- The area invaded by woody species displacing grass cover

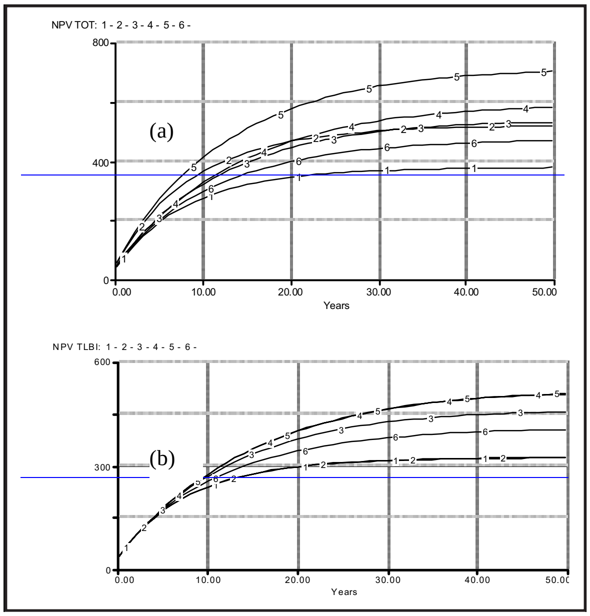
The grazing potential is treated as a state variable that varies both with time and stocking level, since stock of livestock alters the grazing potential.

The key elements for the specification of the dynamics of a pastoral-economy and ecology in this manner are:

- Current state of the variables such as herd size will affect the future rangeland carrying capacity.
- High degree of variance determines the evolution of the system and such variation randomises the trajectories of all variables over time.
- Very high degree of uncertainty that are attached to the future value of state variables.

The total area that can be covered by grass and woody species is constant, while the grazing potential is both a function of livestock levels and extent of woody invasion. The growth rates for livestock and the regeneration rates for grass were treated as normally distributed random variates to incorporate the stochastic effects of rainfall variability. The utility function includes returns from both grass and wood-based economic activity. The short and long-term fate of the grassland is assumed to be irrelevant to the utility maximising decisions of livestock owners. The Net Present

Fig. 4: Net Present Values of (a) Total and (b) LBI over a 50-year Period



Value (NPV) of various income streams and total income from all are computed over a 50-year time horizon assuming a discount rate of 10 percent. The parameter sensitivity analysis was also carried out to determine the response of the system when parameters are varied.

Computer simulations were carried out to examine different resource management scenarios. The Business-As-Usual (BAU) scenario, predictably leads to progressive decline of the grassland. The second case is one of removing all restrictions on wood charcoal making and opening up economic opportunities of the woody sector. This would naturally increase the incomes from woody resource, without making any significant change in the livestock sector, as can be seen from the comparison of Fig. 4(a) and 4(b). Scenario 3 represents the situation where there is a state sponsored effort for removal of woody areas, without attempting to put in place any institutional arrangements or resource management regimes that can check re-invasion of the areas cleared. This case will naturally increase the returns from the grasslands, without any substantial increase in earnings from woody resource. In the long-run, this does not change the fate of grasslands, since all of woody cover cannot be removed in a short period and at low rates of removal, there is enough woody cover left, which can invade the grassland areas. The 5th scenario is of considerable interest, because it envisages woody removal, change in policy environment to alter resource management regime to ensure that re-invasion is checked and legalizing wood charcoal making under a quota based system. The 6th scenario mimics the current efforts involving NGO's to regenerate small grassland plots, which can only lead to a marginal improvement from the current situation.

As it stands, major investments are not needed in the total removal of woody cover as all expenses can be recovered through the sale of wood charcoal in the same year with a net gain. Already 80 percent of grassland is invaded and the task of complete removal in a short time is extremely difficult. Simulations show that even with a removal plan of 5 to 10 percent of invaded area per year and recovering it - as good grassland brings dual economic benefits: increased incomes from grassland regeneration and the returns from wood charcoal produced from the area cleared (scenario 5). All this is subject to the caveat that there is a policy change, altering the management regime to check re-invasion by legalizing the economic stakes. The simulations are over a 50-year span and these economic benefits are sustainable over such a long term. Scenario 5 represents a workable framework, which places certain responsibilities on the Forest Department (i.e., of designating areas for removal of woody cover and auctioning of woody areas for charcoal making). The area from which woody cover is removed will be placed under a joint resource management framework, with well-defined entitlements and usufruct rights to the herders for the use of those grassland tracts. It ensures that they have the incentive to check reinvasion of the grassland tracts on which they have the usufruct rights.

Naliya Grasslands

- ***Income Decomposition***

Most of the households in Naliya are agro-pastoral. The distribution of income from each source and their relative contribution in the total economy of the region is very uneven (SD = Rs.97,247/-). About 77 percent of the total income of the households studied belongs to the richer quintiles, while only about 4 percent income is with the poorest quintile. Table 3 shows that, of the total average annual income, the largest share comes from agriculture (46.5%), followed by livestock (37.2%) and other sources (16.3%). In the poorest group, the largest share of income is derived from grassland dependent livestock (42.9%), and is thus very crucial for their subsistence.

Table 3: Income Share (%) from Various Sources across Different Income Groups

Income Quintile	Mean GAHI (Rs.)	Share of income by source		
		Farm-based	Livestock-based	Miscellaneous
Poorest	12239	19.0	42.9	38.1
Second	24029	27.9	32.8	39.3
Third	35421	30.6	35.5	33.9
Fourth	60099	34.8	48.4	16.8
Richest	186009	57.1	34.3	8.6
Total	**64,275**	**46.5**	**37.2**	**16.3**

The richer section also derives quite a substantial income from the livestock sector, and given their large livestock holdings (mean ACU per household of 19.4 as compared to 1.6 in the poorest), these returns go beyond subsistence. Both farm and livestock based incomes are positively correlated with landholding size. Mean gross annual FBI per household is about Rs.39,500, while that from LBI is about Rs.29,000. Total extrapolated gross income per year for the nine sampled villages is about Rs.48 million (Table 4). It can be seen that about 93 percent of total LBI is derived from milk and milk-based products.

Table 4: Income from Different Sources in Naliya

Source	House-holds*	Mean GAHI (Rs.)	Extrapolated Income# (Million Rs.)
Farm-based	129	39,578	22.3
Livestock-based	140	29,238	17.9
Others	89	20,136	7.8
All Sources	**171**	**64,275**	**48.0**

* There are, in general, multiple income streams for each household, and therefore the values in the column do not add up to those given as the total.

Extrapolation to nearly 750 households (census 1991), based on the assumption that proportion of households depending on the different resources conforms to the pattern reported here. The extrapolated income = *(total households of census data)**(proportion of households by source) *(mean GAHI by source).

- ***Unpaid Costs of Open Access***

The cost of open access to grassland resources, or the unpaid cost of grassland resources used was inferred by the use of imputed values of the fodder consumed from pastures. Only 11.6 percent of the fodder demand is met from the *gauchar* lands during summer, while the same grassland fulfils nearly 86 percent fodder demand during the rainy season. There is a marked variation in the seasonal dependency across different income groups (Table 5). The livestock units were converted to ACU and consumption estimated using the norm of 7 kg intake per ACU per day. The data on seasonal variations in the dependency on pastures was used to estimate the total quantum of fodder extraction in the year from the *gauchar* lands. The total cost of such dependency was arrived at using a notional cost of 50 paise per kg of grass. The unpaid cost incurred by the poorest and richest are about Rs.38,800 and Rs.360,700 respectively. The total unpaid cost per year for the sampled households is about Rs.0.95 million. The extrapolation based on the 1991 census data of the nine villages in the study area works out to be approximately Rs.4.75 million. Analysis shows that the bulk of social cost for the year is accounted for by the richest quintile (38%), while poorest benefits by a mere 4 percent, although the poorest extract higher benefits per animal per year.

Table 5: Annual Social Cost (Rs.) of Free Grazing Across Income Quintiles

Quintiles	Total	%	Per HH	Per ACU
Poorest	38801	4.1	1141	719
Second	179981	18.9	5294	577
Third	144924	15.2	4262	609
Fourth	227471	23.9	6690	589
Richest	360,679	37.9	10305	530
Total	**9,51,856**	100.0	**5,566**	**570**

Convergence Despite Contrasts

Banni and Naliya grasslands provide an unusual study in contrasts, despite the similarities of *de facto* open access resource management regimes. The lack of alternate economic resources such as agriculture and absence of property rights, force the people of Banni to be dependent on the market for their subsistence needs. The case is somewhat different in Naliya, where in view of alternate resource availability for livestock, migration is almost non-existent, while in the case of Banni, migration to other areas, including Naliya, is common. The grasslands of Naliya serve as a refuge for the livestock of Banni during periods of resource scarcity, as was confirmed by the surveys in Naliya. The fallow agriculture fields also offer grazing opportunities for the in-migrant livestock, and even a symbiotic relationship between herders from outside and the farmers: some farmers allow livestock into their fallow fields and use the dung in return. There is no practice of collecting any grazing fee or rent from the migrant herders. Extrapolations show that the milk production of Banni is worth more than Rs.100 million annually, which is likely to be a conservative estimate, since the data of this study is more representative of a dry period, and not of a normal year. The milk production in Naliya, on the other hand, is more for its own consumption than for the market. Nevertheless, it forms an important component of the household budgets of the agro-pastoral communities.

The ability of the herders in Banni to diversify their income sources is controlled by variables like heterogeneity of ecosystems (grasslands) or socio-economic differentiation among the communities. The present study suggests that the rich and poor herders (or owners of different herd types) pursue diversification differently, as different groups do not perceive risks in the same way. Obviously, in the risk management strategies of Banni pastoralists, the income opportunity from the mesquite (realised at present through charcoal and NTFP) plays an important role. Despite the economic significance of woody resource, the Banni herders still prefer grassland-based pastoral mode of income generation. In fact, this study suggests that the management of mesquite is needed, not only to improve the grazing potential of the Banni, but also as an alternative income channel to support the herders during periods of acute scarcity.

The overwhelming perception of the local people point to the possibilities for participatory management of both grass and woody resources (i.e., treat it as an economic resource) in the Banni region. On the other hand, in the case of Naliya, the pattern of resource dependency indicates that there is considerable scope for enhancing the economic outputs from the grassland. The findings clearly point to the need for a strategy to improve the synergy between agricultural and pastoral activities in Naliya. The local people extract the maximum resources during the post-monsoon season, when the area is full of green grass. Incidentally, this is also the breeding season for rare and endangered birds. Therefore, the management goal here becomes one of ensuring the availability of suitable habitats for the wildlife and of rational use of the grass resources by domesticated livestock.

The situation in both Banni and Naliya require innovative and pro-active approaches that will not only regenerate the grassland system, but also rationalise the economic activity based on woody resource in Banni. The approach must also improve the grassland system of Naliya for both livestock and endangered wildlife. In both cases, the management strategy needs to be informed by the recognition that the key stakeholders have crucial economic interests in the resource regeneration, and that the stakeholder involvement can be realised only by altering the open access regimes into one based on legitimate entitlements and for collective usufruct rights. Despite the contrasts, there is a convergence in the management goals because of the sound economic and ecological rationale for grassland regeneration.

This study estimates that the gross output per year from grassland and woody resources of Banni is about Rs.120 million and Rs.28 million, respectively. The estimated social cost of grassland use per year by all the agro-pastoral households in Naliya would be about Rs.4.75 million, without accounting for the benefits enjoyed by in-migrant pastoralists. All indications point to the increasing demand for milk and milk products, and consequently the potential for a vibrant livestock-based economy.

The feasible approach in both cases converges on the need for a very proactive and dynamic joint management framework, in which various stakeholders can be partners who can negotiate their competing claims. Given the current property rights regime, the Forest

Department will have to play a key role in making this possible. This cannot be accomplished by a mere replication of the lacklustre Joint Forest Management (JFM) approach currently implemented in degraded forests; but will have to be based on the recognition that these grasslands are of enormous direct economic values and the joint management has to facilitate efficiency in the economic activity based on the grasslands.

Policy Recommendations

Certain policy initiatives and institutional strengthening will help to realise some of the possibilities for developing models of the stakeholder-driven regime of resource management. The suggestions presented here emerge not only from the data analysed, but also from the extensive consultations carried out as part of the study. It is also enriched by the study of people's perceptions.

The major policy issues that emerge from the study are:

- Need for a three-pronged approach to grassland management: – a) protecting the livelihoods of pastoral communities; b) controlling the woody invasion of grasslands (applied largely to Banni), and c) addressing biodiversity conservation goals (Naliya)
- Restructuring the property and/or resource management regimes and administrative approaches, so as to bring about greater economic efficiency in the grassland resource use through higher stakeholder involvement in the control and economic use of woody biomass
- Need for a critical reassessment of the management of grasslands under the provisions of the Forest Conservation Act (1980) and the approach adopted by the Forest Department for this
- Review of biodiversity conservation strategy for grassland systems, so as to bring about sharing of conservation responsibilities between the Forest Department and local communities in place of excessive reliance on the Protected Area approach in regions like Naliya with extensive dispersal of biodiversity values

Two of the major policy and legal changes relate to: (a) alterations in the resource management regime in Banni, and (b) biodiversity conservation strategy in Naliya. The policy initiative needed in the former case is one of adapting the JFM approach for grassland regeneration, with due recognition of the usufruct rights of the stakeholders. The later case requires the shaping of a participatory biodiversity conservation program, in which the roles, duties and responsibilities of the community and the Forest Department are properly defined. Such policy changes are a pre-requisite for any meaningful and sustainable resource management in the prevailing conditions.

Report on Environmental Conservation and Demand for Nature-Based Tourism in Arunachal Pradesh

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Introduction

After the Stockholm Conference of the Seventies and the Rio Summit of the Nineties, research on environment in general, and forestry in particular has gained momentum. Attention is directed towards issues like timber demand, energy requirement, survival of forest-based industries, and even sustainability of biodiversity. However, very few studies stress on valuation of the recreational aspect of forests. The economic valuation of natural resources like forests, wildlife, etc. have proved to be important tools to focus on economic well-being of the local people and natural resource management and conservation. With this background, the present study intends to examine the prospects of developing nature- based tourism in a hilly state like Arunachal Pradesh, which is very rich in forest resources and biodiversity. This study provides an estimate of the recreational value of nature-based tourism, and estimates the economic potential for the development of such tourism in Arunachal Pradesh. To our knowledge, this is the first valuation exercise on the North-East in general and Arunachal Pradesh in particular that documents the large non-market benefits associated with preservation of forests and wildlife. Arunachal Pradesh as a case study is the centerpiece of this research.

Objectives

The broad objectives of the study are as follows:

- Study the socio-economic characteristics of tourists, such as nationality, gender, age, reasons for visit, household income, educational level, length of stay, cost of travel, etc.
- Determine, as far as possible, the income benefits of nature-based tourism through the existence of natural resources.
- Examine the nature of demand for tourism related services generated by the selected tourist spots of Arunachal Pradesh.
- Elicit relative values placed by stakeholders of neighbouring forests/parts, as well as local people's perceptions of the impacts of tourism.
- Identify and assess the possible negative impact of tourism.

Brief Description of the Study Area

The present study area is Arunachal Pradesh, which is situated between 26°30‘ and 29°30‘ north latitudes and 90°30‘ and 97°30‘ east longitudes, covering an area of about 83,743 square kilometers. Arunachal Pradesh (earlier known as NEFA) is the home of around 26 major tribes and 110 sub-tribes. It is acknowledged to be one of the most splendid and multi-lingual tribal areas of the world.

Bio-geographically, it is situated in the Eastern Himalayan Province, which is considered to be the richest bio-geographical province of the Himalayan zone. The entire territory forms a complex hill system with varying elevations ranging from 50 meters at the foothills to around 7,000 meters in the northern hills. This diversity of topographical and climatic condition has favoured the growth of luxuriant forests, which are home to myriad plant and animal forms, adding beauty to the landscape. A large number of scenic beauty spots, with snow-clad mountains, picturesque and hilly terrain, are located at various altitudes in Arunachal Pradesh, but most of them are yet to be developed. As a result, during the 1990s, the tourism inflow has been very limited, varying from 2,000 to 6,000.

Four relatively developed tourist spots were selected for the purpose of our study. These were Namdapha National Park in the eastern part of the state, Ziro, located in the central part and Bomdila and Tawang in the western part of Arunachal Pradesh (as shown in map-I).

Methodology and Results

The present study was based on multi -stage sampling technique. In the first stage, the four tourist spots were selected by purposive sampling. This was followed by the second stage, in which a stratified random sapling technique was used to determine the proportion in which Indian and foreign visitors should be included in the sample.

During the survey, 309 effective interviews were conducted, out of which 269 were domestic tourists and 40 foreign tourists.

A travel cost model was used to determine the value of tourism and the nature of demand for it. A zonal travel cost model was applied since most of the tourists came from long distances and it was not possible to visit these sites more than once a year. The visitors were divided into zones on the basis of political boundaries within India, like North, West, East, North East, and a foreign zone for foreign tourists coming from abroad. The Delphi technique was used to identify the negative impacts of tourism on environment, which is discussed in the latter part.

A general form of the demand function can be written as:

Vij= f(TTCPP, TLCPP, OPPTIME, ENV, EDU, AGE, AHHI, GEN) Where

TTCPP = Travel cost from place of residence, cost of travel within the selected tourist spots, cost of boarding and lodging, other miscellaneous expenditure

TLCPP = That part of travel cost incurred within the selected tourist spots

OPPTIME = Per-capita household income per day corrected for number of days spent in the selected tourist spots.

ENV = Reason for visiting the selected tourist spots (dummy variable)

EDU = Education (levels of education)

AGE = Age (years)

AHHI = Annual Household Income per Family

GEN = Gender (0 = female, 1= male)

Thus, the demand functions for tourism of the selected tourist spots of Arunachal Pradesh depend on the amount spent on travel, either by way of total cost or by way of local costs, income level measured either by annual household income per family or by the opportunity cost of time spent (which in turn reflects household income), reasons for visiting the selected tourist spots, education, age, gender etc.

The above exploration using a semi-log demand function (both in its total and local cost specifications) indicates that local travel cost is a valid proxy variable for price in determining demand for tourism services.

Now, an attempt was made to estimate the consumer surplus and demand elasticities, which can help in the formulation of policies with respect to management of these places. The consumer surplus gives an estimate of willingness to pay for preservation.

The consumer surplus per person per visit for each zone can be found by integrating the demand curve between the average travel cost for that zone and the 'choke price' (all other independent variables can be taken at their average values). Multiplying this by the total number of visits to and from the zone will give us the total consumer surplus for the zone. Thus, if we add all the zonal consumer surpluses, we can get the total annual consumer surplus of the visitors to the selected tourist spots of Arunachal Pradesh.

Table 1 shows consumer surplus as estimated from the semi log form of function relating the visitation rate to travel cost, taking both it total and local variants.

Table 1: Consumer Surpluses of the Sampled Indian and Foreign Tourists

Model specifications	Consumer surplus per visit (Rs.) (Indians)	Consumer surplus per visit (Rs.) (Foreigners)
Set 1: Using total travel cost variable under semi-log model	40,298	62,377
Set 2: Using local cost variable under semi-log model	995	1232

As expected, the consumer surplus using the total travel cost was higher both in case of domestic and foreign tourists. As we have noticed earlier that the visitation rate was clearly affected by local cost. As the location of the selected tourist spots of Arunachal Pradesh were within easy access of other tourist spots of North East India, it was considered more appropriate to estimate consumer surplus from the local costs only. This amounted to about Rs. 995 per visit for Indian tourist and about Rs. 1,232 per visit for foreign tourists.

The demand functions were used to estimate price elasticities of demand at the mean value of the variable. Table 2 gives the estimates of price elasticities for the different zones.

Table 2: Elasticity of Demand for Tourism Services: Zone Wise

Model specification	Zone 1 North	Zone 2 East	Zone 3 North East	Zone 4 West	Zone 5 Foreign
1.Using total travel cost variable under semi-log model	-0.11	-0.16	-0.12	-0.47	-0.60
2. Using local cost variable under semi-log model	-0.46	-0.69	-0.47	-0.28	-0.17

Table 2 shows that using the function based on TTCPP, the price elasticity was between –0.60 and –0.11 , and using TLCPP the price elasticity was between –0.69 and –0.17.

Thus, as a whole, the demand for tourism in the selected tourist spots of Arunachal Pradesh was price inelastic whether the demand for recreation was based on the total travel cost or the local travel cost. This observation was consistent with previous recreational studies.

The travel cost results showed that the consumer surplus per visit of Indian and foreign tourists was quite substantial. A large part of it could be taxed or visitor charges could be increased to yield additional benefits for tourist spots. Therefore, it called for an increase in entry fee for both domestic and foreign tourists. The results also showed that this would not result in reduction of the tourist traffic, as the demand for services of tourism turned out to be inelastic.

In economic terms, tourism assets and resources are income and employment-generating products par excellence. However, the paradox of tourism development is that the product needs to be consistently protected as it is being marketed. Unregulated tourism endangers and depletes the very resources that attract tourists. Many studies demonstrate that even nature-based tourism can have an adverse effect on natural resources and environment if sufficient safeguards are not adopted. So, it was felt necessary to relate both the aspects of tourism by applying the travel cost method and the Delphi technique. Since Arunachal Pradesh is in the initial stages of tourism development, it was felt necessary to identify only the potential negative impacts of tourism on environment by applying the Delphi technique.

The Delphi technique is considered a potentially valuable technique for identification and assessment of the impacts of tourism. It is one of the most well established means of collecting expert opinions and of gaining consensus among experts on various factors under consideration. The technique we coined in our study followed the technique of Green et. al in their assessment of environmental impacts stemming from a tourism project in England.

A detailed breakdown of the results of first and second rounds is given in Tables 3 and 4 respectively.

Table 3: First Round Delphi Results

Environmental parameters	Mean ranking on five-point scale	Standard deviation	Coefficient of variation (%)
1. Solid Waste Accumulation	4.421	0.935	21.14
2. Depletion of Forests	3.263	0.848	25.99
3. Sewage Problems	3.078	1.155	37.52
4. Depletion of Wildlife	3.052	0.916	30.01
5. Traffic Congestion	3.026	0.959	31.69
6. Deterioration of Water Quality	2.763	0.840	30.40
7. Degradation of Landscape	2.474	1.141	46.12
8. Drainage Problems	2.447	1.311	53.58
9. Air Pollution	2.157	0.960	44.51
10. Soil Erosion	1.789	0.766	42.82

Table 4: Second Round Delphi Results

Environmental parameters	Mean ranking on five-point scale	Standard deviation	Coefficient of variation (%)
1. Solid Waste Accumulation	4.571	0.623	13.62
2. Depletion of Forests	3.857	0.789	20.45
3. Depletion of Wildlife	3.714	0.647	17.41
4. Sewage Problems	3.071	0.923	30.05
5. Traffic Congestion	3.036	0.823	27.11
6. Soil Erosion	2.714	0.749	27.60
7. Deterioration of Water Quality	2.607	0.673	25.81
8. Drainage Problems	2.285	0.795	34.80
9. Air Pollution	2.250	0.829	36.85
10. Degradation of Landscape	2.071	0.593	28.64

Tables 3 and 4 show that the ranking order of the negative impacts changed slightly over the two rounds. Although some of the changes may be attributed to the changing composition of the panel, due to Ist round dropouts, the majority can be attributed to panel members re-evaluating their views. The top five negative impacts on environmental parameters remained the same. In the second round, solid waste accumulation and deforestation had been identified as the most significant potential negative impacts followed by loss of wildlife and sewage problems.

Conclusion and Policy Implications

The present study demonstrates that there are some basic linkages between travel cost results and Delphi results. The travel cost results identified the enormous potential economic gain of tourism, and the Delphi results showed how the enormous potential benefits could be sustained, by identifying the potential negative impacts of tourism on the environment so that these potential negative threats may not become actual threats in the future, and neutralize the benefits of tourism.

The following policies as well as action plans were suggested for maintaining sustainable tourism:

- Creat Arunachal Pradesh Tourism Development Corporation for formulating policies and strategies, and take measures for tourish promotion, publicity and awareness.
- Prepare a tourism master plan and identify circuits and more tourist spots. Detailed circuit routes and location specific recommendations should be drawn in a phased manner. Commercial viability and competitive advantage of each route should be found out.
- Construct good hotels, tourist lodges and tourist huts to attract domestic and foreign tourists.
- Tourist clusters, especially in orange and apple orchard areas, with landscaped huts strewn across the hill side should be promoted which can be taken up by local Stakeholders, in collaboration with private entrepreneurs.
- The Government should encourage private operators to use battery operated luxury minibuses and car fleets exclusively dedicated for eco-friendly tourism. Infrastructural facilities like helipads, helicopters and small aircrafts with short landing run-up, should be constructed by private operators or joint sector ventures. Air taxi operating companies should be requested to provide helicopter sorties for tourists.
- The State Government should incorporate at least one aerial passenger ropeway company to construct ropeways at selected tourist spots of Arunachal Pradesh.
- The Government also should encourage adventure tourism by building necessary infrastructure for angling, river rafting, winter sports, etc.

- Ensure participation of local people in all the above activities.

At the same time, it is to be noted that sustainable tourism has to ensure that a balance is maintained between the activities of tourists and the capacity of the resource base to support these activities without much degradation or depletion of natural resources. Hence, the following guidelines were suggested to maintain sustainable tourism in Arunachal Pradesh:

- Tourists must carry food items/essential items in biodegradable packages in order to reduce solid waste accumulation.

- Provide alternative sources of energy at hotels so as to reduce dependence on forests.

- The roads or trails inside the forest should avoide breeding sites of the animals.

- All tourists visiting the sites should be educated to maintain environment friendly tourism norms.

- No tourist should be allowed to collect any biological material (living or dead) from the forests.

- All developmental activities, particularly infrastructure for facilitating tourism in the selected tourist spots, should be planned with a futuristic view on environmental sustainability.

- A watch dog committee should be set up to monitor the impact of tourism on the physical, chemical and biological entities and its socio-economic implications. The committee should comprise of experts from various disciplines from academic and research institutions and NGOs working on environment to update officials on the impacts from time to time. Based on these studies, the tourist inflow may be restricted in future.

The study showes that sustainable policies and guidelines for nature-based tourism could make Arunachal Pradesh one of the most frequently visited tourists states in the entire North East region of India. This could provide a very significant and much needed revenue and employment for Arunachal Pradesh. However, the challenging task for the Government is to find ways and take necessary steps to realise the economic potential, which also secures the preservation of forests and wildlife resources on which the sustainability of nature based tourism depends.

Natural Resource Management – Sustainable Extraction Level of Forest Products in Assam

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Introduction

Among the states of India, Assam is known for its forests and forest products. Wide varieties of valuable trees are available in the forests of Assam. It is because of such a wealth that the East India Company ventured to establish various Indian trading organisations in Assam. Railway lines were extended to Assam to transport the forest products from this part of the country to various parts of the world. Assam is one of the world's 16 most bio-diverse regions. Apart from valuable trees, the forests of Assam are a habitat for a wide range of flora and fauna.

Large-scale deforestation has become an acute problem all over the world. Forest products are being extracted in an unplanned manner, new plantations have not been taken up to replenish the depletion, more and more forests are being cleared for cultivation and habitation, less forest area has prompted wild animals to cause damage to human habitation, the ecological balance has been enormously disturbed, and the environment has degraded at a fast rate. Assam, once famous for its jungles, flora and fauna, is facing a serious situation arising out of large scale extraction of forest products and the simultaneous destruction of forests. The forest has been decreasing at an alarming rate day by day. Unable to find prey in the forests, wild animals have ventured into rural, and even urban areas in certain districts, making the local people feel unsafe and insecure. The government exchequer has also suffered badly. Against such a deteriorating situation, it has become essential to look into the problem of unplanned extraction of forest products in Assam, and to suggest measures to arrest this trend in order to maintain the desired level of forest and forest products in the years to come.

Objectives

The main objectives of the study are to:

- Portray the forest resource scenario of Sonitpur and Lakhimpur districts in particular, and that of Assam and north-east India in general.
- Identify the existing pattern of extraction of forest products in the study area.
- Identify the reasons for fast depletion of forests in the study area.
- Evaluate the effectiveness of forestation policies and practices.
- Suggest models and policy reforms for sustainable extraction of forest products.

Methodology

Both primary and secondary data pertaining to the problem under study were collected from various sources. The study area was confined to two districts of the state, viz. Sonitpur and Lakhimpur districts. While the secondary data was collected from forest offices, published documents and literatures, the primary data was collected from the villagers staying near the forest, NGO personnel involved with forest preservation, and government officials, among others. Structured questionnaires were used to collect the primary data. The study team also visited many reserved forests and forest villages to obtain first-hand information of forests and their uses. Data and information thus collected have been analysed to know about the characteristics of the problem.

Results

Forest Covered Areas

It has already been stated that the forest cover area is gradually decreasing in all parts of the world. The estimated forest covered area in north-east India for the years 1969, 1989, and 1999 is presented in Table 1.

Table 1: Estimated Forest Covered Area (sq. Km.)

STATES	1969	1989	1999
1. Assam	29535	26058	23688
2. Manipur	6022	17885	17384
3. Meghalaya	8445	15690	15633
4. Mizoram	7938	18178	18338
5. Nagaland	2897	14356	14164
6. Tripura	6300	5325	5745
7. Arunachal Pradesh	51540	68763	68747
8. Total north-east	112677	166255	164286
9. All India	755324	640134	NA

Source: Population and Forests, A Report on India, 2000 by UNFPA

The figures show that in the case of Assam and Tripura, there has been a steady decline in the forest-covered areas. The reasons for such a declining trend are deforestation, less new plantation, flood damage, etc. Table 2 shows the areas under new plantation in the two districts under study over the last decade.

Table 2: Plantation (Hectare) by General Forestry Division (Productive Forestry)

YEAR	SONITPUR DISTRICT	LAKHIMPUR DISTRICT	ASSAM
1990-91	455	160	6300
1991-92	415	190	6339
1992-93	795	200	8925
1993-94	465	190	6646
1994-95	365	190	5806
1995-96	310	95	5421
1996-97	325	120	7658
1997-98	280	200	2440
1998-99	320	100	2870

Source: District Forest Offices

The irony is that the data supplied by the concerned offices do not tally with the actual plantation taken up. It is alleged that most of the time, the money for forestation is diverted to other heads of expenditures and plantation is shown only on paper.

Summary of the Assessment of Forest Value

Regarding the valuation of forest products of the state, assessments were made regarding the direct extractive benefits, direct non-extractive benefits, and economics of plantation of soft wood as against agricultural crops. The summary of the estimates is presented below:

A. Direct, Extractive Benefits (Per Annum):
(Value- Rs in Crores)

I) Timber & Wood products: - 116.75

ii) Non-Wood Forest products: 422.40

TOTAL: 539.15

B. Direct, Non–Extractive Benefits

The total estimated gross income from Tourism = Rs. 11.93 Crores

C. Total Annual Direct Benefits =

Rs. (539.15 + 11.93) = Rs. 551.08 crore

D. Economics of Plantation of Soft Wood (Per Hectare):

i) Total Expenditure over a period of 10 years = Rs. 38,000

ii) Gross Return @ Rs. 840.00 x 320 plants per Ha = Rs. 2,68,000

iii) Net Return (B – A) = Rs. 2,30,000

Considering bank interest and the rate of inflation aggregating 50 percent annually, the current rate of annual return is calculated at Rs.5,685 per ha.

E. Return from cultivation of Sali Paddy crop (per ha) = Rs. 2,800

F. Return from cultivation of Mustard seeds (per ha) = Rs. 2,335

Of the three options, option D is most beneficial even without considering the ecological benefits.

Findings from the Survey

A survey was conducted among forest villagers, forest employees, NGO workers, academicians and social workers, among others. It revealed a number of factors responsible for fast deforestation in the state of Assam. Some Important factors are mentioned below:

- Rich forest and land resources attracted significant number of people from outside the state and country to settle in the present location.
- Forest resources started declining due to encroachment, illegal extraction and weak government policies.
- Forestation process has not been successful due to lack of people's initiative, lack of motivation by concerned authority and social institutions for the purpose.
- The respondents feel that government initiatives were negligible in evicting the encroachers.
- Illegal extraction activities are carried out by bribing and threatening officials, and cutting and stealing trees during the night.
- Need for fuel by the people, and easy accessibility to the forests are the reasons for fast depletion of the forests.
- The forests along the interstate boundaries are being encroached by people from both the states.
- There has been damage to the forests due to flood and erosion.
- Encroachers are responsible for fast depletion of forests.
- Many unemployed youths resort to illegal forest extraction.

Policy Recommendations

Based on the understanding of the forest produce extraction mechanism and after taking into account the viewpoints of the stakeholders, the following comprehensive policies have been suggested:

Changing Economic Activities

Implementation of forest policies to stop the villagers from extracting the forest products would requires provision of alternative means of livelihood. Suggestions include:

Sericulture and Weaving

- Encourage villagers to take up sericulture and weaving.
- Arrange for subsidies and loans, wherever and whenever required.
- Arrange for marketing of the products.
- Arrange for training and workshops.
- Cooperative societies may be formed.

Poultry Farming, Goat Rearing, and Pig Farming

- Encourage villagers to take up poultry farming, goat rearing, and pig farming.
- Arrange marketing of the products.
- Provide veterinary facilities in the rural areas.
- Provide training to the farmers.
- Arrange for providing high breed pigs, chicken and goats.

Alternative Cash Crops

- Educate the people about alternative crops.
- Provide irrigation facilities.
- Arrange for marketing of the products.
- Monitoring by experts and professionals.

Joint Forest Management

- Involve people with JFM through the community prayer houses like Naamghar, mosques, churches and other social institutions existing in the tribal areas. The property right should be given to the Naamghar/mosque. Compounds of the community prayer houses should be converted into forests.

- Competition to be held with regard to achievements among communities/villages.
- Train and educate the people.
- Train the forest personnel.

Economic Instruments

After analysing the existing economic instruments (EI) and their shortcomings, it is felt that additional EIs should be suggested and implemented. A few such instruments are:

Tax on Timber/Wood Products

It is proposed that a heavy tax be imposed on finished products made of wood/timber, so that buyers are discouraged to buy the same because of the high price. This would also generate revenue for the Forest Department.

Sustainable Consumption and Consumption Pattern

One way to control the consumption of forest produce could be the introduction of a quota system with respect to the volume of forest-based products procured in the furniture market. Besides, certain complicated formalities could be introduced to discourage (to act as non-tariff barrier) people from buying wood-based products and to use substitutes.

Subsidies to Wood Substitution Activities

Government can formulate policies to provide subsidies to certain activities that help in saving wood. For example:

- In localities where illegal furniture markets operate, subsidy could be given to dealers of moulded plastic furniture by way of exemption/reduction of sales tax and reduction of municipality tax, etc.
- Cottage industries that utilise agricultural wastes and cattle dung to produce ‘fuel-cakes’ may be given subsidies.
- Subsidies can also be given on improved ‘chullahs’ that would consume less fuel.
- Subsidies may be given on doors and window frames made of non-wood materials.
- Subsidies can be given on bio-gas plants.

Value Addition to Forests

Most of the forests remaining in Assam, and in fact all of India, are degraded or bad forests. Some forests have even been converted to barren land. Thus there is ample scope for value addition to these forests.

Value Addition Schemes by the Government

The first and foremost task before the government is to protect the remaining forests and forestland from further encroachment or destruction. The next step would be to draw plans for enrichment of the forests by way of planting valuable trees, emphasising biodiversity, and protecting the fauna. Fresh working plans for each forest must be prepared carefully, and implemented with dedication and commitment.

Value Addition Schemes by NGOs

The forests of Assam are rich in medicinal plants. NGOs of different regions in the state should concentrate on identifying, rearing, and growing region-specific medicinal plants. The other potential area of value addition is the growing and rearing of orchids which are available in abundance, especially in the forests bordering Assam and Arunachal Pradesh. As the forests grow, birds of various types will nest in the forests. The forests would then attract bird watchers, and thus tourism has the potential to grow.

Resilience of the Forests

The Forest Department should take a pragmatic view regarding resilience of the forests. For this purpose, the forests should be classified into five categories:

- Encroached forest area beyond the scope of eviction.
- Encroached forest area where eviction is possible.
- Barren land created due to massive tree felling.
- Forests with low crown density.
- Thick forests.

The government should immediately concentrate on revival of the third and fourth categories of forests. Massive plantation in collaboration with local NGOs and the villagers from the revenue villages should be started immediately. Simultaneously, plantation of saplings should be carried out in the forests with lower crown density. If experts feel that by giving proper protection to the existing trees, natural regeneration could be achieved, then steps should be taken in this direction for effective natural growth. The next task should be to evict encroachers from forestland. Plantation work in these areas should start immediately. NGOs and villagers from the revenue villages should be included in the vigilance team to watch over the newly created forests.

Renaissance of Cultural Heritage

The following suggestions aimed at medium term and long-term developments have been proposed:

- While framing and implementing policies at national, state, and local levels, national and local cultural sentiments have to be considered.
- People must be motivated to plant more trees in their private holdings and the compounds of their houses.
- Religious-based plantation may be encouraged among all sections of the society.
- While encouraging forest-dependent people to take up non-traditional occupations, their cultural needs and sentiments must be studied and considered.
- People should be motivated to link afforestation program with their rituals:
    - Plantation of trees by newly-wed couples.
    - Plantation of trees on the birth of each child in the community.
    - Annual festival of forest preservation.
    - Community-based forest competition should be launched, which includes new plantations, old forest maintenance, and reduction in forest product consumption.

Systems Approach

There has to be a concerted effort on the part of the common people, social organisations, and government agencies to save the forests of Assam. The following short, medium, and long-term measures are suggested for sustainable growth of the forests.

Short-Term Measures

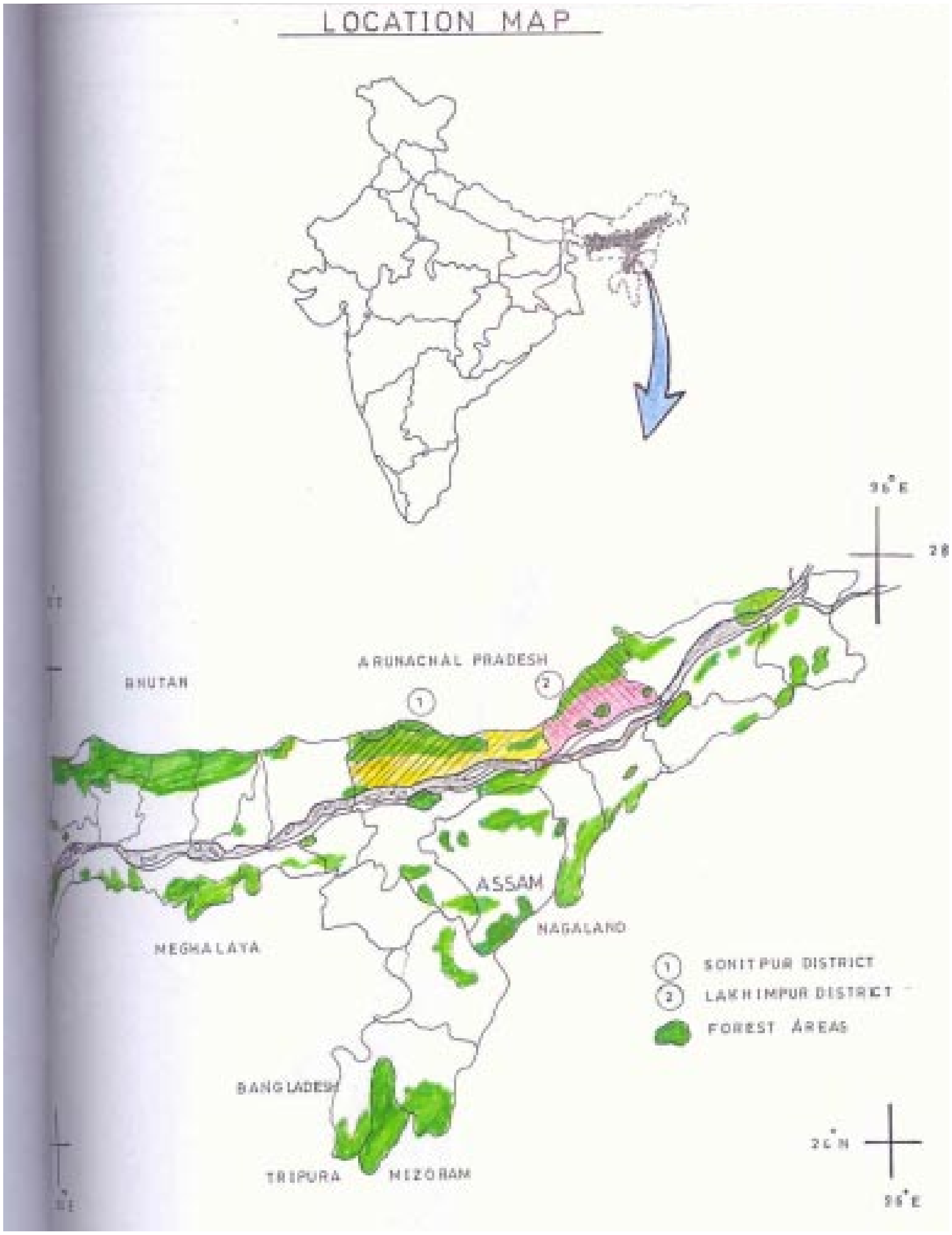
- Required infrastructure to be provided to the forest personnel.
- Strict control over forest personnel to make them work with commitment and dedication for the noble cause.
- Train forest employees, educate common people, and involve NGOs for successful implementation of the JFM scheme.
- NGOs, forest guards and police personnel should put up a joint effort to protect forests.
- Transparency has to be maintained with respect to utilisation of funds received for forest preservation activities.

Medium-Term Measures

- Popularise community, farm and private forests on government as well as private lands.
- Administrative structure of present forest organisation system should be rationalised.
- Plantation of fast growing as well as medicinal and aromatic plants besides religious based plants should be popularised.
- Control mechanisms have to be strengthened to arrest corruption at all levels.
- Utilise NGOs in forest management.

Perspective Planning

- The government should review and re-engineer its forest policies and programmes towards what?
- Any structural changes that are initiated should be linked with all the important sub-systems of the main system.
- Continuous efforts to maintain cultural heritage through various means have to be strengthened.
- Bring about behavioural changes in the Forest Department through training and by injecting ethos and values.
- Changing the mindsets of the forest-dependent people.



Status of Resource Utilization and Management : A Study of the Chenani Watershed (J & K)

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Introduction

The Udhampur district of J&K state was identified along with 147 other district from all over the country as having more than 17 percent of their total geographical area under wastelands by the National Remote Sensing Agency (NRSA), in collaboration with the National Wasteland Development Board (NWDB), Govt. of India. These wastelands possess great potential for providing the biomass requirement of the people, if put to optimal and judicious use. On the basis of an NRSA report, an Integrated Wasteland Development Project (WDP) for the Chenani Watershed of Udhampur district, J&K was implemented by the Forest Department, J&K Government between the years 1992-97 as a centrally sponsored scheme with the help of NWDB. During this project, various development works for the conservation and regeneration of natural resources along with management of wastelands were executed in 30 micro watersheds selected from 24,589 hectares of the Chenani Watershed. The total financial outlay for these activities was Rs.229.50 Lakh.

In this study, the status and condition of natural resources, between the base year i.e., 1991 (period before the onset of the Watershed Development Project) and the current year i.e., year 2000 (period after the completion of the Watershed Development Project) were compared. Efforts were also made to make comparisons between areas where the Watershed Development Project was implemented i.e., Project Area (PA), and areas where no such project was undertaken i.e., Non-Project Area (NPA), regarding land use pattern, carrying capacity and conditions of natural resources and so on.

Objectives

The present study was carried out with the following objectives to:

- Prepare an inventory of natural resources available in the study area.
- Assess the carrying capacity of the area.
- Assess the extent of management efficiency in enhancing the carrying capacity of the study area.

Methodology

To fulfil the objectives, 15 micro watersheds were randomly selected from the project area (PA) and non-project area (NPA) respectively, i.e. in all, a total of 30 micro watersheds were selected. For primary data collection, 10 households, each drawn randomly from each micro watershed were taken. The total sample size was 300 households, comprising nearly 4 percent of the total population size. With the help of primary data variables such as education, income, employment, consumption/ requirement of fuel, fodder, etc., the production potential of agricultural land, posture lands, etc were evaluated. For the estimation of variables such as total study area, land use pattern, status and condition of natural resources, their production potential, etc., satellite images of the study area (for both the base year and the current year) procured from NRSA, Hyderabad were used. The primary as well as secondary data was analysed by using simple averages, frequencies and percentages as analytical tools.

Site

Geographically, the study area was trapezoidal in shape with boundaries stretching between Patnitop ridge in the North, Ladhadhar in the West, Shivgarh Dhar inn the East and Dhar Gaddian in the South. The total study area is almost reniform in its outline, and consists of moderate to very steep slopes with elevation varying from 1,122m at Chenani, 2,450m at Natha top and 2,806m above Mean Sea Level at Shivgarh Dhar **(See Map)**. The demographic features of the study area include a human population of 50,845 persons, out of which 61.8 percent lived in the PA and the remaining 38.2 percent in the NPA respectively. The livestock population in the study area is 67,649 animal heads. The literacy level is 57.3 percent, which is better than the average literacy level of Jammu and Kashmir, which is 54.46 percent (Census 2000-01). In the study area, nearly 41.7 percent of the total population was living Below Poverty Line (BPL) i.e. having an income below Rs 25,000 per annum for a family of five members. The employment level was very low i.e. only 24.6 percent of people in the age group of 18-60 years were employed, and the major employment area was in the agriculture sector, in which 90 percent of the people in this age group were engaged.

Results

Land Use Patterns

From the analysis of Satellite Images, the total study area in the year 2000 was estimated to be 24,753.2 hectares, of which 14,645.9 hectares fall under PA and the remaining 10,107.3 hectares under NPA. Nearly 37.8 percent of the total area was under agricultural use, forests occupied roughly 35.2 percent, scrublands had 24 percent of the area, whereas 2.9 percent of the total study area was under drainage systems.

The description of the land use pattern is given below:

Forest Lands

Forests were categorised on the basis of crown density into three classes:

- Dense Forests: with crown density of more than 40 percent.
- Moderate /Open Forests: with crown density between 10 to 40 percent.
- Degraded Forests: with crown density of less than 40 percent.

The dense forests occupy nearly 60 percent of the study area, out of which only 18.6 percent of dense forests were in the PA and the remaining 81.4 percent in the NPA. Moderate/open forests had 27 percent of total forest area, whereas degraded forests occupied 12.9 percent of the total forest area.

Agricultural Lands

Agriculture was practised on nearly 37.8 percent of the total study area, with 75 percent of total agricultural lands in the PA and 25 percent in the NPA. Agricultural land in the total study area is mostly rainfed with only 18.6 percent under irrigation.

Scrublands

The scrublands were categorised into three classes on the basis of green biomass density (GBD).

- Dense Scrubs (GBD >40 percent) occupied nearly 60.3 percent of the total scrubs.
- Moderate Scrubs with GBD between 10-40 percent occupied 30.6 percent.
- Degraded Scrubs (GBD<10 percent) occupied 9.1 percent of the total scrub area.

Comparison of Land Use Patterns

Forest Lands

Comparisons are made between the land use pattern in the year 1991 and 2000, during which the forest area decreased considerably. The area under dense forests and moderate forest also decreased, whereas the area under degraded forest increased in the current year. The immense pressure on forest lands for fuel wood, timber and fodder requirements could be one of the factors which lead to their over-exploitation and conversion of dense and moderate forest into degraded forests.

Agricultural Lands

The area under agricultural lands increased in the current year from the base year. It was observed that an increase in agricultural area was due to an increase in the population size and lack of employment opportunities in this area. In the absence of alternative employment avenues, people have remained dependent on agriculture for their livelihood (nearly 90 percent of the population of this area is directly or indirectly dependent on agriculture). As a result, many forestlands and community lands had been brought under agricultural use, thereby leaving little or no scope for their regeneration and replenishment.

Scrub Lands

The comparison of the scrub area between 1991 and 2000 shows an increase in dense, thin and degraded scrubs by 4.2 percent, 20.3 percent and 38.7 percent respectively.

Comparisons of Land Use Patterns in Project Area and Non Project Area

During the Base & Current Year

In the present year, the area under dense and moderate forests have decreased considerably in both the PA and NPA, whereas the area under degraded forests increased in the PA and NPA during this period.

The area under agricultural use increased in the present year, both in the PA as well as in the NPA. This increase was estimated to be 105 hectare in the PA, 406.4 hectare in the NPA, with an overall increase of 511.4 hectare for the total study area i.e. 5.8 percent increase from the base year. The increase of agricultural area in the PA was less when compared to the increase in the NPA.

The area under scrublands increased by 11.3 percent i.e. 605.2 hectare from the base year. The increase is scrub area was estimated to be 429.9 hectare in the PA and 175.3 hectare in the NPA. All the three classes of scrub type - dense, thin and degraded scrub - showed an increasing trend as more and more forest area is being converted into scrub area due to over-exploitation of forest resources by a rapidly increasing population size and demand.

The area under drainage systems decreased by 8.2 percent i.e. 65.4 hectare when compared with the base year. The major decrease of drainage area is in the NPA i.e. 47.9 hectare, with a 17.5 hectare decrease in the PA for the same period.

Carrying Capacity of the Study Area

The carrying capacity is defined as the highest population of any society that an ecosystem (watershed in the present study) can sustain over an indefinite period of time. In the first phase of estimation of carrying capacity, production capacity of the study area was estimated in terms of:

- Fuel wood production capacity
- Fodder production capacity
- Timber production capacity
- Resin production capacity
- Agricultural production capacity

In the second phase, the carrying capacity with production capacity was estimated on the basis of per person (TFP), per cattle head (fodder) and per household (fuel wood) of the study area. The fuel wood production capacity of the study area was estimated to be 11807.8 M.T/ yr in a sustainable manner. The forests provide 55.5 percent of this total production, whereas agricultural lands and scrublands provide nearly 39.6 percent and 5 percent of this total fuel wood production. The total fuel wood production in the study area was found to be short of the total fuel wood requirement by 43.4 percent i.e. a deficit of 9059.2 M.T/yr. The alternative sources of fuel like LPG, kerosene, oil, etc. were used by very few people due to their limited availability and high cost when compared with fuel wood.

Carrying Capacity of Fuel Wood

The carrying capacity of the study area in terms of fuel wood was estimated to be far less than the actual requirement of the fuel wood in this area. This was due the fact that the production capacity of fuel wood in the area had decreased in the current year as compared to the base year. Moreover, the increase in population during this period had also aggravated the problem. The decrease in carrying capacity of fuel wood in the NPA was more as compared to the PA during this period. The total fodder production capacity of the study area was estimated to be 1,18,563.8 MT/yr, which falls short of the total fodder requirement by 2,03,881.7 M.T/yr.

Carrying Capacity of Fodder

The carrying capacity of fodder was also less than the actual requirement of the fodder in the study area, as estimated by set standards of the Animal Husbandry Department, J&K Government. The existing carrying capacity could support or feed only 22.7 percent of the total animal population in the study area. The carrying capacity of fodder in the PA was higher as compared to the NPA, as more agricultural areas were under fodder crops in the PA.

Carrying Capacity of Food Grains

The agricultural production capacity in the study area was found to be very low when compared with Average National Production of crops, due to various reasons like lack of irrigation facilities, poor status of land resources and high level of poverty. The major crops in the area were maize, wheat, barley, oil seeds, fodder crops, etc. The total food grain production (TFP) in the year 2000 was estimated to be 6,856.04 M.T, out of which 5,116.34 M.T was produced in the PA and 1,739.7 M.T in the NPA.

Due to low agricultural production, the carrying capacity was also very low i.e. it could support only 70.2 percent of the total population, and the remaining 29.8 percent of the population was creating a burden on the carrying capacity. The carrying capacity of the PA was better than the NPA as it could support 84.8 percent of its total population, whereas the NPA could support only 25.4 percent of its total population from the existing production of food grains.

Production of Timber & Resin

The timber production capacity of the study area was estimated to be 1,59,501.5 cu.ft/yr and the resin production capacity was estimated to be 3,961.3 kilolitres/ yr, out of which 1,101.8 kilolitres of resin was produced in the PA and 2,859.5 kilolitre in the NPA.

Comparison of Carrying Capacity of the Base & Current Year

In terms of fuel wood

Carrying capacity of the total study area in terms of fuel wood had decreased by 4 percent from the base year. The major reason for this could be due to decrease in the forest cover and poor condition of resources in the current year.

In terms of food grains

The carrying capacity of food grains has increased by 4.8 percent compared to the base year, but the burden on the carrying capacity in the current year has increased by 19.6 percent or 2,490 persons compared to the base year due to more proportionate increase in the human population as compared to the carrying capacity.

In terms of fodder

The carrying capacity for fodder increased by 4.1 percent compared to the base year, but the burden or pressure on carrying capacity also increased by 75.5 percent. This was due to the increase in livestock population of this area.

A comparison of the carrying capacity of the resources for the base and the current year showed that the production capacity of resources like forests and scrublands have decreased considerably, whereas the production capacity from agricultural lands have increased in the current year. The main reason for this increase however, is the increase in the area under agricultural development.

The production capacity of natural resources in terms of fuel wood, timber and resin has decreased by 3.9 percent, 8.7 percent and 10.8 percent from the base year, respectively. The production capacity in terms of fodder and total food grain production increased by 10.5 percent and 4.8 percent from the base year, respectively.

Inventory of Natural Resources

Inventory of natural resources i.e. the list of physical resources along with their monetary value at a particular period of time, was made for both the current as well as base year to estimate the change in the value of resources in the study area over a period of time.

In order to prepare the inventory, current market prices in the study area were used for valuation of each resource, along with the products it produced. The products produced include fuel wood, fodder, timber, resin, agricultural crops, etc. The total value of natural resources in the study area during the year 2000 was estimated to be Rs.23,288 million.

The forests were valued at Rs.21,000 millions (approx.), which accounts for nearly 90 percent of the total value of resources. Agriculture lands and products contributed nearly Rs.1,898 million i.e., 8 percent of the total value of resources, whereas scrub areas had Rs.3,901 million i.e., a 2 percent share in total value.

Comparison of Inventories of Base & Current Year

The comparison of inventories of natural resources in the base year (1991) and the current year (2000) were made, and it was concluded that the value of forests and its products have decreased significantly by Rs.3,986 million in the current year. The value of agricultural land and its products have increased by Rs.158 million and the value of scrublands and its products increased by Rs.123 million in the current year. But the overall value of resources in the current year fell by Rs.3,705 million from the base year. The decrease in value of resources in the PA was Rs.1,460 million, which is less than the decrease in value of resources in the NPA to the tune of Rs.2,337 million.

Keeping in mind the deteriorating condition of natural resources due to over-exploitation and misuse, severely affecting the carrying capacity as well as the monetary value of natural resources, various recommendations were suggested for efficient conservation and regeneration of natural resources. These recommendations will help in improving the status and condition of natural resources along with their carrying capacities. Moreover, it will also help in improving the efficiency and cost effectiveness of watershed development projects at various stages of implementation in the future.

Recommendations

Conservation of Natural Resources

• ***Closure formation:*** Effective closure to restrict the entry of humans and animals in forest areas will help to check problems like illegal tree felling, grazing on forest lands, etc. Moreover, species of perennial grasses grow in eroded and degraded areas when gullied areas are closed to all kinds of biotic interferences, soil and water losses decrease progressively and there is a marked quantitative and qualitative improvement in the yield of grasses.

• ***Plantation of trees:*** To rehabilitate and regenerate the degraded forests in the study area, plantation of fast-growing species of trees is recommended. These trees will help improve the ecological as well as environmental situation in this area.

• ***Patches of grasses:*** Patches of fast-growing grasses like Napier grass, red clovers, etc. should be grown so as to improve the percolation and permeability of rainwater to protect the soil from its splashing and dashing actions. Moreover, these patches also help in holding the soil particles, hence saving them from erosion, and improving the soil structure and texture by adding various nutrients to it.

• ***Mechanical measures:*** Mechanical measures consist of construction of mechanical barriers across the direction of the flow of water to retard or retain the runoff, and thereby reduce soil and water losses. As these measures are more costly than vegetative measures, they could be used at places where erosion intensity is very high. Before the use of these measures however, cost effectiveness and local adaptability should be estimated.

• ***People's participation:*** People's cooperation and participation is a pre-requisite for the success of any conservation and regeneration activity for natural resources. Local communities help in resource conservation in various ways like *Shram Dhan* (voluntary labour), *Kulhadbandi* (ban on tree felling), *Charaibandi* (ban on grazing) and maintenance of newly created assets like closures, new plantations, etc. Therefore, local people should be involved right from the planning of conservation work to the implementation of works, and finally in the maintenance of newly created assets so as to make a conservation programme successful, sustainable and cost effective.

• ***Strict legislative measures:*** Through strict legal actions against persons who are guilty of breaking rules and regulations, various evils like illegal felling of trees, encroachment on forest lands, theft of forest products and illegal grazing could be checked. As Gandhiji once said, "Mother nature has sufficient to meet people's need but not people greed". Therefore, strict legislative measures will help in checking people's greed.

Increasing Carrying Capacity of Natural Resources

In order to save the natural resources from further deterioration, and to generate people's cooperation and participation for various conservation and regeneration works, improvement in the existing carrying capacity of the study area is very important. As people in the area are already living on the margins of subsistence, they are not willing to cooperate in conservation works if these works do not provide direct benefits to them. Hence, improvement in the carrying capacity of fodder, fuel wood and food grains will definitely help in attracting people's participation and cooperation for further conservation activities. The measures for improvement in the carrying capacity are given below:

- ***Forest Lands:*** The carrying capacity of forests in terms of fuel wood can be improved by growing more fuel wood producing fast-growing species of trees. In terms of fodder, perennial grasses like Napier grasses can help in improving fodder production. Moreover, open auction of fuel wood and fodder will also help in keeping their prices within the reach of poor people.

- ***Agricultural Lands:*** The carrying capacity of agricultural lands in terms of food grains can be increased by adopting improved scientific methods of cultivation, intensive use of inputs, mixed cropping, intercropping, etc. The carrying capacity in terms of fodder can be improved by relay cropping, growing grass legume mixtures and using overlapping systems of fodder production. Agriculture purposes can also improve the fuel wood situation considerably in this area.

- ***Scrublands:*** Scrublands can be put to efficient use by using cheap local technologies for reclamation. The carrying capacity of these lands, in terms of fodder and fuel wood, can be increased through ecological management, utilisation management or silvi pastoral system of management.

Other measures: Various measures, which can help ease the burden on carrying capacity of natural resources, are recommended. These include:

- ***Reduction in livestock population****:* Only high-yielding, stronger animals should be kept and poor-yielding animals be discarded.

- ***Fodder conservation:*** Conservation of fodder should be done by using silage and hay making for feeding animals during dry or lean periods.

- ***Use of treetops:*** Trees like Sesbonia, *Kubabul,* etc should be used to feed livestock during dry periods.

- ***Alternatives of fuel wood:*** Alternatives of fuel wood like kerosene oil, LPG etc should be made more popular in the area.

- ***Renewable sources of energy:*** Use of solar cookers, solar lights, gobar plants should be promoted as these renewable energy sources have sufficient availability in the study area.

Improving the Efficiency of WDP's

The watershed development project (1992-97) undertaken in this area has fulfilled its pre-set objectives, but lack of efficiency on various fronts was observed due to several reasons. Therefore, to improve the efficiency of the project, various recommendations have been suggested:

- **Launching more watershed projects:** More WDPs should be launched in the study area, as the previous watershed project was conducted on a very small scale (i.e., covering only 22 percent of the PA). While launching such programmes, the needs and requirements of the people, condition and availability of resources in the area, type of people (i.e., SC, ST, OBCs, etc) should be looked into. Moreover, locally acceptable technology should be used for efficient, cost-effective and sustainable development with the people's participation.

- **Trained and experienced staff:** Training of staff at the state and district level, of the project implementation agency, watershed development team, self help groups and user's groups is necessary for the successful implementation and benefit sharing from the project.

- **Better co-ordination among various agencies:** As various agencies are involved in watershed development activities, right from the planning stage to its ultimate execution, these agencies should work in close coordination with each other in an integrated manner rather than working with different sets of objectives and focusing on one or two sectoral activities, leading to confusion and mismanagement.

- **Proper funding and accountability of watershed development programmes:** Regular and timely procurement of funds should be made available from various sources like state governments, central government, multilateral financial institutions or international financial institution. The regular maintenance of quality audit of each activity in the WDP makes it transparent, accountable and verifiable. To improve the efficiency of such projects, meticulous planning and close over runs help in developing appropriate management structures, which trigger responsibility, accountability and efficiency of such projects.

- **Awareness generation among masses:** Awareness among masses should be generated regarding the importance of natural resources with the help of various awareness building measures like film shows, community visits, distribution of literature to locals, etc.

Conclusions

From this study it could be concluded that the condition of natural resources in the study area in general and PA in particular was very poor. The major reasons are poor production capacity of natural resources, higher population pressure and poor management of these resources regarding their maintenance and use. As these problems were more severe in the PA, one Watershed Development Programme on a small scale i.e. covering only 3,300 Ha (22 percent of the total PA), was started with the Central Govt. assisted by the Forest Department of J&K. Various activities for conservation, regeneration and effective management of natural resources were undertaken during this programme. This programme improved the conditions of natural resources in the area as well as their production capacity by generating awareness among the local population on effective management, use and benefit sharing from natural resources. These measures would certainly help in improving the status and conditions of natural resources of this area in the years to come.

Due to an ever-increasing population in the study area, problems like increasing demand of fuel wood, fodder and food grains had exerted a significant burden on the carrying capacity of natural resources of this area, resulting in their over-exploitation and degradation. However, when we compare the status and condition of natural resources in the PA and NPA during the base year (1991) and the year (2000), we could conclude that the problems like decrease in the forest area, increase in agricultural area, and increase in scrub area was less in the PA than NPA. Moreover, the carrying capacity of natural resources in terms of food grains and fodder was better in the PA than NPA. The decrease in the value of natural resources in the PA was also less when compared with the NPA.

Economic Analysis of Impact of Surface Iron Ore Mining on Natural Resources and Economy of Iron Ore Mining Belt of Eastern India

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Introduction

Mining, particularly surface mining has come to be viewed as an environmentally destructive industry. The environmental impact of iron ore mining is wide ranging, occurring at all stages - from exploration to mine closure. Such an impact is also highly site-specific in nature, depending on the environmental settings of a particular mine location. Major impact comes from cutting down of forests for exploration, mining and mine infrastructure development. Removal of vegetative covers makes runoffs contaminated and turbid. Deforestation can also bring about loss of biodiversity, destruction of wildlife habitat, severe soil erosion, as well as siltation of natural water bodies. A secondary effect of iron ore mining is dumping of waste or inadequate management of settling ponds. Runoffs from waste dumps can degrade natural water bodies, quality of potable water, habitat of local flora and fauna, and make future land use difficult for reforestation, agriculture and cattle breeding. Also, flow of suspended solids and sediments from ore processing plants have a severe health impact. High incidence of bronchial diseases is prevalent amongst the inhabitants of the mining areas, mostly due to emission of airborne dust from point and non-point sources within the mine.

Some of these impacts impose external costs (damage cost) to society. These project externalities are seldom taken into consideration in any decision-making process, both at the project approval stage and at the project operational stage. By internalisation of environmental externalities, real costs of the mining projects are reflected. Adoption of a package of policies, which include use of command and control and market based instruments will induce the mine operators to internalise such external costs in the mine cost structure. Prerequisite to any such policy design is extensive research work on economic analysis of varied project externalities. Unfortunately, knowledge and integrated information about economic values of these externalities are very limited. For a rational policy decision on reduction as well as internalisation of damage costs in the mine's costs structure, one needs to generate a database on varied project externalities.

Study Area

Keonjhar and Sundergarh districts of Orissa and Singhbhum district of Jharkand states occupy important place in the mineral resource map of eastern India. In these adjacent districts, high quality iron ore is found under large tracts of forestland, which also harbour rich bio-diversity. The entire forest range is dotted with several surface iron ore and manganese ore mines of varying production capacities. Apart from a few large mechanised iron ore mines (producing few million tonnes), there are several small and medium-sized manual mines scattered over the entire area with vast variation in production levels. Lease areas of different mines also vary from less than 100 hectares to more than 1,000 hectares. Quality variations are considerable and the demand fluctuates rapidly. Iron ore is being marketed in the domestic market as well as exported to other countries. In order to maximize profits, mining contractors resort to unsystematic mining practices by opening up scattered mine workings and dumping waste in a haphazard manner amid rich forest growth. Ownership of these mines is mostly private, barring a few mines, which are under the public sector. The environmental impact due to mining in the area includes both cumulative environmental impacts of several contiguous small and medium sized iron ore mines, as well as the environmental impact of large mechanised iron ore mining projects. In the entire area, different clusters of mines are located depending on deposits of iron ore below the surface. Each cluster comprises of mechanised mines (with varying degree of mechanisation) and several scattered manual mines. The impact of these clusters of mines on forest growth and natural watercourses are of prime concern.

Map showing different study areas

Objectives

Conceptual framework

The current information on mining externalities is insufficient to be useful for framing of policies. Substantial effort is required to establish data for comprehensive data analysis and policy design. An attempt is made here to fill this information gap.

Specific objectives

The objectives of the study are to:

- Carry out economic analysis of environmental impacts of three selected clusters of mines, in combination with manual, semi-mechanised and mechanised iron ore mines under different ownership regimes viz; public and private sector
- Develop knowledge base for economic evaluation of environmental impact of mines operating under similar environmental settings
- Estimate cost of environmental damage in the study areas
- Develop a methodology that can be used to reduce subjective decision making on environmental aspects of mines, both at the operational stage as well as at the project approval stage
- Integration of environmental damage cost into private cost–benefit analysis of a mining project
- Suggest market and non-market based policy instruments to reduce damage cost in different areas

Methodology and Data

The difficulty with or inapplicability of the frequently used valuation methods in the study areas selected for this research is explained below. A poor and underprivileged population inhabits the areas covered in this study where education level is low. Thus, the application of contingent valuation method (CVM) techniques do not appear to be feasible. As there is no tourist spot nearby, travel cost method (TCM) cannot be applied. Due to escalation of land prices near the mines, irrespective of environmental damages, application of hedonic pricing method (HPM) may yield inaccurate results. Thus, the only choice left here is the use of market based valuation techniques through which productivity impact and health impact can be measured. Local market prices of agricultural products and non-timber forest produce (NTFP) are used for estimation of the externalities under consideration.

Broad outlines of methodology

- Three study areas are selected. Each study area comprises of big mines surrounded by a number of small mines.
- Study areas have been selected on the basis of ownership of the mines, presence of small manual mines, production levels, environmental settings and socio-economic conditions. Study areas are selected to represent diverse characteristics of the entire mining belt.

The area falling within 5 km of the active mining area is defined as the buffer zone. Any area falling beyond 5 km is considered as the periphery zone. In each study area, the number of villages are randomly selected.

Sample Design

Sample villages are selected at random from a list of villages (accessible by jeep). Non-inclusion of inaccessible villages is a limitation of this study.

- Variation in primary occupation at the household level is quite significant; therefore stratification is done on the basis of primary occupation.
- Four major strata that could be identified at the village level with regard to primary occupation of households are: Mining labour; cultivator; agriculture wage earner; and others.
- The sample survey has been conducted by filling up detailed questionnaires in about 20 percent of the listed households under each stratum.
- In three study areas, 41 villages are selected for random stratified survey, covering 853 households.
- The questionnaires comprise 31 items covering detailed household information on various household wise socio-economic variables, household earnings from traditional sources, respondents perception about reasons for loss of earning from traditional sources, earning from mining jobs, incidence of various diseases and medical expenses, respondents perception regarding quality of potable water and water for regular use, and activities of rural development societies, etc.

Descriptive statistics (e.g. tables, charts, averages, dispersions, etc.) as well as econometric regression techniques were used to extract relevant information from the available data.

Results

Earning from Traditional Sources

It was observed during the field survey that mining activities have caused degradation of natural resources in the buffer zone. Extensive land damage and pollution of natural water resources are also reported by the respondents in the buffer zone. There is also a significant drop in earning from pre-existing sources (agriculture, NTFP). Field observation is well corroborated by results of data analysis. Few results are discussed below:

Average extent of total land damage (out of total land holding) is high in Study Area 1 and Study Area 2 - 20 percent to 50 percent (on the basis of the respondents reply).

Annual average household NTFP earnings in the buffer zone and periphery zone (in most of the study areas) are below Rs.500 and above Rs.1,400 respectively. Another traditional earning source is agricultural earning. In about 70 percent of the households in both the buffer zone and periphery zone, the average annual agriculture earning per acre is below Rs.1,000 and above Rs.1,000, respectively. The above figures are arrived at considering prevailing prices in the local market.

Household characteristics

One reason for this decline may be zone-wise variations in household characteristics. Several frequency distribution tables reveal that irrespective of various household characteristics, household earnings from agriculture, NTFP are low in the buffer zone.

Examples of household characteristics taken into consideration are landholding sizes, number of literates in household and family size. Results reveal that on zone wise comparison of households possessing landholding within 1–3 acres, the average agriculture earning per acre (Study Area 2) is below Rs.600 (buffer) and above Rs.1,800 (periphery). Frequency distribution tables show that considering households in both zones, with 25 percent of its members literate, annual NTFP earning is below Rs.800 (buffer) and above Rs.1,500 (periphery). Similar trends are noted in the case of households falling under the frequency class of family size within 4–9.

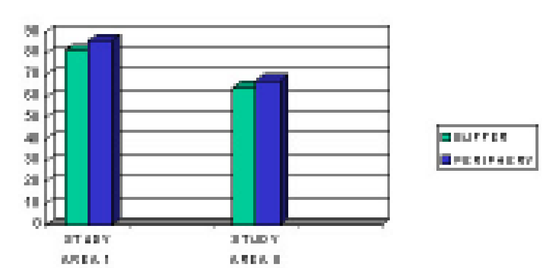
Decline in the above earning from traditional sources is being temporarily compensated by cash earning from casual mining jobs under petty contractors. Ratio of mining income to total average annual household income in buffer zone (above 50%) is high compared to periphery zone (below 20%). It is worthwhile to mention here that all mines have a finite life, and thus these mining jobs can only provide short-term livelihoods.

Agriculture Earnings from Unaffected Land

It is commonly asked whether the villagers (living close to mines) neglect their agriculture work because of availability of mining jobs. It is shown below that agricultural earnings per acre from unaffected land (land not damaged by mining) in the buffer zone are almost similar to that in the periphery zone. This could have never been possible if the villagers would have neglected their traditional livelihood.

Tabular data interpretation fits well with regression results. Distance dummy (nearness to mines) and household earnings from agriculture, NTFP show statistically significant relationships. Tabular analysis as well as regression results corroborate well with field observations and respondent's perceptions of the problem: environmental degradation in the buffer zone due to mining is the major contributing factor behind the loss of earning from traditional sources.

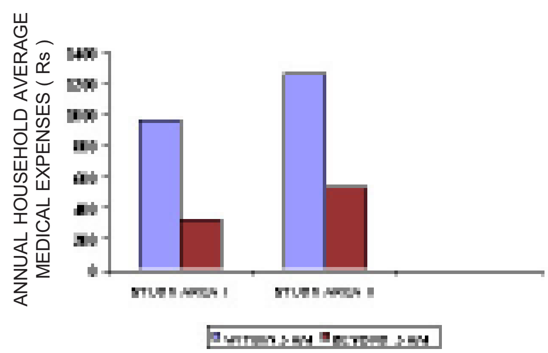
CHART SHOWING PERCENTAGE OF SAMPLE HOUSEHOLDS WITH AGRICULTURAL EARNING PER ACRE ABOVE 1000 RUPEES FROM UNAFFECTED LANDS IN BUFFER ZONE AND LANDHOLDINGS IN PERIPHERY ZONE



Annual Household Medical Expenses

In some of the buffer villages (Study Area 2), there are high incidences of bronchial diseases and stomach trouble. Zone-wise differences in medical expenses could be tabulated for all frequency classes of socio-economic variables like literacy levels, annual household expenses, family size, per capita household income, etc. Few results are furnished here. In households having an income = Rs 30,000, annual average household medical expenses are below Rs.500 (periphery), whereas the same is above Rs.900 for household with a higher annual average income (buffer). A Similar trend is noted for households falling under frequency class of literacy rate above 50 percent. Thus, an increase in medical expenses near mines may not be explained by any zone-wise variations in socio-economic features. Regression results also show good data fit with distance dummy (distance from active mining zone) and household annual medical expenses. Thus, a similar conclusion can be drawn here also.

VARIATION OF ANNUAL HOUSEHOLD MEDICAL EXPENSES DISTANCE FROM ACTIVE MINING ZONE.



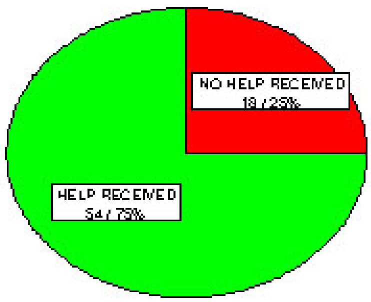
Rural Development

In one study area (Study Area 3), a private company has set up a rural development society to reinvest some of its profit in renewable resources in the surrounding areas. Several charts (e.g. medical help received from the society is given below) are drawn to illustrate the respondent's perception about rural welfare measures implemented by society.

Households receiving help from rural development society

Medical facilities

HOUSEHOLDS RECEIVING MEDICAL HELP FROM RURAL DEVELOPMENT SOCEITY THIS YEAR.



BASED ON REPLIES FROM SAMPLE HOUSEHOLDS FALLING WITHIN 2 KMS. FROM ACTIVE MINING AREA OF STUDY AREA III.

Economic Analysis of Environmental Impact

- Damage cost is calculated on the basis of household sample survey data covering 41 villages in different study areas
- Environmental economic components that are selected for the purpose of damage cost calculation are as follows:

- Loss of annual agricultural earning of households falling in the buffer zone.
- Loss of annual household NTFP earning of households falling in the buffer zone.
- Increase in medical expenses of households in the buffer zone.

Several major environmental economic components that are left out of the purview of the research work (limitation of the study) are as follows:

- Loss of biodiversity
- Loss of wildlife habitat and its consequent damage on human settlements and crop lands
- Loss of timber products
- Deterioration of aesthetic beauty of the area
- Deterioration of quality of water available for regular use and drinking purposes.

- The present study does not take into consideration some of the major environmental economic components, thus, damage cost estimated here may be treated as only a benchmark estimate.
- Damage costs are estimated for only five mining areas (two study areas and three clusters of the other study area). This number is quite insufficient for any econometric analysis. Thus, no further econometric analysis is attempted. Instead, on the basis of results of data analysis, specific characteristics of the study areas are examined. The ultimate aim is to arrive at a broad policy framework for the entire mining belt.
- Damage cost = Multiple of zonal differences in agricultural earning and total landholding in buffer villages + multiple of zonal difference of NTFP earning and number of households in buffer villages + multiple of zonal difference of health cost and number of households in buffer villages.
- A brief account of damage costs estimated in different study areas are furnished below:

As per estimations made, total loss of agricultural earnings in different study areas vary from about Rs.7 lakhs/year to Rs.55 lakhs/year. Households in different study areas also suffered total loss of earning from NTFP in the range of Rs.18 lakhs /year to Rs.36 lakhs / year. Additional medical expenses (total) incurred in villages near to mines vary from Rs.3 lakhs / year to Rs.14 lakhs /year.

- Damage cost per year is significantly low in the case of the study area where mine excavations are restricted by adopting mechanised mining operations. Results pertaining to a mechanised mine, adopting both improved technology as well as rural development measures, reveal that this cost is about Re.1 / tonne of output.
- Damage cost is quite high in the case of manual mines (irrespective of size) - around Rs.80 lakhs per year in some study areas.

Financial Analysis

Small manual mines run at a low fixed cost due to minimum investment, negligible overhead and low establishment cost. Overhead expenses in the case of big manual mines are high and total mining cost per unit output is also high. In one of the study areas, a private mechanised mine (running at its full production capacity achieving high production and productivity) could significantly reduce both fixed and variable costs, on per unit output basis.

Investment Analysis

Small mines are run through contractors without making any significant initial investment in mineral exploration, machinery purchase, infrastructure development, etc.

Most of the big manual mines are run through contractors. At these mines, departmental labourers are mostly engaged in mine development works. Investments were made long back mostly on machines and township development.

To develop a mechanised mine with ore beneficiation facility and other infrastructure facilities, investment will be in the tune of a few 100 crores.

An alternative way to reduce initial investment is by deploying rental machines and engaging a monopoly contractor. Required investment will be a few crores.

Benefit

A rough estimate of project benefit is made by taking into account only the number of mining jobs created in each study area.

All manual mines provide contractual mining jobs to the villagers. However, these mining jobs will not be able to sustain the villagers on a long-term basis. On the other hand, society will continue to bear the damage cost for several years, even after mine closure (till the mine is naturally reclaimed).

In fully mechanised mines, there is limited scope of direct employment at mines. Several contractual transportation and loading jobs are available.

Other benefits like infrastructure development in remote mining areas is not taken into account in the present estimation. This may be noted as a limitation of the present study.

Social Cost-Benefit Analysis (SCBA) and Policy Recommendations

SCBA results provide only a snap shot view; non-availability of time series data is another limitation of the present study.

Ratio of both social benefit/ social cost ratio as well as benefit / damage costs are low in case of manual mines. Mechanised mines (running efficiently at almost full capacity) show high value of the above ratios. In comparison to manual mines, damage cost figures are also significantly low for all mechanised mines covered under this study. Certain policy reform is thus essential to restrict manual mining (except in case of minerals with low national inventory). Based on past experiences, it can be opined that command and control measures will not be very effective in filling up any of the existing policy vacuum. It appears that use of market-based instruments can be an effective tool for future policy implementation.

In general both damage cost and private cost are low, in case of mechanised mines operating at their rated capacity. Thus, these mines could record high values of SCBA.

One of the policy options could be to tax the mine operators on the basis of damage cost that society will have to bear for environmental degradation. In that case, the manual mines would have to bear a high tax burden. High taxation in such cases, may act as an incentive for mine operators to adopt improved technology, which will ultimately reduce both damage cost, tax imposed on them as well as total mining cost.

Results also provide ample evidence to show that mechanised mining can set a balance between economic gains from mines and degradation of natural resources.

Economic Instruments

One of the major constraints in the use of economic instruments for inducing these mines to adopt mechanisation is the huge investment requirement. Imposition of taxes will only eliminate small mine operators. Loss of meagre production from these manual mines can be met by intensification of mining activities at big mechanised units.

Such policies may also promote amalgamation of units under collective ownership. Imposition of taxes will initially deflate the profit margin (of big manual mines) during the mine restructuring period. On a long term basis, by restructuring their units, average variable cost will decline (as is evident from financial data of mechanised mines). Through good financial performance, capacity utilisation and increasing managerial efficiency, it is possible to reduce fixed costs per unit output. By restructuring their units, the mine operators could enhance private benefit from the present level and also build up enough surplus for reinvestment in the welfare of the local people who are adversely affected by mining.

As an additional force to induce the small mines to adopt improved technology, the prevailing restriction on area of operation by MOEF needs to be continued.

Small mine operators are mostly attracted to operate mines to earn quick profits by making very low investments. This necessitates that permission for any manual mining can only be granted in such cases where SCBA indicates high social benefit on longer terms.

Several site-specific variables such policy implementation may be judged as per local geo mining conditions. Implementation of such policies should also take note of the fact that all mineral deposits are not amenable to mechanisation.

Comparing Two Mechanised Mines

On comparison between the financial performances of two mechanised mines, the following factors require needful consideration in policy design.

Efficiency Gains

In spite of huge investment at one mechanised mine (running much below its rated capacity), it is seen that its overall performance is distinctly different from a private sector mechanised mine - both in respect to financial performance and capacity utilization, etc. Geo–mining conditions may not be the major contributing factor as the property was explored well in advance before making investment decisions.

Based on the above fact, it is quite evident that use of economic instruments is likely to fail if the companies cannot record efficiency gains. The companies should attain certain level of efficiency in operation so that the company can build infrastructure for rural development. Incentives for making technology changes to attain the above level of efficiency may be provided in the form of tax relief.

It is found that the private sector mines could transfer some of their efficiency gains by reinvesting proceeds from the exploitation of non-renewable resources in other forms of capital assets that are capable of providing at least the same stream of benefits in the future. Future generations, being deprived of iron resources (in that particular area), will gain higher earnings from agriculture, forestry etc. In order to adopt the above principle of sustainable development, any future policy should aim at inducing the mine operators to invest in renewable resources of the area.

Investments made in the surrounding areas include: agriculture, forestry, medical care, infrastructure, education, etc. Rural development has been established with all necessary facilities. Social benefits are being generated to sustain the local people on a long-term basis. Needless to say, there is scope for further improvement by intensification of welfare activities and mobilisation of funds from other agencies.

Modifications in the Rural Development Model

A modified model of rural development society could be replicated in other mining areas too. The modification that needs to be introduced is to be a collective action of small and medium sized mine owners. Since there is a problem of collective action here, the solution may come as an administrative command and control policy. Alternatively, these small mine owners could be asked to contribute according to their area of operation to a common fund, which could be operated either by some institutions, such as an elected body of their own, or by an autonomous NGO. The government may also transfer a part of the royalty collected from these mines to such restoration activity.

International and government agencies may be encouraged to channelize their available welfare funds to these rural development societies.

Further improvements in the model are suggested here, which include participation of local communities or their representatives in the decision-making, planning and implementing of different welfare schemes. Local people should be involved to know about the perception of problems existing in the area.

Improved Mining Technology

Sustainable Mining Practice - some basic requirements.

Improved technology: Environmentally sustainable mining practices call for systematic mine planning. Prerequisite to mine planning is the development of a database on subsurface iron ore occurrence. In order to maximize their profit margins, owners of small and medium sized mines usually avoid exploratory work. Scattered excavations are made, which is prematurely abandoned causing extensive degradation of natural resources in the surrounding areas. Also, the cumulative impact of these contagious mines is quite significant. Thus, it is essential to restrict mining operations in leaseholds, where there is insufficient subsurface database; barring a few big mechanised mines, this database is not available with other mine operators.

Size of Mines and Mine Operations

To restrict the sizes of mine workings as well as to achieve desired output, mine operations will have to be mechanised - deploying excavators, matching capacity of dumpers, large diameter drills, using mine planning software for precise demarcation of the excavation areas.

Unless strict supervision can be ensured, engagement of contactors may be restricted to the extent possible.

Environmental Pollution Control Measures

It is essential to take immediate decisions on the future working / abandonment of the several existing discontinued mine workings/ waste dumps. Improved waste dump management includes: digging diversion drains all around the dumps, flattening of dump slope, constructing retaining walls and garland drains, terracing of waste dumps, planting quick growing grass on dump surface to check soil erosion, etc. External dumps may be avoided; instead old abandoned excavations may be backfilled.

Water pollution control measures include: periodical checking of all mine discharge, heightening of dams keeping safety norms in view, erection of check dams, digging of diversion drains (to reduce erosion) all around the active mining area to prevent water from surrounding areas from entering into the mines, diversion of mine effluent to settling tanks.

A green belt may be developed around the active mining zone to control air and noise pollution. Crusher units will have to be installed in covered areas with proper water spraying arrangements at dust generating points.

Virgin forest patches may be left intact on areas where no iron ore exists below ground; township and other mine facilities may be preferably built on non-forest land.

Limitations

Sample villages are selected randomly from a list of villages only accessible by jeep.

Non-inclusion of all environmental economic components, as discussed earlier.

SCBA could be conducted for only five mining areas, which is quite insufficient for drawing any marginal cost curves to assess the rate of taxation. This major limitation has also restricted any scope of further econometric analysis.

Several project benefits like infrastructure development in remote mining areas is not taken into account in the present estimation.

Future research areas

Comprehensive SCBA of mining projects based on time series and/ or larger cross section information.

Economic analysis to identify policy measures to provide incentives for mining companies to invest and adopt cost-effective pollution control technologies.

Design of policy framework to induce the mining companies to adopt compensatory and corrective social welfare schemes.

WATER INSTITUTIONS

AND

SUSTAINABLE USE

Environmental Degradation: Market, Policy and Institutional Failure

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Introduction

Water resource management is crucial for food and ecological security. In fact, livelihood security is critically linked with water security. Water security means that people and communities have reliable and adequate access to water to meet their different needs, are able to take advantage of the different opportunities that water resources present, are protected from water related hazards, and have fair recourse where conflicts over water arise. Water security is indispensable for addressing inter and intra regional inequalities as well as inter household inequalities in growth and development, and in sustaining the ecological balance. Despite the importance water assumes in overall human development, it is the most mismanaged resource, especially in the context of developing countries like India. Neglect of this important resource has resulted in environmental degradation of enormous proportions. The present study is an attempt to understand the environmental aspects of water resources. Though limited to the state of Andhra Pradesh, the study reflects the reality in many parts of the world. This study is an attempt to synthesise the problem based on our analysis, from three important perspectives i.e., market, institutional and policy failures. This would help in understanding the problem from different dimensions. The existence and use of water in different forms makes it imperative to examine the different facets of the resource. While it is beyond the scope of the present study to cover all the forms and uses of water resources, it deals with three important aspects of water resources management with a focus on environmental degradation. These include groundwater, surface water and water quality management. The study narrates the context of managing these three aspects of water resources that have led to environmental degradation, threatening the livelihood security of the local communities.

Objectives and approach

This study is an attempt to address the environmental consequences of water, mainly irrigation management practices in Andhra Pradesh with respect to the above trends. Some of the important aspects in this regard include: viability of irrigation practices in the context of land fragmentation and anthropogenic pressure; changes in the policy response to the degradation of water resources due to mismanagement; and the costs of water pollution/scarcity to the rural economies. Besides, the relevance of the recent legislation regarding water user associations is critically reviewed. Specific attempts are made to gain insights regarding the state of water resources and the role of markets, institutions and policy in the case of this particular resource.

The specific objectives of the study are to:

- Evolve/develop an integrated approach on market and institutional failures in the context of natural resource degradation.
- Examine the macro policy perspective of water resource management at the state level and its implications for environmental degradation and water scarcity/pollution.
- Critically evaluate the water user association legislation brought in by the state in the light of environmental problems faced by the command areas.
- Explore the possibilities for integrating institutional and market aspects in water resource management and suggest policy options for sustainable water resource management.

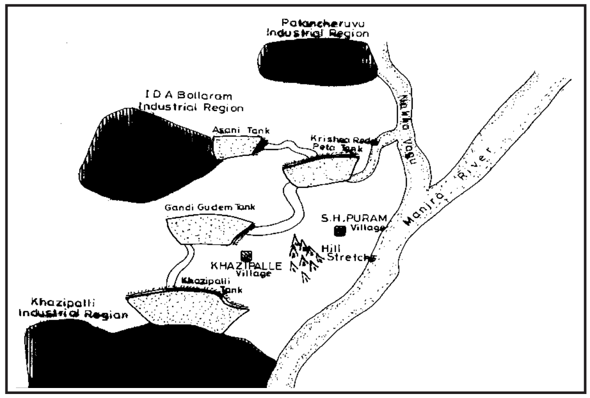
Methodology

This study is carried out at both theoretical as well as empirical levels. For the purpose of empirical analysis, data is drawn from both secondary and primary sources. Specifically, state budget expenditure is analysed for the past seven years to examine the trends in irrigation expenditure in the context of recent irrigation reforms. Besides, data is also drawn from sources like season and crop reports, statistical abstracts, etc. The primary data is collected from different locations (villages) that are experiencing the above said environmental problems. The sample villages represent diverse environments with regard to socio-economic, cultural and environmental aspects, as well as community practices and market mechanisms. Further, the functioning of water user associations is evaluated based on field visits to a number of sites.

Sites

Specifically, five villages from two districts are selected for the purpose of intensive analysis. These districts are Warangal and Medak. The groundwater region is represented by Warangal district, while Medak represents the problem areas related to water pollution due to industrialisation. Warangal district has recorded the maximum number of cotton farmer suicides mainly due to well failure, while Medak district has some of the industrial zones that are associated with the worst impact on rural livelihoods. The sample villages are selected purposively to examine the existing water management practices. Two villages representing well irrigation / groundwater scarcity - one representing well and tank irrigation linkages, and another village pertaining to water pollution, are selected. Both Participatory Rural Appraisal (PRA) methods and survey methods are used as complements in order to get better insights into the problem. PRA methods were used to identify various resources and water use practices at the village level to get the perceptions of the villagers/users regarding resource use and management practices. Survey methods are used to elicit the quantitative information on household features and their economic activities.

Fig. 1: Location of the sample villages



Results

Status of water resources

The present status and trends in irrigation development in the state can be better understood in the macro policy framework. The attitude, philosophy and ideology of the policy makers are crucial in determining the development path. The core philosophy of the policy makers dealing with water has not changed despite the process of reforms for a decade. The philosophy of water resource management continues to be largely supply side and neglects demand side management. The supply side approach aims at supplying bulk water at any cost to meet the demand for irrigable land through development of new supply sources with little attention to charging the price corresponding to cost. In this approach, the emphasis is more on developing new sources of water. On the other hand, the demand side approach stresses making water available to each individual farmer through improved water management. This is possible through reducing the wastage in water, adoption of technologies that would increase water use efficiency, etc. Pricing of water is one of the most effective demand management variables. Effective pricing policies are found to result in conservation and efficient use of water in diverse situations. Hitherto efficiencies were improved through supply regulation in the supply side management by creating scarcity conditions. This however, is only likely to make those farmers already in receipt of irrigation supplies, operate more efficiently and would do nothing for others who may have already been waiting many years for supply. Besides, resource (financial) constraints would further aggravate supply regulation, and hence shortages. The spiralling effect of this would result in acute shortages, as it happened in the case of drinking water. The implications of such macro policies (supply side and biased towards major irrigation) at the micro level are examined with respect to surface water, ground water and water pollution.

Ground water

Groundwater, the single most important source of irrigation, is totally left out of the purview of the water user association legislation. There are no efforts to integrate well and tank irrigation. While water user associations are found to be effective in the canal commands, they are not serving the purpose in the case of tank irrigation, though 80 percent of the associations are for tanks. Unless the needs of these regions are identified and addressed effectively, fragile resource regions will face irreversible ecological problems like desertification.

The first victims in the process (Table 1) are small and marginal farmers. Both direct and indirect costs of degradation are more in the case of small and marginal farmers, especially in degraded environments. The costs of degradation range from Rs.1,300 to Rs.44,000 per acre among marginal farmers as the degradation of groundwater aggravates. The impact of resource degradation on these farmers occurs in two ways. Firstly, while small and marginal farmers dominate the ownership of wells in general and open wells in particular, medium and large farmers dominate the ownership of bore wells. As a result of degradation, a majority of these farmers lose their access to water. They are denied their genuine share in the common pool resource. Secondly, one of the interesting observations of our study is that of late, bore well technology is becoming cheaper, making it size (owned land) neutral, though the process may be slow. As a result, these farmers are also investing substantial amounts of money on bore wells. Such investments become unviable in the event of well failure.

Table 1: Total Costs (direct and indirect) of Groundwater Degradation (Rs./acre)

Village/ Size class	Costs due to groundwater degradation		Total costs (Rupees per acre)
	Direct	Indirect	
Vanaparthy	2744	605	3349
Large Farmers	1782	580	2362
Medium Farmers	4667	1056	5723
Small Farmers	5354	1020	6374
Marginal Farmers	1259	120	1379
Teegaram	3831	1708	5539
Large Farmers	732	1455	2187
Medium Farmers	1889	2236	4125
Small Farmers	5673	1209	6882
Marginal Farmers	11031	3248	14279
Vaddicherla	13159	1910	15069
Large Farmers	6158	2001	8159
Medium Farmers	10694	2733	13427
Small Farmers	17696	2091	19787
Marginal Farmers	36855	7747	44602

Unfortunately, there are no policies so far that address the equity and management aspects of groundwater. Though there are regulations on groundwater exploitation, these are inadequate and ineffective. Even the proposed new policies are on the lines of regulation rather than designing innovative policies that would integrate market and institutional dimensions of resource management. This calls for a shift in the policy from supply side management to demand side management, from populism to economics, from convenience to efficiency, from engineering to institutions, from centralisation to decentralisation, and from a fractured approach to an integrated approach. Water policies should aim at integrating all sources of water in the regional context rather than treating them in isolation. Demand management is equally, if not more important, especially in the context of scarce resources, as the supplies are limited. Demand management helps in efficient and sustainable use of the resource when compared to supply regulation.

Surface water

In a pioneering and unprecedented effort, the Government of Andhra Pradesh has initiated irrigation reforms on a large scale. In fact, these reforms are ranked very high even at the global level, and expected to be a future model in irrigation management. The state has shown that political will is the main ingredient for such initiatives. The most interesting feature of these reforms is that they are 'top down' with a 'bottom up' approach. It has the advantage of greater reach (possible under 'top down') and intensity through involvement of the community (possible under 'bottom up'). These reforms under the guidance of some committed officials at the state level, have taken off in good spirit and received good support at the farmer level. Though one may argue that flow of funds is the main factor in generating such response, it is necessary to support the ailing systems in order to generate trust among beneficiaries. Over the years, farmers have lost the trust in the government and are in no position to respond to false promises. Therefore, the initial boost is necessary to regain the lost credibility and build the trust. Once this is in place, institutional reforms from the top become smooth and easier. But it is necessary to understand the direction in which the reforms are progressing. This direction would ultimately determine the strength and sustainability of the reforms.

Water quality (Pollution)

The impact of industrial pollution on rural communities is quite substantial in monetary terms alone (Table 2). The costs of damage are as high as Rs.19,000 per household. The costs of damage would be much higher if social costs such as alienation of the village (marriages, social visits, etc) by others were accounted for. Similarly, the real impact on health, economic as well as psychological, is difficult to assess. While there is a possibility of over-estimating the damages on the part of respondents, we strongly believe that these would be more if social costs were to be valued. Moreover, the losses due to permanent disability to the chief breadwinner of a household are rather difficult to assess. In this regard, it is difficult to assess the problem in pure economic terms of valuation of losses. Hence, the solution to solving the problem lies not in compensating the loss, but in removing the problem altogether. Here, compensation means giving the right to the polluter to pollute . Looking at the health impact in the present case, no amount of compensation would suffice to address the problem.

Table 2: Total Loss per Household per Annum in Kazipalle Village (Rs.)

Loss on health	3799
Loss on livestock	815
Loss on agriculture	14615
Total	19229

The role of civil society is also not satisfactory in the present case. Protests in front of the State Secretariat in the form of both *dharna* (mass squatting) and *rastha roko* (blocking roads), only resulted in lathi charge and arrests of the villagers and NGOs. Neither the industries nor the PCB responded to the protests. People turned aggressive and attacked the industries. Since then, the industries stopped discharging their effluents into the tank during the daytime. Twice, the villagers caught persons discharging the effluent into the village tank at night and beat them up severely. After that incident, the industries were closed for three to four days, but started again as usual. Despite all these actions, the community did not succeed in influencing either industries or regulatory authorities. Finally, the villagers gave up their struggle out of frustration. Thus, the present case study provides an apt example of failure on all fronts.

Recommendations

Need for an integrated approach

The problems associated with the three aspects of water resources studied clearly indicate the failure of markets, institutions and policies. It may be noted that these failures are defined in a rather narrow sense here, as markets fall in the broader context of institutions. The problems associated with each of the aspects of water are rooted in one or more of these failures. Therefore, it is difficult to identify a particular problem related to water with a specific failure, though each aspect has a dominant failure type, such as groundwater being a case (dominant) of policy failure. Moreover, these failures are interlinked and overlap with one another.

As demonstrated by our case studies, the failures are more due to the partial nature rather than due to their absence, except perhaps in the case of groundwater, for markets fail because they do not have institutional support. We have seen in the case of canal irrigation systems in Andhra Pradesh and elsewhere, that price policies need to be fostered with appropriate institutional arrangements in order to make the former effective. On the other hand, institutions fail in the absence of market mechanisms to sustain the institutions, as institutions cannot survive long only with external support. This could well be the case with the water user associations (WUAs) in Andhra Pradesh, if the system does not adapt to an effective self-financing mechanism through appropriate price polices. The success of some of the initiatives in natural resource management, traditional as well as modern, is rooted in the integration of market and institutional factors. Though our case studies do not deal with such success stories, they clearly drive home the point that the failures could be due to the absence of an integrated approach. Further, there is a need for coordination between water policies and other policies, such as input and output policies. They should work in tandem rather than in diagonally opposite directions. These include input and output policies such as input subsidies (including power), procurement policies, etc.

Such an integrated approach makes sense even on theoretical grounds, as it helps in keeping the transaction costs low, which is crucial for sustaining the institutions.

Pricing mechanism leads to increased cohesion and cooperation within the community, as each member has a stake in the upkeep of the institution, consequent upon his or her contribution.

Increased cooperation means low transaction costs towards organising the community and keeping it together. However, equity in sharing the costs (user charges or contributions) on the basis of resource use is critical for sustaining the institutional arrangements. In the absence of equity, people contributing disproportionately higher shares may tend to undermine the collective action initiatives. Similarly, institutional back up for market approaches also reduces transaction costs, as they make compliance to rules and regulations (including pricing) easier and smooth. Recovery of irrigation charges tends to be high in the presence of appropriate institutional mechanisms. However, the process needs to be dynamic in order to address the changing contexts of the market as well as institutional mechanisms.

In the context of groundwater management the following issues need immediate policy attention:

- Integrated approach of groundwater development / exploitation with surface water bodies like tanks. These two sources of water should be treated as complements rather than substitutes. As a first step, all traditional tank systems should be revived and converted into percolation tanks, wherever necessary. The benefits from such a programme would be enormous when compared to the losses due to degradation, and hence, it makes economic and ecological sense.

- So far, groundwater is regulated through supply regulation of electricity rather than fixing the electricity charges appropriately. Only 9 hours of power supply is being provided in a day in rural areas due to power shortages. Though this has helped in checking the degradation in the short run, it is not a real solution in the long run. By the end of 2002, Andhra Pradesh is set to be a power surplus state. This coupled with subsidised power prices would aggravate the process of environmental degradation. Therefore, economic pricing of electricity with proper monitoring facilities would be more appropriate.

- Institutional arrangements are required to make groundwater a common pool resource in the true sense of the term. In this regard, de-linking of water rights from land rights would help address the equity issues effectively. However, the transaction costs for enforcing such a system would be enormous. In this context, the experiences of some NGO (*Pani Panchayat*) experiments in the country where water rights are given even to landless households, would be helpful. Similarly the experiences of countries like South Africa, where attempts are being made to effectively abolish the riparian rights on water, would throw some light in this regard.

- In the event of high transaction costs involved with enforcing the separation of water rights from land rights, adding the scarcity price of water to electricity, which amounts to discriminatory pricing of power depending on the status of water resources in the region. Resources generated from such scarcity rent can be diverted towards the development of sections of the local community that are unable to have access to water for various reasons.

In the context of surface water management, the following issues need immediate policy attention:

- There is an immediate need to bring the balance between minor, major and medium irrigation systems through judicious fund allocations under the purview of WUAs.
- Minor irrigation sources of tanks and groundwater should be treated in an integrated fashion. For this, groundwater needs to be brought under the purview of the WUAs. This calls for major initiatives in legal and legislative reforms to address the rights on groundwater. The experience of South Africa would help in understanding the issues of delinking of water rights from land. In fact, South Africa has effectively abolished the riparian rights.
- The reforms should initiate the process to convert water into an economic good through introduction of volumetric pricing, at least in the canal commands to start with. Effective reforms require integration of market and institutional dimensions. Though short-run political interests may go against this, it would have a multiplier effect on the long-run political and economic gains. At the same time, proper devolution of powers to local level institutions would help in addressing the political bottlenecks effectively.
- Transfer of powers and responsibilities to the WUAs at the minor level should be done effectively, though in a phased manner. Hitherto, WUAs were entrusted with responsibilities without any rights.
- There is a need for exploring the possibility of integrating the Panchayati Raj institutions into the reform process for sustaining the reforms in the long run. So far, these local bodies have been totally bypassed by the new initiatives.

In the context of water quality management, the following issues need immediate policy attention:

- There is need for strict regulation on the industries to adopt pollution mitigating technologies, or face closure. However, this calls for a close look at the economics of pollution mitigating technologies, which will be a worthy exercise. State policy also has a major role to play in this regard.

Economic and Environmental Aspects of Drinking Water Supply in Rural Tamil Nadu: A Case Study of Tiruchirappalli District

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Introduction

Water is a renewable natural resource, which has no substitute, and must be allocated across sectors like agriculture, industry and domestic use, in developing nations. The domestic sector generally requires less than 10 percent of the total water. Yet one-fourth of the rural population is deprived of access to safe water. Even where provided, the distribution and quality continue to present problems. India, as signatory to the United Nations Resolutions on "International Drinking Water Supply and Sanitation Decade 1982- 90" had assured full support to the action plan under the decadal programme. The launching of the "Rajiv Gandhi Drinking Water Mission - 1986" for rural water supply meant a departure from the conventional way of implementing water supply schemes in rural areas.

Objectives

The objectives of the study are to:

- Understand the economic and environmental implications of rural water supply programmes in Tiruchirappalli district of Tamil Nadu.
- Suggest measures for improving the existing system.

Site and Methodology

Tiruchirappalli district was chosen to conduct the village level case studies. This is one of the 30 districts in the state, comprising 8 talukas, 14 blocks, 408 village panchayats and 2,376 habitations. 311 sample rural households were chosen across 4 talukas, 4 blocks, 5 villages and 46 habitations by using the stratified proportionate random sampling method. Totally, five villages were selected and grouped under four categories - wet, wet and dry, dry, and hilly regions. In three of the selected villages, 10 percent of the sample households were chosen. In the remaining two villages, where the characteristics are mixed, only 5 percent of the sample households were chosen for the study. Besides this, secondary information on the status of drinking water provision across 2,376 habitations was used to prepare a broad profile of rural water supply in the district.

Analysis of data is carried out at two levels. One at the habitation level, based on secondary source of information, and the other at the household level with the help of primary data. Regression analysis was used to analyse both the secondary and primary data sources of information. The Ordinary Least Square (OLS) method is followed with linear formulations for estimating the values. The block rate pricing method is used to estimate the tariff rates for the piped water service connections with the help of the actual village level data.

Existing Water Supply Schemes

Modern provisions through the Tamil Nadu Water and Drainage Board (TWAD) began as early as 1974. At present, 95 percent of the total habitations in the district are covered with hand pumps, while only 46 percent have power pumps viz., Over Head Tanks (OHT) and Ground Level Water Reservoirs (GLWR) through stand posts, and only 6.6 percent enjoyed house service connections. Of the 2,376 rural habitations in the district, 1,347 habitations have been fully covered and 1,029 habitations were partially covered by the Board in the provision of water supply.

Modern sources provided include hand pumps and power pumps (OHT, public fountains and house service connections). 95 percent of the habitations have access to hand pump facilities;. 46 percent were covered with power pumps, and 8.4 percent had pipelines extended from other sources. The provision of hand pumps as against the government norm has not been fulfilled in 73 percent of the habitations. The concentration of OHT facility is higher in wet villages. The capacity of OHT has been lower as against the government norm in all the habitations. In dry villages, the number of stand posts provided per 1,000 population is below the norm.

The Combined Water Supply Scheme (CWSS) is the latest water supply programme under implementation. Of the total capital invested in the district, 56 percent is by CWSS. In terms of coverage of habitations, CWSS could cover even remote villages with potable water where water scarcity is acute . However, CWSS is not cost effective.

Of the total schemes, about 51 percent were installed during 1981-90, during the International Drinking Water and Sanitation Decade. The per capita installation cost per scheme worked out to be Rs.29,000 for hand pumps, Rs.2.89 lakhs for power pumps and Rs.1118.1lakhs for CWSS at current prices. In all, the cost of provision of public water is significantly higher, particularly with CWSS.

In financing the water supply schemes, 49.3 percent of the total cost was borne by loans extended by Life Insurance Corporation. The state contributed 16.6 percent through Minimum Needs Programme (MNP), 6.3 percent came from the local body, 5.9 percent from the Central Government; and 16 percent was contributed by others towards various schemes in the district. The contributions made by international agencies have been less than one percent of the total.

With respect to cost, the provision of water supply is skewed more towards wet, and wet and dry villages than the other categories. Execution of water supply schemes was carried out largely by the TWAD Board, followed by local bodies, District Rural Development Agency (DRDA) and others. Less than 10 percent of houses had in-house latrine facilities and 99 percent of households practiced open-air defecation.

Regression results suggest that variations in per capita water supplied per day are explained by independent variables such as area, stand posts per 1,000 population, and yielding capacity, at the 5 percent level of significance. The R square was 0.22.

Primary Survey

The primary survey of households was aimed at capturing the demand for water at the household level, with respect to quantity, quality, sources, time taken, distance traveled, water collectors, consumption of water by livestock, willingness to pay, access to traditional water sources, health and personal hygienic practices. This is essentially to evaluate the responsiveness of users as against the provisions made by the state.

The demand scenario across five villages showed a varying pattern of consumption behaviour towards modern and traditional sources of water, and the existence of physical sources (hand pump, stand post) and traditional sources (oothu, kudavu , river, stream and open well etc.).

Dependence on modern/mission sources started only after the 1970s, and continues to be a major source at present. Wet villages received greater number of schemes than other category villages. Wet and dry villages enjoyed more of combined water supply schemes. Dry village received less public utility facilities and depended largely on traditional sources. The villages in the hilly regions have been served by traditional source through modern scheme of distribution of water.

Major modern schemes identified in the study villages included hand pumps, power pumps (OHT, CWSS, GLWR), public fountains, house service connections, and agricultural bore-wells, while the traditional sources are spring, kudavu, stream, river, pond and open well. Among the modern schemes, power pumps are the dominant source from which respondents draw water for domestic purposes. Hand pumps are more widely used in wet villages. House service connections are not given in the dry and hilly regions.

The *mean distance traveled* to fetch water in wet, and wet and dry villages was less than 100 meters, the time taken being 62 minutes per day / household. In dry and hilly regions, the mean distance was 775 meters, and households spent on average four hours per day towards fetching water for domestic purposes. The time spent for fetching and waiting time for traditional source ranged from a minimum of one hour to a maximum of six hours during the summer.

The total water drawn for domestic purposes per household is estimated to be 366 liters per day. Water utilized for drinking and cooking alone is 30 liters per household, which constitutes 8 percent of the total consumption. The per capita consumption is 76 liters, of which use for drinking and cooking purposes is 6.1 liters. Seasonal variations in the context of drinking water scarcity aspect were prominent in dry villages. Scarcity was less in other categories of villages due to the availability of sufficient water.

Among the total respondents, the percentage of women water collectors constituted 93.8 percent, inclusive of female school going children. The per capita consumption by livestock is estimated at 10 liters per day. Willingness to pay is positive with 75 percent of the respondents. On an average, the amount of money they are willing to pay is Rs.8 per month per house for improved water supply. Willingness to pay (WTP) for improved quality/quantity is related to collection time, social status (community) and farm size. These three independent variables significantly and positively influence the WTP. The regression analysis also indicates a relationship between per capita water consumption and household area, cooking requirement per day, family size and value of house. These four variables turned out to be significant at the 5 percent level. The value of R square is 0.21. Area and family size showed a negative relationship, while the coefficient of value of house and cooking per day was positive.

Two separate tariff rates for rural water supply, based on the primary survey information have been worked out:

- A rate ranging between Rs.22 to 44, per capita per annum, for recovering replacement cost and O&M cost for all the study villages.
- A rate of Rs.48 per household per month for recovering O& M cost and maintaining quality for those having house service connections.

Environmental Issues

Given the fact that human intervention causes tremendous changes in the ecosystem in general, and water source in particular, the environmental implications of drinking water can be described in the backdrop of the socio-economic conditions. This study addresses five facets of environmental implications of rural water supply, viz; i) degradation of drinking water quality and the health impacts thereof; ii) depletion of ground water resources; iii) increased burden on female children as water collectors; iv) environmental conflicts between agricultural and domestic sector; and v) dominance of modern sources over traditional source.

Water quality of samples drawn was tested for chemical, physical and biological parameters from twenty locations across the study villages. The results showed the surface water samples contained higher levels of fecal coliform during rainy seasons compared to the groundwater source. However, the surface water, which happened to be the traditional source, is comparatively free from physical and chemical contaminants. Chemical and physical contaminants in groundwater were generally well within the permissible level in the select villages.

Health hazards due to unsafe water vary in different regions and sources of water. For instance, people living in hilly regions suffered the maximum from water-borne diseases, while the wet and dry villages were the least affected. Modern sources are not as safe as the state has claimed. Of the total respondents, only 7 percent of the traditional source of water users were affected by water related diseases, whereas, percent of the modern source users were affected. Can we conclude that modern sources are no longer safe, while traditional sources are safer 60 percent of the respondents replied improperly due to lack of awareness of the linkage between health and safe water. However, the fact remains that 75 percent of the respondents were willing to pay for improved water quality and quantity of supply.

If the rate of extraction of groundwater resource exceeds the rate of recharge, then the results would have serious environmental implications. Lowering of groundwater table is observed in the district to an extent of 1.1 meters on an average between 1971 and 1999. Inadequate rainfall, occurrence of rainfall for a few days at irregular intervals, over-extraction of water and lack of replenishment due to rocky formation were the causes expressed by the respondents.

In addition, the impact of environmental degradation in terms of depletion of groundwater resources on females, including female children, is evident in one of the study villages. In a dry village, a large number of female children were collecting water. Females in general, and female children in particular, traveled a distance of 3 km and spent between 1 to 6 hours a day fetching water during summer from a traditional source viz., the spring. Statistical testing showed that there is a significant difference between dry and other categories of villages in terms of the number of female children engaged in carrying water. Indirect cost of time and distance were higher in the collection of water from the traditional sources when compared to modern sources. Modern schemes reduced the indirect cost of collection considerably. Among the modern sources, collection from hand pumps involved more time, distance and energy compared to stand posts.

Environmental conflicts that arose between agriculture and domestic users brought to light a newer dimension to water conflicts. The general tendency is that the increasing number of agricultural bore wells results in depletion of ground water, thereby affecting the drinking water availability. The newer phenomenon observed was that the Combined Water Supply Scheme meant for augmenting drinking water provision has allegedly depleted the groundwater potential, thereby depleting the water meant for agricultural activities.

Controversies over traditional vis-à-vis modern sources have been continuing over the last two decades. Modern schemes have an edge over traditional sources in the recent period. However, traditional sources are handy whenever modern sources fail. Even in some cases, modern technology is applied to distribute water by drawing water from traditional sources. The traditional sources are to be conserved and preserved. The current concept of 'rainwater harvesting' needs to be popularized in rural areas. Modern schemes should supplement traditional water sources, but not supplant the latter.

Conclusions

This study confirms that the implementation of water provision schemes is skewed towards wet, and wet and dry villages, while arid and hilly regions have received less attention. This is evident with respect to the creation of physical assets such as hand pumps and OHTs, capital investment made, per capita availability, distance traveled and so on. Traditional sources of water continued to be handy in villages where government schemes played a lesser role. With regard to water quality, surface water sources were susceptible to biological contaminants, while groundwater is affected to some extent by chemical and physical contaminants. The findings of our study are not in line with the government's stand that modern sources of water are safer, and the conventional sources are unsafe. The policy implications of the study focus on demand focussed rather than supply oriented decision-making in the provision of rural water supply. The latter has proved to be a failure owing to uneven distribution across the categories of villages in the study district. Greater investment is needed in dry and hilly regions of the district, where the existing schemes are small in number, while the demand for domestic use is higher in these two categories of villages. Finally, the "user pay" principle needs to be invoked for rural water supply too. As against arbitrary water tariff, a rate, which ensures continuous operation and maintenance plus good quality, has to be implemented to achieve sustainability in rural water supply.

Reviving a Water Heritage: Economic and Environmental Performance of Traditional Water Harvesting Systems in Western India

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Introduction

The impending crisis of scarcity of potable water, even in high rainfall zones, has emerged as an issue of serious national concern. It is fairly well established by now that it is no longer feasible to meet all the domestic water needs through perpetual and excessive withdrawal of groundwater. While industrial units and urban settlers competing with other users (including agriculturists) continue to remain in the arena of policy debate. Alternative ways and means to meet the growing demand for potable water from the rural sector have come under urgent consideration. This is particularly so as the state-run piped water schemes have left much to be desired in terms of reliability, adequacy and sustainability of water supply in rural India.

The relatively recent initiation of reorientation in rural water supply, as part of the overall sectoral reform initiatives and emphasising user financing and local management, faces a number of constraints. The most notable of these hurdles concerns the inadequate or low recovery from the very poor rural households. Despite the soundness of the 'efficiency' argument, payment for capital expenditure by individual households in poverty remains a complex issue to tackle.

Objectives

The objectives of the study are to:

- Work out the potential of revival and modernization of traditional water harvesting systems.
- Address the vital problem of ensuring that the availability of potable water in rural households is sustainable.

It is important to recognize that much of the "enthusiasm" generated by the decade-and-a-half-old resurgence of interest in Traditional Water Harvesting Systems (TWHS) as alternatives in solving the rural water crisis, needs to be validated against their actual potential. This is important as TWHS depends on collecting and storing surface run-off and rainwater. Therefore, it is an excellent option that does not draw upon the valuable groundwater beyond the rechargeable limit.

While TWHS are thought upon as options based on local knowledge, environment and socio-cultural practices, a large number of them can no longer cater to the total demand for water in a given village in which the population keeps growing. Further, barring a few, in many cases the traditional form of community-based management of the structures has been a matter of past. Gross neglect of these common property resources is evident in the existence of damaged structures, pollution of the water and even forcible possession by vested interests for private purposes.

Despite the indifference meted out to these age-old structures in many regions, especially when attention centred around the solution that was expected to come about through the modern piped water system, TWHS continue to function in numerous villages of India, and if not fully, these sources could fulfil demand for water for domestic use partially, particularly during the summer months.

Study Area

In view of the rather limited and sketchy literature available on TWHS (meant mainly for drinking water purpose) and the growing need to appreciate their environmental and economic performance, this study concentrated on three distinct TWHS as extensively found in the Thar Desert and Central Uplands Regions. The systems studied are bavdis in western Madhya Pradesh, wells (which are primarily recharged by nadis) in western Rajasthan and talavs in the Kutch region of Gujarat.

Bavdis or the community step wells are shallower than wells. They have beautiful arches along their full height. Bavdis can hold water for a long time because of almost negligible water evaporation when compared to other water bodies.

A nadi is essentially a natural surface depression, which receives rainwater from one or more directions. Some nadis have stonewalls on one or two sides to enhance the capacity of water retention.

A talav is a local water reservoir situated in valleys and natural depressions. In old talavs, only the slope side was provided with strong parapet walls to hold the rainwater. Other sides were naturally supported by outcrops of hillocks or elevated rocky formations.

Methodology

Three distinct approaches were followed:

Hydrogeological and engineering surveys were undertaken to understand the functional dynamics of the systems. These also included exploring possible technical interventions and modifications needed to improve the existing structures so as to enhance the availability of water. Estimates of cost of revival/modernization of TWHS were arrived at following these surveys, as well as consultations with locally informed people, NGOs and concerned engineers and hydrologists in the local state/taluka department offices. Similarly, estimates were also prepared for capital expenditure and O&M costs for installing piped water network in the village, so as to provide a tap connection to every household. These sets of estimates were made for all the six sample villages.

Village and Household level surveys were conducted in order to elicit information on demographic and socio-economic variables of the inhabitants and availability of infrastructural facilities. A total of 301 households were surveyed for the purpose. Special care was taken to obtain as much detailed data as possible on water related issues, such as, sources, pattern of use, time taken and distance covered to fetch water, and perception about quality. The household and village level structured surveys were supplemented by fairly well attended focus group discussions (FGDs), oriented in a manner to understand diverse views as expressed freely by the participants. The focus group discussions dealt primarily with the delicate issues of community ownership and management of the existing TWHS.

The third, but vital approach followed in the analysis related to the valuation of popular willingness to pay (WTP) for provision of water facilities through improved TWHS, and water supply through household level tap connections. This exercise was based on structured questionnaires prepared following the Contingent Valuation Method (CVM). The introduction of the option of mode of payment was supposed to help reveal respondents' actual ability to pay for the amenities.

These exercises in ascertaining households WTP from possible water supply devices, proposed through the creation of a hypothetical market scenario, provided the most interesting clues regarding popular perception about the TWHS and/or modern piped water supply, and their readiness to pay for either or both of these systems.

Results

Drawing upon available documentation on TWHS and extensive field surveys in the broad ecological zones of the Thar Desert and Central Highlands, it is obvious that TWHS not only vary substantially in terms of technology and management, but also their functioning depends crucially on the local discrete environment. Keeping these local specificities in view, the potential of selected systems in terms of long-term sustainability can be described in brief as follows:

***Bavdis in Southwestern Madhya Pradesh*:** These exist in huge numbers. But, mainly due to their typically small size and limited storage capacity, these are probably not the best options for meeting community water needs.

However, as observed by the hydro geologists and water engineers, it is possible to deepen existing talavs and dig new ones that, in turn, would recharge bavdis. In Dhababavdi (Barwani district), the two currently functioning bavdis serve a limited purpose and, clearly cannot address the water scarcity problem of the entire village.

Wells in Western Rajasthan: Wells as TWHS in the western parts of Rajasthan have continued to prove useful, even during summer months in the driest geoclimatic region of India. Unlike bavdis, wells are extensively used by the rural communities and are well maintained. All the wells visited in this region during the peak summer season had a good supply of water, and the local perception about its quality was positive. An important hydrogeological characteristic of the wells surveyed was that the structures had been linked to underground perennial streams/channels. Also, these wells had been built with reference to the surrounding nadis (TWHS by themselves) so as to receive water recharged through them. This ingenious selection of location and construction of the structures ensured a steady supply of water in the wells. These wells hold much potential to be revived and modernized. One effective approach would be to desilt, deepen and widen the concerned nadis; this will ensure a substantial increase in availability of water in the wells, which may be stored for a long period of time. These structures are also viable options in these regions, where piped water systems are most likely to fail due to very low groundwater tables.

Talavs in Kutch, Gujarat: Almost all parts of the Kutch region have suffered substantial groundwater depletion and salinity ingress. High incidence of poor groundwater bearing formations has resulted in severe water crisis in the region. Talavs certainly remain an important solution to the water problem in Kutch. In many villages visited, villagers considered water from local talavs to be of good quality, especially since that water is available during prolonged spells of summer. The structures in the surveyed villages are unique examples of interconnected talavs, specially designed to prevent drinking water mingling with water in other talavs meant for washing or bathing purposes. In terms of size and capacity, talavs are of large dimensions. These are in dire need of revival and modernization and can surely prove valuable in addressing the water shortage problem in the Kutch region. Unlike the saline groundwater, talavs retain potable water and also recharge surrounding aquifers, as do other TWHS like wells.

Water Quality

A commonly held observation disfavouring TWHS as potential sources of potable water concerns the ‘unprotected’ and ‘unsafe’ nature of the water. This important dimension of the quality of water of TWHS must be taken into consideration in evaluating their potential. Water samples from the surveyed TWHS were collected for chemical analyses. Of the seven water samples collected from individual TWHS, in all the cases the water was found suitable for drinking; the incidence of total dissolved solids (TDS) was within permissible limits. Bacteriological analyses of the water samples were also carried out in the laboratory following scientific instructions. These tests, however, indicated the unsuitability of the water for drinking purposes due to the presence of very high concentrations of coliform bacteria.

Irrespective of the fact that most villagers use the water of TWHS for drinking, cooking and other domestic purposes, these scientific tests indicate deficiencies in water quality. In most cases, as in the surveyed TWHS, quality of water can be upgraded substantially through cost-effective methods of treatment. Whether some sources are to be abandoned, primarily due to lack of any scope to improve water quality, even up to the level of being used for domestic purposes (other than human drinking) only, should be left exclusively to the discretion of the scientific experts.

Valuation of TWHS

Whereas hydrogeological and structural engineering studies could work out interventions that would revive/ modernize the specific TWHS on a long-term sustainability basis, the estimation of both the capital cost as well as O&M indicates the financial investment that would be required.

Such estimates are likely to represent the total use value of the environmental 'commodity' in question. As the analysis concentrates on potable water meant for domestic consumption only, the existence value of the commodity becomes irrelevant. Also, the nature of benefits of having access to good quality water is very much within the knowledge of the potential users. It may hence, be held that the assessment of WTP undertaken in the study falls within the broad purview of cost-benefit analysis. Assuming that the entire cost of revival/ modernization would be shared between all the households in the village, an assessment of the willingness to pay for the improvised structures was made. The most significant aspect of the WTP exercise was that a substantial 65 percent of all households surveyed were not willing to pay any amount whatsoever for either or both the hypothetically proposed facilities. Despite having a series of independent variables, indicating the most likely socio-economic factors, regressed with the amount of WTP, the state level results showed only per capita consumption of water in Madhya Pradesh and Gujarat, and caste of the household in Gujarat as the significant variables affecting the WTP (Table 1). However, when similar regressions were run for Rajasthan, none of the variables was found to be significant.

Table 1: Overall Summary of Logistic Regression Results

State/ Level of Significance	1% Level of Significance	5% Level of Significance	10% Level of Significance
Madhya Pradesh			PCHUMQ (1.035)
Rajasthan			
Gujarat	CASTE (0.174)	PCHUMQ (1.049)	

In fact, a close examination of the nature and extent of households' WTP provides interesting insights into such a pattern of response. First, most households in the Rajasthan villages live in extreme poverty and, naturally have refused to pay at all for the water from either TWHS or piped systems. The villagers are perfectly aware that the existing wells, from where they have been drawing water free even during the peak summer months, will continue to meet their minimum basic demand for potable water. However, if extreme poverty could lead to a negative response for paying for water, in Dhababavdi (the MP village), quite a few villagers living below the poverty line have expressed their willingness to pay even small sums for water facilities. This is so, as this village has practically exhausted all existing sources and the value for water has clearly risen for them.

Second, unlike the capital cost, most villagers in all the surveyed villages were willing to pay for the O&M for TWHS. In many cases, the estimated contribution for O&M for the proposed piped system was much higher than that for TWHS. People's willingness to contribute free labour indicates the preference for the revival/ modernization of the TWHS. Table 2 presents the proportions of respondents willing to pay for revival of TWHS, laying of piped system, O&M for both TWHS and pipe network and contribution of free labour across sample villages.

Table 2: Willingness to Pay Across Sample Villages

(Percentages)

Particulars	Madhya Pradesh		Rajasthan		Gujarat	
	Dhababavdi	Temla	Nagana	Godavas	Tera	Reha Mota
WTP_{TWHS}	26.8	11.8	14.3	4.7	77.3	11.8
WTP_{PIPE}	22.0	9.8	5.7	-	18.2	7.8
$WTP_{O\&MTWHS}$	39.0	76.5	97.1	100.0	93.2	90.2
$WTP_{O\&MPIPE}$	29.3	13.7	17.1	-	72.7	13.7
$WTP_{LABOURTWHS}$	92.7	84.3	97.1	100.0	77.3	74.5

An important aspect of this exercise in assessing WTP is that even the most sophisticated methods of valuation may be inadequate to elicit information on the WTP behaviour if the respondents refuse to participate in the 'bidding' process, mainly due to abject poverty and rejecting the very proposal that potable water could be priced for the rural poor.

Recommendations

A number of technological options to revive/ modernize the TWHS have been put forth by the hydrogeological and engineering experts. Most of the considered suggestions have been highly discrete (specific to the system or site per se), and have often incorporated ideas from local inhabitants. For instance, as may be seen from Table 3 especially, the bavdis may not prove to be adequate sources of water due to their small size. Table 3 presents brief notes on suggested technological interventions, which may serve as useful guidelines in appreciating the utility and sustainability of individual systems.

Table 3: Structural Issues Relating to the Revival of TWHS

Particulars	Bavdi		Well		Talav	
	Dhababavdi	Temla	Nagana	Godavas	Tera	Reha Mota
Structural Features	Structure is small				Huge capacity and favourable topography	
Potability	Unsuitable for human drinking	Unsuitable for human drinking	Ground water is becoming saline	Increasing salinity	Used as potable water	Reported to be unsuitable for drinking but good for cooking
Technological Interventions	Desilting of catchments would improve water table	Desilting of local talav is essential for recharge of the bavdi	Desilting of local talav would improve the water and reduce salinity		Diseases reporteddue to bacterial contamination of the water during late summers	Desilting would improve the ground water level in the area

Table 4 presents some relevant issues covering management and maintenance of the TWHS. In the case of the well in Nagana in Rajasthan and the talav in Tera in Gujarat, the local community themselves managed and maintained the TWHS . These are the villages where the use of water from TWHS has been extensive, and also the quality of water has been well maintained. In the remaining cases, a preference has been expressed for complete or partial involvement of the state government in managing and maintaining the sources. In these villages, the general lack of confidence in the efficacy of the sarpanches in managing these sources is striking. The possibility of public and private participation in financing the revival of the TWHS in these villages may be explored.

Table 4: Management Issues in Revival and Maintenance of the TWHS

Bavdi		Well		Talav	
Dhababavdi	Temla	Nagana	Godavas	Tera	Reha Mota
Presently privately owned; Government should take-over & manage	Government/ Panchayat managed; Distrust among the people regarding usage of funds	Panchayat managed	Improper local management	Community managed	Government should take up the management
Sarpanch is illiterate; Lack of leadership	Sarpanch is illiterate; Lack of leadership	Leadership is caste biased		Local leaders are highly motivated and concerned about water management	
No participation from women		Women do not have a say in the local management	Lack of sense of responsibility for maintenance of existing structures	People are united for maintenance of the system	Generally people were not interested in taking up the maintenance and management of their water supply

It was apparent that TWHS were not, or will not be able to cater to the total requirement of drinking water in the villages, mainly due to the rise in population in the past decades. Nevertheless, if they are revived/repaired and more importantly, if the ownership is shifted from the present private owners to the original community, these sources can be of substantial use, especially during summer.

Piped water systems, though preferable, have the implications of increasing cost in the future, either due to an increase in population or depletion of groundwater. Additionally, the ubiquitous problem of unreliability of piped water supply has serious implications for considering alternative sources.

Hydrogeology specific technological strategies to harness rainwater and modernize TWHS need to be explored, as enhanced supply per se can reduce costs significantly. In such ventures, whether and how the State can intervene or seek private participation, both for financing and providing technical and management support, is an issue to be explored. In TWHS, the trickier issue is management with community participation. The control over the system by the local dominant group is difficult to wish away.

Interestingly, the large-scale prevalence of TWHS in its varied forms in the three states has not been adequately documented in the rather limited literature on the subject. Locating the TWHS through the field survey *in itself* was an important aspect of the study.

Pricing of Irrigation Water in Kerala with Special Reference to Environmental Management

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Introduction

Economic development in India is heavily dependent on sustainable agricultural production, since agriculture is considered to be the backbone of the nation. Further, water resource availability and the quantum of water available for irrigation determine the sustainable agricultural production in India. It has been estimated that, of the total water use in the country, 80 percent is being used for irrigation. The situation in Kerala is no different. Moreover, irrigation water is not priced properly.

Often highlighted as a state with a high literacy rate, Kerala is also regarded as a place with very low level of water literacy, maybe due to historical reasons. This study was undertaken to assess the value of irrigation water as a basis for pricing of irrigation in Kerala for sustainable and viable performance of the major irrigation projects In the long run, this study may form the basis for developing a strategy for pricing irrigation water that will reflect the true value of the resource.

Objectives

The objectives of the present study are to:

- Estimate the value of irrigation water based on water productivity.
- Identify the non-irrigation uses of irrigation systems, and estimate the non-use value of water in such uses.
- Measure the net benefits of irrigation and estimate the total economic value of irrigation water.

Site

Peechi, one of the major irrigation projects of Kerala, was selected for the study. The project consists of a masonry dam and a storage reservoir at Peechi and a system of irrigation canals which crisscross Thrissur taluk. The project was started in 1947 and completed in 1959. Water was first let out for irrigation in 1953.

The project has been in operation for nearly 40 years and the whole system is in a dilapidated condition. Farms situated at the end reaches of the canals hardly get water to suit their requirements, whereas the farmers at the upper reaches have to struggle to drain water from their lands. A good quantity of irrigation water is being wasted at the upper reaches by seepage. The maintenance grant available for the project is not even sufficient to remove the silt deposit in the canals and branches as well as slips and other deposits

Water Use Trade off in Command Area

The water in the Peechi reservoir satisfies the needs of the community/farmers. Any change in the capacity of the reservoir will directly affect the water supply. The capacity of the dam in 1955 was 113.27 $Mm,^3$ which had reduced to 87.62 Mm^3 in 1980. The projected dam capacity in 2002 is only 74.01 Mm^3. This was mainly due to the sedimentation caused by land use changes in the upstream and deforestation in the area. The poor maintenance of the canal system (mostly unlined) resulted in large-scale losses at the distribution level.

Further, the water release data from Peechi Irrigation System shows a shift in favour of drinking water. The quantity of water released for drinking purposes showed an increase of 83.18 percent over a period of 17 years, while that for irrigation declined by 42.73 percent. The release of water through the Right Bank Main Canal (RBC)/ Left Bank Main Canal (LBC) mainly starts by September-October and ends at the latest by March. During the severe drought periods of April and May, no water is released and the people have to rely on alternate coping mechanisms. For domestic needs, they depend on the closest perennial wells or on drinking water markets. 66 percent of sample farmers resorted to alternate mechanisms, the average cost of which is estimated as Rs.170/ family/ season. This included the time/ effort taken to bring water or the cost incurred on purchase. The effect of shrinking water release to irrigation is manifested in many ways as detailed below.

Declining Command Area and Changing Land Use

The command area of the project has remained unchanged over the years at 18,623 ha, of which 15,808 ha is the cropped area. Only 75 percent of area irrigated in the beginning of the project was being irrigated by 2000, and it had further declined to 63 percent by 2001. The reduction in area was more drastic in RBC compared to LBC. The area under *kole* lands (paddy fields) remained the same. (The *kole* lands are submerged fields below mean sea level, which are used for paddy cultivation during summer. These lands are unsuitable for other purposes). The data projects a situation of declining levels of irrigated area in the command area of the project, against the targeted area. The declining capacity of the reservoir, increasing pressure from the domestic sector, and distribution losses are identified as the major reasons for this decline in the irrigated area.

Distributional Inequality

Consequent to the decline in the release of water, the distributional inequalities result in head reach farmers enjoying more water. The average use of water for irrigation by the head reach farmers is estimated at 14.16 m^3/day/ ha, while it is only 4.7-m^3/ day/ ha in the tail end. In the middle portion, it is 6.93-m^3/ day/ ha. The data on ground water depth also supports this view. The mean water table declines as one moves from head region to middle and tail region. However, it was below 1.5 m. and did not cause any adverse effects, even at the head.

The recharge in wells is influenced by proximity of canal. There exists a moderate degree of correlation (correlation coefficient of 0.2512, which is statistically significant at 5 percent level) between the net recharge of farm wells and the distance of farms from the main canal. It is clear that the canal irrigation provided a positive externality for farm wells, as there is recharge for the summer season. This water was used for irrigating the crops, and thus the canal system indirectly but strongly affected the farm productivity.

All the sample farmers in the tail, 90 percent in the mid and 63 percent in the head reach, opined that there is disparity in water distribution, which is in favour of head reach farms. While a majority in the head portion had no complaints on water availability, all the farmers in the tail region expressed their difficulties. 75 percent of the farmers in the far end attributed this to the excessive use of water by the head reach farmers. Although there is an alternate irrigation mechanism (tube wells) in the tail end, only rich farmers could afford this option.

Shift in Cropping Pattern

The wide inequality/ variability and uncertainty in the distribution of water within the command area is manifested as special and temporal shifts in the agricultural system / practices and performance.

The Peechi project was intended originally for two crops of paddy. The first crop, *Virippu* starts from May and is harvested from August to September. The second, crop, *Mundakan* starts from September and is harvested in December. The third crop, *Puncha* starts from January and is harvested in April. The first crop is rain-fed, and hence no water is released from the reservoir.

Over the period, 1995-96 to 2001-02, the paddy acreage has declined drastically from 62.1 percent to 36.48 percent of the total area. Simultaneously, the coconut and banana acreage has increased. It is noticed that the conversion to non-agricultural uses was only marginal, and crop adjustments within the agricultural area were the major coping strategy. The major shift in paddy lands is mainly in the head reach. There is a large-scale conversion of these paddy fields mainly to banana and vegetables.

The proportion of paddy land is lowest in the head reach and highest in the tail, while the reverse is true in the case of banana and vegetables. In the head reach all paddy lands, except those that are water logged, have been converted for banana cultivation. The conversion of paddy fields for banana cultivation in the head reaches warrants an additional investment of Rs.10,000 per hectare owing to stagnant water. Estimating the proportionate contribution of banana and vegetables to total farm income, it was seen that in the head region, the contribution varied between 60-83 percent, in the mid reach, 30-65 percent and in the tail reach, 0-10 percent.

Banana cultivation is a highly remunerative enterprise, with a significantly high benefit cost ratio compared to rice. The commercial viability of the crop is also very high. The direct benefits enjoyed by the farmers in the head region in the form of higher income, result in higher socio-economic divergence among the farmers in the canal command. Higher concentration of banana cultivation in the canal command creates several negative externalities viz., environment pollution, as well.

Environmental Aspects

Overuse, unscientific methods of selection of chemicals and mode of application of systemic pesticides in banana cultivation are already reported in the command area. The residual effects of these systemic chemicals on produce, soil, water and bio systems are yet to be studied in detail.

Returns from banana cultivation are significantly influenced by the stalking support provided. Since banana has a weak pseudo stem, stalking with appropriate poles in time ensures better yield. Due to concentration of banana cultivation, the demand for poles has increased drastically. It was seen that the sources of 73.5 percent of these poles were from the adjoining Peechi Forest area. Pole harvesting affects regeneration of tree species in the forest area, and this has affected the vegetative structure of natural forests. Species with less regenerating (coppicing) capacity have gradually disappeared, and trees that have seed abundance and good germination rate dominated in the lower girth classes. Moreover, opening up of the mid canopy permitting more sunlight intrusion has resulted in the domination of non-arborescent species. This has lead to a situation of declining biodiversity in the natural forests, which will have adverse effects on the ecosystem as a whole.

Overuse of Irrigation Water

Agronomic estimates of water requirements of important crops are available. However, the present water distribution system and irrigation management is done with little regard for efficiency. The flooding system of irrigation is widely adopted in the canal command area, often beyond the capacity of the farmer to regulate. This results in over irrigation in the head region and absence in the tail end. Estimation of crop wise consumption of irrigation water might have provided a basis for comparison of water consumption at the agronomic optimum. But the garden lands of Kerala are characterised by intercropping, and a majority of them are homesteads. In this situation, estimating the water use of individual crops is rather difficult and is of little practical relevance. Hence, it was not attempted.

Economic Benefit of Irrigation Project

Irrigation investments were mainly aimed at increasing the productivity of crops in the command area. Hence, the efficiency of investment can be assessed with the changes in productivity levels of target crops.

The productivity levels of target crops in the command area compared to that of district average (period: 1985-86 to 1999-2000) is studied in this regard. It was observed that the Peechi irrigation system could not make a significant positive impact on the productivity of any of the crops studied, contrary to what is expected. The most important crops, as per the irrigation requirement criteria - summer paddy and banana - experienced a significant decline in productivity levels compared to the district level averages. Recall that 75 percent of rice and banana in the command area are irrigated crops. However, the yield gap between irrigated and unirrigated systems narrows down. From a financial point of view, the investments can be justified only if the returns are attractive.

Irrigated agriculture has proved to be more financially attractive than unirrigated agriculture. The productivity, farm income and BC Ratio of irrigated plots were found to be higher than that of the unirrigated plots, as evident from several studies. However, in all these estimates, water is taken as a free good. The expenditure connected with irrigation included the labour, machinery and fuel charges alone. In this background, the financial efficiency of irrigation investments will be abysmally low if estimated at the actual levels of water rates for irrigation.

Financial Performance of Peechi Irrigation Project

The financial performance of the Peechi Irrigation Project gives a bleak picture with a very low recovery ratio (ratio of total income collected to total expenditure) of 11.72 percent. The per hectare expenditure for providing the irrigation service is Rs.259, whereas the water charges fixed are only Rs.62 per ha. The actual realised revenue is much lower than this, due to various institutional and management factors.

Valuation of Irrigation Water

The major uses to which Peechi irrigation water is put to may be grouped as:

- Direct irrigation uses
- Indirect uses (through recharge of wells)
- Non-irrigation uses

The valuation is attempted by two methods - A) Cost based, and B) Productivity based

Cost of Supplying Water

In this method, value is estimated as the product of cost of supplying the commodity and the level of use. The Marginal Cost (MC) was estimated from the function, C = a. Qb, by taking the first derivative.

$$MC = b*‘C /‘Q$$

As such, the Marginal Cost per m^3 water released is estimated as Rs.0.14. It is to be pointed out that this is the cost at the point of release, and does not include the various social costs associated with the command area development programme. Different methods are used in the study to assess the value of the irrigation water.

A) Direct Irrigation Uses

1. Cost Based Approach

The average level of irrigation water use in sample farms is estimated based on the demand of 18.9 m^3 per day per ha. Thus, the average cost incurred by the irrigation department on a sample farm per day is calculated as the product of MC per unit of water release and the water use level. The total number of days irrigated in a year is found to be 71 days, and hence, the annual cost is Rs.192 per ha.

2. Productivity Based Approach

The value of water, when estimated based on its productivity, is also attempted. Due to the reasons detailed in the methodology, the whole farm income was taken as a proxy, and the estimation is done for the three regions. An additional unit of ($1m^3$) water applied at the head region results in a decline in farm output (income) worth Rs.2,256 in the head portion, indicating that the farmers are operating in an irrational (third zone) region of classical production function. By virtue of their overuse, the tail end farmers are denied an average income of Rs.52,550/ ha (which is the difference between average farm income in the head and tail region). This amount can be considered as the value of water in the head region.

Middle reach farmers reap an income from each additional unit of water over the mean level, of Rs.38,040 per year/ ha. Earlier studies on the effect of irrigation on productivity and net farm income have established that an irrigated farm generates 4.2 times more income compared to unirrigated farms. Applying this proportion in this case, the value can be fixed at Rs.9,013 per ha per year. Following the same concepts, the value per additional unit of water applied at the tail end is Rs.836 per ha/ year.

B) Indirect uses (Irrigation / Domestic) through recharge of wells.

1. Cost Based Approach

The recharge of the wells due to the proximity of the canal is a positive externality, and on an average, the water table rise is calculated as 12.50 m^3 per well. The MC of m^3 water released was Rs.0.1434, and the total positive externalities associated with the water recharge can be quantified as Rs.226 per well per year (product of marginal cost of water release and quantity of water recharge per year 12.5x126 days). This indicates that the farmers irrigating from recharged wells are receiving this water without payment of a positive externality equal to Rs.226 per well per year.

2. Productivity Based Approach

The irrigation from recharged wells resulted in an average increase in farm income to the extent of Rs.31 for every additional unit of water applied. For this, the average farm level investment was estimated as Rs.13 per m^3 of water. The value of water used for irrigation through recharge is thus Rs.19 for every unit of water (1m^3). However, it was seen that the nearer the farm to the main canal, the water use was above optimum, and hence, it resulted in a fall in total farm income (negative additional income). Hence, for the nearer farms, the difference in farm income between the two groups can be taken as the value of water (Rs. 45,921/ha). For the distant farms, it is Rs. 2,961.

3. Non-Irrigation Uses

Naturally the proportion of sample population who depend on the canal, both for human and non-human uses, decrease with distance from the release point as well as from the main canal. The farther the houses, the fewer the number of people who benefit from the canal water. The proportion of sample respondents who owned wells was inversely related to the distance of their residence from the canal. The average volume of water enjoyed by the respondents further confirmed this. The volume per time of use (day) was the highest for the respondents who resided farther away, as they have to fully depend on the canal for all water requirements. (Own wells were not there and the recharge was poor). However, the farmers towards the mid portion were reluctant to use the canal water for human use, for fear of quality problems. So, it can be concluded that the dependence on canal water for non-irrigation uses is skewed in favour of head region residents, that too within a distance of 200 mts. on either side of the canal.

1. Cost Based Approach

The human uses primarily include bathing and washing of clothes, utensils, and vehicles. Multiplying the consumption level with MC, the value of water used for non-human purposes is estimated at Rs. 216/ year/ family, and for human use it is Rs. 293/ family/ year.

2. Productivity Based Approach

The water used for non-irrigation purposes is not completely consumed in the process. But, quality losses occur. In this case, the benefit over alternate strategy (other than depending on canal water) is taken as the value of irrigation water. Thus, it is estimated at Rs.3024/year.

It was reported by the sample respondents in the mid reach that they do not depend on the canal water for human use, as the head reach residents have already polluted it. However, the value of water for this purpose may be considered as equal to the foregone benefit of mid and tail end farmers. (Rs.22 /day in mid reach, and Rs.42/day in tail reach). Hence, the average value is estimated at Rs. 32/day i.e., Rs. 4,058.46/ year.

Willingness to Pay

Of the total respondents (in all the groups), 16.2 percent were not willing to pay for water, as they felt that water is a free gift of nature, like air.

Most of the respondents (84%), however, were ready to pay, though the extent of payment and conditions varied. While 97 percent of respondents in the non-irrigation group expressed their willingness, 72 percent in the indirect use group (recharge) and 80 percent in the direct irrigation group were willing to pay for the water that they receive. This result is due to the fact that domestic use was given more priority than irrigation. Though the respondents agreed that the recharge facility was due to the canal network, the argument was that they are not directly using the canal water. However, 72 percent were willing to pay.

More than 70 percent were ready to pay a rate that was 25 percent higher than the existing rate of Rs.62/ ha if the supply was satisfactory. Only a meagre proportion (8.6%) wished to pay the existing rate. All of them are obviously residing in the head portion of the canal system. Among the group who were willing to pay, 91.39 percent of respondents expressed their willingness to pay for water if the supply is adequate and timely. This points out the changing mindset of beneficiaries from considering water as a free gift. As one moved farther away from the origin of the canal system, people were ready to pay higher, even up to Rs.153/ ha, under satisfactory conditions of supply. The user's willingness to pay in this case varies between the existing levels of Rs.62/ ha to Rs.153/ ha, under ideal conditions of supply.

This points out to the need for creating water literacy - on its availability (present/ future), use and conservation. In a state like Kerala where literacy level is quite high, this task is easy. On the other hand, the water use pattern of the people of Kerala is to treat water as an abundant free gift of nature.

Recommendations

- The escalating costs and delays in completion of major/ minor irrigation projects calls for a shift in policy in favour of micro irrigation projects.
- The policy shift in irrigation, in selection of crops in favour of farmer preferences and ecosystem and sustainability is to be envisaged. The prioritisation of paddy is to be reviewed.
- Crop scheduling and forecasting in the command areas should be based on realistic statement of water availability. Deviations from suggested cropping patterns is to be restricted.
- The reasons for decline in irrigated area acreage over the years should be assessed and actions must be initiated to prevent the same in the future.
- Programmes for capacity building for all the stakeholders in the water sector, and programmes for complete water literacy are to be initiated urgently. The awareness is to be created that water is an economic good, and all policy decisions on its supply, distribution and pricing are to be based on this principle.
- Pricing is to be used as an effective tool in management of water resources. The divergent objectives of efficiency and social equity can be effectively managed through appropriate pricing strategies.
- Valuation of water, based on its scarcity value and level of use, should form the basis of pricing decisions. As far as possible, pricing should be based on volumetric measurement.
- Distributional inequality in the command areas should be eliminated through policy intervention viz., water cess, for better performance of the irrigation projects in the long run.
- Environmental consequences of overuse of irrigation water and shifting cropping pattern need to be given prime emphasis in short-run and long-run strategies. For this, timely monitoring and assessment is assential.

Rural Water Resources Development, Planning and Management Using GIS and Remote Sensing for Policy Making

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Introduction

Water is an important and scarce common property resource, for which demand is increasing day by day due to population explosion, increase in the living standards, and agriculture development. Irrigation is a technique of supplying sufficient water to reduce uncertainties associated with irregular rainfall, and to ensure cultivation of land otherwise not suited for agriculture. Adequate irrigation facilitates full use of the land under cultivation and increase in crop productivity due to sufficient supply of water. Keeping in view the importance of the agriculture sector in the Andhra Pradesh State economy, much importance is given in the plans for the development of irrigation.

Srikakulam district of Andhra Pradesh, with a total geographical area of is 5,837 sq. km is selected for the study. The average annual rainfall of the district calculated from the data of 19 years is 1191.34 mm. The rainfall from June to October contributed by the south west monsoon accounts for 81.5 percent of the annual rainfall. The principal rivers in the district are Bahuda, Nagavali, Vamsadhara, Mahendratanaya, Suvarnamukhi, Vegavati, Gomukhi, and Champavathi. All the rivers are seasonal, except the Vamsadhara. Agriculture is the main occupation of the people of this district and about 80 percent of the population depends only on agriculture for their survival. Unfortunately, there is an acute shortage of water for irrigation in the district. Due to irrigation water shortage, people are migrating from their villages in search of other employment to nearby towns.

Objectives

The objectives of the study are to:

- Assess water resources - both surface (tanks, canals etc.) and sub-surface (groundwater) - and carry out water balance studies for effective planning and management of water resources.
- Assess the impact of water quality on human health using secondary data and to estimate the cost of treatment/providing alternate wholesome water.
- Evaluate the existing tank conditions using remote sensing and GIS and to make a comparative analysis between the cost-benefit involved in increasing the tank capacities and exploitation of groundwater .
- Carry out economic valuation of water by primary household surveys using the Contingent Valuation Method (CVM).

Methodology

The study area is divided into three watersheds namely, Peddagedda Watershed (PWS), Nagavali Watershed (NWS) and Vamsadhara Watershed (VWS). As a watershed forms an ideal unit for hydrological studies, all the objectives were explored watershed wise. The watersheds are divided on the basis of drainage pattern, stream order and the slope. Surface and groundwater irrigation are the only sources of irrigation in these three watersheds. Due to water problems the farmers are slowly changing the water source and also the cropping pattern from paddy to other crops, which require less water.

Water Balance

The hydrological system is a complex system that maintains balance between precipitation, interception, evaporation, transpiration, run-off, infiltration, and other sub features like seepage, soil moisture, soil retention and stocks. The physical accounting of water and individual contributions of sources in Peddagedda, Nagavali and Vamsadhara watersheds was carried out using a water balance approach. The relationships between inputs viz., rainfall, interception, evapotranspiration, run-off, groundwater recharge, extractions and outflows are studied in the water balance studies.

Secondary data regarding rainfall, temperature, irrigation pattern and other socioeconomic data was collected block-wise from different State and Central government organisations and this data was converted into information for the individual watersheds. Information on the average monthly rainfall of all the three watersheds for the year 1971–95 was obtained from the National Information Center (Srikakulam), and on temperature, evapotranspiration, wind velocity was obtained from the Indian Meteorological Department observatory at Calingapatnam, Srikakulam district, A.P. Intensive field surveys were conducted to study the tanks in the three watersheds, and farmers using the tanks were interviewed using a pre-tested structure to understand their perception on irrigation, water and other socioeconomic aspects.

This study was carried out in four stages, starting from computation of rainfall to the total extractions for irrigation, drinking, domestic and livestock purposes. In the first phase, average annual rainfall for the years 1971 – 95 in the watersheds was calculated, while the amount of run-off into rivers, water stored in tanks, water out flow through run-off was calculated in the second phase. In the third phase soil penetration, seepage losses, soil retention and groundwater percolation was calculated. Finally, in the fourth phase water extractions were calculated and the water balance computed. The study was carried out using the data till 1994-95, as the latest data on watershed basis from 1994-95 are not available.

Water Quality

An attempt has been made to identify the groundwater sources with nitrate and fluoride contamination in Peddagedda, Nagavali and Vamsadhara watersheds. As no secondary data is available for this watershed, water samples from bore wells and open wells, which are frequently used by the villagers for drinking water, were collected during November 1999. In this area, groundwater is recharged during the monsoon season and from irrigation fields as well. Water levels in these wells range from 5 m to 8 m in the pre-monsoon period and 1 m to 3 m in the post-monsoon period from the ground surface. The groundwater flow is towards the main river. Chemical analysis of water samples was carried out for the above samples in the three watersheds.

Tank Studies

In Andhra Pradesh, the north coastal districts -Srikakulam, Vizianagaram and Visakhapatnam have a large number of tanks. Vizianagaram district has the largest number (9,895) followed by Srikakulam district (7,004). A large number of tanks which used to irrigate a vast extent of land in the past now face a serious silting problem, and a good number of potential tanks are now abandoned, either leaving the agriculture land under that tank as fallow or decreasing the agriculture yield.

Remote Sensing

In view of the absence of reliable recorded data on these tanks, it was felt essential to carry out a comparative analysis of the tanks on the basis of the satellite data obtained for two seasons of two different years i.e. 1989 (dry and wet season) and 1998 (dry and wet seasons). Indian Remote Sensing Satellite 1A, LISS II digital data for the year 1989 and IRS 1D LISS I data of 1998 were obtained from the National Remote Sensing Agency, Hyderabad. These data were used to demarcate the variations in aerial extent of water spreads in the tanks over a decade. A total of 23 tanks with settled command areas of more than 100 acres were selected from all the three watersheds. In order to estimate the benefits of tank irrigation over rainfed irrigation, it was ensured that the sample drawn had farmers who own both irrigated as well as rainfed land.

Economics of Minor Irrigation Tanks

The input output data collected during farm surveys was used to carry out the benefit cost analysis at the farmer level and project authority level. The gross returns per acre were computed taking into consideration the value of the main product as well as the by-product, which is mainly fodder. The costs incurred per acre were computed by taking into consideration the expenses incurred at every stage of farming, starting from ploughing to harvesting. On the basis of land holding of individual farmers included in the sample, the weighted gross returns were calculated. Similarly, the weighted net returns were also calculated. These computations were carried out for tank irrigated land and rainfed land at village prices. The net benefit to farmers from tank irrigated land is the difference between the net income from tank irrigated land and that from rainfed land. To compute the cost-benefit ratio, the cost incurred to the farmer for tank irrigated land was taken as the water tax prevalent in the study area.

Willingness to Pay for Irrigation

An attempt has been made to assess the level of service required by the villagers in this area to meet their water demands and the extent of their participation in terms of willingness to pay for the services.

Villages from the three watersheds were selected based on the statistical and GIS analysis. Cluster analysis technique was used considering all the relevant village parameters. From all the three watersheds, fifty villages were selected on the basis of number of households, size of the farmers, water facilities available and other socioeconomic characteristics.

A total of 622 sample households in all the three watersheds were surveyed to study their willingness to pay for irrigation towards capital expenditure and maintenance. The per capita land owned was found to be 1.15 acres.

A majority of the farmers in all the three watersheds belong to backward community (87.15% in Peddagedda, 87.68% in Nagavali and 97.68% in Vamsadhara). It was found that 61.46 percent , 45.45 percent, 34.30 percent of farmers fall below the poverty line in three watersheds respectively.

Results

Water Balance

From the water balance statistics, it was found that:

- in Peddagedda watershed the total water stocks are 31,616.31hectare meter (ha-m), of which contribution by groundwater was about 13,409 ha-m., and 5,928 ha-m. was contributed by tanks.
- the water consumption from tanks was highest (3,241 ha-m.) for irrigation, followed by groundwater.
- The stock in the river water was estimated to be 12,278 ha-m. It was observed that this river water is going entirely waste as run-off into the Bay of Bengal.
- In Nagavali watershed, the total stocks were estimated at as 104,120 ha-m. including river discharge. The groundwater stocks were greater, estimated to be 41,996 ha-m. From the studies it was found that in this watershed the maximum tank water (86%) is used for irrigation.
- Run-off in the rivers and streams was estimated at as 29,732 ha-m. Very little groundwater (6,580 ha-m) was being extracted for irrigation in this watershed.
- In Vamsadhara watershed, the total water stocks were about 74,946 ha-m. The groundwater stock was estimated at as 29,937 ha-m. The amount of water leaving the watershed was about 22,692 ha-m.
- In all the three watersheds together, about 64,702 ha-m. of water was going waste as run-off.

About 95 percent of the farmers in this watershed are small farmers owning 0.5 to 1 acre land holding and they cannot afford the capital cost to exploit groundwater. The results have been tabulated below in Table 1.

Table 1: Total Water Consumption and Balance

	Peddagedda Watershed	Nagavali Watershed	Vamsadhara Watershed
Stocks			
Surface water			
Tanks	5928.5 ha-m	32392 ha-m	22317 ha-m
Rivers/ Streams	12278.31 ha-m	29732 ha-m	22692 ha-m
Ground water	13409.5 ha-m	41996 ha-m (excluding irrigation return flow)	29937 ha-m (excluding irrigation return flow)
Extractions			
Surface water			
Tanks	3241 ha-m	27745 +263* ha-m	18791* ha-m+262 ha-m
Ground water			
Tubewells & Dugwells	2970 ha-m	6580 * ha-m +263*	5424 ha-m+262 ha-m
Outflow	12278.31 ha-m	29732 ha-m	22692 ha-m
Balance			
Surface water			
Tanks	2687.50 ha-m	4384 ha-m	1931.87 ha-m
Rivers/ Streams	12278.31 ha-m		0.00 ha-m
Ground water			
	10439.5 ha-m + 2563 ha-m (recharge from irrigation fields)	35416 + 26436 ha-m (recharge from irrigation fields)	24251 + 24889 ha-m (recharge from irrigation fields)

* It is assumed that 50 percent of livestock consumption is from groundwater sources and 50 percent from surface water source.

Water Quality

From the results, it is clear that the groundwater contains high values of either nitrate or fluoride. The nitrate concentration in groundwater ranges between 25 and 145 mg/l, while the tolerable limit is 45 mg/l, according to World Health Organization standards. Out of 15 samples collected and analysed, 10 wells were found to have excess nitrate concentration. The cattle barns, which act as point sources for nitrate, were reported as main sources for high nitrate concentrations in the groundwater of Vamsadhara watershed. The agricultural practices and soil conditions in Peddagedda watershed were found to be more or less similar to the Vamsadhara watershed. Thus, the higher concentrations of nitrate in Peddagedda are also derived from animal wastes near cattle barns.

The following measures can be implemented to prevent nitrate pollution:

- The unlined sewage system from various houses in the villages should be lined to help carry away the drainage water and to prevent seepage which slowly degrades the groundwater quality.
- Fertilizers should be used according to the optimal requirements to prevent percolation of fertilizers to groundwater.
- Abandoned wells should be closed to stop waste dumping.
- Animals should be sheltered away from the source of groundwater to prevent pollution from animal waste.

Remote Sensing Analysis of Tanks

The study area has a number of tanks of varying sizes. Lack of maintenance by way of disiltation / distillation has been observed to be the major problem with these tanks. As a result, only those few farmers who can afford to invest to tap groundwater are using it. A systematic analysis of 23 tanks with command areas above 100 acres have been selected for the study from all the three watersheds. These tanks were analyzed for their present performance by computing the performance indicators like effectiveness ratio and deviation factors, as seen below in Table 2.

Table 2: Systematic Analysis of 23 tanks

S. No	Tank Name	Village	Mandal	Regd. Bed area	Present bed area (IRS data)	(1/2)	Settled Command Area	Present Command Area	(4/5)
				1	2	3	4	5	6
Peddagedda Watershed									
PW1	Narayana Sagaram	Budumuru	Laveru	300.19	103.72	0.35	697.94	225.60	0.32
PW2	Devala Tank	Bejjipuram	Laveru	160.55	132.92	0.83	500	427.64	0.86
PW3	Raju Tank	Punnam	G. Sigadam	30	19.42	0.65	500	206.00	0.41
PW4	Lanka Tank	Patharlapalli	Ranasthalam	50	47.49	0.95	400	150.00	0.38
PW5	Daba Tank	Chinna Murapaka	Laveru	112.91	22.65	0.20	200	73.61	0.37
PW6	Nidigandlam Tank	Adapaka	Laveru	72	15.04	0.21	162	75.31	0.46
PW7	Pedda Tank	Budatavalasa	Laveru	49.4	19.49	0.39	150	63.87	0.43
PW8	Tammi Naidu Tank	Peda Rompivalasa	Laveru	43.2	18.53	0.43	140	57.23	0.41
PW9	Borra Patuvani Tank	Batuva	G. Sigadam	33.96	16.81	0.49	135	73.29	0.54
PW10	Pedda Tank	Batuva	G. Sigadam	40.14	24.72	0.62	133	92.80	0.70
Nagavali Watershed									
NW1	Pedda Tank	Shermohammad-puram	Etcherla	160	96.1	0.60	312	153.04	0.49
NW2	Tamara Tank	Siripuram	Santakaviti	625	311.67	0.50	784	344.84	0.44
NW3	Mandavakuriti Tank	Mandavakuriti	Santakaviti	300	161.9	0.54	1600	673.08	0.42
NW4	Salavani Tank	Seetampeta	Ponduru	58	48.83	0.84	247	165.56	0.67
NW5	Meduri Krishnamma Tank	Boddavalasa	Rajam	66.66	38.31	0.57	300	121.13	0.40
NW6	C. R. Raju Tank	Unukuru	Vangara	92.74	79.1	0.85	204.7	164.15	0.80
NW7	Subbi Tank	Arasada	Vangara	82.69	78.46	0.95	307	251.13	0.82
NW8	Tamara Tank	Ungarada	R. Amadalavalasa	67	67	1.00	251	208.88	0.83
NW9	Gudivada	Lumburu	Palakonda	113	86.01	0.76	500	309.69	0.62
NW10	Yebbaji Tank	Vadada	Gara	125.8	106.78	0.85	670	412.69	0.62
Vamsadhara Watershed									
VW1	Asarla Sagaram	Temburu	Saravakota	368.26	359.3	0.98	5400	3479.98	0.64
VW2	Ranga Sagaram	Poppangi	Saravakota	326.86	302.33	0.92	1920.68	1429.06	0.74
VW3	Pedda Tank	Kottakota	Sarubujjili	175	153.69	0.88	477.95	319.58	0.67

The results of the cost-benefit calculations at the farmers' level are presented in the following tables. Benefit-Cost Analysis was also done at the project authority level.

Table 3: Farmers' Benefit-Cost Ratio in Peddagedda Watershed

(all costs and benefits in rupees)

Tank No.	Net Benefits (per acre)		Ratio	Increase in land value (per acre)		Ratio	Benefits Due To Tank Irrigation	Cost (per acre)	BCR
	(2)	(3)	(2)/(3)	(4)	(5)	(4)/(5)	(6)	(7)	(6)/(7)
	Tank Irrigated	Rainfed		Tank	Rainfed				
PW1	3862.32	1970.13	1.96	72243.02	37344.47	1.93	1892.19	160.00	11.83
PW2	4509.61	1537.68	2.93	80271.54	41301.69	1.94	2971.93	160.00	18.57
PW3	4347.72	1325.49	3.28	78317.89	39073.98	2.00	3022.23	160.00	18.89
PW4	4208.39	753.92	5.58	89680.39	48535.00	1.85	3454.47	160.00	21.59
PW5	4788.61	1482.71	3.23	79536.02	38153.97	2.08	3305.90	160.00	20.66
PW6	5565.52	1746.92	3.19	82608.99	39615.02	2.09	3818.60	160.00	23.87
PW7	4210.77	1134.79	3.71	91642.30	42337.49	2.16	3075.98	160.00	19.22
PW8	4326.98	1157.03	3.74	88581.86	43350.29	2.04	3169.95	160.00	19.81
PW9	4193.63	1759.50	2.38	98271.69	49524.79	1.98	2434.13	160.00	15.21
PW10	5025.31	1488.72	3.38	76984.06	35950.76	2.14	3536.59	160.00	22.10

Table 4: Farmers' Benefit-Cost Ratio in Nagavali and Vamsadhara Watersheds

(all costs and benefits in rupees)

Tank No.	Net Benefits (per acre)		Ratio	Increase in land value (per acre)		Ratio	Benefits Due To Tank Irrigation	Cost	BCR
	(2)	(3)	(2)/(3)	(4)	(5)	(4)/(5)	(6)	(7)	(6)/(7)
	Tank Irrigated	Rainfed		Tank Irrigated	Rainfed				
NWS1	5128.35	1952.85	2.63	92706.12	46930.59	1.89	3175.50	160.00	15.88
NWS2	3785.02	761.89	4.96	93071.18	40304.17	2.34	3023.13	160.00	15.11
NWS3	5498.75	1465.92	3.75	91450.32	49707.99	1.83	4032.83	160.00	18.09
NWS4	5002.23	1384.88	3.61	98982.74	52474.35	1.87	3617.35	160.00	18.09
NWS5	5097.36	1765.67	2.88	92783.14	41098.58	2.22	3331.69	160.00	16.65
NWS6	4901.45	1667.53	2.94	91618.34	44747.53	2.04	3233.92	160.00	20.21
NWS7	5926.42	1753.85	3.38	74886.31	37158.27	2.03	4172.57	160.00	26.08
NWS8	3680.53	1222.01	3.01	64470.33	25524.72	2.49	2458.52	160.00	15.37
NWS9	3054.39	1902.13	1.61	79986.27	46653.83	1.68	1152.26	160.00	7.20
NWS10	3502.82	1548.21	2.26	56522.23	23900.71	2.28	1954.61	160.00	12.22
VWS1	5616.37	2326.95	2.41	122723.74	57802.19	2.17	3289.42	160.00	16.45
VWS2	5074.49	1253.38	4.05	69687.00	34936.11	2.00	3821.11	160.00	19.11
VWS3	4814.89	1759.82	2.73	90378.90	49751.46	1.83	3055.07	160.00	15.26

Willingness to Pay

The contingent valuation method (Bidding Technique) was used to elicit preference functions for public supplies such as water, and willingness to pay for the services (water supply in the present context).

Table5: Willingness to Pay among all and only payers

		% of willingness to Pay positive sum	Willingness to Pay per HH (Rupees)	
			Among All	Among only Payers
Peddagedda	Capital Cost	93	670	737
	Maintenance	89	94	101
Nagavali	Capital Cost	83	492	612
	Maintenance	82	83	102
Vamsadhara	Capital Cost	76	709	991
	Maintenance	71	97	136

* Capital Cost per HH/only once and Maintenance cost is per HH/year.

Based on the data obtained from the field survey of 109 households from Peddagedda Watershed, 341 households in Nagavali Watershed and 172 households from Vamsadhara Watershed, statistical analysis for willingness to pay for irrigation has been carried out.

The major findings based on the analysis of willingness to pay are summarized below:

- The average willingness to pay in the three watersheds is Rs. 582/- towards capital cost as one time payment and Rs. 50/- paid per acre/year/household. About 18 percent of the respondents expressed their inability to pay due to their low income. It is observed that the willingness to pay increases with the increase in, land ownership from less than 1.5 acres (Rs.388.57) to greater than 11 acres (Rs.873) per household.
- Variables such as total land owned, irrigation output, education, decrease in yield due to lack of water, decrease of water level in wells are positively related in influencing the peoples' willingness to pay for irrigation water.
- Variables such as size of the household, number of days in main occupation, age of the respondent, net income and water tax showed negative relationships with willingness to pay.

Policy Issues

- River water should be conserved properly by following watershed management techniques, by constructing dams/ barrages/anicuts, and to preserve their reservoir capacities, suitable soil conservation techniques should be enforced in all the three watersheds. Desiltation works have to be carried out to restore the tank capacities and command areas, wherever possible. The release of water from tanks is presently unrestricted in most of the tanks. Hence, proper water regulatory structures have to be constructed for effective water management.

- All the tanks within a watershed should be connected. Though most of the tanks are connected in series by streams/canals, the canals also need to be repaired. This helps the farmers not just in the command area of a single tank, but also protects the riparian rights of the farmers in the downstream areas of the watershed. Since there are no major irrigation projects in Peddagedda and Nagavali watersheds, the construction of such a canal network would be extremely beneficial from the socio-economic as well as environmental aspects.

- Farmers should be trained in the balanced and efficient use of chemical fertilizers, bio-fertilizers, and about the environmental problems caused by excess use of them. The waste from cattle farms should not contaminate its water sources.

- The water tax, according to present structure, is very low when compared to the financial resources required for maintenance of the tanks and in no way reflects the value of scarce water resource. The main reason for not increasing the fees is based on the premise that the farmers may not be able to meet the extra financial burden. Water charges should be raised with the assurance of water through the infrastructure improvement. Volumetric pricing of water instead of crop-wise pricing would be more beneficial and can control the wastage of water.

Participatory Approaches and Environmental and Economic Impact: With Special Reference to Integrated Watershed Development Project (IWDP), Hills-II, Jammu and Kashmir

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Introduction

Participatory policies are highly relevant, and are consistent with India's overall development strategy of reducing poverty, protecting the environment, developing human resources, and fostering farm sector growth. The experiences so far show that unless the process through which participation is to be secured is described in detail and monitored, it is likely to be ignored - both because of a lack of commitment among the government staff, as well as a lack of knowledge about the road map to the destination. The environmental and economic issues are highly complicated in the watershed areas with a majority of the people surviving on a hand-to-mouth existence. The environmental and economic benefits accrued from watershed management can be enhanced only when the people are ensured and equipped adequately to make a socially acceptable living. Nevertheless, the achievement of these rests on the participation of the people at different stages of the programme.

Objectives

The short-run objectives of the study are to:

- Examine the participatory processes adopted under IWDP (Hills-II), Jammu and Kashmir with special emphasis on methodological aspects of people's participation, farming system development approach, cost-sharing mechanisms, farming system technology, common property resource management and training needs and institutions.
- Study and analyse elements of successful watershed management e.g. level of people's participation, gender equity, conservation of natural resources and mechanisms of distribution of benefits.
- Assess individual and groups of farmers' contributions to watershed development and protection, and environmental and economic benefits there from.
- Find out the transaction costs involved in evolving and operationalising participatory processes and costs involved in implementing various project interventions.

The long-run objectives of the study are to:

- Document the experiences of participatory approaches in watershed management, its constraints and lessons learned.
- Develop and recommend suitable policy guidelines to strengthen people's participation and minimise the transaction costs in watershed management.

Hypotheses

The hypotheses tested during the course of the study are:

- Watershed development can improve natural resource management and agricultural productivity in rainfed areas, but their success continues to be limited by the extent of people's participation.
- The project interventions seeking to enhance the expected benefits to people, or reduce the expected costs, are likely to elicit stronger peoples' participation.
- A reduction in the transaction costs can increase the efficiency and sustainability of participatory processes by increasing the potential net gains in terms of environmental and economic outcomes.

Study Area and Methodology

The primary data was collected using well-structured and pre-tested questionnaires, participatory rural appraisal (PRA) techniques and group meetings. The study has generated data on four sets of variables: participatory processes, the transaction costs, and environmental and economic issues. Whenever possible and required, secondary data sources were also utilised. To evaluate participatory processes, three Village Development Committees (VDCs) from each sub-watershed, namely Akhnoor and Ramnagar were recovered. Therefore, a total of six VDCs were selected with the consultation of project functionaries at the sub-watershed level. In the non-beneficiary category, 6 sample villages were selected on a random basis, each 20-25 km away from the sampled micro-watersheds villages (*i.e.*, IWDP area). Stratified sampling technique was used to select villages (where VDCs have been created, as well as IWDP and non-IWDP villages). During the stratification, care was taken to include villages in both forested watersheds and agricultural watersheds in order to make a comparative study. For the collection of primary data, a purposive sample of approximately 20 percent of household level respondents in IWDP and non-IWDP areas and all the members of VDCs were covered.

Data and Data Analysis

The primary data was collected from household level respondents, members of VDCs, and user groups, project functionaries and other stakeholders. The secondary data, whenever required, was collected from the project authorities and the government/non-government agencies. The data related to the transaction costs involved in evolving and operationalising participatory processes as well as the costs of various project interventions, was utilised and collected from the project functionaries at the sub-watershed level and village level stakeholders. The general description of socio-economic, institutional context and technical aspects of the participatory processes were comparatively presented by using descriptive statistics. The content analysis technique was used to analyse the data and information qualitatively and quantitatively (using descriptive statistics). Factor analysis and multiple regression techniques were used to analyse social and economic dimensions of participation. Besides the above, the study also used Ostrom's model "Crafting Institutions for CPR" to evaluate the participatory processes and their impact.

Results

I. Participatory Processes

In order to operationalise the institutional arrangement, the following participatory processes were followed, with minor variations across the forested and agricultural watersheds in the project area.

Preparatory activities: At the beginning of the project, a period of three to six months was devoted to preparatory activities, which included: review of existing information, tentative identification of the communities and sites in the project area, and preliminary visits to the short-listed local communities.

Reviewing existing information: Participatory rural appraisal (PRA) exercises were conducted to assess the local situation and identify the most important and urgent goals to be pursued through participatory action. Another objective was to collect additional and more detailed information on the local environmental and socio-economic setting, according to the local perception.

Shorter meetings and formation of groups: PRA ended with a series of shorter meetings, followed by formation of village development committees (VDCs) and user groups. The main activities carried out during these meetings were as follows: feedback of PRA information to communities; identification, analysis and prioritisation of problems by participants; identification of solutions; and drafting of a tentative action plan.

Participatory feasibility analysis: Project management and field staff reviewed participating community members' ideas for action that were developed during the participatory planning meetings, with the aim of assessing the feasibility of the proposed action in the light of the existing conditions.

Operational agreements and group strengthening: Following the feasibility study, operational agreements for implementing the activity were made. Strengthening VDCs and user groups and meeting basic needs figured prominently at the beginning of the participatory and integrated watershed management process, whereas later, attention progressively shifted towards environmental issues. Project field staff assisted user groups in such areas as organising and conducting meetings, defining group constitutions and keeping records.

Participatory monitoring: Participatory monitoring consisted of the continued follow-up of the organisational and technical aspects of implementation. The local participants conducted it, with some support from project staff. Participatory monitoring paralleled the implementation process and was intended to enable participants and staff to conduct the following tasks: assess the progress made in implementation; identify and address difficulties and constraints in implementation; and revise the implementation plans accordingly.

Participatory evaluation: Participatory evaluation aims at extracting the lessons from the implementation experience. Participants and staff conducted this exercise through interactive techniques. It strives to identify both the positive and negative aspects of the work completed and to provide suggestions for future plans.

Promoting forums for collaboration: The project helped local government and non-government agencies to strengthen the planning strategies and included these strategic elements of participatory and integrated watershed management.

II. Methodological Aspects of Participation

At the initial stages of the second phase of IWDP (Hills-II), the village *panchayats* were non-existent and elections for *panchayats* took place later in the year 2001. Therefore, projects formed separate committees in order to operationalise participatory watershed management.

Formation of village development committees (VDCs): In the presence of village communities, project field staffs formed the VDCs by adopting the process of selection of the members of VDCs. Mandatory gender and disadvantaged groups' representation were ensured.

Membership procedure: Membership procedure was rigid in most of the cases. No change in VDCs membership took place once the VDCs were formed by selection.

Women participation: At least 2-3 women were made members of the managing committee. A majority of the women VDCs members were in the age group of 30-45 with poor educational attainment. Their participation in VDCs has been veiled and passive and too restricted to facilitate dynamic and vibrant participation.

Meetings: Every VDC convened a monthly meeting as a routine affair to discuss the problems confronting watershed management. In some cases, fortnightly meetings of Executive Committee (EC) also took place to discuss the pertaining issues.

Decision-making: In most of the cases, decisions were taken by a majority vote, although cases were also reported where influential members got their decision enforced, whereas in some cases decisions were taken at the behest of project functionaries.

Preparation of village development plan (VDP): VDCs were responsible for the preparation of a VDP based on demands and priorities put forward by the village communities. After preparation of VDPs, a general Memorandum of Understanding (MOU) would be signed with the President and Secretary of the VDC, which highlighted the roles and responsibilities of the VDC as well as the project staff.

Financial management: The system of financial management adopted by the VDCs has not been satisfactory. Joint bank accounts were opened for most of the VDCs. VDCs were supposed to maintain record of all transactions. However, the IWDP was reportedly playing a major decisive role in utilisation of funds and keeping the records of all transactions in the name of VDCs.

Interaction with project functionaries: There was a lack of development of more balanced partnerships between IWDP functionaries and VDCs, which is reflected in the imbalance in power and control between IWDP and VDC. The project has not made any attempt to give a legal status to the VDCs created and none of the VDCs had been registered so far.

Interaction with other agencies: One of the purposes of VDC creation was to encourage forward and backward linkages between the villagers and the development agencies. VDCs have interacted with local non-government organisations (NGOs) on the issues like organising, initial guidance and capacity building, which have been facilitated by the IWDP.

III. Social and Economic Dimensions of Participation

The factor analysis yielded two factors viz. social and economic, which reveals the dimensionality of participation. In the social factor, all coefficients related to meetings dominated. In the economic factor, the coefficients related to economic aspects of participation dominated. On the combined level, there was a clear division of the participatory choice into two components, where social considerations are most important, and economic considerations constitute the second main important factor. Regression outcomes are quite diverse for the institutional settings, but some general patterns are apparent. The level of resources is always positively linked to participation, and significantly in eight out of twelve cases. This shows that participation is enhanced when people perceive their resource as being of a good quality. A similar conclusion can be drawn for the forest dependence. This link is also positive in all cases, and significantly so in ten out of twelve cases, meaning that high dependency on common resources stimulates people's participation in watershed management. Better resources and increased dependency on the common resource lead to a higher level of participation.

IV. Cost Sharing Arrangements

Over the period, the idea of cost sharing has gained momentum, and beneficiaries' contribution has shown an increasing trend. In 1999-2000, 14.2 percent of the project cost on rainfed crop demonstration was shared by the beneficiaries, which increased to 36.3 percent in 2000-2001, and declined marginally thereafter to 34.2 percent in 2001-2002. In 2000-2001, the scheme of provisioning of vegetable kits was implemented in a big way, for which beneficiaries contributed approximately 34.1 percent of the project cost. The beneficiaries shared as high as 56.8 percent of the cost of constructing vegetative field boundaries and 76.8 percent towards rainfed horticultural demonstrations.

V. Benefit Sharing Arrangements

The pastoral households have been encouraged to form groups to manage the pastures in a sustainable manner. A member pastoral household was permitted to graze 30 sheep/goats and 10 buffaloes on a common pasture. A system of user fee per extra animal was put in place, which varies across the project area and was decided by the user groups themselves. The funds so raised were deposited in a common fund used by the group to meet contingencies such as expenses on animal health services.

In the case of forest user groups, there was a complete ban on entry into the protected forests for one year, so that the resources regenerate. Only the members were permitted to reap the benefits from the regenerated and protected forests. An individual member was permitted to carry one head load of dry fuel wood per household per week from CPRs for a family of five persons, and in case the family size was more than five persons, they were permitted two head loads of fuel wood per household per week. The members had to ensure that the weight of a head load of dry fuel wood did not exceed the agreed norms of 10 kg. Fodder user groups were also created for rational use of fodder during the rainy season (mostly July to September) each year. An individual member of the fodder user groups was permitted to carry one head load of 20 kg. of green fodder per household per day.

VI. Training Needs and Institutions

Farmers were trained on biophysical aspects of watershed development. Extension activity, viz., farmers' fairs, field trips and exposure visits have provided excellent opportunities for the project officials to elaborately orient the farmers about the details of watershed management. These activities were planned and organised at the sub-watershed level by the extension wing of the project. The impact of farmers training was visible in increased production levels, which were almost stagnant for many years. Likewise, other training inputs have resulted in improved performance in production and productivity. The training in the development of peoples' organisation seems minimal, although VDCs and user groups are indeed covered.

VII. Common Property Resource Management

IWDP in association with VDCs/user groups has indirectly created assets by closing degraded forestland and village common lands (VCLs). Water user associations (WUAs) have been involved in repair, maintenance and improvement of the physical structures, as well as water management within the sub-watershed on a cost-sharing basis mainly in the form of voluntary free labour. IWDP provided the funds and supervised the entire work. WUAs along with VDCs undertook the responsibility for repairing the water harvesting structures, the branch and distribution channels up to the outlets, as the case may be. The users were motivated to construct field channels beyond this level and to make necessary land levelling improvements, and other on-farm works.

VIII. Environmental-Economic Impact

The environmental-economic impact of participatory approaches adopted under IWDP (Hills-II) are highlighted as under:

Reduction in runoff water and sediment yield: The effect of regeneration of vegetation, along with soil and water conservation measures on hill-slopes and wastelands was substantial. In the *Shivaliks*, the run-off soil loss on barren hills was 23. 70 tons in the baseline period, which fell to 9.65 tons per hectare after treatment. The progressive reduction in soil loss and sediment yield, as a result of quick recovery of vegetation on hill-slopes and lands adjoining the foothills, has resulted in improving surface and ground water regime of the selected sub-watersheds.

Augmentation of ground-surface- water resources: Status of water resources in terms of average number of natural water points, gravity based water points, hand pumps and water harvesting structures per village have improved considerably with project intervention. With increased water potential, the area under irrigated cropping increased significantly. However, marked differences in irrigation intensity have been noticed. The differences in irrigation intensity were 2.9 percent and 13.1 percent respectively, in forested and agricultural sub-watersheds in the project area with VDC and without VDC, and differences in irrigation intensity in the project area with VDC and non-project area was very glaring.

Increase in crop productivity and cropping intensity: As a result of the improved soil moisture regime, the increase in irrigation resources and use of fertilizers (including cow-dung), the cropping intensity has improved in the IWDP area compared to non-IWDP area. The productivity of selected crops is comparatively higher in agricultural sub-watersheds than forested sub-watersheds. The yield difference between IWDP area with VDC and non- IWDP area was 2.1 quintals, 0.8 quintals, 0.64 quintals and 1.36 quintals per hectare; and 2.2 quintals, 1.7 quintals, 0.5 quintals, and 2.1 quintals per hectare respectively for maize, paddy, pulses, and wheat in forested and agricultural watersheds.

Change in livestock composition and increase in yield: Households have been progressively reducing holding of drought animals and increasing their stock of milch animals, which has resulted in significant changes in the composition of cattle population. In the forested watershed, the difference in the average number of milch animals in IWDP area with VDC and without VDC was 0.4, whereas in the agricultural watershed, the difference in IWDP area without VDC and non- IWDP area was 4.0. A significant differential in milk yield was observed between IWDP area and non-IWDP area. The difference in milk yield of cows and buffalo stood at 1.0 kg and 1.31 kg respectively. Similarly, wool yield was as high as 3.1 kg per sheep in the forested watershed and 2.4 kg per sheep in the agricultural watershed in the project area with VDC, whereas in the non-project area, it was comparatively low at 1 kg and 0.8 kg respectively.

Decline in animal grazing on CPRs: Before intervention through IWDP, on an average more than 7 animals per households were grazed on CPRs in the forested watershed and about 6 animals per household in the agricultural watershed. After project intervention, the average number of livestock grazed on CPRs declined to less than 4, and such a decline is in the range of 38 percent to 52 percent, the lowest in the agricultural watershed and highest in the forested watershed. The decline in number of animal grazing days has also been reported - in the range of 48 days to 51 days in the project area with institutional arrangements, and 40 days to 42 days in the project area without institutional arrangement.

Increase in fodder production: The IWDP area with VDC has shown a remarkable performance in terms of both green and dry fodder productions. The difference between fodder yield between the IWDP area with VDC and non-IWDP area was as high as 95 kg and 245 kg of green fodder and 26 kg and 23.4 kg of dry fodder respectively in forested and agricultural watersheds.

Food security and wage employment: IWDP was not able to provide food security in agricultural watersheds, and a significant proportion of the households are facing food insecurity spread over six months to a year, which is to be mitigated by providing alternative livelihood strategies. In IWDP area with VDC, wage employment is available to about 40 percent and 54 percent of respondents for an extended period of 6 months a year in forested and agricultural watersheds respectively. In the IWDP area without VDC and non-IWDP area, wage employment is available to about one-fourth and one-fifth of the respondents respectively for more than 6 months a year. Thus, project interventions have generated much needed wage employment and supplemented the livelihood strategies of the rural poor.

Collection of CPR products: With project intervention, the fuel wood and fodder collected from CPRs for household consumption has declined very sharply. The decline in fuel wood collected from CPRs was approximately 51.95 percent and 60.86 percent respectively in forested and agricultural sub-watersheds in the project area with VDC, and 20.86 percent and 49.58 percent respectively in the project area without VDC. More or less, a similar trend is noticed for fodder and non-timber products collected from CPRs.

Decline in consumption of fuel wood: The decline in average fuel wood consumption was reportedly higher in the project area than in the non-project area. On an average, the decline in fuel wood consumption was 44.22 percent and 46.13 percent; and 37.83 percent and 40.18 percent respectively in forested and agricultural watersheds in the project area with VDC and without VDC.

Benefit-cost ratio: The livestock intervention has the highest benefit-cost ratio, and in case of sheep rearing, the benefit-cost ratio is estimated at 1.66. Project intervention in rainfed crop demonstration has a low benefit-cost ratio and intervention on CPR closures, plantations, etc. has a high negative benefit-cost ratio of 2.79. This is due to the fact that CPRs were mainly closed for regeneration and even the benefits, which the beneficiaries were driving before project intervention, were not accruing to them due to strict enforcement of rules by the VDCs. On the whole, the benefit-cost ratio is estimated at 1.9, which is very significant.

IX. Transaction Costs

The average transaction costs incurred in decision-making for resource allocation and establishment of institutional structure and its maintenance has been estimated as Rs.75.5 and Rs.225.5 respectively. The difference between average ex-ante and ex-post transaction costs is estimated at Rs.99 per beneficiary. Individual resource users have incurred a very high transaction cost on attending meetings, followed by travel costs, which are estimated at Rs.60 and Rs.52 in forested and agricultural sub-watersheds respectively. Average transaction cost incurred on establishment of WUA is estimated at Rs.33.5, which is comparatively higher than the transaction costs incurred on development and maintenance of irrigation infrastructure i.e. Rs.21. Thus, the participatory approach in water management has contributed in minimising transaction costs.

Policy Recommendations

The following suggestions should be taken into account while initiating and operationalising participatory process in watershed management to maximise environmental-economic impact and to minimise transaction costs.

- In the future, linkages need to be established which should make user groups independent of project support. There is a need to transfer all the operation and maintenance functions to the user groups. Under IWDP (Hills-II), the policies are best geared to the improved management of enclosed VCLs, forests, grazing lands, water harvesting structures, gravity based irrigation channels, and other resource conservation and protection activities. Policy changes are imperative for better trade-offs between environmental protection and poverty reduction.

- It is suggested that the poor villagers be recognised not only as beneficiaries of the participatory resource management, but also as stakeholders in real practice, and that they be provided the opportunities to participate not only in the conservation and protection phase, but equally in the pre-project phase also. This will help realize the goal of minimisation of transaction costs. All funding of these activities should be directly handed over to these farmers' groups, once they are formed and trained in handling and managing the funds.

- It would be advantageous to include farming system-zoning exercise in the pre-project stage to identify homogenous areas for project interventions. The agricultural wing of the project along with VDCs should play a significant role in carrying out farming systems zoning exercise, so that different project interventions could be implemented in a holistic manner. Directly income generating activities like dairy and poultry keeping, agro-forestry, horticulture and vegetable farming should be given more importance over the construction of purely engineering structures for water harvesting and soil conservation.

- In order to facilitate the participation of women user-groups in the decision making process, the objectives of the project implementing agency and the plans for intervention in the watershed should be made available to them from the very beginning. In addition, these plans should be discussed separately with the women in smaller groups to obtain the viewpoints of different categories of resource users.

- Beneficiaries' contributions will become a necessary condition to ensure that people's participation is genuine. It can also pave the way for beneficiaries to make larger contribution to the cost, reducing the financial burden on the development agencies. The principle of 'users must pay' can, over a period, be extended to the principle 'payment of cost should depend upon the extent of benefit'.

- For watershed programmes to be sustainable, local institutions need to be strong and effective. The training meant for grassroots organisations should deal with the formation and structure of village institutions, user groups and water users associations; their roles and responsibilities; and account-keeping and financial management. There should also be technical training on the range of physical aspects of watershed development and management (soil and water conservation, water harvesting, afforestation, water-supply systems and animal husbandry) with a view to build institutions that can make watershed management programmes sustainable.

Designing Methodologies for Evaluation of Economic and Environmental Implications of Groundwater Depletion and Quality Degradation Effects: A Study in Karnataka Peninsular India

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Introduction

Groundwater as a source of irrigation has gained considerable prominence in the water starved semi-arid regions of Karnataka. Currently, around 55 percent of total irrigation in the state is through groundwater. In Tumkur district, the study area, total irrigation through groundwater is over 73 percent. Farmers abstract water from dug-wells, dug-cum-bore wells, shallow and deep bore wells, the numbers of which have grown exponentially since the 1960's. As a result, many parts of the state where there is no assured source of perennial irrigation, are experiencing increasing signs of hardship due to over-exploitation of groundwater. This has created severe imbalance between extraction and recharge leading to depletion.

The groundwater scarcity has not only exhausted the available groundwater supply, but has also impaired its quality. Of late, water quality issues from point and non-point polluting sources are increasingly causing environmental concern as groundwater serves many purposes.

Objectives

The objectives of the study are to:

- Devise a framework and typology for evaluating sustainability, efficiency and equity issues concerning groundwater overdraft and quality degradation in different water exploitation regimes.
- Evaluate the economic consequences of groundwater depletion on food security and sustainability.
- Analyze the economics of conjunctive use of groundwater and surface water resources in ameliorating quantitative and qualitative depletion of groundwater.
- Study the economics of alternative options that reduce the environmental problems associated with groundwater irrigation.
- Study the groundwater regulation in the state, and examine the relationship with other institutions such as land reforms, credit system, electricity reforms and markets.

Data Base

The study was undertaken in Tumkur district, a typical hard rock area in Karnataka, as it has the maximum number of dark blocks representing overexploitation. In the same district, areas having access to canal and tank irrigation have been selected to study the effect of conjunctive use on groundwater overdraft. Secondly, in order to analyse the economic and environmental implications of groundwater quality on agricultural production, human and livestock health, and surrounding ecology, Vrishibavathi Valley in Bangalore rural district, where groundwater pollution is a serious problem, has been selected. Based on PRA survey and personal interviews, a sample of 35 farmers from each of these three areas having - groundwater irrigation (GW), tank irrigation supplemented with groundwater (CUTI), and canal irrigation supplemented with groundwater (CUCI) - were drawn for empirical analysis to study the case of groundwater depletion. To address water quality issues, a sample size of 30 farmers in the affected area, and as a control, a sample of 30 farmers in the normal area, were drawn for empirical analysis.

Methodology

Indicators

The physical indicators used in sustainability analysis are:

- Well density
- Well age
- Yield of irrigation wells
- Area irrigated per well
- Water extracted per annum
- Rate of well failures
- Reduced yield of water from the wells
- Increased depth of irrigation wells
- Replacement of pump with higher capacity.

Adoption of coping mechanisms includes drip/ sprinkler, crop pattern changes, and distortion in balance of food and non-food crop area.

The economic indicators of sustainability / unsustainability used in the study include:

- Increased cost of the well deepening.
- Increased cost of extraction of groundwater.
- Investment on additional wells.

Physical efficiency was analyzed in terms of output per acre-inch of water used, while economic efficiency of water use was analyzed in terms of net income per acre-inch of water, estimation of marginal value product of water through residual method, net returns per acre of gross irrigated area considering irrigation cost, net returns/per acre inch of water and benefit cost ratio for different crop enterprises. Economic efficiency measures in the conjunctive use system cannot fully reflect the resource cost, as it involves public and private investments. While private investment can be included, public investment, which largely comes as a subsidy, is not accounted. Hence, economic efficiency indicators are quasi indicators of the true cost since only groundwater costs are included, while that of tank and canal water is not. The cost of groundwater in conjunctive systems is lower than a pure groundwater system due to the positive externality of recharge from tanks/canals. For analyzing equity, measures such as wells owned by different categories of farmers, area operated by them, and irrigation cost and proportion of water extracted were considered. In addition, Lorenz curve and Gini coefficients were estimated to assess the extent of inequality in groundwater irrigation.

Partial budgeting technique is used to evaluate the economic feasibility of adoption of drip system of irrigation (conservation) over drilling an additional well (depletion). Discounted cash flow techniques are used to evaluate the appraisal of investment on drip system versus an additional well, following flow method of irrigation for coconut gardens.

The empirical framework to assess the impact of water quality problems includes change in crop productivity, loss of earnings, avertable expenditure, replacement and transaction cost. The land degradation ratio was used to estimate the percentage of area lost due to the poor quality of water. Partial budgeting technique was employed to evaluate the economic feasibility of ameliorating strategies.

Results

Impact of Groundwater Depletion

The average life of a bore well in the GW system for the past two decades (1980s to 2000) has decreased from 11 years to 3 years, whereas the bore wells under conjunctive use systems have served more than 15 years. This situation warrants concerted efforts to recharge the water table to sustain the irrigated agriculture.

Between 1985 to 2001, temporal indicators such as increased depth of water table (from 80 feet to 496 feet), decreasing groundwater discharge (from 3,500 to 800 gallons/hr) increased irrigation pump capacity (3 to 7.5 HP), premature failure of wells, increased depth of placement of pump from the top (80 ft to 230 ft) are physical indicators of overexploitation of groundwater. The increased investment on bore wells (from Rs.34,460 per well during 1985 to Rs.74,190 in 2001), additional deepening cost involved in rejuvenating failed bore wells (Rs.17,880 during 2001), increased investment on additional wells (Rs.15,000 in 1985 to Rs. 35,290 during 2001), increased expenditure on pump repairs (from Rs. I,000 in 1985 to Rs. 4,000 during 2001), cost of pump replacement (Rs.I0,000 in 2001) were found to be the partial indicators, where rise in cost of labor and capital cost could also have played a role.

Sustainability

The implications of groundwater overexploitation include increased depth to water-table due to competitive deepening, reduced life of all types of wells, high rate of initial well failures, reduced gross irrigated area per well, reduced groundwater output and increased costs of well drilling and repairs to pump-sets. This has severe implications on equity. The proportion of failed wells out of all the wells is over 50 percent. Dug-wells are completely in fructuous in the GW system, and only 14 percent of the dug-cum-bore wells were functioning. All the bore wells and dug-cum-bore wells are productive, and nearly 60 percent of the dug-wells were functional in the conjunctive use systems. The spatial indicators of sustainability such as density of wells per unit of holding size, varied from one well for every two acres in the GW system to one well for every five acres in CUTI and CUCI systems. This implies the extent of spread of bore wells and acuteness of the water scarcity. Though the increase in the number of wells in the GW system indicates wider access, the resource needed to own a well is beyond the reach of the small and marginal farmer. The cost per acre-inch of groundwater (Rs. 264) in the GW system is nearly two times higher than CUTI and in CUCI system.

Efficiency

In terms of physical efficiency, the GW system is more efficient compared to the other two systems, which is mainly due to scarcity of the resource. On the other hand, measures used to capture economic efficiency are not in favor of the GW system indicating the high cost of irrigation. In the GW system, there has been upward trend in the annual maintenance and repairs costs, and the electricity charges due to the high pump capacity and increasing depth of the bore wells. In the case of CUTI and CUCI, the annual cost of groundwater irrigation and the cost per acre-inch of water have been constant due to positive interaction effects of recharge. The physical scarcity in terms of decreased water yield from the wells and economic scarcity in terms of rise in irrigation cost per acre-inch in GW is evident. With regard to efficiency, the measures adopted do not fully value the water, especially in the conjunctive use systems, since the conjunctive use systems considered in the study involve both private and public investments. As public investments suffer from subsidy distortions, the true value of water does not reflect its marginal cost. Besides, over application of water leading to inefficiency is evident in most of the tank and command area because of poor pricing of water not reflecting its scarcity value. Notwithstanding these limitations, the above measures have successfully reflected the ground realities.

Equity

With respect to equity, out of the total irrigation wells, medium and large together comprising of 69 percent of total farmers owned 80 percent of the wells. Similarly, 88 percent of the wells in the gross irrigated area were operated by medium and large farmers. This clearly reflects the inequity persisting in groundwater irrigation, in addition to existing inequity in landholding distribution. This skewed distribution of wells and lopsided irrigated area in the groundwater system, revealed that resource rich farmers have better access to the groundwater in areas where groundwater is scarce. Both temporal and spatial inequities persist in overexploited areas. The measures formulated to analyze equity have fairly captured the extent of inequity in the study area. The study further draws the attention of policy makers to provide / offer policy support for small and marginal farmers through different programs.

Cropping Pattern

Area under non-food crops is growing at the compound growth rate of 4 percent per annum, whereas area under food crops is declining at the rate of one percent per annum in the study area. The analyses at the household level indicate that most households invariably allocate a large proportion of their dry land to food crops, which take care of household food security. Though perennial crops dominate in irrigated tracts, the impact of GW depletion on food security is not discernible with the primary data.

The negative externalities in well irrigation, especially in the overexploited area, is manifested in terms of increased investments on drilling deeper wells, colossal investment loss due to cumulative well failures, and increased investments in coping mechanisms.

Coping Mechanisms

In response to physical scarcity of groundwater, various coping mechanisms adopted include well improvement like deepening, drilling additional wells, transfer of water from source to far off places, adopting drip irrigation system, buying water and shift in crop pattern in favor of coconut. The first three coping mechanisms like drilling additional well (s), well improvement (deepening) and adoption of drip irrigation, which are capital intensive, are generally adopted by large farmers. The coping mechanisms, such as adoption of indigenous drip system and buying water, which are less capital intensive, are largely adopted by small and medium farmers.

On an average, the drip system requires an investment, which is half the investment on an additional well. The associated benefits include about 44 per cent saving in water, additional improvement in yield of about 20 percent and high water use efficiency. The partial budgeting analysis of drip adoption over flow method with an additional well proved the economic feasibility of drip irrigation. Further, the economic measures of IRR (36% for drip irrigation with existing well and 33% for flow irrigation with additional well), NPV (Rs.1.12 lakhs for drip irrigation and 0.45 lakhs for flow irrigation) and BCR (1.9 for drip irrigation and 1.5 for flow irrigation) indicated that the investment on drip irrigation is economically feasible. Although in both the cases the investment is feasible, from the viewpoint of conservation of the resource for present and future development, drip irrigation is desirable.

Conjunctive use systems facilitated realization of higher incomes over the GW system due to recharge of wells, which decrease the failure of wells. The groundwater recharge could be experienced both in terms of physical as well as economical impacts. Increased well life, negligible well failure, increase in the water yield of the wells and higher crop diversity are some of the main physical impacts of the conjunctive use in the CUCI and CUTI areas. The economical impacts are negligible with little or no investment on the coping mechanisms like drilling additional wells, deepening of wells and adoption of the drip system. The farmers will have the advantage of lower irrigation cost and higher income from their irrigated lands. Thus, the conjunctive use of surface and groundwater had a positive effect on sustainability of the groundwater promoting intra and intergenerational equity.

The flat rate policy has virtually doubled the use of electrical power for irrigation in Karnataka. Electricity charges on pro-rata @ Rs.1 per kwh for a 5 HP pump, were approximately Rs.6,750 per well per annum, while on a flat rate basis farmers currently pay around Rs.1,500, which is almost 4 times lower. The difference in the electricity charge was the implicit cost to society, which was not accounted by the private well owners. The marginal productivity of water suggests pricing of electricity for lifting groundwater on a modest scale to restrain overdraft.

Water Quality-Environmental Implications

About 22 percent of the open wells and 80 percent of the drinking water wells were abandoned due to groundwater pollution. The percentage of land degraded was 58 and 61 percent for small and large farmers respectively, while it was 100 percent for marginal farmers. Land degradation ratio revealed that 18.5 percent of the cultivable area was lost due to use of ‘poor’ quality water. Due to land degradation, land value dipped by 50 percent compared to normal land. The productivity of paddy and sugarcane with poor quality water declined over the years. The growth rate in the yield of paddy (-6.28) and sugarcane (-3.8) has been declining affecting sustainability. Due to the use of 'poor' quality groundwater, farmers were forced to incur extra cost for the production of paddy and sugarcane. This negative externality cost for paddy production formed 18.5 percent of the total cost.

As the paddy crop grown using 'poor' quality water had a blackish tinge, the demand was reduced as reflected in a 20 percent lower price compared to 'normal' paddy. The price of sugarcane cultivated using polluted groundwater was lower by 37 percent compared to 'normal' crop, as the sucrose recovery was 4 percent compared to 'normal' where the sucrose recovery is 8 to 10 percent.

Use of polluted groundwater resulted in allergic dermatitis, skin irritation and gastrointestinal problems. Due to this, the additional health care expenditure was Rs.2,616 per year per family. In addition, livestock also suffered from skin rashes and edema. The loss in employment in agricultural activities due to illness caused from exposure to the polluted water is 40 man days per year, valued at Rs.2,327. In the area, ecological imbalance was evident in terms of reduction in bird population, crab, frog, and fish catch in the open wells, and prolific growth of weeds *(Basophylls)* was noticed all through the fields. Marginal farmers were the worst hit from pollution.

The incremental return to provision of surface drainage for paddy, a measure to reduce groundwater pollution was Rs.487. The cost of supplying treated water was around Rs.130 per acre-inch of water.

Policy Recommendations

Regulatory Interventions

- There is a need for institutional restructuring of groundwater regulations such as using permits for drilling wells, maintenance of inter-well space, optimum number of wells, use of efficient pump technologies and banning additional wells in overexploited areas till the groundwater situation improves.
- State policies such as subsidized electricity for groundwater irrigation have an adverse impact on groundwater development. Hence, appropriate pricing, incorporating marginal cost of extraction is desirable.

Demand side Interventions

- Adoption of drip irrigation should be made mandatory in dark talukas, where farmers have invested in additional wells, to sustain groundwater irrigation.
- Groundwater depletion is also attributed to cultivation of water intensive commercial crops on a large scale. Thus, there is a need for benign crop pattern, which needs less water.

Supply side Interventions

- Efforts should be made to bridge the gap between extraction and recharge, on the community basis through people's participation for the construction of water harvesting structures, and desilting the existing tanks so that groundwater supply can be augmented through recharge.
- Government should consider artificial recharge projects in dark and grey talukas on priority basis.

Other Interventions

- The problem of inequity existing in well irrigation, where physical and economic access to groundwater is restricted for the poor, could possibly be addressed by promoting group investment programs like Ganga Kalyana Yojana for the benefit of small and marginal farmers.
- Since farmers are the bulk users of groundwater, they need to be educated regarding the scarcity value of this precious resource through maintenance of well-logs by the groundwater department to include well location, well

type, well depth, power of the pump used, pump placement, date of drilling, length of casing, and so on.

- Details such as water yield of the well, water quality in different seasons and water abstracted from the wells need to be continuously recorded with the help of flow meter and water quality tests.
- The farmers need to be educated regarding the flow meter data which will show them the extent of withdrawal of groundwater from their irrigation wells so that they can appreciate the predicament, and even adopt coping mechanisms such as use of drip / sprinkler irrigation measures and adopt a suitable crop pattern towards a sustainable groundwater use.

For water quality issues, the policy options *inter alia* include:

Economic instruments such as:

- Polluter pays principle, which should be used by imposing a tax on polluters, and resulting revenue should be used to treat the water.
- Capital subsidy for treatment plants is to be provided to encourage abatement process.
- Green tax on polluting industries may be imposed in order to refrain them from polluting water resource.
- Pollution Control Board should strictly monitor whether the polluters adhere to the standards attained while letting in the effluents to water bodies.

Technological Solutions

- Varieties of crops, other than paddy and sugarcane that are suitable to be grown under adverse water quality conditions, such as sweet flag (*Acorus calamus*), a medicinal plant that thrives fairly well in polluted water, could be explored.
- Recycling of wastewater for agriculture and industrial use needs to be encouraged through private participation/ co-operatives.

MARINE ECOSYSTEMS AND SUSTAINABILITY

An Economic Analysis of the Sustainability of Marine Fish Production in Karnataka

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Introduction

Continued economic productivity of fisheries depends upon the current biological and economic conditions, and sustainability implications of continuing current exploitation rate and methods. The 1990s have seen global crises in marine fisheries, and the maritime state of Karnataka is no exception. The modernisation of fishing fleets and the uncontrolled expansion of fishing efforts are the main reasons for declining growth rates of total marine fish production. In the course of the past five decades, the annual marine fish production of India increased from about 0.9 million tonnes in late 60s to the current level of 2.6 million tonnes. The total fish production increased from 75,793 tonnes in 1969 to 2,51,012 tonnes in 1989, and started declining thereafter with a production of 1,39,676 tonnes. The contribution of annual pelagic fish production varied between 80 percent in 1975 to 50 percent in 1994. The percentage of demersal fishes varied between 9 percent in 1971 to 30 percent in 1983. Crustaceans, which accounted for a small proportion, during 1970s increased its share to 25 percent in 1987 and declined thereafter.

The marine fisheries are one of the major industries in coastal Karnataka. In the state's exclusive economic zone of 87,000 sq. km., fishery resource is estimated to yield 425,000 tonnes per year. The extraction of fishery resources has undergone major changes in the last few decades. In the 1950s, the state fisheries were characterised by small-scale with fixed fishing gears such as shore seines. The total catch was low and the fish caught were destined for local markets. However, in the early 60s there was a shift in preference towards more mobile fishing gears, which allowed the fishermen to actively pursue fish. The emphasis of the state program was to increase fish production for domestic consumption and export. This had been sought through various devices such as motorisation, port development and providing new boats and fishing gears. As a result, during the period from the 1970s to the early 1990s, fish catch increased at a record rate and became highly diversified in terms of species landed. As of now, more than 80 species are commercially harvested throughout the state's coast. Fishing technology also was highly diversified. As per the latest estimates, there are more than 2,098 shrimp trawlers, 378 purse-seiners, 1,180 gill-netters, 1,179 other mechanised boats, and 11,958 non-mechanised boats in Karnataka.

The fishery modernisation in the state has had mixed results. On the one hand, despite the growing size of the fishing fleet, the industry has by no means attained its full potential. For instance, Karnataka's average annual fish landing has remained around 142,000 tonnes in the last 10-15 years, much below its estimated total annual potential of 425,000 tonnes. On the other hand, there are growing signs of biological and socio-economic unsustainability that threaten the coastal fisheries. The introduction of trawlers has adversely affected other shore seines' and its own catches. The Karnataka State Department of Fisheries reported symptoms of over fishing in shrimp and other high valued fishes. Also, trawlers are alleged to have interfered with the fishing rights of traditional, small-scale fishers in the near shore areas, leading to rising social rifts between the two groups. The traditional rampani nets, which once accounted for 50-60 percent of the annual catch, have almost disappeared. There were episodes of clashes over resource users, which sometimes resulted in the loss of assets.

In the meanwhile, realising the possibility of overexploitation, particularly along the inshore, the state government enacted the Karnataka Marine Fisheries (Regulation) Act (KMFRA) as early as 1986. The Act empowers the State Fisheries Department to regulate fishery through licensing. The overall package seems to prescribe limited entry, a standard policy instrument. The Act has also banned mechanised fishing during the monsoon, which is the breeding season for most of the pelagic species. In addition to compulsory registration of vessels, this legislation imposed restrictions on fishing in specified areas, and on the number of vessels in specified areas and seasons. The compulsory registration of all the vessels, both mechanised and non-mechanised, also served as an authentic record on the number of various types of fishing vessels operating from the coast.

After 15 years of KMFRA implementation, a number of issues still confront fishery managers in Karnataka, including the lack of understanding of the fishery-wide impacts of regulations, conflicts between small and commercial fishers, and declining stocks of certain fishes. Fishery regulation has never been based on a scientific understanding of how certain policy instruments might affect the biological sustainability and economic viability of target species. Species vary widely in their economic and biological productivity. Also, the technical efficiencies of different gear types are not the same. In a fishery that produces multiple species obtained through different types of gears, there could be technical interactions among species and gear types. The limited-entry policies of KMFRA do not seem to recognise these technical interdependencies among species and gears, or the productivity differences across gear types. Such policies only have the illusion of keeping control over the total fishing effort. They could still fail to stem the depletion of certain primary or secondary target species. No effort has been made as yet to analyse the biological and economic effects of alternative management policies on different species.

Objectives

This research is an attempt to address certain management-related questions concerning the process of fishery modernisation and the concurrent regulations in Karnataka. The key research questions explored include:

- Assess the current biological and economic conditions of commercially important species in Karnataka.
- Evaluate the future sustainability implications of the current level of fishing effort.
- Suggest policy options for fishery management.

Methodology

In order to address the above objectives, we need to develop appropriate analytical tools to first estimate stocks and stock-effort-catch relationships, and then to characterise the optimal mix of fishing fleets under alternative management scenarios. Such an exercise is hoped to better inform the management process in its effort to move toward more sustainable fishing.

Data Sources

The data for the descriptive and modelling part of Karnataka marine fisheries comes from mainly two sources. The landings and effort data for the period from 1994-98 was drawn from Central Marine Fisheries Research Institute (CMFRI). The second set of data on costs and earnings, harvested price, labour share and income, and other economic parameters were estimated through a sample survey of the fishery vessels in coastal Karnataka. In this study, the data was collected for the two coastal districts namely Dakshina Kannada and Udupi districts for the fishing season of 1999-2000. The data on costs of fishing trips, capital and fixed costs of crafts and gear was collected from 15-20 fishing units in each vessel class to estimate the economic efficiency of each selected vessel. The construction of multi-species optimisation model required three types of data: (a) economic data consisting of market prices, fishing costs, storage capacity and labour requirement; (b) technological data including vessel-to-species effort conversion parameters, effort standardisation parameters, catchability co-efficient and annual available fishing capacity; and (c) biological data that included initial period stock estimates and growth parameters.

Market price data for the selected species is collected from field observations. The costs per actual fishing hour (AFH) are computed using data from a primary survey of different fishing firms. Based on this computation, the unit fishing costs are estimated at in Rs/actual fishing hours 410, 919, 460, 70, and 100 for technology classes multi day trawl nets, purse seines, trawl nets, outboard motor boats, and non-mechanised boats respectively. However, these costs represent the cost of fishing efforts that landed all the reported species in the port. For certain individual vessel classes, particularly for outboard and non-mechanised nets, the species included in the model represent a small portion of the vessel's total effort. The unit costs are therefore prorated based on the proportion of the vessel's effort directed toward the model species.

Model Development

In this study, we employ both single-species static models and multi-species dynamic (mathematical programming) models. The purpose of the first set of models is two-fold: first, these models would enable us to assess the sustainability of individual species at the state level; and second, these models provide various techno-economic and biological parameters, and stock estimates required for the multi-species programming model. The multi-species model is designed for individual port-levels. A state-level multi-species model would not be inappropriate since there is a large variation across ports.

The results of the estimation of maximum sustainable yield and maximum economic yield indicate that the difference between cost and price reflecting the surplus is highest for pomfrets and shrimp, followed by sharks and rays. Interestingly, the current harvest levels for these species have far exceeded the sustainable yield. Motivated by the higher economic surplus, the fishermen try to harvest more, resulting in biological unsustainability of these resources. The estimated values of yield, effort and cost of MSY and MEY levels for the selected demersal species against the harvest quantities of the base year 1998 were studied. The results show that for most of the species, the current harvest has exceeded both MEY and MSY, indicating some degree of overexploitation. For example, by spending 19,183 actual fishing hours, the fishery could have harvested 8,400 tonnes of MEY and 8,327 tonnes of MSY. However, by spending almost the same level of effort (19,719 actual fishing hours), the current yield (1998) was only 2,516 tonnes, which represents the excess of fishing effort and hence, societal loss. In the case of many other species, the current harvest quantity is more than the MSY and MEY.

Model Results

The estimated value of MEY and MSY pelagic fishes shows that for some of the species such as mackerel, the symptoms of unsustainability are very clear. By spending 67,582 actual fishing hours, an MEY level of 30,848 tonnes could have generated maximum revenue surplus. The comparison with the 1998 yield and effort shows that by spending almost the same level of fishing effort (65,288 actual fishing hours), the yield is 27,257 tonnes, indicating that the fishery is operating at the maximum economic yield level and any further increase in effort could lead to decline in the fishery rent.

The sustainability of demersal species in value terms under three scenarios is estimated. Scenario 1 and 2 represent the value of the catch with the restriction of MSY and MEY. This means that if the fishery manager were to impose the restriction, the actual total catch value should have been only Rs.786.01 million of MSY or RS.736.79 million of MEY. However, the actual (1998) harvest value for most of the species have exceeded both MSY and MEY levels, representing excess harvest value over and above the sustainable level, with a total of Rs.1,540.32 and Rs.1,615.41 of MEY and MSY respectively. The results indicate that for tunnies, seer fish and stolephorus, there has been excess harvest over and above the sustainable level. Though an accurate estimation of sustainability for these species is difficult because of their highly fluctuating nature, the results indicate that they are also under threat from the viewpoint of sustainability.

The multi-species optimisation model is simulated for the Mangalore port. The Mangalore port is the largest fishing port in Karnataka, constituting 35 percent of the state's total fish landing in 1998. Seventeen of the most important species, which contributed more than 1.5 percent of the total port landing during 1994 to 1998, are included in the model. Based on the 1998-reported catch, these 17 species constituted more than 85 percent of the total fish catch in Mangalore. The top five species harvested in 1998, in the order of their weight, are breams, Indian mackerel, stolephorus, sardine and cephalopods. For the same period, more than 10 different types of fishing vessel technologies are reported to have been employed. For the purpose of this study, these vessel classes are regrouped into five homogenous vessel classes: mechanised trawlers nets (MTN), purse seiners (PS), trawler nets (TN), out-board fishing nets (OBU), and non-motorised boats (NMB).

The catchability coefficients for most model species of the Mangalore port are assumed to be the same as the estimates developed for the Karnataka state in the previous sections. For certain model species, state-level estimates are not available. The catchability coefficients of most closely related species are used for such species. The annual capacities of fishing vessels in AFH are assumed at the 1998 levels.

The initial year exogenous stock levels are computed using the Fox model. For using the Fox model, the 1998 levels of standardised efforts are first computed for each model species of Mangalore port. These standardised effort values along with the estimates of catchability co-efficient and the observed quantities of species catch are plugged into the Fox model equation to estimate the initial year stocks. However, when we run the baseline simulation model, our goal is to make sure that the model-generated catch values come as close to matching the observed catch values for the year 1998. Of the four variables above, catchability coefficients are estimated using the state-level data of 10 years, which we think are more reliable than the initial year stock estimates for Mangalore. The 1998 observed catch and effort values are certainly more accurate than the unobserved stock estimates. Therefore, for the purpose of this analysis, we calibrate the initial exogenous stock values so that the baseline model generates species catch distribution as close to the 1998 observed catch distribution as possible.

The mathematical programming model is solved using the Generalised Algebraic Modelling System (GAMS) software. This software has a routine for solving non-linear programming models. The model is run for a period of 10 years with annual increment. The baseline model has a total of 663 equations (belonging to 11 separate blocks of equations), 563 variables, and 2,362 non-zero elements. Several sensitivity analyses are also carried out to evaluate various management and policy scenarios.

Before a model can be used for any meaningful policy and management analyses, the model results must first be validated with reference to some historical or observed outcomes that the model is trying to predict. In an optimisation model like the current one, validation cannot be done by simply comparing the model-estimated values with some historical values, since the model optimises effort and catch. The reason is that the observed values may not be optimal to begin with. Alternatively, we force the endogenous effort levels for all the model years to be equal to the observed effort level of 1998. Then we compare the 1998 model catch values and the observed catch values. We call this the baseline simulation. This effort restriction on the model also allows us to understand how harvesting at the current effort level would impact the sustainability of the fishery stock and catch.

A comparison of the 1998 observed catch and the model-estimated catch is made. For most species, the differences between the model and observed levels of 1998 catch are within 11 percent. For ribbonfish and stomatopods, the difference is around 18 percent of the observed level. For pomfrets, there is a wide relative gap between the two values. There was a wide year-to-year fluctuation in the pomfrets catch during 1994 to 1998. Also, this is one of the least significant model species in recent years. There may be errors in the specification of the unobservable biological parameters, and errors in collecting the third party data on catch and effort. Given these factors, we consider the model's overall performance quite satisfactory.

In the baseline simulation, the stocks of 9 out of 17 model species will be declining over time. These are Indian mackerel, rock cods, bream, ribbonfish, other carangids, black pomfrets, prawns, stomatopods, and cephalopods. Stocks of six species - sardine, stolephorus, thryssa, other perches, and soles - will be increasing. Stocks of two other species - other sardines and scads - remain stable. The most interesting result to watch is mackerel. This species would become most unsustainable in terms of both stock and catch in 10 years if the exploitation continues at the current effort intensity. Mackerel, which is only second to breams in catch with 5,246 tonnes in 1998, experiences more than 40 percent reduction in catch. Similarly, other species that suffer a drastic decline in stock and catch are prawns, stomatopods, and cephalopods.

The baseline harvesting results in total market revenue over a 10-year period of little over Rs.4,929 million, whereas the total cost of harvesting is as high as Rs.4,844 million. That leaves a net fishery rent of only Rs.84 million or 1.7 percent of the total market revenue. Relative to the total market revenue, the rent margin under the current harvesting scenario is insignificant. The crewmembers salary is estimated at Rs. 1,391 million or 28.23 percent. Since trawlers, both mechanised and multi-day, catch mostly the demersal species, the trawler industry would more likely be affected by this decline. Concurrently, the employees of this industry would be adversely affected too.

Our next goal is to run the model to characterise the optimal combination of vessel efforts. We run the simulation again without forcing endogenous effort values on the model, like in the baseline run. The only restriction we would put is the minimum and maximum constraint on the effort. The minimum effort constraint is included to reflect the political reality that no single vessel class could be completely eliminated from the fishery. The maximum constraint is necessary to avoid the model to become unbounded. Also, there are real-world capital constraints on the limits to which fishery capital can expand in a given time period. The maximum fishing efforts are assumed to be 25 percent above the 1998 observed levels for all vessel class except NMB. For the latter, the effort restriction is placed at twice the current level. The minimum efforts are assumed at 50 percent of the current level.

The multi-species optimisation model is simulated for the Mangalore port. The Mangalore port is the largest fishing port in Karnataka, constituting 35 percent of the state's total fish landing in 1998. Seventeen most important species, which contributed more than 85 percent of the total port landing during 1994 to 1998, are included in the model. Based on the 1998-reported catch, these 17 species constituted more than 85 percent of the total fish catch in Mangalore. The top five species harvested in 1998, in the order of their weight, are threadfin breams, Indian mackerel, stolephorus, sardine and cephalopods. For the same period, more than 10 different types of fishing vessel technologies are reported to have been employed. For the purpose of this study, these vessel classes are regrouped into five homogenous vessel classes: mechanised trawlers nets (MTN), purse seiners (PS), trawler nets (TN), out-board fishing nets (OBU), and non-motorised boats (NMB). (Repeat of para on pgs 6-7)

The results of the optimal harvesting simulation presented in the report show that while there is still some degree of overfishing in some cases, the stocks of all but four species either increase or remain stable. Indian mackerel, black pomfrets, stomatopods, and cephalopods still experience a decline in stocks. However, the rates of this decline, particularly for stomatopods and cephalopods, are much slower than what they experience under the baseline scenario. Interestingly, the rates of stock and catch decline for Indian mackerel remain the same as the rates under the baseline situation. This is because of the fact that under the optimal scenario, the number of fishing hours by purseienes, the efforts of which are mostly dedicated mackerel, increases quite substantially. This increase in purseseine effort is offset by any reduction in the effort by other vessel classes, for instance, outboard motor boats.

Another interesting finding is that the optimal model results show that there is almost no change in the total value of harvest (Rs.4,969 million) from that of the baseline simulation (Rs.4,929 million). However, there is a substantial reduction in the cost of fishing from the baseline level of Rs.4,844 million to the optimal level of Rs.3,155 million, resulting in a profit of Rs.1,814 million or 36.50 percent of the total market value. This is due to both biological and economic reasons. Biologically, more number of species become sustainable, stable or less unsustainable over the ten-year period under the optimal scenario. This certainly increases the total catch of certain species. Economically, the model allocates more effort toward high value species and high-productivity (or unit cost) vessel. This helps the fishing industry realise higher rent from fishery. Thus, the optimal effort distribution not only increases fishery rent, but also increases the chance of several model species to become either sustainable or more sustainable.

The results of the single species model estimated the sustainable yield and maximum economic yield without considering interactions between stocks, species, gears, labour, processing and marketing factors. On the other hand, the multi-species model presented in this section incorporated the dynamic nature of the fishery and multi-gear technology interaction into a management plan in order to assess biological and economic sustainability. We conducted several simulations of the model. In the baseline model, the endogenous effort level was forced on all the future ten years based on the observed effort level of 1998. This effort restriction enables us to understand the future sustainability of catch and stock given the current effort level. The result of the baseline model shows that stocks of most of the model species are declining over the period. The mackerel, which is one of the most important pelagic species, clearly suffers unsustainability in the future catch and stock if the current effort level is continued.

The above results clearly support the view that the fishing industry in Mangalore spends too much effort and cost to realise their market income. Through optimal re-distribution of its effort, the same market value of fishery output can be obtained at almost 35 percent less cost. For the optimal scenario, the amount of labour payment is estimated at Rs.1,425 million, only a slight increase from the baseline estimate (Rs.1,391 million). Since the wage payment is a fixed portion of the market value of the catch, and the total revenue does not change much, this small increase in the wage is reasonable.

The model captures the dynamic nature of fishery through an inter-temporal stock growth equation. This equation balances the stock in each period to the previous period's stock, plus net growth minus harvest. This gives the model the ability to track the impact that the current fishing effort (technology and capital) has on future sustainability of fish stock. We can also impose a separate sustainability constraint that requires that each year's stock be more than or equal to the last year's stock. Through such a constraint, one can analyse the trade-off between biological sustainability and social welfare impact on the fishing community.

Current fishing intensity in the study area is both biologically unsustainable and economically inefficient. A significant portion of the effort is wasted, a common symptom of the "tragedy of commons" problem. The optimal re-allocation of existing vessel technology could improve this situation by allowing more productive technology like purseseine to intensify their effort. Such reallocation not only increases fishery rent but also make fishery resources biologically more sustainable than what the current industry can do.

Recommendations

Fishery management policies in India are broadly governed by the Indian Fisheries Act of 1897 and the Marine Fisheries (regulation) Acts of the respective states, which were enacted in the eighties. The Karnataka Marine Fisheries (Regulation) Act of 1986 provides for the regulation of fishing through seasonal closure of fishing operations by specified vessels, restriction of fishing in specified areas and control of indiscriminate fishing of brood stock and juveniles through regulating mesh size. In Karnataka, for instance, mechanised fishing vessels are prohibited from fishing during the monsoon season for two to three months. However, most part of the Act has not been implemented due to a lack of information on the impact of such policy measures on different stakeholders. In this section, we calibrate our model to simulate the impacts of various fishery regulation policies, such that the results of the simulation will help to shed light on how the unsustainable harvesting as seen in the baseline or optimal fishery simulations can be corrected. For the purpose of the analysis, we consider two policy scenarios:

Policy Scenario I (Restricting Harvest Technology):

Under this scenario, we analyse the effects of placing restrictions on harvesting technology that reduces the harvesting capacity of purse seines. Under both the baseline and optimal harvesting scenarios, this vessel type is found to promote an unsustainable harvesting of mackerel, one of the commercially important pelagic species. The technology restriction may be implemented by changing the mesh size of nets that are used on this vessel. This policy change represented in the model reduces the effort standardisation parameter for purse seines from the baseline level of 1.0 to 0.7.

Policy Scenario II (Seasonal Restrictions):

For this scenario, a seasonal restriction of two months on all mechanised vessels such as purse seines, trawlers and outboard fishing nets is considered. This policy allows stocks to rejuvenate during the spawning season and directly impacts the total annual effort expended by fishers. Moratorium on harvesting is most common under the Karnataka laws. Therefore, maximum effort constraints are reduced by 2/12 of the baseline levels for the above vessel types.

The alternative management options discussed in the report are only indicative and not exhaustive. The impact of many other options such as restrictions on fishing in different depth zones to protect the interest of the small-scale fishermen could be introduced to enhance the equity aspects. Thus, the introduction of management regulations would improve not only the sustainability of the resources, but also the economic returns from the fishing industry.

The study presents the estimated values of stocks of selected species, gross returns, total cost, net profits and wage payments under Policy Scenarios I and II. The initial stock (actual stock in 1998) allows comparison of the effectiveness of each of the policy options in enhancing stock levels and also economic costs and returns. It is clear that the two policy options have different impacts on individual species. For most of the species, both scenarios will result in much higher stock levels through to the year 2007 than the optimal harvesting scenario discussed earlier, except in the case of species such as stomatopods and cephalopods. It is interesting to note that under the optimal harvesting plan, there is a decrease in the mackerel stock to almost half of the initial stock. However, each of the policy scenarios discussed here show an improvement of the stock. The stock of the oil sardines and stolephorus also improve under both the scenarios.

It could be observed from the results that some speciesthat are unsustainable under the optimal harvesting scenario such as prawns, pomfrets and scads, becomes sustainable under each of the policy scenarios discussed. The sustainability of prawns, one of the most highly targeted species by the trawlers, improves under Scenario II and I. The stock level of scads, which reduced under optimal harvesting strategy to 10,613 tonnes from the initial stock of 13,000 tonnes, increases to 14,799 tonnes under Scenario I, and to 12,843 tonnes under Scenario II.

As expected, the economic returns accruing to fishermen and payment to labour are slightly lower under the subject scenarios. The gross returns diminished from Rs.4.97 billion under the optimal harvest level to Rs.4.21 billion and Rs.4.56 billion under Scenario I and Scenario II, respectively. Similar trends can be observed with respect to labour payment. The total cost of harvesting also slightly decreases from Rs.3.16 billion under optimal harvest levels to Rs.2.93 billion in Scenario II due to the impact of reduced fishing efforts for two months.

Although the two-month moratorium on fishing efforts (Scenario II) improved long-term stock levels of most species considerably, the major species of the Mangalore port such as Indian mackerel, experience a setback in stocks by the end of the simulation period by as much as 25 percent. High value species like cephalopods and stomatopods also lose their stock level significantly. It is clear that the current policy of seasonal restriction of two months is not fully potent in stemming the unsustainability problem of at least some major species.

The optimal simulation is developed without current level effort restrictions. The results of the optimal model reveals declining stock levels of selected model species such as mackerel, cephalopods and stomatopods. The estimated total revenue from both the models are almost same. But the cost of harvesting from the baseline level to optimal level decreases by 54 percent, and hence profitability increases by 21 percent. Thus by promoting the effort combination, the biological and economic sustainability can be improved.

The above results clearly support the view that the fishing industry in Mangalore spends too much effort and cost to realise their market income. Through optimal re-distribution of its effort, the same market value of fishery output can be obtained at almost 35 percent less cost. For the optimal scenario, the amount of labour payment is estimated at Rs. 1,425 million, only a slight increase from the baseline estimate (Rs. 1,391 million). Since the wage payment is a fixed portion of the market value of catch, and the total revenue does not change much, this small increase in the wage is reasonable. Some of the important recommendations of the study are:

- The increase in fishing efforts during 1970s and 1980s led at first to rapid increase of commercial landings, which grew at the rate of 2.6 percent and 5.95 percent until the early 1990s. During the 1990s, there was a negative growth of total production. The legal framework to control the fishing efforts was not enforced for socio-economic reasons.

- In order to study the biological and economic sustainability of the Karnataka fishery, a single species model was constructed to help the fishery management authorities to limit the effort level. The results of the single species model, shows that most of the species are harvested at very close to maximum sustainable yield levels and above the maximum economic yield.

- Multi-species mathematical programming models implemented for – Mangalore port estimate the response of stock and catch levels under various scenarios. The objective function was to maximise the net benefits from a fishery, given a set of constraints. The results of the baseline simulation model with of the 1998 effort level on the next 10 years shows that most of the model species are biologically and economically unsustainable. The policy simulation of effort restriction and seasonal moratorium indicate that these policies do help sustain some species, but fail to protect most popular species like Indian mackerel, and high value species like cephalopods and stomatopods.

- As shown by the results, we cannot expect to get increased catches by simply increasing fishing effort. On the other hand, we can improve the sustainability by changing the exploitation pattern. At present the fisheries exploitation is based on fishing through trawlers of different types. It is possible to achieve important economic and biological benefits by proper re-allocation of fishing efforts and keeping fishing costs at their minimal levels.

- With rebuilding of stocks through increased mesh size, closing areas and seasons for fishing, at least for destructive fishing, the sustainability can be improved.

Economic and Social Management of Estuarine Biodiversity on the West Coast of India

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Introduction

Estuaries are coastal ecosystems that sustain human life in many ways. They provide a variety of livelihood opportunities for rural communities. Fishing, paddy cultivation, traditional prawn cultivation, clam fishing and lime shell collection, salt making, coir fibre making, traditional ferry services, clay and sand mining, etc. were the major occupations of rural communities. Since these activities used traditional technologies to meet their own subsistence needs, local communities could not accumulate wealth to make fresh investments on modern economic activities.

Due to the influence of globalisation, of late, these systems are being intensively exploited by modern industrial enterprises, resulting in the degradation of biological diversity that leads to food insecurity. Although these concerns were discussed at length in many national and international forums, the role played by tropical estuaries to sustain global biodiversity has not been fully recognised for want of sufficient empirical studies on the use and abuses of these ecosystems. In India, very few attempts have been made to study them in detail - to value them, look into the causes and consequences of degradation, particularly the socio-economic issues and management. We wish to overcome these lacunae by making an attempt to understand an estuarine system, which is intensively used by various stakeholders along the western coastal belt of the Indian peninsula.

Objectives

The major objectives of the study are to:

- Characterise the nature of fish and shellfish diversity, and to describe the ecological services of major estuaries along the West Coast of India.
- Estimate the direct, indirect and non-use values of estuarine biodiversity, and to compare the economics of degraded and undisturbed areas in the selected estuaries using appropriate methodology in environmental economics.
- Identify the major causes of biodiversity erosion in these estuaries and document these processes in detail.
- Explore how different stakeholders have enforced their claims on the estuarine environment and to examine the role of various institutions in the development of such rights and economic activities.
- Suggest appropriate socio-economic strategies for the prudent use of estuarine resources and biodiversity.

Methodology

Since estuarine uses are influenced both by natural and socio-economic forces, a multidisciplinary approach is essential to understand the uses and abuses of resources. This study therefore, begins with characterising the fish and shellfish diversity in selected estuaries, and proceeds further to valuation of the ecosystem. Biodiversity of Indian estuaries have been declining over the last few decades due to state interventions and industrialisation that encouraged intensive use of resources and environment. Economists argue that biological diversity degrades due to market failures, institutional failures and policy failures. Since biodiversity, being an environmental good, could not be traded in a formal market, the diversity degrades when markets fail. There are many reasons for this. Failure to internalise externalities, public good features, absence of well-defined property rights, creation of an appropriate structure of property rights are all

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[1] *Rice variety*

responsible for this. Therefore, if biodiversity were to be preserved, governments should ensure well-behaved markets by preventing market failures.This study examined the various issues related to markets, government, policy and institutional failures that cumulatively contribute to environmental degradation in estuaries. The study then estimated the economic values - direct, indirect, option, bequest and existence - of estuaries using the popular neo-classical environmental economics taxonomy. Accordingly, the summation of direct, recreational and non-use values would provide the total gross economic value. To simplify the calculations further due to lack of time, only the important traditional and modern activities are included in the present analysis. Activities like fishing, wetland agriculture, prawn filtration, aquaculture, sand mining, navigation and ferry services, etc. have formal markets, and hence their respective values are approximated to the gross revenue produced by the units operating in these activities. Indirect use value of estuaries, especially backwater tourism, is estimated using the **travel cost methodology (TCM)**, and the non-use economic values are estimated using **contingent valuation method (CVM)**. Total economic value of the estuary is then arrived at by summing up the direct, indirect and non-use values. This value is divided by the total geographical area of the estuary to arrive at the per acre value of the estuary as a natural resource. This in fact, is an underestimate, as it has to still account for many other implicit values accruing from the uses of mangroves, minerals etc. It is expected that these estimates, being a first approximation, would be useful for policy formulations involving the use of estuarine ecosystems.

Study Areas

Two estuaries (Cochin estuary in Kerala and Kali estuary in Karnataka) along the Southwest coastal zone of India were selected for this study. **Cochin estuary** of Kerala is one of the largest brackish water bodies in India. It stretches to over 24,000 ha in area and contributes to about 50 percent of the total area of estuaries in the state. **Kali estuary**, on the other hand, is one of the smallest estuaries in the North Kanara district of Karnataka state, situated at 14° 50' 21"N and 14°10'06". The Cochin estuary has been exposed to the influences of international markets and commercialisation of economic activities from an early date. To appreciate the changes experienced by this system and to provide a comparative perspective, the Kali estuary of Karnataka State, which has not been commercially exploited until recently, is selected.

Sources of Data, and Modes of Data Collection

Two types of databases have been used in this enquiry. The first set of data refers to the hydro-biological processes (water quality, composition and diversity of living organisms as well as ecological process), while the second set falls under the economic and social domain of fishing communities, gazni/ pokkali[1] farmers, and households engaged in prawn filtration, sand mining, traditional ferry services, etc. Economic activities are valued using separate sets of questionnaires. In a few instances, secondary data like the Census reports, administrative reports and village/panchayat reports have also been used. The modern stakeholders are identified as the Cochin Port, those involved in modern aquaculture, navigation and tourism activities.

Major Results

Causes of Degradation

The study revealed a high growth of Industrial pollution, sediment accumulation, dredging, construction activities and reclamation in Cochin estuary, affecting fishing activities, agriculture, water transport and trade.

Decline in Fish and Shellfish Species Diversity

One of the major emphases was to characterise fish and shellfish diversity in estuaries, and to describe their ecological services. 73 finfishes and eight shellfishes were recorded during 2001-2002 in Cochin estuary, while 63 finfishes and nine shellfishes were reported in Kali estuary. The lowest specie diversity was recorded in Fort Kochi bar mouth region due to specialised use of Chinese nets. The northern bar mouth region on the other hand, recorded species availability between 61 and 68. High species diversity was recorded in the southern side of the medium saline zone (ranging between 68 and 71), while the diversity recorded along the northern side of the medium saline zone varied between 26 and 53. In the fresh water zone, on the other hand, the species diversity varied between 68 and 70. Comparing different zones in Cochin estuary, we found that diversity is higher in the southern side of the medium saline zone, followed by the fresh water zone, the northern part of the medium saline zone, northern bar mouth station, and finally the Cochin bar mouth station. Comparing these estimates with previous studies, we noticed a definite reduction in the availability of estuarine fishes in Cochin estuary.Previous researchers had listed 150 fish species belonging to 100 genera under 56 families from this estuary during the early 1980s. From this comparison, it appears that a large number of species, especially finfishes from Cochin estuary vanished during the last 20 years, although it would still be difficult to pinpoint them due to the methodological differences between the study undertaken by our team and earlier studies. However, the fact that large numbers of species have vanished warrants our concern.

Decline in the Catches and Value of Fisher

The lowest level of production is recorded in Zone II B, which is badly affected by the effluents and waste emissions of the modern manufacturing industries. The average level of estuarine fish production in the Cochin estuary is estimated as 4,300 Kg/ha, while the lowest productivity (288 kg/ha) is recorded in Zone II B. The medium saline zone (Zone II A) recorded the highest yield of 2,773 kg/ha, followed by the Munambam bar mouth region (2,761 kg/ha), fresh water zone (Zone I) with 1,169 kg/ha and Cochin bar mouth with 642 kg /ha.

Paddy Production in Pokkali Fields

The total production during the year is estimated to be 6,568.5 tonnes. The annual production of pokkali paddy in Zone II B is 2,168.6 tonnes (33.02%), followed by Zone I with 2,094.7 tonnes (31.89%), 9,876.856 tonnes (30.07%), Zone II A with 1,773.05 tonnes (26.99%), Zone III B with 350.17 (5.33 %) and Zone III A with 182.01 tonnes (2.77%).The productivity in this zone (977.30 kg/ha) exceeded the overall average wetland paddy productivity (854.5 kg/ha). This shows that no clear proof exists to indicate that traditional wetland paddy cultivation is affected by biodiversity degradation, especially in areas that are highly polluted. This may be attributed to the active presence of traditional institutions and agrarian organisations in this region.

Gross Values of Major Activities

The total gross direct value generated by both the traditional and modern stakeholders from Cochin estuary for the year 2001-02 is Rs. 409.85 crores. Around 77 percent of this is the contribution of modern stakeholders. Estuarine capture fisheries contributed around 22 percent, while agriculture contributed only one percent. The available evidence indicates that the pokkali paddy farming fields are being converted to modern aquaculture, although there is local resistance towards such commercialisation. Since no institutional arrangements exist to negotiate an arrangement beneficial to both traditional and modern stakeholders and the environment, modern development activities are likely to ruin the ecosystem and the people alike.

Local Institutional Arrangements

The process of resource sharing and the economic organisation of various production processes had been influenced by local perceptions about ecosystem services and functions, and are internalised in traditional social institutions. The traditional common property institutions regulated fishing activities, the ***padashekara committees*** that supervised crop rotation in wetlands and the institution of ***kalakkippidutham*** regulated labor allocations and circulation. Rights over fishing grounds/ territories were enforced by respective gear groups by defining territorial boundaries and rules for fixing nets within such defined territories during the process of fishing. The respective gear groups excluded outsiders from these territories while involved in the activity of fishing, and these territories remained open to all other stakeholders as soon as they finished fishing. The agrarian communities organised their activities through “***padashekarams”,*** local organisations of peasants to initiate collective action. These organisations reduced risks and uncertainties, minimised transaction costs, legitimised labour recruitment and supervised crop rotation in saline wetlands. The ***Padashekarams*** also controlled the socio-political life in many villages. These arrangements stand out clearly as social arrangements for ecological and socio-economic sustainability of estuaries. Although the traditional economies appeared to be equitable and sustainable, they could not generate enough economic surpluses to undertake any substantial investment for development.

State Failures

The study revealed that the state has failed to recognise the role of traditional coastal zone institutions/organisations in the control of resources and estuarine environment. Modern institutions did not perform either. Although there exist a variety of formal rules for regulating estuarine activities (fisheries, agriculture, aquaculture, water quality and pollution, biodiversity protection, reclamation, dredging, resource ownership, movement of cargo and trade), these policies are scattered, and hence the government does not have a holistic vision for crafting policies for estuarine governance.

Policy Recommendations

This study suggests both immediate and long run measures to slow down, if not stop, the process of degradation in Indian estuaries.

Short Run Policy Measures

- The Cochin Port Trust should explore the possibility of developing markets for dredged materials by introducing appropriate economic incentives and fasten measures to internalise the ecological and social costs of dredging activities.
- The government has to adopt a differential policy for allowing reclamation that supports livelihood of traditional estuarine communities, and implement it immediately through local bodies (grampanchayats). At the same time, the government should discourage large-scale reclamation by modern enterprises through legal or economic instruments, and integrate the initiatives of various government departments and agencies through district panchayats.
- Steps may be taken by the Kerala State Pollution Control Board to mitigate industrial pollution using environmental economic principles. The Board should develop, implement and monitor concrete action plans for mitigating brackish water pollution with the participation of various stakeholders and local bodies.
- Immediate measures should be taken by the concerned departments (Public Works Department of the State/Central Government, Greater Cochin Development Authority (GCDA), Goshree Island Development Authority (GIDA), etc) to remove barriers obstructing the tidal functions of estuaries.

Long Run Policy Measures

Evolving a National Policy on Estuaries

The Ministry of Environment and Forests should draft a comprehensive “estuarine development and management policy” to ensure equitable and sustainable use of estuarine resources and environment. The proposed policy document should indicate the rights and responsibilities of the Central, State, local Self-Governments and other local stakeholders in the use of estuarine resources and environment.

Empowering Local Institutions for Governance

Once the shift in the approach towards governance is established through the policy declaration, the state has to initiate a process to empower local communities, local self-governments, informal institutions and organisations to undertake the task of resource management. Structural reforms, including enactment of legal codes and informal codes of conducts, are therefore required at the grassroot level.

Enacting Legislation

The Government of Kerala State should enact legislation to empower local grampanchayats as nodal agencies responsible for the control and management of estuarine resources and environment.

Co-management of Estuaries

The state has to ensure the participation of local stakeholders in the management and governance of estuaries. We have already indicated that the partnership between the public and private stakeholders could deliver an outcome that is acceptable to various parties, and environmental economic approaches are helpful in deriving such arrangements of good governance

Traditional Knowledge Systems and Institutions

Traditional coastal zone/estuarine institutions have to be studied in detail, and indigenous knowledge systems have to be properly integrated for the better governance of estuarine systems in India.

Environmental Movements

The State should view public resistance and agitation against environmental degradation in the proper spirit, and attempt to integrate these feelings into environmental policies. Oppression of social and environmental movements brings more harms than good.

Conclusion

The limitations of this approach are also obvious. As repeatedly claimed in this study, valuation of environment supported by the appropriate institutional and organisational arrangements can only resolve the evolving crisis of the estuarine economies. The state has to accept and learn from the experiences of traditional coastal zone institutions. Moreover, it has to initiate the crafting of appropriate modern institutions, if necessary, for the better governance of these ecosystems. The collective action necessary for the healthy co-existence of various stakeholders can only be generated through this process. This study is only a beginning to convey this message.

Environmental Economic Analysis of Inshore Fishery Resource Utilization of Coastal Kerala

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Introduction

The coastal zone, which is an interface between land and ocean, has enormous socio-economic importance, as these areas are characterised by an abundance of natural resources. The coastal belt of Kerala, about 590 kms long, has 226 marine fish landing centres and an equal number of fishing villages with high population density. The coastal habitat is under severe threat due to human intervention in the forms of excessive fishing in the inshore waters, shallow water mining, lifting of coastal sands, destruction of mangroves, inflow of pollutants, growing urbanisation, construction of sea walls and other related activities. These activities are bound to disturb the coastal ecosystem, affecting the sustainability of fishery resources and livelihood security of the vast majority of inhabitants. Besides, the technological advancements in fishing methods, coupled with increasing export demand for fish, lead to over-crowding of fishing units, especially during peak seasons. This condition affects the very sustainability of ecosystems and increases the need for environmental quality and conservation of resources.

Objectives

The specific objectives of the present study are to:

- Examine and document the extent of recent changes in the techno-exploitation pattern of inshore open access marine fisheries and socio-economic condition of stakeholders.
- Assess the economic impact of such changes on structure, composition and productivity of inshore marine fisheries and the livelihood security of the coastal population.
- Evaluate the economics of operation of different fishing units and their impact on fishery resource conservation, and to suggest policy measures for sustainable development of the coastal zone.
- Estimate the economic loss due to the environmental degradation of inshore marine ecosystems, and to provide sufficient socio-economic indicators to administrators and policy makers for decision-making in regional environmental planning.

Site

A preliminary survey was conducted in all the fishing villages covering the entire study area from Poovar in the south to Munambam in the north along the southern Kerala coast to identify representative sample villages of mechanised, motorised and non-mechanised fishing centres. The villages and landing centres were selected for detailed study on the basis of use patterns of marine coastal resources and intensity of operation of different craft-gear combinations, both in artisanal and mechanised sectors of Southern Kerala. (Fig. 1)

Fig.1 Map showing selected centres for the study in Southern Kerala

Methodology

The villages were classified into highly degraded, moderately degraded and comparatively undisturbed categories in relation to the intensity of environmental pollution as well as fishing. The costs and earnings data for all types of fishing units were collected on sample days from each landing centre, and the economics of different fishing units were evaluated, covering all seasons in a year (2001-2002). The socio-economic survey was conducted in all selected centres to analyse the socio-economic framework of the coastal rural sector. Secondary time series data from 1962 to 2000, relating to species-wise catch was obtained from the National Marine Living Resources Data Centre of CMFRI. It was used to study the extent of variation in catch composition, production trend of inshore marine fisheries and the impact of technological advances on marine resource base. In order to evaluate the response of those involved in fishing and allied activities regarding environmental and conservation problems of natural fishery resources, an opinion survey was also conducted in all the selected villages.

The sample centres selected for detailed study were Munambam, Cochin, Alappad Neendakara and Kochuveli for the highly degraded category; Arthungal, Valanjavazhi, Thangassery and Vizhinjam for the moderately degraded category; and Kattoor and Poovar for the comparatively undisturbed category. Among the selected centres under the highly degraded category, Munambam, Cochin and Neendakara were predominantly mechanised fishing centres having serious environmental and conservation problems. The major environmental concerns of these centres were excessive fishing pressure on the inshore region, heavy destruction of the bottom fauna, juvenile fishing, by-catches, discards and coastal pollution. Another highly degraded area covered under the study was Kochuveli village in Thiruvananthapuram District, where a large industrial unit producing titanium products is situated. Large quantities of acid wastes from this industry flow into the sea, which causes many health hazards. Some centres under the study area were considered degraded due to sea erosion and sand mining. Alappad village in Kollam district was one of the most affected and degraded villages due to the invasion of the furious sea, especially during the monsoon season.

In the moderately degraded areas, the proliferation of motorised gears, operating within the near shore areas create heavy threat to the habitat. The indiscriminate operation of a large number of mini trawl and ring seine units, operating from the landing centre at Valanjavazhi and Pallana, led to the depletion of some species of fish of commercial value and importance. The predominant use of gears with reduced mesh size leads to juvenile fishing, and thereby over fishing of many important species of fish. A large proportion of the catch in mini trawl units is composed of juveniles/sub-adults of the flatfish Cynoglossus macrostomus and shrimp Parapenaeopsis stylifera, causing damage to recruitment. Oil spills from outboard engines in the bay-landing centres such as Thangassery and Vizhinjam led pollution in the near shore waters.

The Kattoor coast of Alappuzha and Poovar in Thiruvananthapuram district are comparatively undisturbed areas. Kattoor is a natural landing centre with motorised and non-mechanised units under operation. Most of the gears under operation in Poovar are non-mechanised units, such as Catamarans (Plank built canoe), shore seine units and motorised plywood boat with gill net/ hooks and line.

The extent of damage caused by technological advancements, and thereby destructive fishing by the mechanised as well as the motorised sectors was analysed. The economic loss due to juvenile fishing by different fishing units was estimated using suitable models developed during the study. Cobb-Douglas production function was used to evaluate the economic efficiency of input utilisation in trawler operation in three different regions. The Net Present Value (NPV) was calculated for discounted economic loss due to various environmental factors.

Results and Findings

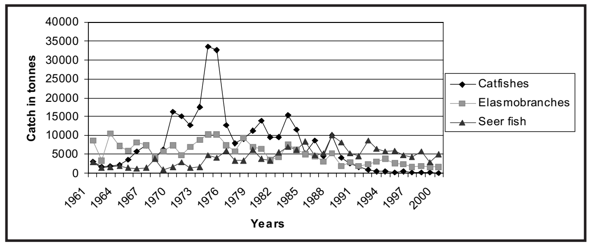
Fish landings

The analysis of species-wise annual landings of Kerala during the last four decades clearly indicates that the effect of technological changes in fishing methods such as introduction of mechanisation and motorization of country crafts had affected some of the marine resources, leading to their depletion. The catfish fishery along the Kerala coast is the best example of the depletion of a resource due to indiscriminate fishing by the mechanised sector. The average annual catch of cat fish in 1961 was 3,114 t, which rose upto 33,526 t in 1974 owing to the large-scale exploitation by the mechanised trawlers and purse seiners. During the intensive mechanisation period, this came down to only 103 tonnes in 2000 (Fig. 2) .The major reason for the decline of this particular species was the over fishing of brooders by the mechanized purse seiners and trawlers.

The pelagic fish, such as the carangids, tunnies and seer fish were exploited maximum between 1985 to 1990, mostly by the motorised country crafts, especially using ring seines, gill nets and hooks and line. From then on, the catch showed a declining trend in spite of the increase in the number of motorised units in the area. Another endangered species is the polynemids, collectively called threadfins. The major cause of their depletion was the destruction of their nursery grounds by mechanised trawlers. The annual production of elasmobranches was also shown to be declining ever since their peak landings of 10,338 t in 1974, which was reduced to only 2,832 t.in 2000 (Fig.2). The heavy exploitation of sharks by the mechanised vessels along the coast reduced the catch from 7,747 t in 1983 to 1,706 t in 2000.

Certain less priced fish such as threadfin breams, lizard fish and ribbonfish considered by-catches in the mechanised trawlers, recorded an increasing trend in their catch. It was estimated that, in the total trawl landings, more than 45 percent was composed of by-catches, which included other than the above mentioned species, the juveniles and sub-adults of a wide variety of commercially important fish. The increase in the landings of the cephalopods, mainly an export item, was also noticeable in recent years.

Fig.2: Catch Trend of Cat fish, Elasmobranches and Seer fish



Socio-economics of Fishing Communities

The selected villages along the coastal stretch of Kerala between Munambam and Poovar were surveyed to assess the socio-economic status of the fishermen and the other people depending on the coastal resources for their livelihood. The total number of households ranged from about 1,000 in Kochuveli to 12,000 in Thangassery. In each village, the coastal wards, predominantly inhabited by fishermen, were covered under the survey and information was collected on socio-economic indicators such as housing pattern, family size and demographic features, literacy level, ownership of fishing equipment and employment pattern with special emphasis on fishing people, income distribution, consumption and expenditure pattern and indebtedness.

Regarding the ownership of fishing implements, the non-mechanised fishing vessel owners were more in Kochuveli and Poovar where 18 and 20 percent of the families respectively had non-mechanised catamarans with gill nets. The percentage of families having non-mechanised shore seine were 7 percent in Poovar and 4 percent in Kochuveli. In Alappad and Kattoor, 5 percent of the families were the owners of non-mechanised dinghies with gill nets. In Kochuveli, the livelihood of the fishing community was seriously affected by pollution, which was indicated by the non-existence of any improved technology in this area. Fishermen mostly used country craft and catamarans without any sort of mechanised device. In Poovar, more families were operating non-motorised catamarans and country crafts, mainly because it was an economically backward village having no facility for institutional credit. In Vizhinjam, 23 percent of the families were owner-operators of plywood boat units with gillnet/hooks and line. Motorised mini trawl units were found more in Valanjavazhi with 24 percent of the families owning them. The households that owned mechanised trawlers were 5, 4 and 4 percent in Alappad, Neendakara and Munambam respectively.

Table 1: Ownership Pattern of Fishing Implements – Percentage Distribution of Families

Village	Non-mechanised			Motorised			Mechanised
	Shore seine	Catamaran & gillnet	Dinghy & gillnet	Plywood boat & gillnet	Ring seine unit	Mini trawl unit	Trawler
Poovar	7	18	-	8	-	-	-
Vizhinjam	-	3	-	23	-	-	-
Kochuveli	4	20		2	-	-	-
Thangassery	-	-	-	7		2	-
Neendakara	-	-	-	4	-	-	4
Alappad	-	-	5	6	4	-	5
Valanjavazhi	-	-	-	-	-	24	-
Kattoor	-	-	5	-	3	4	-
Arthungal	-	-	2	-	1	12	-

Out of the total, 69 percent of the adult population in Arthungal was employed, followed by Poovar (67%) and Valanjavazhi (61%). The lowest level of employment was in Kochuveli (47%), followed by Thangassery (51%), where most of the women were housewives. About 50 percent of the employed population in Vizhinjam, Valanjavazhi and Kattoor were wage earners in the motorised fishing units, which provided better income to fishermen. About 47 percent in Neendakara and 48 percent in Munambam were employed as wage earners in the mechanised fishing units. Only 21 percent of the people in Kochuveli and 19 percent in Poovar were engaged in fish marketing, mostly representing the women head load vendors, generating additional income to support their families. In Kochuveli, because of the discharge of effluents from the titanium factory into the sea, the intensity of fishing had come down, causing detrimental effect on the fishery. There had been a considerable shift in occupation from fishery to non-fishery activities. Many had migrated to other places for employment. About 28 percent in Valanjavazhi were engaged in processing work, mostly ladies working in shrimp peeling sheds.

On the whole, in all the villages, the expenditure pattern indicated that about 80 percent of the household expenditure was for consumption purposes. The average annual household expenditure ranged from Rs.19, 600 for the families of shrimp peeling workers in Kattoor, to Rs. 65,412 for the mechanised boat owning families in Munambam. . However, it was observed that medical expenses of families in different villages had no significant relation with the intensity or incidence of pollution. The credit utilization pattern clearly indicated that in most villages, maximum loan was availed for productive purposes.

Costs & Earnings

In the mechanised sector, the annual net profit from the trawlers having an Overall Length (OAL) of 36-42ft, 45-48ft and >50ft operating from Cochin Fisheries Harbour during 2001-2002, worked out to Rs.3.66 lakh, Rs.6.98 lakh and Rs.4.14 lakh. About 40 percent of the total expenditure was for fuel, followed by 25 percent for wages. Regarding the purse seine units, the annual net profit worked out at Rs.14.36 lakh, and was maximum for the above 50ft craft category, with the highest rate of return of 87 percent. The average revenue obtained for the mechanized gill net units was Rs.20.87 lakh, with a net profit of Rs.4.69 lakh.

The annual profit for the operation of the ring seine units with a craft of >50ft at Valanjavazhi was Rs.3.75 lakh. The major expenditure was labour charges (40%) as crews of 20-30 people, depending on the size of the craft, were engaged in a single day trip. The annual net profit obtained from a motorized mini trawl unit during the above period was Rs.1.48 lakh at Valanjavazhi and Rs.0.93 lakh at Arthungal, with the highest rate of return of 168 percent for the former landing centre. The average annual revenue from a plywood boat with gill net, operating from Vizhinjam centre was Rs.5.73 lakh with a net profit of Rs.0.77 lakh, and the net profit from the same type of unit at Thangassery centre was calculated at Rs.1.11 lakh.

Comparatively higher rates of return were obtained from the non-mechanised units, such as catamaran and shore seine units, mainly because of lower investment. The only exception was the non-mechanised dinghy with gill net, for which the rate of return was only 19 percent. The net profit from a shore seine unit worked out at Rs.1.14 lakh at Poovar and Rs.0.90 lakh at Kochuveli, with a rate of return of 126 percent and 103 percent respectively, and 95 percent of the expenses were towards labour costs. At Kochuveli, due to pollution, the average catch per unit of catamaran was much less than that of Poovar, but the average revenue was high because fishing was extended to interior ground, therefore they could get quality fish fetching higher prices.

The key economic indicators of operations of all types of fishing units were calculated and compared. Among the mechanised units, the average catch per day of operation was highest for trawlers, and the lowest was for gill net, but in terms of value realisation, it was *vice-versa.* Labour productivity was more in trawlers. Among motorised units, the catch and revenue per day of operation was highest in ring seine. Average revenue realisation was high in mini trawl due to the landings of penaeid prawns. Labour productivity and the rate of return were also found to be higher in mini trawl units. Among non-mechanised units, shore seines obtained the highest catch per day of operation. Quantity of fish produced per man, per day in shore seine was very low indicating high labour involvement in its operation.

Production Function Model

The production function analysis using Cobb-Douglas model indicates that there is scope to enhance the net profit of trawlers by increasing fishing days and the area of operation at Neendakara and Munambam, whereas at Cochin Fisheries Harbour, it is almost at the optimum level. At Neendakara landing centre, fishing days in a year can be increased from the average level of 193 to 204, and in Munambam from 203 to 229 days, to get the maximum profit. Even though the number of days fished in a year are not upto the optimum in all the major centres, it was observed that there was still excessive fishing pressure due to over crowding of fishing units.

Economic Loss due to Juvenile Fishing

The economic loss due to juvenile fishing by different fishing units was estimated using the model developed on the basis of the quantity of juveniles landed by different gears, price level of juveniles and adult fish of each species, and the approximate period of juveniles to attain adult or marketable size. Even though the annual revenue generated by a purse seiner is Rs.20.7 lakh, the annual economic loss due to juvenile fishing by the same unit works out to Rs.39.6 lakh. In the mechanised trawler, the economic loss due to juvenile fishing was Rs.28.3 lakh as against its gross annual revenue of Rs.31.2 lakh. In the motorised sector, a ring seine contributes a loss of Rs.19.1 lakh, which is higher than that of the annual revenue generated by the same unit (Rs.12.4 lakh), and for the mini trawl, the annual economic loss was estimated at Rs.6.9 lakh. Among different centres, the highest economic loss was at Neendakara harbour with Rs. 239.1 crores/year, followed by Cochin Fisheries Harbour and Munambam. As a whole, the economic loss due to juvenile fishing in the study area alone is estimated at Rs.600 crores per annum, in which the highly degraded centres contribute about 82 percent.

Economic Loss due to Pollution

Environmental problems at Kochuveli and Alappad were discussed in detail, and their effects on fisheries of the area were worked out in terms of Net Present Value (NPV) of loss of fishing income due to pollution for the next 15 years, discounted to the present level. At Kochuveli, because of the pollution problem, people are reluctant to adopt improved technologies of fishing. Due to this, the fishing intensity also has come down. Taking into account the major factors influencing the level of effort and the catch and value, the Net Present Value of estimated loss to the village due to pollution for the next 15 years comes to around Rs. 23.7 crores. Since there can be a flow of future benefits in coming years, a cost benefit analysis is done and the NPV is calculated for 15 years with a discount rate of 12 percent. NPV calculated for Kochuveli is Rs.157.4 crores. The low level of annual landings from Alappad landing centre is mainly due to the sand mining and sea erosion, resulting in the construction of a sea wall, which obstructs the landing centre facilities. The annual economic loss due to these factors amounts to Rs.97.4 crores. The economic loss in terms of Net Present Value calculated for 15 years is Rs. 647 crores.

Loss due to Over-Fishing

Economic loss due to the extinction of some of the species of fish because of over-exploitation was worked out. The net loss due to over-fishing was estimated in terms of Net Present Value of MSY for 30 years, discounted to the present level, which was Rs.160.6 crores for catfish, Rs.458.5 crores for elasmobranches and Rs. 3.9 crores for goatfish. An additional loss of 30 percent of this amount comes in the form of consumer surplus.

Opinion Survey

An opinion survey was conducted on government policies on the conservation of resources, covering 100 people in each of the selected villages, who in one way or other are involved in fishing activities, either as fish workers, fish traders or boat owners. The survey reveals that more than 80 percent of the respondents are aware of the importance of environmental management for the conservation of natural resources, especially fishery. Many of the respondents in the degraded area believed that many economically important species of fish have disappeared or declined from that area, especially from Kochuveli. About 60 percent of the interviewed people at Alappad demanded the construction of a sea wall to protect the shore, and 100 percent to stop sand mining. All the respondents, except those involved in the operation of mini trawl, consider this net as highly destructive and detrimental to the growth of fishery in the long run. However, most of the fishermen interviewed were very cautious in making any response to the restrictive measures, which would affect their present benefits. A majority are in favour of a fishing holiday, but there is no unanimity in the type of unit or duration.

Recommendations

Policy measures have been recommended for the conservation of resources and environmental problems along the study area.

- In Kochuveli, where environmental problems affect the future benefit from fishery, it is suggested that the industrial effluents should be treated before discharging them into the sea through a buried tunnel.
- To prevent the indiscriminate exploitation of fishery resources, there should be fishing holidays for all types of mechanised fishing units and their socio-economic impact should be properly assessed.
- Since mini trawl is comparatively highly profitable and less capital intensive, there is every chance for its expansion. But, it is detrimental to the sustainable development of the fishery. Hence, further proliferation of this unit should be restricted.
- As the economic loss due to juvenile fishing is substantial, the standardised mesh size regulations should be introduced and implemented with proper monitoring for all types of gears in order to avoid juvenile fishing.
- All types of construction along the seashore, even those for developmental purposes, should be regulated, and the CRZ Act should be strictly enforced for the environmental protection of the coastal area
- Due to the economic loss due to the extinction of three species - elasmobranches, catfish and goatfish because of intensive over-fishing, other endangered species such as carangids, seer fish, threadfins, etc. have to be protected by restricting indiscriminate fishing by mechanised as well as motorised fishing units.
- Integration of coastal mariculture with small-scale inshore fisheries issuggested as a viable alternative to enhance the earnings and livelihood security of coastal fisherfolk without endangering the environment.

Conflicts of Water and Soil Resources over Aquaculture Production in Tamil Nadu and Pondicherry

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Introduction

Marine product exports from India depend heavily on the availability of shrimp as it commands a high unit value combined with heavy worldwide demand. The decline in the natural fishery stock has developed the potential of aquaculture to meet the challenges of food security and generate employment and foreign exchange. This has led to the rapid expansion of this sector, which has grown at an average annual rate of almost 10 percent since 1984, compared with 3 percent for livestock meat and 1.6 percent for capture fisheries production. However, the inexorable expansion of shrimp farming generated by market demand, short term gain and government support because of export earnings, has brought with it super–intensive systems, nomadic farmers, environmental and sociological disputes, water quality and disease problems resulting in a decline in shrimp production. All of these appear to be threatening the long-term sustainability of what has undoubtedly become the world's fastest growing aquaculture industry.

A major portion of the conflicts arising from this expansion of shrimp farming is the result of environmental and social degradation that is not included in the costs of shrimp production, where the industry assumes no responsibility for damages to other groups arising from its activities. Mangrove destruction, flooding of crops, salinisation or pollution of land and water associated with the expansion of shrimp farming altogether form degrading factors that affect the surrounding population are dependent on these resources. Further, abstraction of the freshwater from underground aquifers and release of saline water due to semi-intensive shrimp farming are some of the major issues against shrimp culture that seem hardly justified in either the social or economic terms. The impetus given to shrimp aquaculture is mainly due to its lucrative foreign exchange earning capacity. These are the important conflicts that have emerged with the aquaculture industry in Tamil Nadu.

Though the development of the aquaculture industry along the coastal regions of Tamil Nadu and Pondicherry appears to be booming due to a tremendous increase in the revenue of India, environmental degradation due to pollutants from the industry has been recognised to be controversial by environmentalists. If not properly planned, the spread of brackish water shrimp culture into other user area will lead to adverse effects on natural habitats and social customs. Therefore, it is essential to assess and evaluate the environmental impact of shrimp culture resulting in conflicts since it causes unprecedented pressure on natural resources such as water and soil, so that a sustainable aquaculture industry with increased production can be met for the future generations. The major goal of society should be to stimulate production and consumption that do not diminish the capacity of life-support systems to recover after disturbance, which remains within the carrying capacity of the supporting eco-systems.

Status of Shrimp Culture

- Shrimp culture in India is synonymous with coastal aquaculture.
- It stands for export-oriented aquaculture.
- About 1,94,000 ha are under shrimp culture, producing about 1,27,170 MT of shrimps.
- Aquaculture shrimp production today contributes substantially to shrimp exports – 74,826 MT by weight and Rs. 3, 545 crores by value.

Objectives

The objectives of the study are to:

- Evaluate the environmental impacts of aquaculture farms in Tamil Nadu and Pondicherry in the Bay of Bengal region.
- Find out the impact on groundwater and surface water and measure the environmental cost of water salination.
- Calculate the economic benefits of aquaculture in Tamil Nadu and Pondicherry.
- Analyse the degradation/encroachment of agricultural lands and mangroves.
- Value soil degradation of coastal land nearer aquaculture farms.
- Suggest policy measures for sustainable aquaculture in India.

Methodology

A survey-based method is used to assess the socio-economic implications in the following four zones covering Tamil Nadu and Pondicherry.

Zone 1 - Chennai, Ponneri, Minjur, Kancheepuram

Zone 2 - Pondicherry, Cuddalore, Parangipettai, Chidambaram

Zone 3 - Nagapattinam, Sirkazhi, Vedaranyam, Thanjavur

Zone 4 - Pattukottai, Thondi, Mimisal, Ramnad

Hedonic pricing method analysis was carried out based on land evaluation and cost of decay. Contingent valuation analysis was done based on pollution abatement and willingness to pay for pollution abatement.

Sampling was carried out at 3 levels

- Prawn cultivators and owners.
- Farm agriculturists and landowners nearer to aquafarms.
- Workers in aquaculture.

This analysed the socio economic benefits, effects on living standards, consumption patterns, employment and standard of living conditions. The hedonic price version was used to predict the changes in the prices of extent measurement by the increases in values and depletion measured by increase in values.

Information was collected from agriculturists and aqua culturists using a land survey and through questionnaires distributed to them by the project researchers. Soil and water samples were collected from problematic zones at the respective areas and analysed for their impact.

Impact of Aqua Effluents

The release of effluents is rich in organic matter and results in siltation, changes in productivity and community structure of benthic organisms. The creeks and canals receiving the discharge also get silted up as a result of organic matter discharged from shrimp farms, which leads to the depletion of dissolved oxygen levels in the receiving waters. Further, the discharge of nutrients carries the risk of eutrophication, and the sudden outburst of algal blooms in coastal waters affecting the environmental conditions and ecology of the area. It is to be pointed out here that even though the disease outbreaks are directly linked to environmental factors, no conclusive study is available to understand the pathways of disease-causing pathogens and the interactions involved. Another prevailing environmental issue is that the fertilisers and bio-pesticides applied in aqua farms also degrade the soil quality, according to the opposition groups. However, it was found that the main chemicals used in aquaculture are lime and chlorine. There is so far, no scientific evidence to show that these two chemicals will lead to irreversible soil degradation. It is therefore wrong to say that shrimp culture is a short-lived industry. The aqua farmers in India largely practice extensive farming, and there is therefore no need to apply a large quantity of lime and chlorine as is the case in Thailand and Taiwan. Unlike toxic pesticides used in agriculture, aquaculture does not involve usage of such concentrated chemicals, except use of medicines / antibiotics and probiotics to ensure the steady growth of the shrimps, and to prevent diseases and mortality in intensive culture systems. In the preliminary stages of aqua farming, chemical components such as lime and zeolite are used as disinfectants and to maintain the alkalinity and fertility of the soil and water.

Impact of Aquaculture on Water Quality

The salinisation of surface water from shrimp farms to the receiving waters also impacts water quality. Shrimp farming causes dispersion of salt into the land around the shrimp farms, thereby increasing the salinity intrusion affecting the paddy fields and other plantations. The soil salinisation further results in devaluation of marginal agricultural land. Abstraction of fresh water from underground aquifers for intensive shrimp farming has also resulted in saltwater intrusion and salinisation of fresh water aquifers. While fresh water aquaculture poses little negative impact on ground water and aquifers, brackish water aquaculture is detrimental to subterranean water resources. This issue concerns the proper site selection and engineering rather than negative aspects of aquaculture.

An investigation on water quality has been carried out in 14 villages in the coastal areas (Sirkazhi Taluk) of Nagapattinam district. Out of 14 villages, eight were found near shrimp culture ponds, viz. Thirumullaivasal, Thazhanthondi, Radhanallur, Vazhuthalakudi, Thirunagari, Thirukovalur, Annappanpettai and Konaiampattinam. Another five villages were found in agricultural areas, viz. Amaipallam, Vadakal, Thirukarukavur, Keeranallur and Semmangudi. Water samples were collected on monthly intervals and analysed for physico-chemical parameters to find out the quality and suitability for drinking purposes. Drinking water samples from Thazhanthondi, Vazhuthalakudi, Varusapathu and Thirukarukavur were found to be safe for human consumption. There is no substantial amount of data regarding water quality in this particular area for pervious years to compare the quality. These findings clearly indicate that shrimp farms have not salinated their neighbourhood as claimed by the anti-aquaculturists.

Impact on Soil

Soil samples were collected from the agricultural / non-agricultural areas close at the aqua farms at varying distances (1km, 3 km, 5 km) to determine the impact on soil quality. Based on the analytical data, it could be inferred that among the 42 soil samples collected in the 4 zones, certain areas (10 samples) in Nagai district and Ramnad district (2 samples) were found to be slightly influenced by the shrimp farms with increased pH (8.4 – 9.9), tending towards alkaline soil and increased electric conductivity values (4.7 –30.0), which depicts the increase in the salinity of the soil. However, no other changes were noted in the soil quality. Most of the sample soils were under paddy cultivation. The impact on the water quality also shows a slight change in the pH (8.3) in the Kurichi area of Nagai district (1 sample) and slightly increased EC values in Minjur (Kancheepuram district) (3.0) (1 sample) and Nagai district (3.0 – 7.6) (12 samples). Other chemical components are found to be within the permissible limits. Based on this environmental analysis, it could be confirmed that shrimp culture activities may result in slight disturbances in areas at the vicinity of the shrimp farms (1–3 km), whereas areas away from the farms (5 km) are less affected.

It was also found that many aqua farms in Nagai and Ramnad districts were situated in the coastal areas close to the sea or backwater areas. Even in areas where there are no shrimp farms, the lands and ground water are saline because of the nearness of the sea and regular tidal flushing, seepage, humid climate, and meagre and narrow fresh water tables in the coastal belt. The normal soil texture appears to be sandy loamy soil with saline patches on the surface layers, which attributes to the coastal salinity from seawater intrusion. Therefore, it is not correct to say that shrimp culture is the only causative factor for soil salinisation or water contamination in these areas.

The only problem identified by our survey is that the shrimp farmers directly discard wastewater without treatment into the public canal, coastal area or rivers and inshore areas, which results in conflicts. If the effluents from aqua farms are treated before reaching the environment, particularly when the organic load is high at the time of harvest, and such effluents are passed through primary sedimentation and secondary biological oxidation treatment before discharging them into the water bodies, there may be an amicable solution for the development of the industry.

Degradation of Mangroves from Aquaculture

The loss of mangroves on account of shrimp culture is diminishing because of regulations imposed by the government. It is also recognised that shrimp farms on mangrove land often support profitable shrimp culture for only short periods of time. In other words, mangroves are not normally the places for sustainable shrimp farming. The acid sulphate soils common in mangroves can also affect the sustainability adversely.

Degradation / Encroachment of Lands

Shrimp culture in Tamil Nadu was introduced with the full support of the State Government as a viable alternative to paddy cultivation, and also for utilising the barren and uncultivable alkaline lands profitably. The area occupied by shrimp / prawn farms in the taluks of Sirkali, Tharangampadi and Nagapattinam is about 2,000 ha, less than 2 percent of the total geographical area. These farms have actually paved the way for the utilisation of the barren, uncultivable lands. This area is situated at the tail end of the River Cauvery irrigation system, and the prospects of cropping have been dim and disappointing due to inadequate and untimely water supply. Hence, the farmers were frantically looking for an alternative use of their lands or for disposing them off for good prices. Due to shrimp farming, the value of land has increased manifold. Before the commencement of shrimp farming, the land value was only about Rs.18,000 to Rs.20,000 per ha., but this has increased to about Rs.1.5 lakhs to Rs.1.8 lakhs per ha., i.e. 10 times, when shrimp farming gained popularity. The ownership pattern of land has also radically changed. About 20 percent of the coastal land holdings were sold to big aqua farms as the size of the lands were small (less than one ha). 40 percent were sold due to high price, 30 percent due to inadequately profitable crop production and 10 percent because of non-availability of labour.

Conflict

The opposition to shrimp aquaculture stemmed from both environmental and socio-economic problems. The socio-economic problems arise from issues like land alienation, displacement of coastal communities from open access public lands used for fish drying, net drying, grazing, subsidence cultivation, etc., Additionally, the conversion of paddy lands, resulting in the loss of employment and local level food security and problems of access to the sea for fishermen, were also encountered in many areas.

In the wake of its growth, the aquaculture shrimp industry farming also posed a number of social, ecological and economic issues mainly on account of improper planning and unregulated and uncontrolled growth of the enterprise. The experience gained in the Asian countries including India, has clearly shown that if this activity is not scientifically managed and judiciously monitored it will not be sustainable and may cause a number of environmental and social problems, as well as increased incidence of disease outbreaks. It is therefore, necessary that the various issues encountered during the past be given careful consideration while developing future strategies for the sustainable development of this sector.

Hedonic Pricing Model for Land Quality

The hedonic pricing approach is based on the assumption that the environmental factors are attributes of goods or factors of production that are traded in the markets. The benefits/ damages, according to this approach, due to improvement/decrease in the environmental quality could be captured through the market price of the related goods.

This is modelled as follows:

$$P_L = f(X_1, X_2, X_3, X_4, \ldots\ldots X_n) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

The above model describes the relationship between the price of land and other independent variables affecting the land price, including the environmental quality. More precisely, P_L the dependent variable, stands for the price of land and $X_1, X_2, X_3, X_4, \ldots\ldots X_n$ refer to the independent variables, including the soil quality, which are assumed to influence the price of land.

In the study, it is assumed that the price of the land in the affected areas is lower than that of the non-affected areas by aquacultural activities. This is described as follows:

$$P_{ag} (X, X_1, X_2, X_3, X_4, \ldots\ldots X_n) > P_{ab} (X_1, X_2, X_3, \ldots\ldots X_n)\ldots\ldots\ldots(2$$

Apart from the soil quality, the land price is affected by N number of other variables described in the model. To understand the nature of influence of these variables, including soil quality, a log-linear regression model is used, which is as follows:

$$P_L = a + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + \ldots\ldots + b_n X_n + z$$

In this model, α is the constant and β is the coefficient and **z** is the error term. If **X** value were substituted with the variables derived from the farmers' survey, it would be able to predict the nature of the influence of the independent variables on the land prices in affected and non-affected areas. One of the aspects to be noted is that even though the mean value of the price of the land differs between the two time periods, it is not sure whether the difference is 'statistically significant'. Testing the statistical significance in the land price is a necessary condition because, if the difference in the land price were not statistically significant, then the underlying assumption in the hedonic pricing model would become meaningless. To understand the statistical significance of the difference in land price, 'Paired Samples T –Test' has been used.

The mean value of the difference in the land value between the two time periods under consideration stands at Rs.22,510.8. Since the study is more concerned in understanding the statistical significance of the difference in the land values, the t-value is worth noting here. It should be noted that the t-value is significant at one percent error level. This means that the difference in the land value between the two time periods is highly significant.

The important point to be noted is that the price of the land, rather than declining due to the environmental impact of aquaculture, has increased in between the two time periods. As noted before, the difference in the land price might have been caused by other factors as well. In other words, the negative influence of the environmental impact on land price might have been offset by the positive impact of the other factors. This needs to be investigated further so as to understand the nature and extent of the influence of various factors on land price.

Willingness to Pay (WTP)– The Model

As in the case of the hedonic pricing model discussed above, the WTP value for the pollution control measures at the farm level by the owners of the farm depends on different kinds of factors. This can be described as follows:

$$WTP_{PC} = ¦ (PC_{0i}, PC_{1i}, Y_i, S_i) + z_i$$

WTP_{PC} stands for the WTP value of the ith farm owner

PC_{0i} refers to the prouder surplus <u>without</u> pollution control measure

PC_{1i} refers to producer surplus with pollution control measure

Y_i, income of the farm owner

S_i refers to other variables affecting the WTP value

z stands for the error term.

To understand the influence of each variable on the WTP value, the following log-linear regression model will be used:

$$Log_{WTP} = a + Log\ b_1 X1 + Log\ b_2 X2 + Log\ b_3 X_3 + \ldots\ldots + Log\ b_n X_n + z$$

It should be noted that the WTP value for the treatment of effluents emanating from the aqua farms is influenced by certain factors. Some of these factors influence the WTP value more strongly, and the influence of some other factors is only minimal.

The variable size positively influences the WTP and the influence is highly significant. This suggests that the larger the size of the farm owned by the respondent, the higher the WTP value. In the case of initial investment made by the respondent, represented by the variable capital, the influence is negative, which means that if the size of the initial investment made is greater, the willingness to pay for treatment is less and vice versa. However, the influence of the size of the initial investment on the WTP value is not significant. But the size of the variable cost (i.e. operational) influences the WTP value negatively and significantly. This implies that if the variable cost in running the farms at present is high, then the WTP value, which would add to the existing variable cost, would be less and vice versa. The volume of effluent represented by the variable volumeff, positively influences the WTP value but not significantly. Another important variable that influences the WTP value significantly is the annual income. The sign and the magnitude of this variable suggest that the respondents who derive more amount of annual income from the aqua farms are willing to pay more for treating the effluents.

Another factor that potentially determines the WTP value is whether the capital employed is borrowed or owned. The sign of the variable suggests that if the capital is borrowed, then the level of WTP value is less and if it comes from their own sources, then the WTP value is higher. However, the influence is not significant.

Regression Model for Agricultural Productivity

$Y = a + b_1$ paddy $+ b_2$ fertiliser $+ b_3$ source $+ b_4$ category $+ b_5$ existence $+ b_6$ awareness $+ b_7$ frequency $+ b_8$ salinity $+ z$

- The cropping pattern (indicated by the variable Paddy) is found to positively influence the productivity. This means that the productivity is found to be greater in those areas where paddy is being cultivated rather than other crops.
- The amount of fertilisers used (expressed in value term) is found to significantly influence the productivity. Other things remaining the same, the more the amount of fertiliser used, the greater the productivity in the study area.
- The source of irrigation is also found to positively influence the productivity. The productivity is found to be higher if the crop is irrigated with surface water rather than the ground water.
- The level of productivity also depends on the farmer's category. The productivity is higher for the large farmers category to the small farmers.
- Existence of aqua farms within a 3 km circle positively influences the productivity, but not significantly.
- If farmers are more aware of the environmental damages caused by aqua farms, then the productivity is found to increase. This may be due to the fact that the farmers may take up some defensive measures against the ill effects of aquacultural farms.
- The frequency of cultivation is also found to increase the productivity.
- There is no correlation between the general soil salinity and the productivity. This may be due to the fact that farmers may apply more amounts of fertiliser to mitigate the ill-effects of soil salinity.

The productivity measured in terms of net farm income, is expressed in terms of average net farm income between different areas in the aqua farm region. It may be noted that the average net farm income in the three areas i.e., less than 1 km, 1 – 3 km and above 3 km does not differ much. However, the difference between less than 1 km distance and above 1 km distance is greater than that of 1 – 3 km and above 3 km distance. Note, this simple analysis reveals much about the statistical significance of the difference in the net farm income. Hence, we have used a regression analysis to find out the productivity difference caused by the distance between the location of the agricultural land and the aquaculture farms.

Pollution Cost Abatement using ETS

To overcome the environmental constraints of disposing the farm effluents in a safe manner without conflicts, the Aquaculture Authority has made it mandatory that all shrimp farms of 5.0 hectares water spread area and above located within the CRZ, and 10 hectares water spread area and above located outside CRZ, should install an effluent treatment system (ETS) or effluent treatment facility so that the shrimp farms effluent's effect could be minimised within the prescribed standards and mitigate any adverse impact on the ecology of the open waters.

For aqua farms, an Effluent Treatment System (ETS) is proposed recently which consists of 3 types of ponds viz., settlement ponds, bio-ponds and aeration ponds. The cost estimate for the construction of a 0.5 ha proposed ETS is Rs.5,48,200 /-

Management Measures

Based on these conflicts, the productivity rate of aquaculture in some areas of Tamil Nadu and Pondicherry areas met a downfall, mainly due to the havoc caused by the opposition groups against aquaculture. Therefore, these issues were analysed to identify the areas for increased productivity and for appropriate research, development and policy interventions. Evolving appropriate polices and development of sustainable shrimp farms in India is handicapped by the non-availability of quantitative and qualitative scientific data on the factors responsible for degradation of the environment. Therefore, the environmental impacts remain largely speculative and unproven.

- Intensification / diversification of farming systems has received hardly any attention, in spite of technological possibilities for productivity advance, rural income and employment generation.
- Further, the envisaged growth cannot be achieved through technological intervention alone in the absence of development efforts and benign public policies. Sustainability from both ecological and economic angles is important, so that the country could lead in the progressive export trade of aqua products.
- Development and extensive adoption of location-specific farming aiming at higher productivity, better returns and year-round employment would help to improve the quality of life inhabiting the long coastal areas.
- High investment in research and development coupled with favourable public policies are important for achieving sustainable growth in production of shrimps, when the existing base and technological strength would be too inadequate to meet the future production challenges.
- The contemplated research and development strategies towards achieving the production goals should be ecologically and economically viable, causing the least damage to our fragile natural ecosystems/ foundations.
- Adequate consideration given to legal and social aspects, policies lay out, enforced through legislation, will ensure the carrying capacity of the ecosystems.

AGRICULTURE, ENVIRONMENT AND ECONOMICS

Economic Valuation for Sustainable Land Management of Watersheds in Different Agro-Climatic Zones of Karnataka*

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Introduction

Economic valuation of environmental resources helps in making meaningful decisions on resource utilisation and allocation of scarce resources to improve environmental quality. Such evaluation calls for identification and confirmation of use or non-use of each land unit that is technically appropriate, economically viable, socially acceptable and environmentally non-degrading.

Objectives

The specific objectives of the project are to:

- Survey biophysical resources for natural accounting and quantifying land potentials and constrains
- Survey the socio-economic and institutional constraints and potentials
- Evaluate the impact of soil conservation measures
- Design spatial information systems for integration of socio-economic and biophysical data
- Bio-economic modelling for development of optimum land use plans for sustainable land management, keeping in view economic and environmental benefits and costs

Site

The project has made an attempt to assess the economic value of land resources in four watersheds - Garkahalli (GWS) Nalatwad (NWS), Pettamanurhatti (PWS) and Molahalli (MWS), which fall under the National Watershed Development for Rainfed Agriculture in Karnataka. The watersheds represent four different agro-climatic zones in the state.

Methodology

Different steps followed in soil survey and final map generation were identification of different physiographic units by rapid traverse of the area, and soil profile pits were dug at close intervals along the slope based on physiographic units. Soil profiles were examined at regular intervals down to parent material or 150 cm for morphological characterisation, and soil samples collected were analysed in the laboratory. The soils were mapped as phases of soil series. Fertility status of the farm holdings was determined by analysis for available N, P, K, Zn, Fe, Cu and Mn in surface soil samples collected from points located on an 80-m grid.

The farm households of the watersheds were enumerated (764 farmers) for assessment of socio-economic constraints and potential in natural resources management. The economic land evaluation was undertaken by econometric approach to study the effect of biophysical degradation on land productivity, replacement cost approach for estimating the cost of soil erosion, and project evaluation technique for estimating the viability of public investment on soil conservation. The cost of misapplication of soil nutrients was estimated using soil test crop

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response models. Soil potential index was estimated for rating the soil units.

Linear programming was applied to draw up optimum land-use plans for each watershed. Biophysical and socio-economic data were integrated through a Geographic Information System (GIS) for designing a spatial decision support system.

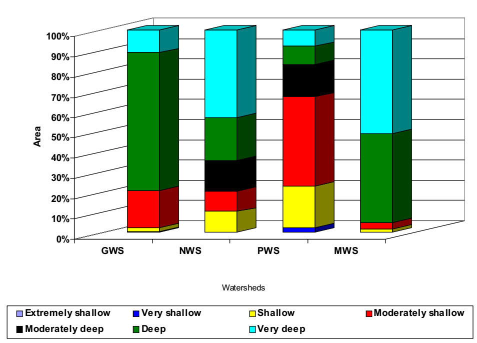
Results

Biophysical Accounting of Land Resources

Soil Depth

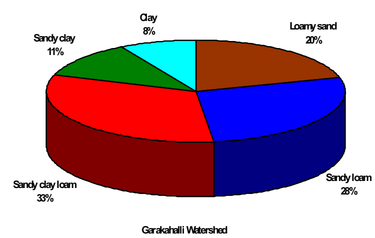
Of the four watersheds (Fig.1), Pettamanurahatti had the largest extent (130 ha) of shallow (<50 cm depth) soils, followed by Nalatwad (57 ha), Garakahalli (10 ha) and Molahalli (6 ha). Only a limited range of crops can be grown on these shallow soils, particularly short-duration crops. These soils are best suited to pasture, silvipasture and agroforestry. Moderately shallow and moderately deep soils (50–100 cm depth) covered a large extent in Pettamanurahatti (350 ha), followed by 138 ha in Nalatwad, 96 ha in Garakahalli, and least in Molahalli watershed (16 ha). Some short and medium duration crops can be grown successfully on these soils. Deep soils (>150 cm depth) occurred to the largest extent in Molahalli (415 ha), with Nalatwad (358 ha) and Garakahalli (350 ha) close behind. Pettamanurahatti watershed had about 100 ha. All types of agricultural and horticultural crops can be grown successfully on these soils.

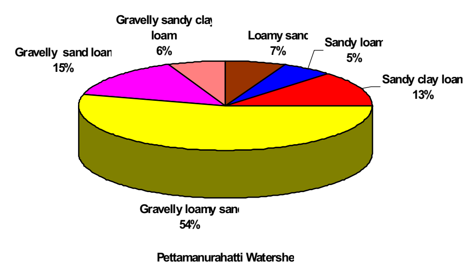
Fig. 1: Soil Depth in Different Watersheds

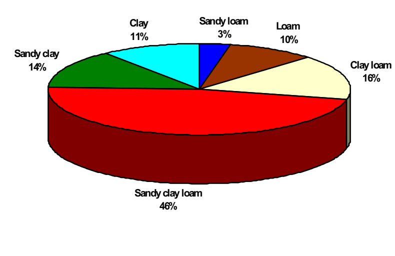


Surface Soil Texture

Surface soil texture as encountered in different watersheds is given in Fig.2. Pettamanurahatti watershed had the largest area of soils with sandy (loamy sand) surface texture. Of the other three, only Garakahalli watershed had a much smaller area (90 ha) of such soils. These soils are very poor with respect to available water and available nutrients. Loamy soils (sandy loam, loam, sandy clay loam and clay loam) were predominant in Molahalli (330 ha), Garakahalli (265 ha) and Pettamanurahatti watersheds. Nalatwad watershed had no soils with surface texture coarser than clay. Loamy soils have the advantages of high potential for available water, and are medium in available nutrient supply. They are greatly amenable to seed bed preparation and seedling emergence. About 107 ha in Molahalli and about 86 ha in Garakahalli have surface texture of clay. These clayey soils have high potential for available nutrients and available water, but drainage and tillage operations are major problems in black clay soils.







Surface Gravelliness/Stoniness

The problem of surface gravelliness and/or stoniness was not encountered in Nalatwad and Molahalli watersheds. It was a major problem in Pettamanurahatti, where soils with >35 percent gravel covered about 158 ha, with 15–35 percent gravel in about 278 ha and <15 percent gravel in 145 ha. Most of the area (340 ha) in Garakahalli had no problem of gravel. Only about 71 ha had <15 percent gravel and about 29 ha had 15–35 percent gravel. High surface gravel content was a problem in seedbed preparation and seedling emergence.

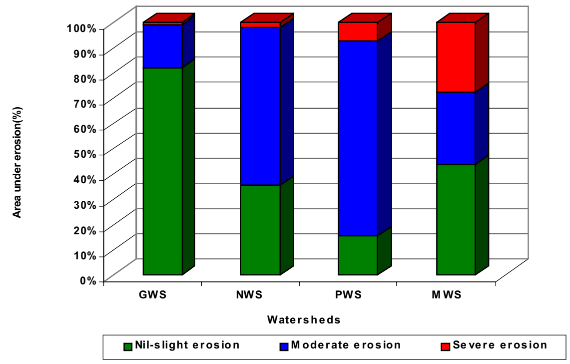
Soil Slope

In Nalatwad, most of the area was covered by very gently sloping (1–3% slope) or nearly level (<1% slope) lands. Only a very small area had gently sloping (3–5% slope) lands. In Pettamanurahatti, about 350 ha had very gently sloping lands, 129 ha gently sloping lands and 94 ha nearly level lands. Only about 8 ha had moderately sloping (5–8% slope) lands. Most of the area of Molahalli had nearly level and gently sloping lands. About 60 ha was covered by moderately sloping and strongly sloping lands (5–10% slope). Most of the area of Garakahalli watershed had very gently sloping and gently sloping lands. About 45 ha of land had major problems with slopes, and were hence unsuitable for agriculture.

Soil Erosion

Soil erosion (Fig. 3) was lowest in Garakahalli watershed, where an area of about 362 ha had no erosion or slight erosion and about 75 ha moderate erosion. Only 3 ha suffered from severe erosion. Nalatwad and Pettamanurahatti watersheds had large areas with moderate erosion and small areas under severe erosion. Erosion was rampant in Molahalli watershed with about 120 ha under severe erosion and about 125 ha with moderate erosion. About 192 ha had no erosion or slight erosion as most of this area was under rice cultivation with the land well protected by bunds and terraces.

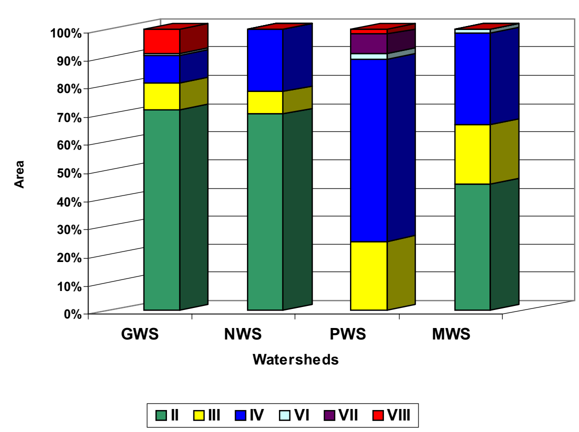
Fig. 3: Soil Erosion Status in Different Watersheds



Land Capability

The area under different land capability classes is presented in Fig.4. Three watersheds - Nalatwad, Molahalli and Garakahalli had maximum area under good cultivable lands (Class II), a small area under moderately good cultivable lands (Class III) and very negligible area (in Molahalli and Garakahalli) under fairly good cultivable lands (Class IV) suited for occasional cultivation. Most of the area of Pettamanurahatti watershed had fairly good cultivable lands suitable for occasional cultivation because of the dry climate. About 145 ha had moderately good cultivable lands and about 63 ha was not suitable for cultivation but well suited for pasture or forestry.

Fig. 4: Land Capability Classes in Different Watersheds



Land Irrigability

Molahalli and Garakahalli watersheds had about 170 ha and 323 ha, respectively under lands with moderate limitation for sustained use under irrigation. The latter had about 42 ha of lands with severe limitation and about 70 ha of lands that were marginal for sustained use under irrigation. Molahalli had 268 ha of land not suitable for irrigation. Nalatwad had mostly lands that are marginal for sustained use under irrigation because of shrink-swell clay soils. Pettamanurahatti had a large area of land that was marginal for sustained use under irrigation, and about 52 ha not suitable for irrigation.

Soil Fertility Status

The data on soil fertility status is presented in Tables 1and 2. Nitrogen status was predominantly low in Nalatwad (99%), Garakahalli (78%) and Pettamanurahatti (98%), whereas it was medium in 63 percent of the area of Molahalli watershed. Available phosphorus level was mostly low in Nalatwad (74%) and Molahalli (51%) watersheds. In the other two, low and medium levels were fairly equally distributed (38% and 37%, respectively, in Garakahalli; 44% for both in Pettamanurahatti).

Table1: Macro Nutrient Status (NPK) in Different Watersheds of Karnataka

Watershed/Nutrient	Fertility Status (% to total area)		
	Low	Medium	High
Garakahalli			
Nitrogen	78.1	5.48	16.42
Phosphorus	37.91	36.89	25.2
Potassium	23.55	46.85	29.6
Nalatwad			
Nitrogen	98.79	0	1.21
Phosphorus	74.28	21.58	4.14
Potassium	0	5.06	94.94
Pettamanurahatti			
Nitrogen	97.53	0.52	1.95
Phosphorus	44.46	44.03	11.51
Potassium	4.9	72.41	22.69
Molahalli			
Nitrogen	25.66	62.76	11.58
Phosphorus	50.55	31.05	18.4
Potassium	70.67	22.52	6.81

Table 2: Micro Nutrient Status in Different Watersheds of Karnataka

Watershed/Nutrients	Fertility Status (% to total area)	
Garakahalli	**Deficient**	**Sufficient**
Zinc	63.61	36.39
Iron	11.57	88.43
Manganese	0	100
Copper	0	100
Nalatwad		
Zinc	97.84	2.16
Iron	56.36	43.64
Manganese	0.07	99.93
Copper	0.01	99.99
Pettamanurahatti		
Zinc	85.85	14.15
Iron	68.7	31.3
Manganese	1.05	98.95
Copper	12.62	87.38
Molahalli		
Zinc	51.81	48.19
Iron	0.02	99.98
Manganese	3.56	96.44
Copper	1.41	98.59

Available potash levels were mostly high in Nalatwad (94%), medium in Pettamanurahatti (72%) and Garakahalli (47%), and low in Molahalli (71%). Among the available micronutrients (Table 2), zinc was deficient in very large areas (52–98%) of all the watersheds. In Nalatwad, 56 percent of the area was deficient in available iron in Pettamanurahatti. Most of Molahalli (95%) and Garakahalli (72%) had adequate levels of available iron. Most areas of all the watersheds had adequate levels of available manganese (84–99%) and copper (84–99%). Nitrogen, phosphorus and zinc were the common limiting nutrients in all the watersheds.

Land Suitability for Crops

Land suitability in each watershed was highly variable from crop to crop. In Garakahalli watershed, the lands were mostly as moderately suitable for coconut, finger millet and groundnut, unlike for banana, for which no land was highly suitable, although 76 percent of the area was moderately suitable. Nalatwad watershed was only marginally suitable for sorghum and wheat, while large areas were not suitable for sunflower (39%) and Bengal gram (29%), with the rest being marginally suitable. Almost the entire area of Pettamanurahatti watershed (98%) was marginally suitable for groundnut, finger millet and sorghum, whereas 70 percent was moderately suitable and 27 percent marginally suitable for rainfed pearl millet. In Molahalli watershed, the 162 ha under forest was not evaluated but was included in the area not suitable. For rice, the marginally suitable area (37%) and moderately suitable area (23%) add up to 60 percent of the area of the watershed. Plantation crops that were compatible with land qualities in the watershed were arecanut (21% highly suitable, 17% moderately suitable) and coconut (14% highly suitable, 20% moderately suitable). Evaluation of the lands for cashew resulted in 14 percent area being moderately suitable and 24 percent marginally suitable.

Socio-economic Features of Farm Households

Most of the farm households had marginal and small holdings (<2 hectares), accounting for 80 percent. About 85 percent of the farmers possessed land records in their name, mainly for security and for availing of crop loans. Illiteracy was widely prevalent among marginal and small farmers; institutional participation was very low among these households. Large farmers had better institutional participation. Crop production was the main occupation for 72 percent farm households along with business, dairy enterprise, agricultural labour, sheep (and goat) rearing as subsidiary occupations. Average annual household income was highest among large farmers followed by small and marginal farmers.

The working population was engaged in different activities/occupations as seen in the data on occupational pattern presented in Table 3. Of the farm households in Garakahalli, 113 (45%) were engaged in crop production and sericulture; no households in the other watersheds practiced sericulture. In Nalatwad and Molahalli, around 4 and 34 percent, respectively, of the farm households (5 and 50) did not have any subsidiary occupation, and were dependent on crop production as their main source of income. The combination of crop production and agricultural labour accounted for 14, 10, 13 and 38 percent of households in Garakahalli, Nalatwad, Pettamanurahatti and Molahalli watersheds, respectively.

Table 3: Farm Household Occupational Pattern in the Watersheds

Occupation		Garakahalli		Nalatwad		Pettama-nurahatti		Molahalli	
Main	Sub-sidiary	Num	%	Num	%	Num	%	Num	%
Crop production	—	0	0.00	5	3.70	0	0.00	50	34.01
Crop production	Seri-culture	113	45.02	0	0.00	0	0.00	0	0.00
Crop production	Agric. labour	35	13.94	14	10.37	29	12.55	56	38.10
Crop production	Sheep, goat rearing	14	5.58	2	1.48	78	33.77	0	0.00
Agric. labour	Crop production	32	12.75	0	0.00	24	10.39	0	0.00
Sheep, goat rearing	Crop production	0	0.00	0	0.00	13	5.63	0	0.00
Crop production	Dairy enterprise	46	18.33	38	28.15	60	25.97	18	12.24
Rural artisans	Crop production	1	0.40	1	0.74	23	9.96	2	1.36
Business	Crop production	6	2.39	61	45.19	2	0.87	14	9.52
Govt. service	Crop production	4	1.59	14	10.37	2	0.87	7	4.76
Total		251	100.00	135	100.00	231	100.00	147	100.00

Crop production as main, and sheep and goat rearing as subsidiary occupations were prominent among Pettamanurahatti households (78% and 34%). The number of households with this combination of occupation was 14 in

Garakahalli and 2 in Nalatwad. Sheep and goat rearing was a main occupation (13 households, 5.63%) only in Pettamanurahatti.

The combination of agricultural labour as main, and crop production as a subsidiary occupation, was practiced by 32 (13%) households in Garakahalli and 24 (10%) in Pettamanurahatti. In Nalatwad and Molahalli however, agricultural labour was not a main occupation.

Crop production and dairy enterprise as main and subsidiary occupations were practiced by 46 (18%) households in Garakahalli, 38 (28%) in Nalatwad, 60 (26%) in Pettamanurahatti and 18 (12%) in Molahalli. Business and crop production as main and subsidiary occupations were followed by 61 (45%)households in Nalatwad and 14 (10%) households in Molahalli. This combination was not common in Garakahalli and Pettamanurahatti. Rural artisanship and crop production as main and subsidiary occupations accounted for 0.4, 0.7, 10 and 1 percent of the household income in Garakahalli, Nalatwad, Pettamanurahatti and Molahalli watersheds, respectively. Government service and crop production as main and subsidiary occupations, were practiced by 10 percent or less of the households in the four watersheds.

Population pressure in the four watersheds is presented in Table 4.The average size of land holding was 4.15 ha in Nalatwad, 2.25 ha in Pettamanurahatti, 2.05 ha in Molahalli and 1.22 ha in Garakahalli. The availability of land per person in Nalatwad was 0.56 ha, in Pettamanurahatti 0.35 ha, in Molahalli 0.3 ha and in Garakahalli 0.21 ha. On the other hand, the availability of land per animal was 1.55 ha, 0.35 ha, 0.33 ha and 0.16 ha in Nalatwad, Molahalli, Garakahalli and Pettamanurahatti watersheds, respectively. Nalatwad ranked first in terms of availability of land per person and also per animal. Garakahalli ranked first in density of human population and Pettamanurahatti in density of animal population.

Table 4: Population Pressure in the Watersheds

Item	Garakahalli	Nalatwad	Pettama-nurahatti	Molahalli
Number of farm households	251	135	231	147
Cultivable land (ha)				
Rainfed	222.96	559.60	474.45	261.46
Irrigated	83.69	0	45.12	39.49
Human population	1454	993	1489	1020
Animal population	927	361	3318	858
Density (per hectare)				
Human	4.74	1.77	2.87	3.39
Animal	0.60	0.65	6.39	0.81
Average size of				
land holding	1.22	4.15	2.25	2.05
Cultivable land available (ha)				
Per person	0.21	0.56	0.35	0.30
Per animal	0.33	1.55	0.16	0.35

The use of inputs in crop production by all the farmers was lower than the package of practice recommendations, and so was the output obtained, which may be attributed to non-availability of inputs, financial position, untimely application and poor crop management practices. The wide gap in inputs adopted in cultivation of all the crops in the watersheds reflects the farmers' inability to use the inputs due to financial constraint and availability, and poor management practices. Further, climatic and soil conditions play a major role in the quantity of output realised. Crop production was the main source of income of Molahalli and Garakahalli farmers. Sheep and goat rearing was a major source of income for Pettamanurahatti and petty business for Nalatwad's watershed farmers.

Impact of Watershed Development Programme

Soil and water conservation measures were given the greatest importance under the watershed programme by investing a minimum of 98 percent of the total outlay on them. About 80 percent of the farm households received benefits. Fallow area decreased after the watershed programme.

There was a marginal increase in agro-biodiversity. The watershed programme increased the average annual household income through crop production and dairy enterprise among farm households. Among marginal farmers, the increase in income was more in crop production, while for small farmers it was in dairy enterprise followed by crop production. The overall food consumption and calorific intake increased in farm households.

Impact of Watershed Development on Net Income of the Farmers

The pooled net income of the farmers in the watershed before the watershed development programme was instituted, was lowest in Nalatwad watershed (Rs.15,67,855) and highest in Garakahalli (Rs.100,16,315). It was about Rs.46 lakhs in Molahalli and Rs.55 lakhs in Pettamanurahatti (Table 5). After the implementation of the watershed programme, the net income improved by less than Rs.1 lakh in Molahalli to nearly Rs.3 lakhs in Nalatwad. The change in income was a function of the area under cultivation, type of crops and fertility of the soil.

Table 5: Impact of Watershed Programme on Pooled Net Income of Farmers of the Watersheds

Item	Garakahalli	Nalatwad	Pettama-nurahatti	Molahalli
Net income before development Rs.	10016314.80	1567855.00	5522793.42	4574472.42
Net income after development Rs.	10255289.39	1860698.00	5742835.00	4667169.00
Incremental income Rs.	238974.59	292843.00	220041.37	92696.73

Economic Evaluation of Investment in the Watersheds

The worthiness of the investment was evaluated using four criteria - pay-back period, net present worth, B: C ratio and IRR (Table 6). All the four criteria revealed the economic feasibility and commercial viability of the investment of about Rs.20 lakhs in each watershed for various soil and water conservation measures, including land development activities.

Table 6: Economic Evaluation of Investment in the Watersheds

Criterion	Garakahalli	Nalatwad	Pettama-nurahatti	Molahalli
Pay-back period, yrs.	6.42	7.00	7.25	6.5
NPW @ 12%, Rs.	195379	288441	24375.34	93060
NPW @ 15%, Rs.	–85225	–102285	–233997.24	–15785
B:C ratio	1.146	1.13	1.132	1.151
IRR, %	13.39	14.2	12.19	13.71

In general, it would be possible to recover the entire macro-investment made in the watershed programme in 6 to 7 years. The benefit-cost ratio indicated that every Rupee of investment in the watershed yielded an incremental net return of at least Rs.1.13. The internal rate of return was greater than the opportunity cost or the present lending rate, and hence the investment in the four watersheds was economically viable, commercially feasible and financially sound.

Farmers' perceptions of soil constraints were that the soil slope, loss of topsoil and nutrients due to soil erosion, and perennial weeds reduced the crop yield by 19 percent, which in turn decreased the land value in the watershed. All the farmers used soil and water conservation practices like sowing across the slope, application of farmyard manure, small section bunds and contour bounding. The perception among the farmers was that non-adoption of these measures would result in crop loss between 5 and 38 percent.

Bio-economic Modelling

The methodology for integration of environmental and economic aspects into bio-economic modelling develops a framework for environmental-economic decision-making that includes environmental and economic sustainability criteria, and local people's preferences in the context of a rainfed agriculture system using multiple objective programming.

Derivation of sustainability criteria at the watershed level may range from defining a concept as maintenance of resource productivity over time to a socially acceptable agricultural system. The criteria may include:

- Maintenance of soil health and soil qualities of the resource base
- Low dependence on external inputs
- Economic viability
- Local farmer-acceptability

The land capability and suitability analysis is considered a governing criterion to maintain the resource base in the long term. Input-output ratios with consideration of environmental costs (soil nutrient depletion) are considered to be environmental and economic indicators reflecting the second and third criteria above. Local people's preferences and choices from various available alternatives are considered farmer-acceptability criteria.

Land Capability/Suitability Criteria

This criterion was related to maintenance of the soil resource base and agricultural productivity. However, it was rather difficult to measure this over time and provide its value in economic terms. The spatial-sustainability analysis using land capability and suitability provides a sound basis as governing criteria for maintaining the soil resource productivity over the long run, and integration of ecological sustainability criteria into the cost-benefit analysis valuation of soil phases. Hence, maximisation of the total net income resulting from optimum cropping area based on land suitability analysis was considered as an objective.

Input-Output Ratio

One main concern for achieving sustainability is to increase resource-use efficiency. Minimisation of labour (both manual and animal) used for crops provides a basis for selection of the most efficient area allocation for increasing resource use efficiency. This was accommodated through minimisation of manual and animal labour requirement in farming as objectives.

Environmental Criteria

Selection of a mix of crops that utilise the maximum farmyard manure and minimum of chemical fertilizers is the main concern for sustainable land use. Hence, the objectives were set as maximisation of farmyard manure and minimum use of chemical fertilizer (NPK) for cultivation of crops.

Farmers Acceptability

Another major concern of agricultural sustainability is local farmers' acceptability. Farmers' preferences play a very significant role both in planning and implementation of alternatives aimed at sustainable use of resources. The households' food needs were estimated and incorporated in the model as the minimum area under food crops to reflect their minimum food needs and self-sufficiency.

The results of linear programming models using multiple objectives suggested different sustainable land use alternatives for four micro-watersheds. These models are normative plans, which reveal what ought to be the cropping pattern and land use as well as net income as per each objective. It is interesting to note that all the nine optimisation models in all the four watersheds, clearly recommended larger areas under cereals like finger millet, sorghum and paddy, depending on the soil suitability, for maximisation of net income of the farmers, except in Pettamanurahatti where groundnut is grown in a larger area.

The normative plans showed better use of land and other inputs, which were reflected in terms of high net income and lower cost than the existing levels. The least increase in net income (over the existing level) was 12.87 percent in Molahalli, while the highest was at 138.45 percent in Garakahalli. The efficiency in cash expenses through reduced costs varied from a minimum of 17.74 percent in Molahalli to a maximum of 53.99 percent in Garakahalli.

Similarly, the total use and use/ha of men and women labour days, nitrogen, phosphorus and potash were lower in normative plans than the existing patterns in all the watersheds. The recommended total use and use/ha of farmyard manure was higher in consonance with the objective set forth in the model.

An examination of net income realised and the cost incurred per hectare between existing and normative plans in all the watersheds, revealed that the possibility exists of increasing the net income by at least Rs.873/ha in Molahalli, Rs.1,575/ha in Nalatwad, Rs.1,762/ha in Pettamanurahatti and the highest of Rs.17,971/ha in Garakahalli watershed.

The increase in net income in percentage and per hectare through adoption of the normative plans in all the watersheds definitely shows the possibility of improvement in the land productivity through resource allocation in accordance with land capability and suitability.

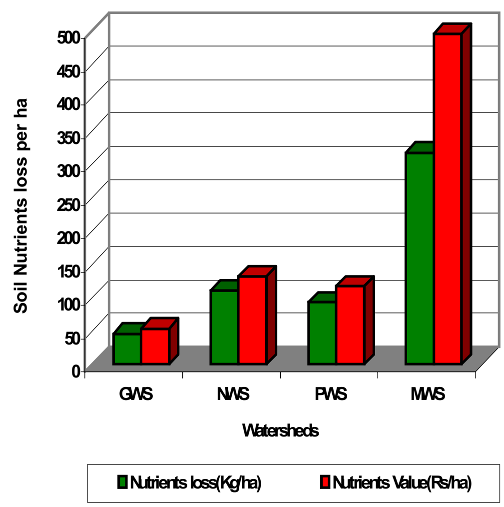
Economic Land Evaluation

Evaluation of the cost of soil erosion and benefits from productivity depend on how the soil is valued. As a natural resource, soil may be viewed in different ways. It has a direct-use value as a medium for plant growth, and an indirect-use value in terms of absorbing rainfall and mitigating floods. Other kinds of value are bequest value (to future generations that will rely upon it), and existence value in global terms for biodiversity and habitat for plants and animals. The total economic value of soil is the sum of all these values. The direct-use value expressed in this watershed was based on soil productivity, which concerns land users the most.

The Replacement Cost Approach

The replacement cost approach looks at the cost of restoring a damaged resource asset. This approach focuses on the loss of nutrients and its costs, which are valued at the market price of organic and inorganic chemical fertilizers containing the same quantity of nutrients depending upon the degree and extent of soil erosion in each watershed. The total annual soil nutrient loss due to soil erosion was maximum in Molahalli (Rs.1,39,336) followed by Nalatwad (Rs.61,294), Pettamanurahatti (Rs.54,271) and minimum in Garakahalli (Rs.20,155). The per hectare soil nutrients loss in different watersheds are presented in Fig. 6.

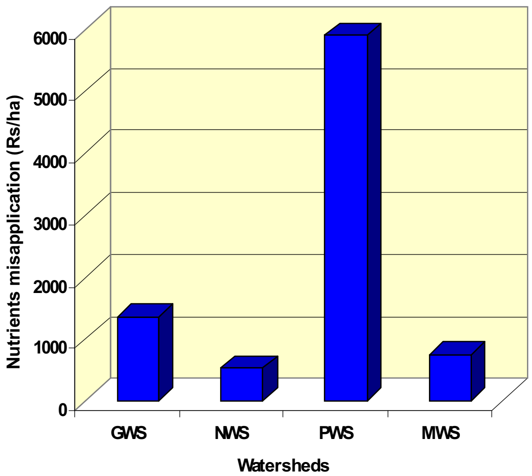
Fig. 5: Annual Soil Nutrients Loss due to Erosion



Cost of Soil Nutrient Misapplication

The cost of misapplication of soil nutrients was estimated taking the absolute difference between the levels of nutrients actually added by the farmers and the nutrients required for achieving the farmer's yield based on soil tests. The results indicated that the per hectare misapplication cost for NPK was maximum in Pettamanurahatti (Rs.5,903), followed by Garakahalli (Rs.1,365), Molahalli (Rs.752), and minimum in Nalatwad (Rs.523).

Fig. 6: Cost of Nutrients Misapplication in Crop Production



Production-function Approach

The production-function analysis done separately for each crop revealed that the soil depth had a significant influence in increasing the crop yield, and with increase in soil erosion, would cause a corresponding decrease in yield.

Characterisation of Farm-level Sustainable Land-management Indicators

Sustainable farming is the process by which a farmer manages soil and water, relying on on-farm resources to enhance productivity and maintain it to meet farm and family needs without affecting the production environment. The farm-level analysis of sustainability involves identification of components that reflect sustainability, and can be operationalised and measured spatially. There is unanimity in the understanding that sustainability of a farming system has three dimensions - ecological, economic and social.

The ecological dimension consists of nutrient management. The economic dimension includes land productivity, input productivity and crop yield security. The social dimension contains input self-sufficiency and family food sufficiency.

The mean value sustainability index was highest in Garakahalli (54.55) followed by Molahalli (51.90), Nalatwad (50.25) and low in Pettamanurahatti (48.08). The low sustainability in Pettamanurahatti watershed was mainly due to low ecological safety, as their nutrient management index was poor, and low family food sufficiency as they were not growing their food requirement, but purchasing food grains, which resulted in low sustainability of farming.

Sustainability is not limited to maximising production, and includes ecological sustainability, which is essential for long-term viable crop and animal production. Major problems that hindered Pettamanurahatti farmers from attaining high sustainability were: non-application of bio fertilizers and crop residues, mono-cropping, untimely farming operations, dependence on external inputs and large family size.

Organic farming, which includes usage of farmyard manure, green manure, crop residue and bio fertilizers, enhances soil health, provides required nutrients for crop growth and improves productivity. Other possible recommendations for minimising long-term damage to the soil could be improvement of livestock possession, crop rotation with leguminous crops, making the farm self-sufficient with own inputs, and bringing about awareness of the benefits of soil and water conservation, especially in dryland agriculture.

Conclusion and Policy Implications

- The land resources are limited in all the four watersheds as almost all arable land is already under cultivation. Rainfed agriculture in these watersheds is characterised by low quantity of input use and low level of productivity. Being dependent on rainfall, crop production is subjected to considerable instability from year to year. The food security issues therefore, need to be addressed through sustainable intensification and more efficient use and management of land.
- Soil degradation processes are driven by socio-economic factors, which lead to mis management of land.
- The available soil database indicates the actual/potential productivity under different land use systems. The information on loss of soil nutrients due to erosion helps policy

makers and planners identify policies that minimise soil degradation.

- The data on misapplication of soil nutrients emphasise the need to shift the emphasis on soil fertility *per se* to imbalance between nutrient input and output. This calls for refinement of fertilizer recommendations. The environmental effect of such misapplication and nutrient mining calls for integrated nutrient management strategies for soil health restoration.

- The extent and cost of land degradation are high and alarming. Adequate land use policies and land management programmes must combine development and environmental goals, and implement them through an integrated and participatory approach. Generation of off-farm employment opportunities can reduce the pressure on marginal land.

- The environmental and economic impact assessment of watershed development programmes in the four watersheds indicates that the efforts of watershed development on soil and water conservation are economically viable.

- There is no follow up and maintenance of soil and water conservation structures after implementation of the project. The watershed *sanghas* are defunct in these locations. The investment in human and social capital in terms of improving skills and creation of awareness about soil use and management has been given less priority in the present pattern of watershed development programmes. There is a need to give importance to this, as it will directly contribute to planning and capacity building in farm households.

- Government policies with respect to fertilizer subsidies and support prices have an impact on land resource use and management. Increase in support price/market prices of groundnut increased the pressure on marginal lands and depleting of soils. The differential pricing of fertilizer subsidies leads to imbalance in the use of fertilizers (more of N and P and less of K).

- Based on scientific assessments and farmers' knowledge systems, the problems of land use and management and production constraints were identified and ranked according to severity of problems. These should be used for research prioritisation in natural resource management and development of location-specific policy strategies and measures for sustainable land management.

- The legal aspects of land use and land ownership indicate that people who possess land records are better at managing the land than the other groups who do not possess land records. This justifies the need for giving priority attention to this area by government policy for providing land titles to the farmers.

- Sustainable land management could only be a success once soil health care is ensured. In order to ensure soil health care, the introduction of soil health cards in land development programmes is essential. The objective of the soil health card is to generate awareness among farmers about the vital natural resources for its optimum use, and to adopt land use as per land capability. It provides vital information for policy makers, and for soil conservationists to implement development programmes and research prioritisation.

- A people-centric approach should be well adopted in the implementation of optimum land use plans as per the soil capability/ suitability that can improve the productivity and net income of farm households on a sustainable basis.

- The suitability and productivity of crops depends on *in situ* land qualities. There is a positive relationship of land productivity with soil depth and water holding capacity, and a negative relationship with soil erosion, gravel, salinity and slope of land.

- The accessibility of ready market and transport facilities influence the type and intensity of land use. Garakahalli watershed farmers with good accessibility to Bangalore markets, are growing more commercial crops like mulberry, banana and coconut compared to Nalatwad, where they are growing only sorghum due to lack of accessibility and markets.

- The spatial attributes of size of land holding influence the intensity of input use and the land slope, shape and size of the plot, influence on adoption of soil conservation and the land management practices.
- The economic value of a land use system implemented on a given land area (land evaluation) is not equal to the market value (land valuation), although the predicted returns to a land unit of various land uses obviously influences its price. It was found that there is a positive relationship (R^2 =0.91) between the economic value estimated by land evaluation and farmers' perceptions of market value of land in all the four locations.
- Sustainable land management is only possible through precision farming. Precision farming is the term used to describe the goal of increased efficiency in the management of agriculture. This study assessed the spatial variability of soil nutrients and gave an insight into the need for practicing precision farming by following different levels of soil nutrients, depending upon the soil fertility and yield potential of the crop in the watershed.
- This study calls for use of both biophysical and socio-economic considerations in planning and implementation of government development programs in the management of natural resources. The optimum land use plans provide site-specific conservation programmes and crop management, bringing out economic and environmental considerations in land management.

Environmental, Socio-Economical and Institutional Aspects of Technology Adoption: Integrated Pest Management (IPM) in Rice Cultivation in the Union Territory of Pondicherry

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Introduction

Integrated Pest Management (IPM), a new concept in the field of crop protection, emphasizes the simpler and ecologically safer measures for pest control to reduce the environmental problem and other problems caused by excessive and indiscriminate use of pesticides. Agenda 21 of the United Nations Conference on Environment and Development (UNCED) at Rio de Janerio in June 1992 identified IPM as one of the requirements for promoting sustainable agriculture and rural development. The Government of India recognized the benefits of IPM and adopted it as the main plank of the plant protection strategy in its overall crop production programme. The Pondicherry administration has introduced IPM for rice from 1994-95, and since then pesticide consumption has shown a declined trend. Hence, this study was undertaken to evaluate IPM adoption by the rice growers in Union Territory of Pondicherry, India.

Objectives

The objectives of the present study were to:

- Examine the impact of Integrated Pest Management (IPM) technology in rice cultivation on the pesticide use, residual toxicity, yield of rice and other production related parameters in Pondicherry.
- Study the factors responsible for the adoption of IPM along with the institutional arrangements, which further the adoption of this technology.
- Document the problems and constraints faced by the farmers in the adoption of IPM, and to gain an insight into how IPM can be promoted by addressing the binding constraints.

Methodology

The study was based on a sample of 500 respondents comprising 450 farmers and 50 extension workers. Major statistical techniques employed were factor analysis, frontier production function, logistic regression and relevancy rating index. Besides the above econometric tools, biodiversity index were developed based on field observations, residue analysis were carried out on the products from farms, and soil micro-organisms were also studied on soil samples collected from rice fields.

Results

The findings from the study were as follows:

- Contrary to the belief that IPM leads to reduction in yield, the yield level of rice among adopters was 2018 kg/acre, as against the non-adopters who produced only 1783 kg/ acre.
- To determine the relationships between the output and its determinants, a Cobb-Douglas regression was fitted to the data on total output. The independent variables such as Plant Protection Chemical (PPC) was found to be negative in both adopter and non-adopter farms, clearly indicating that it is overused and its use could be reduced.
- Comparing the output difference of rice between the adopters and non-adopters, it was found that the difference of around 19 percent could be attributed to the adoption of superior technology (53 %) and use of inputs (47 %), which proves the superiority of IPM technology over the conventional method of rice cultivation.

- Farmers used pesticides over and above the recommended levels as they felt that the recommended doses were insufficient to control pests. The reverse reason was put forth by the respondents to explain the sub-optimum level of pesticides usage to lack of knowledge with regards to the efficacy of pesticide use, and was an important determinant for the sub-optimal use of pesticides in rice cultivation.

- Since the adverse impact of pesticides is not immediately visible, a majority of the farmers (50 %) opined that it had little or no effect on humans, livestock and the environment. About 42 percent opined that it would have a moderate effect and only 8 percent felt the impact would be serious. However, over 80 percent of both adopters and non-adopters took safety measures during the application of pesticides.

- A majority of the respondents did not observe any apparent effect of pesticides on livestock and human beings, whereas adverse effects on beneficial insects and butterflies were reported.

- The Biodiversity index in adopter farms was more diverse than non-adopter farms, so was the case with reference to Evenness index, indicating more stable IPM farms than non-IPM farms.

- The residue analysis of rice grains, straw, husk, bran and soil revealed that the residues of organochlorine compounds were found Below Detectable Limit (BDL) in adopter farms, whereas it was found above BDL and below the Maximum Residue Limit (MRL) in non-adopter farms. With regard to organophosphorous compounds, the residue of monocrotophos was above BDL as well as MRL in non-adopter farms, whereas it was below detectable limit in adopter farms.

- Small and marginal farms were influenced by membership of several organisations and contact with Agricultural Extension Personnel (AEP). On the other hand, the IPM traps influenced large farmers. However, the overriding consideration for the adoption of IPM was the idea of reducing the use of pesticides. This was an important factor influencing IPM across land holding groups.

- Education and experience was in general, higher among the adopters.

- Farmers adopting IPM had higher agricultural incomes per household per annum. The same was true of non-agricultural income.

- Training in IPM had a bearing on the levels of adoption of the technology. 75 percent of the adopters were trained, whereas only 33 percent of non-adopters were trained.

- About 75 percent of the adopters had frequent contact with the Agricultural Extension Personnel, whereas among the non-adopters, only 35 percent of them had this vital contact. This underscores the importance of the AEP in promoting IPM in a big way.

- Training on IPM is an important determinant of adoption and shall be strengthened. Farmers preferred to have training in the nearby fields, rather than in the village or office.

- 64 percent of Agricultural Extension Personnel (AEP) have felt the need for personal incentives, which is likely to improve the efficiency of their work and thereby, the adoption rate of IPM., incentives also need to be given to farmers need to be given as opined by 86 percent of AEP.

- The post-training contact between farmers and AEP was fulfilled in about 86 percent of cases, whereas the remaining 14 percent have not been able to take additional trips due to added work and other reporting procedures that curtailed their time.

- Over 70 percent of the AEP respondents felt that they were indeed important functionaries in promoting IPM, and that fixing of targets for training was essential. 66 percent also felt that) the farmers should be attracted to attend these training programmes through inducements as incentives, etc., and that wide publicity should be given for IPM through fellow IPM adopters.

- It was observed that the major problem faced in the adoption of IPM was scarcity of labor, compounded with increased wages and the time consuming nature of IPM practices.

Recommendations

Based on the findings of the study, the following important recommendations are suggested:

- Government intervention to influence farmers' choice of technology can be justified by the environmental and public health implications of pesticide use. Hence, there is a need for orientation of research and technology policies to generate a steady supply of relevant pest management information and technologies, including adequate budget allocations for research, extension and training.
- Establishment of a national IPM policy framework providing a useful first step in implementing an IPM strategy at the national level.
- Develop a system that increases the awareness of policymakers, consumers and producers of the hazards of pesticide use.
- The adverse impact of pesticides was not felt by a majority of the farmers. Therefore, educational activities must be organised to create awareness on the ill-effects of pesticides and to develop a more positive attitude towards IPM.
- Monetary benefits are the major driving force behind decisions made by the farmers. The Agricultural Extension Personnel need to be trained on the economic advantages of IPM adoption so they inturn can disseminate this information effectively to the farmers.
- The analysis of the efficiencies suggest considerable room for productivity gains for IPM adopter farms, and thereby an increase in their income through better use of available resources, given the state of technology. Consequently, policies must be suggested to improve education and extension services by further investment in human capital and related factors.
- Dissemination of IPM practices by fellow farmers should be given importance during trainings as it could have a significant influencing effect.
- The number of beneficiaries per training or the number of trainings per year is to be increased so as to disseminate the information on IPM widely, and to minimize the effect caused due to neighbouring fields. As the government machinery may find it difficult to achieve this in the immediate future, steps may be taken to encourage voluntary agencies and private institutions to participate in the programme.
- In general, the adopters and non-adopters were unaware of the toxic residue of pesticides and their harmful effects on human and cattle population. Hence, pesticide toxicity and its residual effects need to be highlighted in trainings.
- The result of residue analysis reveals that the IPM products have low pesticide residues. One of the incentives hitherto lacking in India is premium price on pesticide-free or low pesticide residue product. This is s due to lack of domestic market for such products. On the other hand, consumers are becoming aware, and particularly in the case of better-off/ better-informed, preferring the given low pesticide residue alternative solution. If there are backed up, dependable standards, there may be potential for growers to receive a premium for supplying certain markets. There may be good prospect for the development of potentially lucrative export markets if farmers can establish and maintain quality.
- Efforts need to be taken by research institutions in identifying and developing practices that are time saving, cost effective and sustainable in the long run.
- As the major problems faced with regard to adoption have been the labour requirement and thereby additional wages, labour saving technologies need to be developed.

- Apart from imparting IPM training, the department has to take efforts to enthuse its staff in making frequent trips to the fields so as to provide farmers with regular information on IPM practices.
- The efficiency of Agricultural Extension Personnel can be improved by providing them with incentives. Similarly, farmers need to be paid incentives in the form of cash and kind to lure them into IPM adoption.
- Wide publicity and emphasis through easy-to-read and colourful printed materials regarding IPM practices needs to be made available to farmers to reinforce the message given to them.
- Variations in the extent of IPM adoption by farmers call for the intensification of educational efforts by Agricultural Extension Personnel.
- Human resource development in IPM needs to be given a time-bound priority through utilization of trained resource manpower for imparting training to extension functionaries and to farmers at grassroots levels.

Economic and Environmental Impact Assessment of Biodiversity On and Around Farms

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Introduction

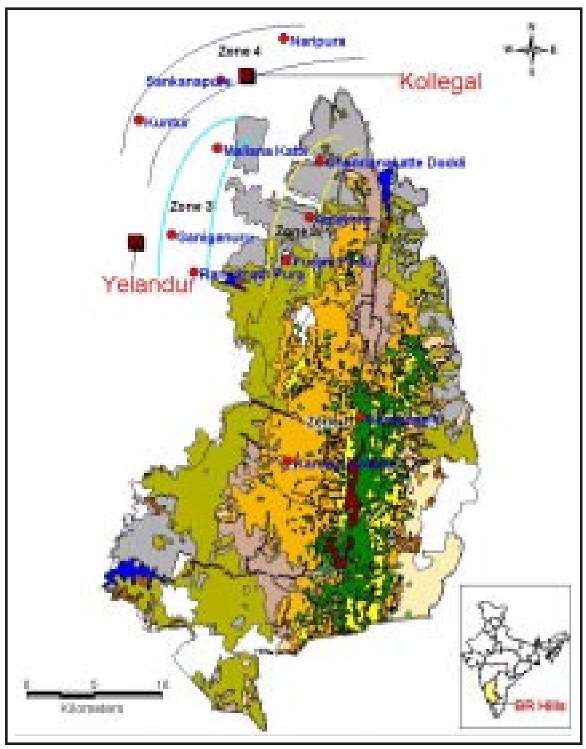
The need for maintenance of Biodiversity On and Around Farms (BDOAF) is important because the biodiversity ecosystem is complex and fragile. Moreover, it provides various economic and non-economic benefits. Traditionally in many regions of India, eco-friendly farming systems have been practiced. Due to apparently high profits of mono-species cropping systems (High Yielding Varieties and hybrids), the free-rider problem associated with common property resources (CPRs), market failures and the loss of biodiversity due to unabated degradation of ecosystems, society is inadvertently losing many of the direct and indirect environmental and material benefits from these areas.

According to the tenets of ecology, a certain minimum level of biodiversity has to be maintained for the sustenance of the ecosystem. In this study, the *'Soliga'* community, which continues to practice eco-friendly agriculture that is akin to the BDOAF concept, was studied. The BDOAF is viewed as a benefactor of a multitude of direct benefits and environmental services to the system vis-a-vis modern agriculture. Further, there is a need to demonstrate the benefits and services, and valuation of these benefits and services. The study draws a comparison between farms located in zones with different levels of biodiversity.

Study Area

The Biligiri Rangaswamy Temple (BRT) Wildlife Sanctuary (Fig. 1) along the eastern part of the Western Ghats, (Chamarajanagara district, Karnataka) presents an ideal setting for the study. The BRT sanctuary is spread over an area of 540 sq. km. located in the confluence of the Eastern and Western Ghats, and harbors different types of forests ranging from shrubs, deciduous evergreen sholas to grasslands. An indigenous tribe, *'Soligas'* inhabit the sanctuary. The tribe practices agriculture in the most traditional way at the core of the forest, while relatively input-intensive farming systems are located in the periphery of the sanctuary. Outside the sanctuary, farming systems are commercial in nature, which adopt input-intensive farming methods. The agriculture at the core of the forest practiced by the *Soligas,* is characterized by biodiversity rich surroundings and derives a lot of ecosystem benefits, whereas the agriculture outside the sanctuary is biodiversity poor and depends on external sources for inputs.

Fig. 1: Map of Biligiri Rangaswamy Temple (BRT) Wildlife Sanctuary (Study Region)



Sampling Design

Farms were selected from four zones, namely core (Zone-1), buffer (Zone-2), periphery (Zone-3) and outside the sanctuary (about 4-5 km away from the boundary of BRT - Zone-4). These four zones represent varying levels of biodiversity, and hence the nature of farming practices differs. From these four zones, 30 farmers each (a total sample size of 120 farmers) were selected. From the farms, data pertaining to various facets / aspects of farming systems and activities were collected using both structured and unstructured schedules which were developed for this purpose.

Objectives

The objectives of the present study are to:

- Establish the degree of influence of BDOAF on resilience and sustainability of farming systems.
- Study the institutional and social factors those sustain traditional farming.
- Assess economic, environmental and supplementary benefits, and associated direct and indirect costs in traditional farms (BDOAF) vis-a-vis commercial agriculture
- Study inter-sectoral flow of resources, backward and forward linkages and determine the extent of dependencies of farm families on BDOAF.
- Study the resource use pattern and resource allocation efficiency of farms with varied levels of BDOAF.

Methodology

The sustainability and resilience of the spectrum of agro-economic-systems with varying levels of biodiversity were analyzed using economic, ecological and environmental indicators determined *a priori*. To examine sustainability, the indicators computed are: degree of crop heterogeneity on farms; share of eco-friendly inputs in the total cost of cultivation of the crops; ratio of cost of various inputs to the total cost of cultivation of the crops; net energy efficiency and income diversity index. For assessing the resilience, the indicators considered are: average cash cost per unit of output; average cash cost per rupee of gross returns; sensitivity analysis; Herfindahl index; Simpson index and threshold yields.

Information on formal, informal and social institutions prevalent in the area and attitudes and perceptions of people in sustaining the traditional farming were elicited.

To assess economic benefits, the total economic value of BDOAF was computed considering the returns or the benefits from and the associated costs of crop and livestock diversity, kitchen garden and trees on farms, and Non-Timber Forest Products (NTFPs). To assess environmental benefits, the flow of environmental benefits from the BDOAF were identified and expressed on a four-point scale in order to reflect the magnitude of flow of these services in each zone. The three environmental goods and services, namely chemical-free products, medicinal plants and eco-tourism, were quantified using Contingent Valuation Method (CVM), Replacement Cost Approach and Travel Cost Method (TCM) respectively. To assess the supplementary benefits, the value of benefits from NTFPs, kitchen garden and trees on farms were considered. These products were valued by considering the value of close substitutes or opportunity cost.

The Social Accounting Matrix (SAM) approach was employed to study the inter-sectoral flow of benefits between forestry (NTFPs), agriculture, livestock and other sectors of rural households and dependency of farms on BDOAF. The production multiplier matrices of different zones helped to prioritize investment decisions, which would enhance the welfare of the economy.

Resource-use pattern was studied to assess the extent of use of various inputs by the farmers. Allocative efficiency of input use in crop production was studied to know the scope for additional input use to maximize profit.

Environment Economics Component

- *Economic value of reduction in dependence* of farms on external inputs due to environmental and economic benefits from eco-friendly farming system of BDOAF was estimated for all the zones by computing shares of farm and non-farm sources of inputs.

- *Ecosystem health indicators* were assessed by considering the extent of use of inputs and agricultural practices, which do not interfere with the ecology of the system. The indicators of general health of the ecosystem, namely, the level of use of mechanical and chemical energy, crop and tree diversity and value of eco-friendly food produced on the farm were considered.

- *Quality of life* of the people in different zones was analyzed in terms of nutritive foods (in value terms) and proportion of this derived from farm sources. It was hypothesized that the higher the proportion of nutritive foods derived from the farm sources, the better would be the quality of life as food derived from the farm sources is normally free of chemicals.

Table 1: Environmental Economics Component

Characteristic	Zone-1	Zone-2	Zone-3	Zone-4
Reduction in dependency on external sources for inputs (Rs & %)	2257.59 (100.00)	2442.74 (91.18)	1188.38 (34.94)	855.28 (36.53)
Total purchased inputs on farm (Rs)	0	236.27	2213.17	1486.23
No. of farmers using plant protection measures for ragi crop	0	0	1	2
Fertilizers (kgs)				
- Ragi	0	22.09	34.33	43.24
- All crops	0	34.86	187.38	233.97
Simpson index for tree species diversity on farms	0.56	0.41	0.24	0.20
Percent acreage under input intensive crops	0	20	77	91
Usage of mechanical power (Mega Joules / acre)				
- Ragi	0	0	14.70	179.20
- Paddy	-	0	653.60	345.20
Chemical-free foods available to households (Rs /household)	1911.35	1190.85	0	0
Number of different crops on farms (crop diversity)	3.8	3.03	1.53	1.60

Results and Major Findings

- The socio-economic profile of the sample respondents in the four zones revealed that the average size of the family in households in all the zones was almost the same at six persons per family. The family composition was more or less similar in all the zones except in Zone-1, in which the number of males per family was relatively more than the number of females. The literacy levels of respondents was higher in Zones 3 and 4 than those of Zones 1 and 2, mainly because of greater awareness, proximity to schools, proximity to roads, good transportation facilities, etc. Lack of schools and poor transportation facilities in Zones 1 and 2 resulted in low literacy levels, and consequently in poor development of these areas.

- In general, households in Zones 3 and 4 had higher levels *of* productive assets in terms of land, livestock (cattle, goat, sheep, poultry), irrigation facilities and other resources than households in Zones 1 and 2. Farmers in Zones 3 and 4 had irrigation facilities, and therefore they could grow commercial crops. Hence, agriculture in these two zones was highly commercialized, whereas households in Zones 1 and 2, practiced only traditional agriculture. Consequently, expenditure on purchased inputs and yields of crops were relatively lower in these two zones.

- Farmers in Zone 1 produced mainly ragi along with cereals and pulses. In recent years, organic coffee is emerging as a cash crop in this region. However, it has still not attained the scale of commercial nature. In addition to ragi, farmers in Zone 2 cultivated paddy also under assured irrigation. Households in Zones 3 and 4 cultivated ragi, paddy and commercial crops, notably sugarcane, as there was a canal irrigation facility.

- Farms in Zones 1 and 2 were more sustainable ecologically than farms in Zones 3 and 4, as revealed by the indicators of the degree of crop heterogeneity, application of eco-friendly inputs, ratio of purchased inputs to total costs, income diversity index and net energy efficiency. Thus, a relatively more traditional nature of agriculture in Zone 1 was contributing to ecological sustainability of farms in this zone as compared to other zones.

Table 2: Indicators of Sustainability of Farming Systems

Sl. No.	Indicator	Zone-1	Zone-2	Zone-3	Zone-4
1.	Degree of crop heterogeneity on farms	3.8	3.03	1.53	1.60
2.	Percent area under input intensive crops	0	20.00	77.00	91.00
3.	Quantity of fertilizer (kgs per acre)	0	34.86	187.38	233.97
4.	Pesticide use (Rs. per acre)	0	13.81	121.15	118.59
5.	Eco-friendly inputs (Rs. per acre)	0	165.74	520.18	497.10
6.	Ratio of cost of purchased inputs to total cost of cultivation	0	0.17	0.86	0.88
7.	Income diversity index	2.45	3.89	2.29	2.15
8.	Net energy efficiency	3.90	2.29	1.85	2.44

- The resilience of farms was relatively greater in Zones 1 and 2 as indicated by their ability to produce crops more economically, ability to withstand effects of variations in input and output price, lower threshold yields and supplementary benefits from BDOAF. The aggregate collection pattern of selected Non-Timber Forest Products (NTFPs) from BDOAF in Biligiri Rangaswamy Temple (BRT) area revealed that there was no definite trend in the collection pattern of NTFPs, except in the case of gooseberry in which there was a discernible sustainable extraction pattern over a five-year period. The institutions operating in the BRT area have initiated various educational programs to conserve biodiversity through participatory resource monitoring by involving the *Soliga* tribe.

- Major economic and environmental benefits that households in Zones 1 and 2 derived from surrounding BDOAF included numerous NTFPs for market and consumption requirement, supplementary benefits such as fruits, tubers, vegetables, fuel wood and other-related products. The average value of NTFPs derived by households in Zone 1 and 2 were Rs.10,497 and Rs.4,972 per household respectively. Among various NTFPs collected, four products, namely lichens, moss, gooseberry and honey contributed significantly to cash income from NTFPs in Zone 1, whereas, in Zone 2, gooseberry, lichens, fuel wood and honey contributed bulk of NTFPs cash income. Households in Zones 3 and 4 derived comparatively more income from agriculture and livestock activities than households in Zones 1 and 2, due to the commercial nature of agriculture and livestock activities, particularly dairy enterprises in these two zones. However, households in Zones 1 and 2 obtained utilities from kitchen gardens to the extent of Rs.780 and Rs.221 per household per year, which was lacking in Zones 3 and 4. Though households in Zone I had a wide range of livelihood options, the total income of the households from various sources was highest in Zone 4 (Rs.65,066). In other zones, it was Rs.56,181, Rs. 21,622 and Rs.18,889 in Zone 3, Zone I and Zone 2 respectively.

Table 3: Indicators of Resilience of Farming Systems

Sl. No.	Indicator	Zone-1	Zone-2	Zone-3	Zone-4
1.	Average cash cost per unit of ragi output	0.13	0.95	6.22	2.67
2.	Average cash cost per rupee of gross returns from ragi crop	0.03	0.19	1.21	0.53
3.	Percent reduction in net returns from ragi crop (sensitivity analysis), due to				
	- 25 % increase in price of inputs	0.72	5.22	314.01	28.32
	- 25 % decrease in output price	25.72	30.22	339.01	53.22
4.	Herfindahl index	0.63	0.69	0.78	0.76
5.	Threshold yield (kgs / acre)	4.35	57.83	589.03	366.52
6.	Per capita household expenditure (Rupees)	9903	11163	23631	21100
7.	Simpson index	0.56	0.41	0.24	0.20
8.	Supplementary income (BDOAF sources) (Rs)	5265.68	3019.01	129.47	88.33

- The major source of income for the *Soliga* tribe in Zone I was NTFPs collection, which contributed about 49 percent to the total household income. For households in Zones 2, 3 and 4, agriculture was the major source. Over a period of seven years, the importance of NTFPs as a source of income for households in Zones 1 and 2 is declining revealing a diversification of livelihood sources.

- Households in biodiversity rich zones were deriving various environmental (direct and indirect use, and non-use values) from surrounding BDOAF. We attempted the valuation of three environmental benefits (direct use values) namely, chemical-free products, medicinal flora and recreational benefits. Results of the *Contingent Valuation Method* (CVM) revealed that consumers were willing to pay an average price premium ranging from Rs.1.00 to Rs.4.50 for quality products *of makaliberu,* soapnut, turmeric and honey extracted from BRT region. Consumers with higher income were willing to pay higher premium for these products. The replacement cost approach indicated that average annual savings due to use of local medicines prepared from biodiversity sources instead of using allopathic medicines for common ailments worked out to Rs.749 and Rs.360 per household in Zones 1 and 2 respectively. The BRT area has a great potential for eco-tourism as revealed by the results of individual travel cost method (behavioral linkage method). Results of the *Travel Cost Method* (TCM) showed that the average non-consumptive use value derived by each tourist from visiting BRT was estimated to be Rs.352. A CVM survey showed that visitors were willing to pay an average amount of Rs.205 for maintenance of the recreation site.

- The average supplementary benefits realized by the households in the form of NTFPs for self-consumption, nutritious food from kitchen gardens, small timber and medicinal plants was highest in Zone 1 (Rs.6,014) and it was lowest in Zone 4 at Rs.88.

- The production multiplier matrices (SAM analysis) revealed that in all the four zones, the dairy sector and ragi crop sub-sector of agriculture had the highest multiplier values, implying that any new investment in these areas would generate relatively greater returns when compared to that in other sectors / sub-sectors. Out of the expected increase in income due to new investment in dairy sector and ragi crop sub-sector of agriculture, the marginal households were expected to benefit the most, followed by small households.

- The degree of dependence of households on BDOAF in terms of direct economic value derived, employment generation and consumption pattern for their livelihoods was the highest (52.71%) in Zone 1, while the least was in Zone 4, which was 0.38 percent. Among different components of BDOAF, the dependency on NTFPs was high in Zone 1. The BDOAF sources generated employment opportunities to the extent of 38 percent in the form of NTFPs collection for households in Zone 1and 33 percent in Zone 2. The BDOAF related employment generation was almost negligible in the other two zones. The dependency of households on BDOAF was striking in Zones 1 and 2 as more than 56 percent of food requirement was met from BDOAF and farm sources. Households in Zones 3 and 4 met a major share of their requirement from the market. Thus, the importance of BDOAF on the livelihoods of people was strongly pronounced in Zones 1 and 2.

- Farms in Zone I used only farm-based inputs, mainly seeds, whereas farms in the other zones applied purchased inputs such as FYM and fertilizers. The usage of fertilizers increased from Zone 2 through Zone 4. The highest quantity of 520 kg. of fertilizers per acre of sugarcane was applied in Zone 4. The application of chemicals for plant protection in the three zones exhibited similar trends. The resource productivity, which was estimated using appropriate functional forms and allocative efficiency (based on MVP-MFC ratios) for ragi crop in all the zones showed that there was scope for increasing area under dry land ragi and enhancing FYM use in Zones 3 and 4. In Zones 1 and 2, farms only had scope for increasing returns by way of using more seeds.

- The environmental economics aspects of biodiversity were examined in terms of the following four components: reduction in dependence of farms on external inputs, ecosystem health, quality of life and direct use values. The economic value of reduction in dependence of farms on external sources due to environmental and economic benefits from eco—friendly farming practices was highest at almost 100 percent in Zone I due to non-application of external inputs. It was lowest in Zone 4 at 36.53 percent. Though Zone 1 was on a strong ecological foundation, the value of output and consequent income levels were very low as compared to Zone 4, which had a poor level of biodiversity. The ecosystem health (viewed, in terms of eco-friendly inputs and practices) was relatively higher in Zones 1 and 2 than Zones 3 and 4. The degree of eco-friendly input usage was greatest in Zone 1; therefore, the farms in this zone were on a relatively stronger ecological foundation. The quality of life, as viewed primarily from the intake of nutritive foods such as fruits, vegetables, etc., supplied from surrounding BDOAF, appears to be high among households in Zones 1 and 2. In value terms, expenditure on milk and non-vegetarian foods and other human development components was lower among households in Zones 1 and 2. The average consumption expenditure was the highest among households in Zone 4 at Rs.23,025, and it was lowest in Zone 1 at Rs.9,904 per household. The direct use values derived from the households from surrounding BDOAF were estimated and expressed as consumptive and non-consumptive use values. The average consumptive use values derived by the households in Zone 1 and Zone 2 were the highest for NTFPs at Rs.4,914. The consumptive use values for quality products collected from BRT area ranged from Rs.I.00 to 4.50.Households in Zones 1 and 2 realized an average consumptive use values worth about Rs.554 from medicinal flora. The magnitude of non-consumptive use values (recreation) derived by individuals visiting the BRT area was estimated to be about Rs.352.

Table 4: Direct Use Values of Selected Benefits (Services) from BDOAF

Sl. No.	Type of Benefit	Category of Use Value	Average Value
1.	NTFP extraction (Rs. / household / annum)	Consumptive use value	4914.00
2.	Chemical-free products (Rs. / kg)	Consumptive use value	1.00 - 4.50
3.	Medicinal flora (Rs. / household / annum)	Consumptive use value	554.30
4.	Recreation (Rs. / household)	Non-consumptive use value	351.69

- The results of the study show that BDOAF provided a wide range of livelihood options to the *Soliga* tribe. But this has not transformed into livelihood certainties, as income levels of the *Soliga* tribe from agriculture and BDOAF related activities were lower. This predicament originates primarily due to lack of property rights on the lands they cultivate and NTFPs collection, particularly in Zone I. Consequently, the general consumption level and expenditure on human development components among the *Soliga* tribe were lower than those of households in Zones 3 and 4 that had a high degree of livelihood certainties. Hence, there is a need for evolving alternative income generating activities, which not only ensure livelihood certainties of these communities but also minimize pressure on BDOAF resources.

Recommendations

The results of the study will be useful in evolving policy recommendations for management of biodiversity resources. These resources have characteristics of public goods. Hence, utilization of these resources needs to be regulated in order to ensure intergenerational equity and sustainability for the future.

- Development and conservation of BDOAF in biodiversity poor regions may help in sustaining ecology of the region, besides supplementing dietary compositions of households. Hence, educational and participatory programs may be formulated and implemented to create awareness about the importance and need for establishing adequate BDOAF.

- Dairy sector and ragi crop sub-sector of agriculture generate relatively greater returns when compared to that in other sectors. Hence, investments should be directed towards these sectors. Such investments will not only transform the traditional crop and dairy enterprises into more viable economic activities, but will also reduce the pressure on forests for NTFPs. Due to increase in income from new investment in the dairy sector and ragi crop sub- sector of agriculture, the marginal households were expected to benefit the most, followed by the small households. This will result in more equitable distribution of income in the economy.

- The rich biodiversity around farms in Zone 1and Zone 2 provides usufruct utilities to tribal households. However, it is not very clear whether all NTFPs are being extracted in a sustainable manner by the *Soliga* tribe. Therefore, it is worthwhile to examine whether NTFPs are being extracted in a sustainable manner without affecting ecology of the system by analyzing influence of market and institutional factors on the extraction patterns.

- A systematic documentation and extraction for medicines can be developed so that valuable medicines can be extracted with a major share of proceeds from such mechanisms being directed towards the tribal welfare. Local institutional networks may be involved to a larger extent to facilitate documentation, although currently this activity is being undertaken by only one NGO. The systematic documentation of traditional medicinal practices is essential because only a few people are aware of the knowledge of their use and preparation, and the same is passed on orally to the next generation.

- Long term research forays need to be initiated to determine optimal mix and level of BDOAF, which ensures and/ or maximizes social welfare in tune with ecological harmony.

- Many usufruct benefits from BDOAF, their cash income and quality of life are low. In this regard, cash income generating activities may be initiated to augment their meager income levels. This may also reduce pressure on BDOAF.

- In general, tourism potential and in particular, eco-tourism needs to be exploited. Sites that have such potential including the BRT area can be developed into good eco-tourism centers. This was evident by the willingness of tourists to pay (WTP) for the maintenance of the recreation site. This was also reinforced by the use values (consumer surplus) estimated from the study for the BRT sanctuary area.

- In order to know the total value of BDOAF, a more detailed multidisciplinary study can be initiated so that the total impact in terms of climate, soil, physical and other aspects of BDOAF can be quantified.

INDUSTRIAL POLLUTION AND POLICY

Economic Assessment of Environmental Damage: A Case Study of Industrial Water Pollution in Tiruppur

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Introduction

Rapid growth of industrial output and exports has taken place in certain sectors during the post-liberalisation period. In particular, the cotton textile and garment industries have grown due to availability of cheap labour and raw materials. The percentage share of textiles in total exports almost doubled from 17 % in 1981-82 to 31.6 % in 1998-99. However, the bleaching and dyeing units in the textile industry in Tiruppur, Tamil Nadu have caused severe environmental pollution problems. While the government has passed different laws for controlling pollution, the major enforcement agency, the State Pollution Control Board (PCB) has not been able to implement the pollution control measures effectively, due to the large number of small units. The bleaching and dyeing units use a large quantum of water. Most of this water is discharged in the form of effluents into land and water, polluting the local environment. However, these industries provide substantial employment and income to the region and foreign exchange to the country. Considering these facts, an appropriate strategy is needed for balanced development. The present study makes a preliminary attempt to use the principles of environmental economics to analyze the underlying issues.

Objectives

Major objectives of the study are to:

- Examine the growth of the hosiery industry and exports in Tiruppur, in the context of the overall growth of textile industries in Tamil Nadu and India.
- Study the functioning of the textile processing activities in Tiruppur with emphasis on water consumption, input use, effluents and treatment, and pollution load. Assess the pollution abatement cost incurred by the textile processing units.
- Estimate the physical impact caused by pollution to surface water and ground water, etc., and value the damage to drinking water, agriculture and fisheries in the study area.

Conceptual Framework

All the polluting units are required to meet the effluent standards prescribed by the PCB. For the smaller units, the cost of effluent treatment may be as high as the existing capital investment for production. These units have to either close down or utilise a Common Effluent Treatment Plant (CETP). Others who can afford their own facilities have to set up their Individual Effluent Treatment Plants (IETP) if they are to meet the standards.

Since standards are set without considering either treatment cost or damage, it is unlikely that the current policy has been designed to meet economic objectives like efficiency, cost-effectiveness or equity. Both in terms of abatement cost and damage, the units have to be viewed collectively. As mentioned earlier, those participating in the CETP programme share the costs of treatment. There may be economies of scale due to treatment, but there may be diseconomies of CETPs due to transport (the piping and costs of connection may be substantial). On the damage side, the impact is collective and not attributable to any one unit. Hence, in this analysis we discuss the pollution impact of the 702 bleaching and dyeing units as a collective entity. The PCB on the other hand, has to view each unit separately with regard to the legal requirements.

Environmental economics treats pollutants discharged in any particular period as temporal. The assumption that pollutants get assimilated or degrade in the next period is rarely true. Many pollutants exhibit stock characteristics. Thus, the damage in any period is a function not only of the pollutants discharged in that period, but the accumulated pollution from previous periods. In certain cases like ground water, saturation may occur. This means that the damage function may be non-convex.

The pollution problems of Tiruppur can be viewed in a social benefit – cost framework, where the value added by industry is the net benefit, and pollution is the social cost. In this study, we focus only on the cost side – the cost of abatement and the cost of damage. The empirical literature tends to consider only abatement cost as the externality cost of pollution. However, treatment does not eliminate damage totally because there may be residual pollution causing damage. This is particularly true when there is accumulated pollution. Thus, we need to measure the pollution load over time, as well as the consequent damage.

Study Area

Tiruppur is a fast growing hosiery industry city in Coimbatore district of Tamil Nadu. It is located on the bank of the Noyyal River, a tributary of the Cauvery. At present, the 9000 knitting, processing, manufacturing and other textile units that are functioning in Tiruppur provide employment for more than 2 lakh people. The direct export earnings in 1999 were Rs. 37840 million. The bleaching and dyeing units use large quantities of water, but most of the water used by these units is discharged as effluents containing a variety of dyes and chemicals (acids, salts, wetting agents, soaps, oil, etc.). These units discharge more than 80 million litres per day (mld) of effluents on land or into the Noyyal River, leading to contamination of the ground and surface water, and soil in and around Tiruppur and downstream.

Methodology

In this study we have estimated the quantity of water used, effluent generated and characteristics, the pollution load, and the efficiency of treatment and its cost using secondary data. We have also tried to value the damage in monetary terms in the agriculture, fisheries and urban water sectors, using existing secondary data collected from different government agencies as well as from case studies. Field level information was also gathered through focal group discussions with NGOs and farmers from the affected area to strengthen and add to the case study results.

Results

Scale of Production and Water Pollution

Of the 702 bleaching and dyeing units that are functioning, some are involved in bleaching, some in dyeing and the rest are engaged in both bleaching and dyeing activities. The gross fixed assets are Rs. 1318 million and cloth processed is 14,924 tonnes per month. The total water consumption by these units is about 86 mld, while the water used per kg. of cloth processed is 144.8 litres. Water consumption per kg. of cloth processed has declined from 226.5 litres in 1980 to 144.8 litres in 2000. It may be because of non-availability of local water due to the textile pollution. The total annual water cess collected by the PCB from the 702 units is Rs.2.94 million at an average of Rs.4191 per unit. The water cess provides some revenue to the Board, but does not act as a disincentive either in the use of water or the discharge of waste water.

Pollution Load

The discharge of effluents has caused severe pollution of both the surface and ground water in the region, and has also contaminated agricultural land. Due to pressure from NGOs and farmers' organisations through the High Court, the PCB has insisted that the units either connect to a CETP or have their own treatment plant. As a result, 424 units have constructed IETPs and 278 units are connected to 8 CETPs in Tiruppur. Around 164 units that were not connected either to CETPs or which do not have their own IETPs, have been closed down by the order of the Madras High Court. Even though the remaining units are treating their effluents through CETPs or IETPs, the treated effluents do not meet some of the standards prescribed by the Tamil Nadu PCB especially for parameters like total dissolved solids (TDS).

The Tamil Nadu PCB has generally categorized the industrial units as red, orange and green, based on the intensity of pollution discharged. According to the PCB rules, the red and orange category units should be situated 1000 metres away from a river / stream or any other water source. However, according to information gathered from PCB records, in Tiruppur around 239 units are located at a distance of less than 300 metres from the Noyyal River. So, there is a high possibility of the effluents polluting the river. Around 83 percent of the IETPs discharge their effluents directly / indirectly into the water bodies.

The pollution load was calculated from 1980 to 2000 with the help of PCB data. During 1980 to 2000, the accumulated TDS load was 2.35 million tonne, of which Chloride was 1.31 million tonne and Sulphate 0.12 million tonne. Other parameters include COD of 0.09 million tonne, BOD 0.029 million tonne and Oil and Grease measuring 1000 tonnes. From 1980 onwards, the effluents have gradually accumulated causing pollution of the river and groundwater in Tiruppur and in the downstream areas. This has been verified by a number of studies conducted by academic researchers and different government agencies. Further, these studies have pointed out that in and around Tiruppur the water is unsuitable for domestic / irrigation purposes.

Efficiency of Treatment Plants in Tiruppur

To determine the overall efficiency of treatment in all the units, a comparison was made of the pollution load before and after treatment. The average values of quality of treated and untreated effluents were obtained by the PCB from the samples tested by the Board at different points of time. In the IETPs there is substantial reduction in Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD) and Oil and Grease after treatment. Although the TDS and Chloride declined after treatment, these parameters did not meet the PCB standard. In the case of the 8 CETPs only pH and Sulphate values are within the permissible limit, while most of the other parameters increased after treatment.

Size Distribution of Units

The size composition of the 702 bleaching and dyeing units indicates very wide variation from small units with gross fixed assets (GFA) less than Rs. 0.2 million to large units with GFA that exceeds Rs. 5 million. However, 70 percent of the units fall in the intermediate categories of Rs. 0.2 – Rs.1.5 million, and 17 percent between Rs. 2-5 million. The size distribution of units is of some importance with respect to water use, and also in terms of the mode of treatment. Although there is considerable variation in the size of the units (as measured by gross fixed assets), the average quantity of cloth processed remain more or less constant between 17-20 tonnes per month. Of even greater importance from an environmental perspective is the fact that water use, and therefore effluent discharge increases with size. In other words, there may be uneconomic use of water, which increases the variable cost since water has to be purchased or transported. When too much effluent is generated, the cost of treatment also goes up.

The choice between individual versus common effluent treatment plants seems to be governed by both economic and non-economic factors. While the large majority (82%) of the extremely small units (less than or equal to Rs. 0.2 million) have joined CETPs, those in the other size ranges did not show a marked preference. Even the larger units (GFA more than Rs. 5 million) seem to be evenly divided on this issue. This ambivalence towards CETPs is probably due to the earlier policy of the PCB of not permitting IETPs. The Board relaxed this policy midstream permitting IETPs.

Pollution Abatement Cost

Table 1 gives the cost of effluent treatment through CETPs and IETPs. The variable cost is much higher both in the case of IETPs (86% of total cost) and CETPs (73% of total cost) compared to the annualized capital cost. In the case of the CETPs, the capital cost is subsidized by the Central and State governments. Since there is no corresponding subsidy for operating costs, there is virtually no incentive for good treatment.

Table 1. Effluent treatment cost (cost / KL Effluent) for IETPS and CETPS in Tiruppur

Mode of Treatment	No. of Units	Annual Effluent (KL)	Total Capital Cost (Rs. Lakh)	Annual (Rs. Lakh)			Cost per KL (Rs.)		
				Capital Cost	Variable Cost	Total Cost	Fixed Cost	Variable Cost	Total Cost
IETPs (424)	424	14089920	2043.95	326.42	1934.4	2260.82	2.31	13.72	16.03
CETPs (8)	278	11849448	2724.00	435.05	1184.9	1619.95	3.67	9.99	13.66
Total	**702**	**25939368**	**4767.95**	**761.47**	**3119.3**	**3880.77**	**2.93**	**12.03**	**14.96**

Note: The numbers provided in the brackets are number of plants

Source: Computed from PCB data, 2000

Economic Analysis of Damage

Damage assessment has been attempted for the agriculture, fisheries and domestic sectors using appropriate techniques. For valuing the damage in the agricultural sector, the study area was divided into two categories. The first category consists of 25 villages (regional study) situated in and around Tiruppur. Four villages heavily affected by pollution were purposively selected for the case study. The regional study data shows that the total irrigated area declined from 16,262 ha. to 14,262 ha. between 1985-87 to 1997-99. On the other hand, rainfed / non-irrigated land increased from 2108.3 ha. to 2668 ha. Around 13percent of irrigated area was lost, and the net loss of area under cultivation was 7 percent. In the four case study villages, both irrigated (500 ha to 144.6 ha) and unirrigated (2308 ha to 1861 ha) area declined between 1985-87 and 1998-99. The loss in the gross value of output of crops in the four case study villages was estimated. Irrigated crops like paddy have completely disappeared, resulting in an output loss of Rs. 0.86 million at 1994-95 harvest prices. The gross output loss for all crops in the four villages is Rs. 2.52 million.

The focal group and opinion survey also confirm that the pollution problems are very specific to those villages that are severely polluted, but not significant at the regional level. The second category is the command area of the Orthapalayam Irrigation Project, downstream of Tiruppur. Since water in the reservoir is unfit for irrigation, the foregone value of irrigated crop is estimated for a year, as compared to the return from existing rainfed agriculture. Around 10,875 acres of land was to be irrigated, from which an output of 10,000 tonnes/year of paddy was expected. Following the closure of the dam due to pollution, the farmers are not able to cultivate irrigated crops, and the foregone value of 10,000 tonnes of paddy is estimated to be Rs.52.6 million. Even though the dam was closed, the farmers continue to raise the rainfed crops in the command area. The opportunity cost to them is the difference between the value of the irrigated crop (paddy) and value of the existing rainfed crops, estimated to be Rs.41.3 million.

In order to value the damage in the fisheries sector, the total value of fish productivity loss is estimated for Noyyal River, system tanks and Orthapalayam reservoir. The total annual loss in the fishery sector is Rs.1.47 million, which includes Rs.15,000 from the Noyyal river, Rs.0.25 million from the system tanks and Rs.1.2 million from the Orthapalayam reservoir.

For the urban water sector, the damage is calculated on the basis of replacement or opportunity cost of fresh water transport and supply for Tiruppur due to the pollution of the local water sources. Since the industrial units pay Rs.450 per tanker load of water (12,000 litres) from neighbouring villages, the foregone value of the local ground water (78.6 mld) is estimated to be Rs.98 million per year.

Conclusion

Despite the construction of individual and common effluent treatment plants at considerable cost, salts, mainly chloride, continue to be discharged unabated. The local environment, soil, water, etc. can assimilate only a certain quantity of the effluents. Although each individual unit discharges only a small quantity of effluents, the combined discharge of more than 700 bleaching and dyeing units outstrips the assimilative capacity, causing damage to agriculture, fisheries, and local ground water in and around Tiruppur.

The units could have considered technologies that use less water and discharge less salts. Although these are capital intensive, the units could have saved resources in terms of (a) water purchased; (b) water cess; (c) treatment costs, and possibly compensation for damage. Total dissolved solids, one of the measures of pollution caused by the bleaching and dyeing activity, cannot be controlled by conventional effluent treatment. Removal by expensive technologies like reverse osmosis (similar to desalinization) has high capital and operating costs. However, the treated water can be recycled, saving the cost of purchasing water. Another option would be to make technology changes that use less water and discharge less salt. Unfortunately, the end-of-pipe regulation has precluded these possibilities.

The study points out the limitations of conventional methodology, which for the most part ignores stock pollution and the consequent damage. Since many pollutants, including greenhouse gases have "stock" characteristics, environmental economics methodology should take into account the damage due to stock pollution.

Policy Recommendations

- The study clearly indicates the need for the Pollution Control Boards to develop suitable strategies for clusters of small-scale industries. Common effluent treatment plants have to be monitored carefully to ensure that the level of treatment is satisfactory. It is not enough to design or construct CETPs or individual effluent treatment plants; it is equally important to ensure proper operation and maintenance. The high variable cost of operation (75 % to 85 %of the total cost) is a major reason for not operating the treatment plants. In the absence of operating subsidies, compliance monitoring by the PCB and/or by the community is essential.

- In the particular case of the textile industry and also the tanning industry, the salts or total dissolved solids (TDS) are a serious problem. Salts like chlorides may not be toxic but can cause salinity problems. On the other hand, removal of TDS may be extremely expensive. However, even preliminary damage assessment exercises show that not removing TDS can result in output losses in other sectors like agriculture, drinking water and fisheries. Hence, the expenditure in TDS removal, either by end-of-pipe treatment or reduction at source through clean technology, may be worthwhile in the long run.

- Cleaner production technologies may have to be considered not only to reduce the salt problem, but also the quantity of water used for processing. However, only the large units could probably afford to switch to clean technologies. Smaller units may be forced to close down. This may be an inevitable consequence of controlling pollution from small-scale industries like textile or tanneries. Provisions may have to be made to find alternative employment for those affected by such closure.

An Exploratory Study of Environmental Pollution in Small Industry Clusters

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Introduction

Small Scale Industry (SSI) occupies a prominent place in Indian economy due to its contribution to industrial production, exports and employment (Government of India, 2002). However, majority of these units have also been known to manage with meager financial, technical and infrastructural resources. Recently there has been considerable concern about the environmental implications and impact of small-scale industries in India. The environmental impact of an individual SSI unit may be small but the combined effect of operation of a large number of SSI units on the environment can be high, especially when they are clustered in certain locations closer to residential or commercial centres.

The Indian environment policy regime largely belongs to the Command and Control (CAC) category. Economic instruments comprising tax incentives and subsidies are the other dimension of the policy regime. Though the environmental policy regime is applicable to all economic activities in the country, the SSIs have to obtain a No Objection Certificate (NOC) and consent from the Ministry of Environment and Forests, Government of India only in 17 product categories, which are considered highly polluting. However, in Karnataka, every SSI unit has to obtain consent from the Karnataka State Pollution Control Board (KSPCB) and renew it every year, while tiny SSI units have to renew the permission once every ten years. But the State Pollution Control Board had a list of only 6000 units as against the SSI population of 0.25 million in Karnataka at the end of March 2001. Therefore, the state machinery does not have the full knowledge of the environmental status of SSIs, comprising kinds and levels of pollution generation, causal factors, etc. in different sectors and clusters of the State.

It is with this backdrop that the current study is undertaken with reference to four small industry clusters in the state. There are about 2000 traditional rural clusters of small enterprises apart from 350 Small and Medium Enterprise (SME) clusters in India. Thus, traditional clusters account for a considerable share of SSI population in India.

We have chosen four natural and traditional clusters of small firms in Karnataka because:

- They use obsolete technology that generates pollution.
- Entrepreneurs are likely to be less educated and have less environmental awareness.
- Entrepreneurs' level of income will be low and therefore, cannot think of substituting 'better technology', even if its availability is known.
- Lack of understanding on the technical specification and implications of pollution standards; and
- Low level of managerial and technical ability and skills among owners and managers.

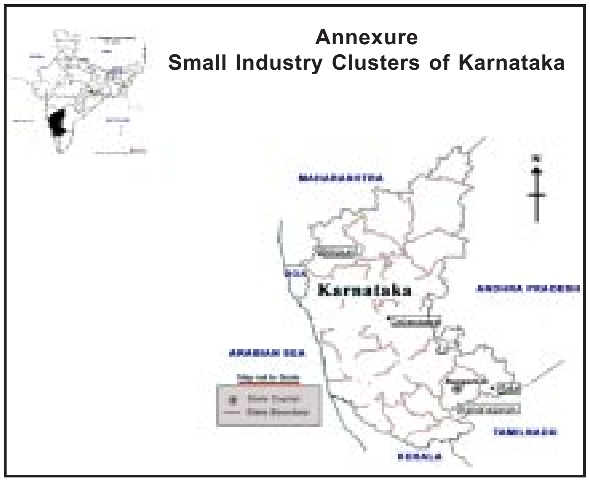
Clusters, in principle could offer scope for collective action for their own improvement through either technology development and joint R&D or joint marketing strategies, training programmes, etc. However, in the Indian context, limited empirical evidence based on a few clusters reveal that small firms in clusters have not initiated any joint action on their own to reduce environmental pollution.

Objectives

The major objectives of this study are to:

- Probe and ascertain the nature and magnitude of environmental pollution in small industry clusters of Karnataka.

Annexure
Small Industry Clusters of Karnataka



- Identify the pollutants and develop a pollution profile for each cluster.
- Probe the factors that cause the current level of pollution.
- Identify the appropriate pollution abatement measures and determine their costs and benefits.
- Develop a policy framework to promote environmental friendly small industry growth in the state.

Methodology

Four environmentally polluting small industry clusters in the State were chosen. Brick & tiles cluster in Malur of Kolar district, silk reeling cluster in Ramanagaram of Bangalore rural district, puffed rice units cluster in Davanagere of Davanagere district and foundry cluster in Belgaum of Belgaum district (see map in the annexure). As the nature of each of these four clusters in terms of technology, material and energy inputs, skill composition of labour force is different, separate questionnaires were developed for data collection. However, the questionnaires in general, covered four sections: (1) Basic information on the industry, (2) Materials consumed/produced, (3) Technology and (4) Human resources.

There was no scope for scientific random sampling due to the absence of systematic and comprehensive data on all the functioning units in the cluster. Therefore, the attempt was to gather data from at least 40 units from each of the four clusters on a random basis. The data was gathered from 45 units in the bricks cluster, 55 units in the silk reeling cluster, 46 units in the puffed rice cluster and 43 units in the foundry cluster.

The pollutants are identified and a pollution profile is developed for each cluster by studying the basic characteristics of the units in each cluster in terms of technology in use, nature of manufacturing, kinds and quantum of material as well as energy inputs, kinds and quantum of wastes, by-products and final products. The pollution levels are determined by the consumption of material and energy inputs used for the production process. Thus, quantum of pollution is estimated based on the data gathered from the sample units on these variables and by making use of standard pollution coefficients (emission factors) for various energy inputs from the literature. In addition, the various kinds of wastes generated during the production process are estimated.

The factors - human resource, technological, process, external and structural - influencing the level of environmental pollution are logically identified in consultation with literature and experts. By using multifactor analysis of variance (ANOVA), the significance levels of these factors in explaining the variations in the energy use and thereby pollution levels are determined. It also facilitated to identify and develop appropriate pollution abatement measures within the constraints of clustered units and their respective costs and benefits. These analyses along with a study of the appropriate and relevant literature and discussions with experts enabled us to propose an alternative policy framework to reduce the environmental impact of small industry operations.

Results

Bricks and Tiles

The emergence of a large number of brick making units, irrespective of the kind of kilns used, is attributed to the abundant availability of Chinese clay in the region, which has got powerful plasticity and can withstand any form of weather conditions. This plasticity is the main requirement for manufacturing tiles and bricks.

All the sample units used biomass as the source of energy – while some used exclusively firewood, others used branches and leaves of eucalyptus, and coal. Brick making units engaged both skilled and unskilled labour; the former was used mainly for brick moulding and brick firing, and the latter for transporting materials, moulded and burnt bricks. Most of these units had poor ventilation design and building conditions, house keeping and storage facilities for the bricks. Ash and waste bricks/tiles were found dumped on the unit premises.

On the whole, air pollution due to the consumption of eucalyptus leaves, firewood and coal, is the major environmental concern identified in the brick units' cluster in Malur. On an average, one thousand bricks consumed 7,702 MJ energy and generated CO (8 kgs), TSP (4 kgs), NOx (0.78 kgs), SO_2 (0.55 kgs), CH_4 (0.23 kgs) and N_2O (0.03 kgs), apart from waste bricks (85 nos) and ash (19 kgs). The CO_2 emission is not considered because all firewood and eucalyptus leaves and twigs have been obtained in a sustainable manner.

The analysis (through ANOVA) revealed that labour skill levels and owner's qualification and technology levels are the most important factors, which determined the level of energy consumption and thereby pollution levels. Therefore, the pollution abatement measures through efficient use of energy and materials have to focus on the human resource factor, particularly labour skill levels, along with the technology factor. Even the total cost per 1000 bricks reduces with an increase in labour skill levels. It is observed that if a brick unit changes the ratio of skilled to unskilled labour from 1:1.6 to 1:0.47, it will realise cost savings to the extent of more than Rs. 7/- per 1000 bricks. Of course, such a shift leads to a higher labour cost but the savings due to the reduced energy costs are nearly five times the additional labour cost that a unit has to incur (Table 1).

Table 1: Cost & Benefits of Abatement Measures for Brick Industry Cluster

Performance Measures	Labour Skill Set Up-gradation			Technology Change	
	Low - Medium	Low – High	Medium - High	IDK (Biomass) to VSBK (Coal)	IDK (Coal) to VSBK (Coal)
Cost of Saved Energy (Rs./GJ)	6.97	12.36	19.35	1.04	1.65
Value of Saved Energy (Rs./GJ)	35.57	30.34	23.56	3.77	72.57
Savings in Energy (%)	14.69	26.03	13.28	51.27	40.00
Possible Reduction in Pollution Levels %					
CO	10.80	26.81	17.95	98.26	40.00
CH_4	10.80	26.76	17.89	95.19	40.00
N_20	10.81	25.96	16.99	46.37	40.00
SO_2	11.61	23.77	13.75	-177.63	40.00
NOx	10.80	24.53	15.39	-38.46	40.00
TSP	10.80	26.73	17.86	93.32	40.00
CO_2	—-	—-	—-	—-	40.00
Waste Bricks	22.23	-51.08	-94.27	—-	—-
Reduction in Ash	4.65	5.85	1.26	—-	—-

Another abatement measure that was examined was to reduce pollution through technology change. Certain types of kilns can help reduce pollution, such as: (1) Rural Clamps or Brick Clamps, which is the oldest method of firing bricks, (2) Intermittent Draught Kiln (IDK), which is a batch type kiln, (3) Bull's Trench Kiln (BTK), a continues type kiln, and (4) Vertical Shaft Brick Kiln (VSBK), which represents the latest technology and is the most energy efficient. In Malur, majority of the sample units used IDK technology and only a minority used conventional rural clamps technology. They can shift the traditional IDK (biomass) to VSBK (coal) or IDK (coal) to VSBK (coal). The additional investments required for the shift are not very high and the savings in fuel consumption are quite significant in both kinds of shifts. When there is a shift from IDK (biomass) to VSBK (coal), it is found that there is substantial reduction in pollution levels due to the emissions of CO, CH_4 and TSP, but at the same time there is a significant increase in the emission levels of SO_2, NOx and CO_2. The combination of pollutants that could be reduced and those that could increase due to the shift includes both local and global pollutants. The shift from IDK (biomass) to VSBK (coal) would cause a substantial increase in CO_2 emissions. Further, for Malur's brick units, such a shift may not be advisable because their fuel requirements are met locally in a sustainable manner. Therefore, economically as well as environmentally, it may not be justifiable to replace the biomass based IDK technology with VSBK technology, at least in Malur (Table 1). It would be appropriate that Malur's brick units should be encouraged to focus on skill upgradation of labour as this will lead to substantial reduction of energy consumption and therefore, pollution.

The pertinent question is: who will bring about skill upgradation of labour, and who has to bear the cost and how? Because improvements of labour skills will lead to more benefits than the costs involved, through improvements of material and energy use, the owners of the units themselves should bear the cost as it is they who realise the benefits subsequently. To achieve this, policy makers through the KSPCB can play an instrumental role, first by using communicative instruments such as seminars and distribution of pamphlets in the cluster informing the entrepreneurs about the benefits that would accrue to them and to their community by opting for skill upgradation of labour. If that fails, they should adopt economic instruments: 'local pollution tax' should be imposed based on the relative composition of unskilled and skilled labour. It should be progressive and should increase as the proportion of unskilled labour increases. The imposition of 'pollution tax' however, is easier said than done because it would be virtually impossible for the authorities to get reliable figures on the composition of skilled and unskilled labour from the entrepreneurs. The other alternative could be conducting training on a regular basis every year for upgrading the skills of labour in the cluster itself by the Taluk Industries Centre at a nominal fee. The local brick makers' association should be involved in conducting such training programmes. This would facilitate pollution abatement to a great extent in the cluster.

Silk Reeling

Silk reeling is the intermediate stage in the process of silk production (which links cocoons with silk weaving). Silk reeling can be done through three alternative techniques: Traditional manual techniques using charakhas, semi – mechanized technique using cottage basins, and advanced Multi-end reeling machines. Ramanagaram in Bangalore rural district is one of the well-known silk reeling clusters in Karnataka, which comprises units using all the three mentioned technologies. Data is gathered from 22 charakhas and cottage units each and 11 multi-end units. Silk reeling units, particularly charakha and cottage units generated three kinds of pollution: water, land and air pollution. Cocoon cooking results in water pollution, dumping of cocoon & pupae waste and raw silk waste in the unit premises cause land pollution and the process of cooking cocoons with paddy husk, coal, saw dust and firewood not only causes gas emissions but generates ash and stinking smell all around.

On an average, to produce one tonne of raw silk output the 55 silk reeling units generated nearly six tonnes of pupae & cocoon waste, 116 KL of waste water, about two tonnes of ash, 3,382 kgs of CO_2, 331 kgs of CO, 173 kgs of TSP, 38 kgs of N_2O while consuming about 348 GJ energy.

Based on ANOVA results it was found that the technology level and the human resource factor comprising only labour skill levels are the important factors explaining variations in the levels of energy consumption, value of output and cost of production. However, the analysis did not facilitate the arrival of a definite conclusion. There were also no discernible patterns emerging out of this analysis to indicate the direction of the relationship between the above independent factors and energy consumption levels. Neither upgrading labour skills nor adoption of improved technology indicated the possibility of efficient energy utilisation and pollution reduction.

Therefore, the existing system - conventional wood based system - is compared to an energy efficient technology, a gasifier-based system. It is found that such a shift would result in enormous energy cost savings and substantial reduction in pollution levels (Table 2). However, such a shift is possible only if it is wholly financed by the government. Neither communicative and economic instruments nor CAC instruments could be successful as the silk reelers belong to the economically weaker sections. The only alternative is to encourage them to form a silk reelers' cooperative and adopt a gasifier-based system.

Table 2: Cost & Benefits of Abatement Measures for Silk Reeling Cluster

Performance Measures	Technology Change	
	Conventional (Cluster Average) to Gasifier System	Conventional (Standard) to Gasifier System
Cost of Saved Energy (Rs./GJ)	12.28	21.05
Value of Saved Energy (Rs./GJ)	115.08	51.53
Savings in Energy (%)	59.99	46.67
Possible Reduction in Pollutants %		
CO	55.61	46.67
CH_4	55.92	46.68
N_20	60.55	46.50
SO_2	75.76	46.67
NOx	66.41	46.67
TSP	56.11	46.67
CO_2	100.00	0

Puffed Rice Making

Puffed rice making is a labour skill based activity in Davangere and therefore, does not involve any machinery. The process of puffed rice making involves two phases: the first phase consists of conversion of paddy into rice and the second phase comprises conversion of rice, after mixing with salt water, into puffed rice. The boiling of paddy to convert it into rice and the heating of sand to convert the salt water mixed rice into puffed rice require energy inputs. Puffed rice makers in the Mandakki Layout of Davangere used rice husk (which is the byproduct of the conversion of paddy into rice) and scrap tyres as the energy inputs – both lead to air pollution, apart from the generation of ash, which adds to the unhygienic environment of the locality.

The use of energy inputs, particularly scrap tyres, lead to significant air pollution, through the emission of gases like CO_2, NOx, SO_2 and TSP (apart from CO, CH_4 and N_2O, which are contributed more significantly by rice husk). This is substantiated by the fact that the entire atmosphere of Mandakki Layout in Davangere is thickened with black smoke emanating from the heavily concentrated puffed rice units. The estimated pollution for the 600 units in the area would include about 3838 tonnes of CO_2 and about 144 tonnes of CO emissions in an year, apart from TSP (93 tonnes), NOx (39 tonnes), SO_2 (29 tonnes), CH_4 (4 tonnes) and N_2O (0.56 tonnes).

Within these constraints, the only solution to pollution abatement is to encourage puffed rice makers to use only rice husk and not scrap tyres, which generate huge amounts of CO_2, NOx, SO_2 and TSP, apart from many carcinogenic chemicals.

Decreasing pollution in the Mandakki Layout is a major challenge, and it was difficult for us to arrive at an easy solution. The units are small in size, and mechanized technology is neither readily available nor a feasible alternative, given the impact it would have on employment and the investment requirements. Within these constraints therefore, we felt that the only feasible means of pollution abatement would be to encourage puffed rice makers to use only rice husk and not scrap tyres. In this case, to mitigate pollution, particularly to avoid the use of scrap tyres, it would be appropriate to ban their use for puffed rice making through legislation.

Foundry Cluster

Foundry in Belgaum is the only relatively modern industry among the four clusters covered. A foundry is a casting manufacturing system. Casting is the process of forming objects by pouring liquid metal into prepared moulds and allowing the melt to solidify. The foundry operations generate different kinds of air pollution, depending on the kinds of furnaces in use as well as the kind of energy inputs that they use. The three kinds of furnaces that a foundry unit could use are cupola, blast furnace, electric arc furnace or electric induction furnace. A total of 43 foundry units were covered in Belgaum. Majority of the foundries used cupola furnaces whereas the rest used electric arc/induction furnaces, cold/divided blast furnaces and crucible/OHF. The foundries are machinery-oriented units. Therefore the proportion of unskilled labour accounted for just about one-third of the total labour force, considerably less than that employed in the bricks, silk reeling and puffed rice clusters. The pollution profile of foundry units comprised slag, ash and gases. The 46 units, on an average, generated about 76 kgs of slag, 25 kgs of ash, CO_2 (774 kgs), SO_2 (5 kgs), CO (2 kgs), NOx (1.6 kgs), among others, while consuming about 8 GJ of energy per tonne of castings.

Cold/divided blast furnace units are the least expensive, least energy intensive and least polluting among all the units. It is found that the units that are energy inefficient are unproductive in terms of the whole production process. Using ANOVA, it was found that human resource factors comprising labour skill, owner's qualification and value of labour are the most important factors determining the variations in the energy consumption levels of a foundry unit. Technology level is the second most important factor. Therefore, for pollution abatement, the focus should be on human resource factors along with the technology factor.

A shift of units from low to high human resource quality will result in fuel savings, which will be more than the additional human resource cost that has to be incurred for improving workforce quality and a drastic reduction in pollution. Therefore, to reduce energy consumption levels and thereby pollution levels, the foremost activity at the foundry cluster could be to upgrade the Human Resource Quality (HRQ) set by providing appropriate training to the existing workers or hiring required skill set of workers at a proper compensation package (Table 3).

To analyse the technology shifts, two alternatives are considered – from conventional hot blast cupola to lined hot blast cupola and from cold blast furnace to divided blast furnace. In the case of both the shifts, the value of saved energy is significantly higher than the cost of saved energy, indicating the economic feasibility of the shifts. Even the overall pollution reductions in both the shifts are positive and significant (Table 3). To encourage the technology shifts to reduce pollution, economic instruments should be used. As the level of education of the entrepreneurs is fairly high, mere communicative instruments will not be effective. Those foundries that use conventional technologies and cause higher degree of pollution should be charged with 'local pollution tax' and those who are willing to adopt 'more efficient technologies' should be encouraged to do so by means of subsidised credit by the District Industries Centre.

Table 3: Cost & Benefits of Abatement Measures for Foundry Cluster

Performance Measures	Human Resource Quality Up-gradation			Technology Change	
	Low - Medium	Low – High	Medium - High	Conventional Hot Blast Cupola to Lined Hot Blast Cupola	Cold Blast Furnace to Divided Blast Furnace
Cost of Saved Energy (Rs./GJ)	13.51	74.97	184.87	8.83	69.64
Value of Saved Energy (Rs./GJ)	40.86	102.32	212.24	1022.96	261.45
Savings in Energy (%)	25.20	39.29	18.84	4.85	36.98
Possible Reduction in Pollutants %					
CO	33.64	54.34	31.19	-69.25	42.95
CH_4	32.46	59.71	40.34	-141.81	49.60
N_20	28.16	40.85	17.66	3.71	35.98
SO_2	13.50	28.02	16.78	22.84	35.04
NOx	3.97	22.50	19.30	24.10	36.14
TSP	24.65	53.22	37.92	-85.68	49.01
CO_2	20.44	31.67	14.12	17.25	30.10
Ash	14.89	30.18	17.97	18.65	35.70
Slag	7.07	6.83	-0.25	10.60	-26.24

The present analysis probed the scope and feasibility of pollution reduction through economizing the consumption of energy inputs, which has a direct bearing on the cost of production and therefore, competitiveness of a small firm. As ascertained n the context of bricks and foundry clusters, a reduction in the consumption of energy inputs and therefore, in the cost of production as well as pollution can be achieved through not only technology shifts but more importantly through improvement in the quality of human resources comprising labour skills and entrepreneurial qualifications.

Recommendations

On the whole, we would like to state that the contribution of SSIs to CO_2 emission is not considerable, though their operations do have significant implications for the local environment. Given this, it would be appropriate to focus on economizing the use of energy inputs through variations in labour skill composition and shifts to feasible alternative technologies, wherever possible.

- It is imperative to strengthen the infrastructure of State Pollution Control Board in terms of adequate technical personnel. This will enable them to conduct periodic surveys of pollution intensive industries, large as well as small, and to ensure that they adhere to the environmental laws and regulations of the state.
- New SSI units must not be allowed to come up without the consent of the State Pollution Control Board, irrespective of the size of investment. These units must be allowed to come up only in designated industrial areas/ industrial estates, as this will enable effective monitoring by the officials of the State Pollution Control Board.
- In pollution intensive industries, new entrepreneurs must be encouraged to adopt environmentally sound technologies, wherever feasible.
- As the nature of technology, required labour skills and environmental problems differ between industries/clusters, the State Pollution Control Board should conduct industry-wise/cluster-wise studies to suggest ways and means for pollution abatement and efficiency improvement.
- Currently, the Ministry of Environment and Forests, Government of India has been promoting a scheme for adoption of clean technologies by SSIs through the provision of interest subsidy, apart from knowledge diffusion and database development. This is a welcome step and needs to be intensively pursued at the regional level.
- Technology up-gradation alone will not result in efficient use of material and energy. The quality of human resource available with the SSI is also equally significant in determining the level of energy use. A perfect match between the technology and quality human resource is essential to optimize the resource use and thereby reduce the environmental impacts.
- Technology upgradation in a unit should be preceded by having quality workforce in place.
- Waste minimization is a new and creative way of thinking about products and their processes. The Ministry of Environment and Forests has already established Waste Minimization Circles (WMCs) for SSIs in 40 different industrial sectors all over the country. There is an urgent need to involve state governments and small industry associations at the regional level in the propagation among SSIs to adopt waste minimization.

The promotion of clean technologies, skill up-gradation and awareness training to the workforce, and waste minimization techniques along with strengthening the State Pollution Control Board with adequate staff would go a long way in achieving the objective of pollution abatement and environment friendly small industry development.

Sustainable Regional Comparative Advantage: Environmental Costs in Selected Heavy Industries

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Introduction

The districts quintet, Burdwan, Hooghly, Birbhum, Bankura and Purulia in the state of West Bengal comprise an interesting agglomeration from the standpoint of economic interdependence, environment and sustainable development. The total geographical area is 30.39 percent of that in West Bengal, while the total population is 26.43 percent. Environmental degradation is caused by economic activities with large-scale productions being a major factor. This production deteriorates the environment through various stressors coming out from the production processes. Hence, the present study would help to devise policies to enhance the quality of life in the region significantly.

The present project investigates the share of ECC (full form) in the cost of operation of some important industries, present for a considerable time in the district of Burdwan, namely, coal, iron and steel and electric locomotive engines. Large-scale industrial activities in a region are sustained because of come (?) location-dependent comparative advantage in the particular activities in the region. This is known as regional comparative advantage in the pursued industrial operations in a region, and is reflected in lower unit cost of production of the commodities of advantage.

Conventional considerations on cost generally do not take account of the costs inflicted by damages caused on the environment. Environmental damages resulting from industrial production affect the regenerative forces of nature adversely. As a result, degenerative forces gradually become dominant. The process implies continuous rise in costs through some channels not present in the conventional cost analysis. As a result, the cost advantages may not be present or sustainable if the costs include the costs of mitigations or compensation for environmental losses (ECC). It is possible that the comparative advantage in terms of the conventional approach might have been misplaced.

Methodology

The environmental economics component of the study is mainly the evaluation of ECC done in major industrial activities in a region and the nature of the burden, if any, on the Decision Making Units (DMUs) in this aspect. Whether the activities can be retained after taking adequate environmental care is the main environmental economics component of the work.

For our purpose the public sector DMUs appeared most suitable and this led us to select DMUs by purposive sampling. *Prima facie* the three selected units appear significant in terms of their share in the district GDP and as they involve inputs and processes likely to generate externalities. We selected Durgapur Steel Plant (DSP) in iron and steel, Eastern Coal Fields Ltd. (ECL) in coal and Chittaranjan Locomotive Works in the heavy engineering sectors.

As ECL contains quite a large number collieries (more than 110) in the district, we selected the first 15 units irrespective of whether they are open cast (OC) or underground (UG) in the district or adjacent area in descending order of profitability. We selected the best three from that list at first, such that we do not pick up grossly inefficient mines. As most of the profit-making collieries are open cast, we had to include one underground mine, which according to ECL authorities was average.

Before collecting the required material and also during the entire work period we organised a number of advisers' meetings, which helped us to fix the basic equation we have estimated.

Estimation of the following was needed

Ct : The estimated unit cost

CE : The estimated unit cost INCLUDING ACTUAL E-COST (ECC)

CE* = Ct + E*; E*, the ECC- Cost AT THE EFFICIENCY LEVEL

We work out: - (i) (CE* - Ct)/ CE* & (ii) (CE - Ct)/ CE; we also worked out (iii) (CE* - Ct)/ Ct

If (i) IS < 3% THE INDUSTRY IS CLEAN AND If (2) (ii) IS < 3% COMPARATIVE ADVANTAGE OF THE PLANT IS SUSTAINABLE; IF > 3%, SUSTAINABILITY IS DOUBTFUL.

Now if (iii) is not very high according to the above standard, then the concerned DMU should not bypass incurring this rate of ECC.

Questionnaires were filled by interviewing the concerned people, and systematic data was collected on production, distance of input sources, input-output relations, environmental impacts, costs of various kinds on the concerned DMUs, both of our district and other parts of the country. We used *international data* to surrogate *unavailable domestic normative figures*.

Subsequent series of field trips and visits yielded many other relevant papers, information, annual reports, project appraisals, input-output statements, balance sheets, internal environmental assessment reports of the firms selected, policy statements and existing EIA reports on the selected industries. We also used the Environmental Laboratory in the Department of Chemical Engineering at the Regional Engineering College in Durgapur to carry out some laboratory analyses. Sifting through the available relevant literature, these reports and our own, we identified the environmental stressors, prepared our database and made our own statistical analyses. To study the *environmental impacts* through laboratory analysis finally we identified seven stressors at different receptor layers, e.g. water, air, human bodies directly and some other immediate parts of the ambience.

In calculating Environmental Control Costs we followed two routes, the results of the first of which remained incomplete. This is our own approach to all environmental costs, actual or potential, if all the damages are taken into account. This is where the data that has come, as will be clear from the enclosed database schedule, is very poor. We could not calculate the full environmental control cost as a result along this route.

The other route was to take the reported ECC at the DMUs as the mitigating costs that enables retaining the comparative advantage, provided they are close to what other efficient domestic arms and internationally efficient firms in similar activities expend.

Brief Analysis of Data

Coal

We briefly present the processed data below for three collieries of our sample. The data analysis according to the methodology is presented next.

Table 1: Cost Break up for Chitra, Rajmahal and Sonepur Bazari *(Amount in Rs. Lakhs)*

Year	Chitra			Rajmabal			Sonepur Bazari		
	1	2	3	1	2	3	1	2	3
1989-90	158.5	757.89	3532.53	483.52	502.02	3712.64	208.11	332.75	1372.36
1990-91	284.5	803.15	3742.73	618.62	617.7	9133.23	41.53	83.81	387.48
1991-92	396.75	965.22	2973.02	1090.72	771.95	9500.3	293.69	404.76	1914.88
1992-93	459.45	1212.63	3348.84	1666.5	977.82	11040.63	304.69	478.09	2687.84
1993-94	494.03	1384.12	3623.01	3675.3	1221.9	14148.59	399.44	665.93	3233.06
1994-95	649.67	1469.08	3964.25	4356.92	1528.53	22191.66	781.2	921.93	6317.62
1995-96	580.48	1773.07	4183.98	3899.43	1782.26	374299.2	1064.58	1186.21	12282.42
1996-97	697. 17	1942.14	4830.48	5360	1902.93	36247.7	1520.91	1347.73	12399.73
1997-98	696.48	1878.1	4523.5	5812.17	2117.75	33001.18	2495.18	1615.16	14468.72
1998-99	1108.93	2195.73	5939.05	5787.85	2330.05	28758.44	2711.46	1860.38	14272.77

1 = Material Cost 2 = Labor Cost 3 = Financial Cost

Note: 1) Figs as per cost sheet 2) Material Cost as per stores cost
3) Labor Cost as per salaries & wages (direct)
4) Financial Cost as per total cost (stores cost & salaries & wages, depreciation)

Source: Processing of the information received in filled in Questionnaire schedules designed for the project.

The analysis is presented in tables 19 - 25 given in the main report. We present our analysis and evaluation briefly, renumbering the tables.

Table 2: Sonepur Bazari

Table 3 RCA Analysis: Sonepur Bazari

Year	Cost of Production (CP) (Rs.Lakhs)	Total Production (TP) (Tonne)	Envimamental Control Cost (ECC) (Rs.Lakhs)	Discounted $(l+12/100)^n$ n=4,....,1 (NPVCP) (Rs.Lakhs)	Discounted $(1+12/100)^n$ n=4,....,1 (NPVTP) (Tones)	Discounted $(1+12/100)^n$ n=4,....,1 (NPVECC) (Rs.Lakhs)
	Col.1	Col. 2	Col. 3	Col. 4	Col.5	Col. 6
95-96	14533.21	1854000	18.66	9256.82	1180891.72	11.88
96-97	15268.37	1751000	18.66	10905.97	1250714.28	13.32
97-98	18579.06	2403000	18.66	14863.24	1922400	14.92
98-99	18844.61	2281000	18.66	16825.54	2036607.14	16.66

Table 3 continued

Unit Cost (Ct) Rs. Te	Unit Cost Including ECC (CE) Rs./Te	$(CE - C_t)$ / CE (%)	ECC/TP = EC Rs.Te	Normative Environment cost Rs./Te	Unit Cost Including normative ECC (CE*) Rs./Te	$(CE^* - C_t)$ /CE* (%)	(CE*-Ct) / C_t (%)
Col. 7	Col. 8	Col. 9	Col. 10	Col. 11	Col. 12	Col. 13	Col 14
783.88	784.&8	0.127	1.01	11.20	795.08	1.40	1.42
871.97	873.04	0.122	1.06	12.30	884.27	1.39	1.41
774.16	773.93	0.099	0.77	13.55	787.71	1.72	1.75
826.15	826.37	0.025	0.81	14.91	841.06	1.77	1.80

We now come to the summarised information on our reference coal mine Chitra, situated in Jharkhand but which lies within the Raniganj coal belt in Burdwan district, and hence is an interesting case by itself.

Table 3: Chitra

Table 3A RCA Analysis: Chitra

Year	Cost of Production (CP) (Rs. Lakhs)	Total Production (TP) (Tonne)	Environmental Control Cost (ECC) (Rs. Lakhs)	Discounted $(1+12/100)^n$ n = 8,....,1 (NPVCP) (Rs. Lakhs)	Discounted $(1+12/100)^n$ n = 8,....,1 (NPVTP) (Tons)	Discounted $(1+12/100)^n$ n = 8,....,1 (NPVECC) (Rs. Lakhs)
	Col. 1	Col. 2	Col. 3	Col. 4	Col.5	Col. 6
91-92	4334.99	1113307	18.66	1755.05	450731.57	7.55
92-93	5020.92	1118000	18.66	2271.90	505882.35	8.44
93-94	5501.16	800098	18.66	2792.46	406141.11	9.47
94-95	6083	811105	18.66	3456.25	460855.11	10.6
95-96	6537.53	706572	18.66	4164.03	450045.85	11.88
96-97	7469.79	802902	18.66	5335.56	573501.42	13.32
97-98	7098.08	604930	18.66	5678.46	483944	14.42
98-99	9243.71	931436	18.66	8253.31	831639.28	16.66

Table 3A continued

Unit Cost (Ct) Rs./ Te	Unit Cost Including ECC (CE) Rs./Te	$(CE - C_t)$ / CE (%)	ECC/Q = EC Rs./Te	Normative Environment cost (Rs./Te)	Unit Cost Including normative ECC (CE*) (Rs./Te)	$(CE^* - C_t)$ / CE* (%)	(CE* – Ct) / C_t (%)
Col. 7	Col. 8	Col. 9	Col. 10	Col. 11	Col. 12	Col. 13	Col. 14
389.37	391.05	0.431	1.67	7.65	397.02	1.92	1.96
449.09	450.76	0.370	1.66	8.41	457.5	1.83	1.87
687.55	689.89	0.339	2.33	9.26	696.81	1.32	1.34
752.26	752.26	0.305	2.30	10.18	762.44	1.33	1.35
925.24	927.88	0.284	2.64	11.20	936.44	1.19	1.21
930.34	932.67	0.246	2.32	12.30	942.64	1.30	1.32
1173.33	1176.45	0.265	3.08	13.55	1186.88	1.14	1.16
992.41	994.41	0.201	2.00	14.91	1007.32	1.48	1.50

Comparison between Sonepur Bazari and Chitra

Table 3B: SONEPURIBAZAR - CHITRA

Year	$(CE - C_t)$ / CE (%)	$(CE - C_t)$ / CE)%)
	Col. 9*	Col. 9*
95-96	0.127	0.284
96-97	0.122	0.246
97-98	0.099	0.265
98-99	0.025	0.201

* brought down from the related tables above.

Steel

The methodology is more or less the same as that for ECL. We could fruitfully access relevant data for five years only. We compared the results with information on TISCO. To surpass the heterogeneity of output we used all saleable steel as the product and calculated unit costs accordingly. For this industry and CLW, we used information on international ECC at the efficiency level of either the same or product/ process-wise close industries taken from World Bank Working Paper No. 159.

Table 4 RCA Analysis: Iron & Steel, DSP.

Year	Cost of Production (CP) (Lakhs)	Total Production (TP) (Tonne)	Environmental Control Cost (ECC) (Lakhs)	Average Envimamental Control Cost (ECC) (Lakhs)	Discounted $(l+12/100)^n$ n=4,....,1 (CP) (Lakhs)	Discounted $(1+12/100)^n$ n=4,....,1 (TP) (Tonne)	Discounted $(1+12/100)^n$ n=4,....,1 (ECC) (Lakhs)
	Col I	Col. 2	Col. 3	Col. 4	Col.5	Col. 6	Col.7
96-97	148924	1093000	3657.75	922.93	94856.05	696178.34	587.85
97-98	164840	1259000	0	922.93	117742.8	899285.71	659.23
98-99	148258	1319000	21	922.93	118606.4	1055200	738.34
99-00	180892	1402000	13	922.93	161510.71	1251785.71	824.04

Table 4 continued

Unit Cost (Ct) (Rs. /Te)	Unit Cost Including ECC (CE) (Rs./Te)	$(CE - C_t)$ / CE (%)	Normative Environmental control cost (E*) lakhs	Unit Cost Including normative cost (CE*) Rs./Te	$(CE^* - C_t)$ /CE* (%)	(CE*- Ct) / Ct (%)
Col.8	Col. 9	Col. 10	Col. 11	Col. 12	Col I3	Col. 14
13625.25	13709.69	0.615	654.62	13719.28	0.685	0.690
13092.93	13166.23	0.556	718.80	13172.86	0.606	0.610
11240.18	11310.15	0.618	792.20	11315.25	0.663	0.667
12902.42	12968.25	0.507	871.80	12972.62	0.541	0.544

The *formula* mentioned at the methodology section is tested in the Column 10 in the above table, which shows ECC at DSP to be considerably less than 1 percent. Coming to the normative ECC we find the actual is almost half the normative RCA percentage (Column 13). Even if this normative amount is incurred, it is revealed that the measure will be much less than 3 percent (Column 14). We present necessary remarks in our calculations below.

Locomotives

Even though the CLW entrepreneurs remained cooperative, we could only collect production and cost of production data, and that too on heterogeneous output to be measured in terms of any common unit (tonnes, for example). We collected total turnover as the value of output, and instead of estimating unit cost of production, we had to be a little roundabout. We worked out share of cost in one Rupee worth of output, the conjugate being an indicator of profitability (going by the Austrian methodology). This ratio was taken as a surrogate unit cost with which we only could add the normative ECC as a ratio of one Rupee worth of output.

The percentage at this normative level set as mentioned earlier, was sustainable and clean with respect to regional comparative advantage. In this case also, our conclusion is similar to the other two industries.

Results

Coal

In all the collieries we examined we found less than 1 percent measure of ECC, and hence apparently the RCA (regional comparative advantage) in the industries in the district of Burdwan is environmentally ‘sustainable’ along our definition. However, the measure fails under scrutiny, as in terms of the normative cost considerations, the should-be ECC turns out to be much higher. Still, the should-be measure is also considerably less than 3 percent, and hence the RCA is retained for the district in the industry.

Table 5 RCA Analysis of CLW

Year	Value of Production (VP) (Lakhs)	Cost of Production (CP) (Lakhs)	Normative Envimamental Control Cost (ECC) (Lakhs)	Discounted $(l+12/100)^n$ n=9,....,1 (CP) (Lakhs)	Discounted $(1+12/100)^n$ n=9,....,1 (TP) (Tonne)	Discounted $(1+12/100)^n$ n=9,....,1 (ECC) (Lakhs)	$(CE^*- C_t)$ $/CE^*$ (%)
	Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7
90-91	3371258	69127	13.79	1217060.65	24955.59	4.97	0.019
92-93	4736673	90326	16.69	1917681.37	36569.23	6.75	0.018
93-94	5260024	84386	18.35	2380101.35	38183.71	8.30	0.021
94-95	6342781	91084	19.66	3219685.78	46235.53	9.97	0.021
95-96	5524307	85730	22.21	3138110.79	48710.22	12.6	0.025
96-97	6140658	123462	24.43	3911247.13	78638.21	15.56	0.019
97-98	6956438	61213	26.88	4968884.28	43723.57	19.2	0.043
98-99	8619126	286208	29.56	6895300.80	228966.40	23.64	0.010
99-00	7614702	718517	32.52	6798841.07	641533.03	29.03	0.004

We found that the ECL mines have only recently started taking into consideration the environmental aspects and carrying out EMP. They have been allocating spending in all areas relevant to environmental effects neutralisation, such as Biological Reclamation, Compensatory Afforestation, maintaining national standards on ambient Air and Water Quality, Rehabilitation to some extent and the other similar areas.

There is appreciable comparative advantage in coal production in this part of the country. Good quality coal is available at a moderate cost, though not at the lowest, because the industry operates with too many distortions (distortions not highlighted). However, both the normative and the actual ECC for this industry and ECL as a percentage is lower than 3 percent, implying 'sustainability' of regional comparative advantage in this industry.

ECC obeys economies of scale in production. However, the scale of ECC is rather low to examine economies of scale in ECC itself. As we compare the relevant percentage for Jhanjra (actual ECC) with another hypothetical domestic mine of comparable size that incurs necessary EMP expenditure, Jhanjra shows inefficient performance, though its percentage is lower. This is clear in the diagrammatic analysis also (Figure (3) in the main report). It only reiterates our previous finding that these mines incur considerably less in ECC than they should, (Column 15) if adequate mitigation activities have to be undertaken.

Steel

The *formula* mentioned in the methodology section is tested in Column 10 in the above table, which shows ECC at DSP to be considerably less than 1 Percent. Coming to the normative ECC, we find the actual is almost half the normative (Column 13) RCA percentage. Even if this normative amount is incurred, it is revealed that the measure will be much less than 3% (Column 14). We present necessary remarks on our calculations below.

One interesting finding is that both *unit cost of production* and ECC per unit are lower in DSP than in TISCO. The finding strongly endorses the regional comparative advantage of Durgapur in steel. Regarding the proportion of ECC, we conclude that ECC is considerably less than it should be.

An important finding is that DSP incurs nearly the efficiency level ECC in terms of international standard, to the extent our improvised standard setting is more or less close to reality. The industry with adequate ECC is clean and sustainable.

Thus, the comparative advantage in steel in this region is sustainable.

Locomotives

Our methodology in this case has not been able to produce many useful results, not because of the methodology, but because of unavailability of data. The percentage at the normative level set as mentioned earlier and as could be worked out in some round-about manner (mentioned in the section on discussions), was sustainable and clean with respect to regional comparative advantage.

General

The study reveals that the ECC is only about 0.5-1 percent if efficiently done through adequate EMPs. It is important to note once again, that noticeable economies of scale in ECC with respect to output and costs of production.

We have carried out some meaningful sensitivity analysis also to examine the strength of regional comparative advantage in the industries and the existing advantages were endorsed even with the average ECC slightly higher than the benchmark we set.

Discussion

As our task was not to estimate any cost function, we simply scanned through different important aspects of coal costing and related cost of Environmental Programmes (EMF) using secondary materials. Then we processed our own database for the variables and estimated our equations. This we did by deciphering the balance-sheet features of debit-credit and allocations break-ups.

The discount rate has been taken to be 12 percent as has been done by few other cost-estimation related works. This seems plausible considering a 10 percent per annum inflation on an average, along with the assumed presence of other interrelated factors of time preferences such as the trajectory of the bank rate, the behaviour of the Sensex indices in the recent past and other related factors. We tried to work on the basis of data of 10 years, over the 1990s through the century. However, as we could collect all the data for four /five years for some of the mines only, we had to make compromises in the respective cases.

For coal, we believed that the incurred ECC is short of what it should be, though it trivially satisfies our criterion of sustainability of regional comparative advantage. This is so because the percentage spent on ECC is less than 3 percent, which is the benchmark that we set, because they spent less, not because the necessary expenditure was within the limit, which eventually happened to be so. We used the domestic ECL colliery Rajmahal and an average of other collieries from other parts of the country as the data we found in a BICP report on Environment and Coal Mining.

A larger amount appears to have been spent per unit in Chitra than Sonepur Bazari, due to the fact that the cost of production at Sonepur Bazari is appreciably higher than the reference mine, Chitra. This is because the cost of production comes in the denominator of our RCA measure. The reason behind the lower unit cost in Chitra seems to be the lower variable cost components as its capacity per year is significantly lower than Sonepur Bazari. We also found that our measure was less than 1 percent but greater than Sonepur Bazari (Column 9 of the earlier table). Hence, once again in terms of our definition, the value of the RCA measure reflects a strong case for regional sustainability. However, our observation that the ECL mining operation has been under-spending with respect to EMP also holds good in this case.

Our purpose has been to examine current costs and not the comprehensive long run costs of production. We have looked into labour cost, material cost, inclusive of depreciation per year, financial cost of investments currently affecting per year cost of mining in the region. Then we processed the information on environment and related costs. (For reference to source-tables, please see the database EE1 – EE28 annexed with the final report). The details of calculation are given below, immediately after the tables on the three collieries

For Iron and Steel industries, we summarised environmental impacts of steel-making in brief, and also examined the nature of control costs incurred. The main problem was accessing the relevant data. Toward this end, two of our assistants registered for special training imparted by the Training & Personnel Management cell of DSP.

The findings strongly endorse the regional comparative advantage of Durgapur in steel. Regarding the proportion of ECC, we conclude the same way as in the case of ECL. ECC is considerably less than it should be, as we found from our normative ECC in steel that we set on the basis of information available in World Bank Working Paper No. 159. Nevertheless, if the plant had been incurring the normative ECC, its regional comparative advantage would still be retained.

For Locomotives, our methodology could not produce useful results because of unavailability of data. The required data on ECC could not be figured out, as according to CLW administration, CLW had shut down their mini steel foundry for about three to four years. The major processing work involves heavy duty electrical networking in the machines and heavy duty welding work, which was done using electrical machinery and power, which it is believed, do not create environmental damage. Their technology was also modernised according to ISO-14000 standard apart from routine afforestation annually.

Due to the paucity of data, only the following points may be made: CLW seems to be unaware of their environmental role and position. They grossly under spend on this account. However, had they been incurring adequate ECC, their regional comparative advantage would have been retained

We end this discussion with a summary of major conclusions and policy recommendations drawn for the individual units.

There is an appreciable comparative advantage in coal production in this part of the country. Good quality coal is available at a moderate cost, though not at the lowest cost as the industry operates with too many distortions (distortions not highlighted). However, both the normative and the actual ECC for this industry and ECL as a percentage is lower than 3 percent, implying ‘sustainability’ of regional comparative advantage in this industry.

This is true about steel and DSP. An important finding is that DSP incurs nearly the efficiency level ECC in terms of international standard; to that extent our improvised standard setting is more or less close to reality. The industry with adequate ECC is clean and sustainable.

CLW seems to be unaware of their environmental role and position. They grossly under spend on this account. However, had they been incurring adequate ECC, their regional comparative advantage would have been retained.

Policy Recommendations

- Governments at the Central, State and local levels have to act on ameliorating an indifferent attitude towards the environment. There is a corroboration of so-called lack of awareness among the decision makers in industrial units on the environmental implications of their actions and inactions. This is more or less true in all the three units we examined. It has also been perceived that there is a feeling of costliness of mitigating EMP among the people who matter, as well as a feeling of subterranean guilt about inadequate care of the environment. It has to be made clear that environmental impacts are neither abnormal nor costly to undertake compensating actions. The study reveals that the ECC is only about 0.5-1 percent if efficiently done through adequate EMPs.
- Bulk of EMP-infrastructure should be promoted by cooperative actions by DMUs located in a relatively small neighbourhood This has to include governments as members and would be less costly for individual companies. Common Environmental Management Programmes and a common pool of funds may be amassed without burdening any single DMU. Otherwise, wasteful repetitions may occur, discouraging intending incumbents because of inherent externalities and free riding possibilities. Fragmented environmental research should be stopped as coordinated more useful incurring lesser cost can access information

- Though the size of the sample is not significant enough for such a conclusion, we have found noticeable economies of scale in ECC with respect to output and costs of production. This is another very strong reason why the governments at all levels should provide infrastructural support to a common organisation of multiple impacting industrial units.

- Apart from these commonly applicable implications a coal-specific one is in order. In some cases the toxicity and other negative proprieties of coal in this region have been pointed out to be adverse when the cost of extraction is low, as is evident from the information. While this information is somewhat exaggerated, it may be argued that since the abatement cost of pollution is low and with appreciable economies of scale, use of this coal should not be discouraged unless the marginal net benefit of using the coal including the cost of abatement by users, is negative.

- As demand for steel is continuously increasing because of rising developmental activities in LDCs, and also in the developed countries, production of steel in India will increase. This will be aided by liberalisation across the world. It appears that production of steel in this region is cheaper as compared to other regions of the country, including the cost of environmental management. The policy implication is that incentives should be created for full utilisation of the potential so that all costs, including ECC, operate at the efficiency level.

- Chittaranjan Locomotive Works seem to be mistaken regarding their potential EMP costs in case they undertake it more rigorously. The report obtained from WBPCB clearly shows that they generate adverse impacts, but does not imply costly abatement activities. Hence the responsibility of the public sector unit should lie with the central government. The Government administration at the decision-making level should eliminate these inactions.

- We analysed some prima facie policy implications for the local, state and the national governments so that they induce the units to be more active in proper and adequate EMP, and promote permanent sustainability of regional comparative advantage in these industries. Our endeavour to work out a DALY-type evaluation was futile because, as will be evident from the fuzzy nature of responses to our schedules, the relevant information is simply not available, not systematised nor preserved carefully. The required data has to be generated at the source and its maintenance should be made mandatory.

- The implications will be clearer from the detailed report if given a thorough and sympathetic perusal.

- [The *Data Base* has been submitted along with the questionnaires with the final report.]

Market Based Instruments for Regional Air Environment Management at Jamshedpur

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Introduction

Market-Based Instruments (MBIs) are regulations that encourage behaviour through market signals rather than through explicit directives regarding pollution control levels or methods. These policy instruments, such as tradable permits or pollution charges, are often described as "harnessing market forces," because if they are well designed and implemented, they encourage firms (and/or individuals) to undertake pollution control efforts that are in their own interests, and that collectively meet policy goals. MBIs have three goals: cost effectiveness, decreased externalities and revenue generation.

The two economic principles for MBIs are polluter-pays and precautionary:

- The polluter-pays (or user-pays) principle requires that polluters should internalise the cost that would not normally be incurred by the polluter or user (externalities)
- The precautionary principle provides a mechanism for dealing with the uncertainty of impacts

Emission Trading

Emission trading is a market-based system that allows firms the flexibility to select cost-effective solutions to achieve established environmental goals. With emission trading, firms can meet established emission goals by:

- Reducing emission from a discreet emission unit
- Reducing emission from another place within the facility
- Securing emission reduction from another facility
- Securing emission reduction from the market place

Emission trading encourages compliance and financial manager to pursue cost-effective emission reduction strategies, and provides incentives to emitters to develop the means by which emissions can inexpensively be reduced.

Environmental Bubble

A bubble is a regulatory concept where by two or more emission sources are treated as if they were a single emission source. This creates flexibility to apply pollution control technologies to whichever source under the bubble has the most cost-effective pollution control option, while ensuring that the total amount of emissions under the bubble meets the environmental requirement for the entity. Bubbles are closed systems. They allow flexibility to the existing sources in meeting required emission limits, by treating multiple emission points as if they face a single, aggregate emission limit. This allows the firm to rearrange discharge points within the plant in the most cost-effective manner.

Emission Offset

Offset is a form of credit-based emission trading. Offset is created when a source makes a voluntary, permanent emission reduction that is in surplus to any required reductions. Existing sources that create offsets can trade them with new sources to cover growth relocation. Regulators approve each trade. Regulators normally require a portion of the offsets to be retired to ensure an overall reduction in emission. Offsets are an open system. One offset is an emission reduction that a pollution source has achieved in excess of permitted levels and or required reductions. The excess amount is the credit and can be sold in the market. The offset programme was developed in 1976 to reduce the conflict between economic growth and progress towards air quality standard levels in non-attainment regions.

In the present study two market-based instruments – environmental bubble and emission offsets - are developed and evaluated.

Objective

The objective of the project was to:

- Design and assess market based instruments to improve economic and environmental performance of the industries in Jamshedpur region.

Study Area

The study is limited to Jamshedpur region. Jamshedpur is located in the state of Jharkhand, and covers an area of 64 sq. km. The population of the city is 570,349 (Census, 2001). Two important rivers viz. Subarnarekha and Kharkai flow in the region.

Data Collection and Analysis

Major air polluting industries in the Jamshedpur region include iron and steel, engineering and locomotive, agricultural tools, tube manufacturing, etc. A report on Tata Iron and Steel Company Ltd. (TISCO) and a carrying capacity report developed by NEERI were considered to identify potential air polluting sources. Based on field visits and gathered information, the following polluting companies were selected in the region for the study:

- TISCO
- Tata Pigments Ltd.
- Tata Rayerson Ltd.
- Tata Engineering and Locomotive Company Ltd. (TELCO)
- Tinplate Company of India Limited (TCIL)
- Telco Constructions and Equipment Company Ltd.
- Tata Cummins Ltd.

A survey was conducted to collect data on air emissions from different sources, and cost and efficiency of existing abatement devices in all the selected companies. Another survey was conducted to find out possible alternate abatement devices for each emitting source. The cost and efficiency data of each such device were also gathered.

A list of best available abatement technologies (BATs) was developed for each emitting source from among existing and alternate abatement technologies suited at that source on the basis of unit abatement cost of the technology.

Data Analysis

The collected data from the selected companies reveal that no NOx abatement device has been installed at any source. Therefore, NOx data are not used in further calculations. The five companies have installed suspended particulate matter (SPM) abatement devices to check dust emissions. Data on gas volume, concentration of SPM at inlet and outlet are used to estimate annual SPM emissions and abatements by existing measures at each emitting source.

TISCO alone generates 7.267 kg/s of SPM and 257.03 g/s of NOx before abatement. While all selected companies, including TISCO generate 7.308 kg/s of SPM and 257.25 g/s of NOx, it shows that TISCO generates 99.44 percent of SPM and 99.91 percent of NOx before treatment in the selected group.

Two types of analyses are carried out – one considering the capital cost, and another without taking capital cost into consideration. In the first category, the capital costs have been annualised using a discounted cash flow technique. The present value of the capital cost is multiplied by the capital recovery factor, which is given by the following formula:

$$C.R.F. = r\,\frac{(1 + r)^{T}}{(1 + r)^{T} - 1}$$

where, r is the discount rate and T is the lifetime of the device in years. For r = 10% and T = 15 years, the capital recovery factor is 0.131474. Annual total abatement cost is calculated for each existing and alternate technology by adding annual operating cost to the annualised capital cost.

Development of abatement cost curves and market based instruments (including capital cost of the devices)

Construction of Cost curves

An abatement cost function is developed and parameters are estimated using annual abatements and costs data for all existing pollution control devices. With the help of these parameters, annual abatement costs are estimated for the same level of abatement. The abatement devices are ranked on the basis of the difference of observed and estimated annual abatement costs. The top rank (1) is given to the technology having the most negative value of the difference between observed and estimated costs. The last rank is given to the technology having the most positive difference. All the abatement devices are rearranged as per their ranks from first to last.

Abatement cost curves are drawn for all existing abatement technologies in the selected companies. The x-axis contains cumulative abatements and the y-axis, its cumulative costs. The abatement cost curves are also drawn for all the abatement measures installed at various polluting sources in TISCO alone. Marginal abatement cost curves are also drawn for the technologies installed in all companies, as well as in TISCO. The y-axis in marginal cost curves contains marginal abatement costs, while the x-axis contains cumulative annual abatements.

The suppliers of alternate abatement devices were contacted to collect data on alternate devices for abatement of SPM at different sources. Data on capital cost, operational cost and efficiency were collected. Abatement cost curves and marginal cost curves are drawn for all the alternate abatement devices. Similar curves are also drawn separately for the alternate devices at different emitting sources in TISCO. Similarly, marginal abatement cost curves are drawn for the alternate devices in all companies and in TISCO.

Annual abatement costs and abatements are also calculated for the best available abatement technologies as per the procedure adopted earlier. An abatement cost function is also developed for ranking all these best available technologies. Abatement cost curves are drawn for the best available technology in all the selected companies. The similar curves are also drawn for the best available technology for the different emitting sources at TISCO. Similarly, marginal cost curves for the best available technologies in all companies and in TISCO are also drawn.

Development of Market Based Instruments

The cost curves are used to estimate abatement costs for different target levels of abatement. A bubble with its limit equals to the sum of existing SPM emissions from all five selected companies is developed. The existing abatement cost is estimated for the bubble from the abatement cost curve of existing abatement technologies in all the companies. The abatement costs are also estimated from cost curves with alternate and best available technologies for keeping the limit of the bubble unchanged.

Two offsets of 5 MT and 8 MT of SPM abatement are developed, and associated additional costs were estimated for alternate and best available technologies.

Development of Abatement Cost Curves and Market Based Instruments (excluding capital cost of the devices)

Construction of Abatement and Marginal Cost Curves

The capital cost can be treated as sunk cost for abatement devices. In such cases, only annual operating costs will be considered for development of abatement cost curves and market-based instruments. This section develops market-based instruments on the basis of operating costs only. The abatement technologies are ranked as per their unit operating abatement costs. The highest rank is given to the technology having the least per unit abatement cost.

The abatement and marginal cost curves are drawn in a similar manner as done earlier in case of including capital cost. The curves are drawn for all three sets of technologies.

Development of Market Based Instruments Using liner programming Model

The cost curves are used to estimate abatement costs for the bubble and proposed offsets.

Environmental Bubble

The optimum abatement from alternate measures are calculated using the LP model. It is found that all optimum abatements are at TISCO only. As per the current situation, TISCO abates 212.54 MT SPM under CAC with a cost of Rs.345.92 million (including capital cost) or Rs.81.72 million (operating cost). For the environmental bubble, TISCO may abate 213.22 MT of SPM with an abatement cost of Rs.205.34 million (with capital cost) or Rs.74.07 million (without capital cost). It shows that there is a lot of cost saving. The additional abatement made by TISCO can be rewarded as emission reduction credits (ERCs) to TISCO, which can be sold in the market to other companies.

In the case of the best available technologies as well, most of the optimum abatements are at TISCO only. Tata Pigments is the company that has a cost-effective abatement device, but it cannot reduce more, therefore, it can be allowed to make its own required abatements. TCIL has less per unit operating costs, and hence, its abatement is optimum under operating cost (without capital cost) category only. But, if we see total cost including capital cost, then its abatement is not cost effective. Anyhow, the company is not in a position to abate more, therefore, it cannot be considered as a candidate to earn ERCs. TISCO is the only company in the group that has the capability to reduce more and at less cost.

The results obtained from the abatement cost curves and the model are compared in Table 1 for net SPM abatement of 213.22 MT.

Table 1: Comparison of Abatement Costs for the Bubble (Rs. Millions)

Abatement Technologies	Total Abatement Cost			
	Including Capital Cost		Excluding Capital Cost	
	Using Cost Curves	Using LP Model	Using Cost Curves	Using LP Model
Existing or under CAC	346.26	346.26	81.80	81.80
Alternate	231.75	205.34	74.07	74.07
Best Available (BATs) technology	177.43	175.14	56.95	56.94

The annual abatement costs with BATs are much less than existing / alternate technologies. Huge cost saving is an incentive to the companies to adopt the bubble policy.

Emission Offsets

The offsets of 5 MT and 8 MT of SPM abatements have been evaluated with alternate and best available technologies. For offsets of 5MT / 8MT, total annual abatements would be 218.22 MT and 221.22 MT respectively. It is found that further abatement is possible with TISCO only. Therefore, for the proposed offsets, TISCO will make the required abatements and earn ERCs.

With Alternate Abatement Technologies

The model results show that the optimum abatements, in addition to those required for the bubble, for developing an offset of 5MT would take place at the blast furnace and refractory material units of TISCO.The refractory material unit of TISCO will abate more for the offset of 8MT. The optimum abatements are the same under both the cases of cost considerations.

The cost (including capital cost) of the offsets of 5 / 8 MT will enhance by Rs. 15.28 / 24.73 million. The operating costs for offsets of 5 MT and 8 MT will increase by Rs.6.29 million and Rs.12 million respectively.

With Best Available Technologies

The model results show that the optimum additional abatements for creating 5 MT offset will take place at power house # 3 (4090.3 T) and blast furnace (8859.7 T) of TISCO and boiler of TCIL (50 T). The total additional cost (including capital cost) for this offset would be Rs.7.92 million. For 8 MT offset, further optimum abatement of 3 MT will take place at the blast furnace of TISCO, with an additional cost of Rs.9.05 million. The total abatement cost for 8 MT offset would be Rs.16.97 million.

If we consider only operating costs of the devices to evaluate optimum abatements for creating 5 and 8 MT offsets, then the model results indicate that the additional abatements for 5 MT offset will take place at sintering plant (4040.3 T) and blast furnace (831 T) of TISCO and Wartsilla DG 2 of TELCO (28.7 T), with a total additional cost of Rs.3.6 million. For 8 MT offset, further optimum abatement of 3 MT will take place at the blast furnace of TISCO with an additional cost of Rs.2.71 million. The total abatement cost for 8 MT offset would be Rs.6.31million.

The results for offsets of 5 and 8 MT of SPM abatement are compared in Table 2. The results show total / additional costs calculated from cost curves and LP model for the proposed offsets. The total cost includes the bubble cost and the offset cost, with same abatement technologies.

The cost saving is much more with best available technologies for both offsets. The required abatements for the offsets are made by only TISCO in almost all the cases. Therefore, TISCO can be allowed to earn the credits, and other cost intensive companies can purchase these credits from TISCO.

Results and Discussion

The abatement cost calculations from cost curves and LP model for the environmental bubble indicate that the cost saving is much more with BATs. Therefore, it is suggested that if inter-firm trading is introduced, then companies will focus towards cost effective measures i.e. BATs. These measures are also capable of abating more SPM emissions, and the companies would try to abate more SPM with BATs and earn ERCs. As TISCO is the only company in the selected group that can abate more with less cost, emission reduction credits will be earned by TISCO, and other companies for whom SPM abatement is cost intensive can purchase those credits from TISCO.

Table 2: Comparison of Abatement Costs for the Proposed Offsets (Rs. Millions)

Offset Quantity	Total / Additional Cost with Alternate Technologies				Total / Additional Cost with Best Available Technologies			
	Including Capital Cost		Excluding Capital Cost		Including Capital Cost		Excluding Capital Cost	
	Using Cost Curves	Using LP Model	Using Cost Curves	Using LP Model	Using Cost Curves	Using LP Model	Using Cost Curves	Using LP Model
5 MT	238.09 / 6.34	220.62 / 15.28	80.37 / 6.30	80.36 / 6.29	183.72 / 7.30	183.06 / 7.92	60.56 / 3.61	60.54 / 3.60
8 MT	241.90 / 10.15	230.07 / 24.73	86.08 / 12.01	86.07 / 12.00	192.76 / 16.34	192.11 / 16.97	63.27 / 6.32	63.25 / 6.31

Similarly, the cost saving is much more with best available technologies for both the offsets. The required abatements for the offsets are made by TISCO only in almost all the cases. [Therefore, the TISCO can be allowed to earn the credits and the other companies having cost intensive devices can purchase these credits from TISCO].

The proposed LP model gives more cost effective schedules for required abatements in all the cases. The development of the model for the environmental bubble and offset is also simple, and takes less time in comparison to the development of abatement cost curves. It shows that the LP model can be used effectively for such calculations.

Recommendations

The results show that there are huge cost savings in reducing the emissions with best available technologies. Cost saving is a good incentive to attract the players to adopt emission trading schemes.

Two types of emission reduction trading schemes recommended are:

Inter-firm Emission Reduction Trading

TISCO is responsible for more than 90 percent of the SPM emissions in the Jamshedpur region, and also has low cost options of further reducing the SPM emissions. Available technologies, players and their roles severely restrict an emission trading market system to operate.

However, it is recommended in this specific circumstance, that all the major industries in the region be asked by the Pollution Control Board to reduce their emissions by 5 percent below the consented SPM emission levels (in the consent to operate and establish under Air Act). They could be given two options for complying with the additional SPM emission reductions:

- Reduce the emissions at their own site
- Procure Certified Emission Reduction

The industries can be allowed to bid for emission reductions based on validated proposals - baseline being the present emission permits (in the consent to operate and establish under Air Act) only. Validated emission reduction proposals can be registered, and based on an annual monitoring of emission reductions, the Certified Emission Reductions can be granted. These certified emission reductions could be the basis for assessing the compliance by the industries of the additional 5 percent reduction.

The institutional mechanism to implement these additional emission reductions could be led by a voluntary association of industries or a citizens/stakeholders forum to improve the environment in Jamshedpur. This forum could establish a registry, designating, validating and monitoring entities. The operational framework could be similar to that of emission trading under Kyoto protocol.

The effective emission trading activity can take place only among the equivalent players. It is really not present in the selected group because TISCO is the only major player in Jamshedpur. Hence, TISCO may dominate, and a monopoly can take place in long run and that would not be good for the proposed inter-firm trading. But, in order to get an experience of the process, the pilot emission reduction trading (PERT) can be introduced at Jamshedpur among the local companies.

Intra-firm Emission Reduction Trading within TISCO

TISCO alone has 11 emitting sources with substantial emissions. Total SPM emission load (before treatment) from TISCO is 229.17 MT p.a. TISCO also has a separate environmental division to take care of all environment related problems. The validating and monitoring activities for emission reduction certificates will not add much extra financial burden on TISCO. Healthy competition can be established among the emitting sources of the company, if each emitting source is considered as an independent unit. Even we will not have a large number of players to decide the market price of the ERCs, but intra-firm emission reduction trading within TISCO can improve its abatements with less cost. Therefore, intra-firm trading within TISCO is recommended to experience the process of emission reduction.

Strategy for Techno-Economic Feasible Treatment

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Introduction

Kolhapur city, with a population of around five lakh, is subject to recurring out-breaks of water-borne diseases and epidemics like Hepatitis and Gastrointestinal diseases. This is due to the fact that the Panchganga River, a major source of drinking water for the city, is polluted by total discharge of municipal wastewater. The estimated municipal wastewater is approximately 81 million liters per day (MLD). This wastewater is discharged through four major open nallahs (sewage channel).

Nallah	Direction	Discharge capacity (Million liters per day)
Jayanti	South – north	49
Dudhali	South – north	17
Line Bazaar	East – west	6
Bapat Camp	West - east	10

Inadequacies of the Existing Wastewater Treatment Facility

The Kolhapur Municipal Corporation commissioned a sewage treatment plant for municipal wastewater in the year 1976. This facility is grossly inadequate in terms of quantity and extent of wastewater treatment.

The present treatment capacity of 29.8 MLD is inadequate against a discharge flow of 81 MLD. Consequently, excess sewage water reaching the treatment plant gets discharged into the river in its untreated form. Moreover, the plant provides only primary treatment, which is not adequate to treat sewage confirming to the river discharge standards.

General maintenance and up-keep of the treatment facility is not up to the mark, and hence sewage and municipal waste pollutes the Panchganga River. The pumping equipment too has become old, depleted and inadequate, often resulting in a breakdown of the sewage treatment plan.

It is against this background that the present study makes an investigation into alternative techno-economic feasible treatment.

Objectives

The objectives of the present study are to explore options available to:

- Prevent pollution of Panchganga River by domestic wastewater from the Kolhapur Municipal Corporation
- Reduce the hydraulic load on the sewage treatment plant (STP) located near the banks of the River Panchganga
- Reduce the cost of treatment by treating the wastewater to irrigation standards
- Reuse of treated domestic wastewater
- Provide irrigation water to needy demand areas for social forestry, afforestation, cash crop and horticulture development
- Improve overall sanitary conditions of the city
- Develop the green belt in the city

The present study envisages preparing a proposal for treatment of sewage for Kolhapur city to irrigation standards. The treated sewage can be used for irrigating lands inside the municipal limits, as well as lands available adjacent to the Kolhapur Municipal Corporation (KMC) limits.

Economic Analysis Component of the Study

The basic objective of water quality management is to determine the environmental controls that must be instituted to achieve a specific environmental quality. In order to attain the same, efforts and activities have to be centered upon the assignment of allowable discharges to a water body so that designated water use and water quality standards are met using the basic principle of cost-benefit analysis. Hence, it is generally insufficient to simply carry out an engineering analysis of the effect of waste load inputs on water quality. The analysis also has to include the economic impact analysis, which in turn has also to take into account the socio-political and financial constraints that are operating in the overall context.

Methodology

The survey method was adopted and the questionnaire method was used to collect the necessary primary data. The E ward of Kolhapur city and all wards of Ichalkaranji were selected for study. The E Ward of Kolhapur mainly consists of the University area, Rajarampuri, New Shahupuri and Nagala and Tarabai Park area of Kolhapur. There are twelve main wards in Ichalkaranji. In Kolhapur, representative sample family units were identified from each area. The universe area was divided into:

- University area: University campus, Rajarampuri, Salokhe Nagar
- One to 14th lane, Rajarampuri area
- New Shahupuri
- Nagala and Tarabai Park area, Bawada and Kadamwadi

From the above areas it was decided that as Rajarampuri and its extension form a major part of the E ward, 50 percent of the sample family units would be selected from this area, and the remaining 50 percent from the other areas. The Rajarampuri area has fourteen main lanes and the population here is a mix of lower, middle and upper class families; thus, a selection of samples here offered adequate income-wise representation.

Ichalkaranji and its neighbouring areas too had to face severe water-borne disease. Ichalkaranji has twelve main wards. Hence, it was decided to select samples from each ward. Similarly, the following villages around Ichalkaranji were selected for survey:

- Rui
- Chandur
- Kabnur
- Shirdhon
- Shirdawad
- Abdullat
- Korochi
- Takawade.

50 percent of the sample size was chosen from Ichalkaranji and 50 percent from the above eight villages.

Two hundred families from Kolhapur (E ward) and 200 families from Ichalkaranji and its neighbouring villages were selected as the sample size. In Kolhapur, 100 families out of the sample size of 200 were selected from Rajarampuri and the remaining 100 from other areas. Of the 200 families from Ichalkaranji, 100 families were chosen from Ichalkaranji and 100 from the neighboring eight villages. 4 to 5 families were randomly selected from each lane of Rajarampuri, with care being taken to see that of the sample family unit selected, two / three came from lower and middle income class and the other two were from higher middle / high income groups. Thus, the 100 sample units from Rajarampuri were representative in nature. The remaining 100 sample units were randomly selected from other areas. Only 125 of the 200 families chosen from the E Ward of Kolhapur responded to the questionnaire that was circulated among them. In the case of Ichalkaranji, 100 families were selected from the 12 wards, and each ward sample family units was 2-4. 100 families were selected from the remaining 8 villages on a random basis. Here too, 128-125 responses were received. The survey work was carried out in between October and November 2000. Two investigators carried out the survey – one each in Kolhapur and Ichalkaranji.

Cost of Illness Studies

A survey of the cost of illness was conducted on sample family units in Kolhapur, Ichalkaranji and a few villages near Ichalkaranji as mentioned in the methodology of study. Two hundred families from each of these above mentioned sectors were randomly selected, covering different sizes and income groups. The survey method was adopted and the questionnaire method was used to collect the necessary data. The findings were classified as follows:

- Nature of Illness
- Hospitalisation period
- Hospitalisation expense
- Other expenses
- Loss of working days due to Illness

The survey also included preventive analysis and Willingness to Pay analysis.

- **Nature of Illness:** The survey revealed that outbreak of Hepatitis, typhoid and gastrointestinal diseases were more pronounced. In addition to this, throat infection was also commonly observed.
- **Duration of Illness:** Illness varied from 1 to 15 days, and in some cases, more than a month.
- **Hospitalisation cost:** The survey revealed that the average cost of hospitalisation was Rs.7,450/- per indoor patient.
- **Other expenses:** The survey included cost of medicines, consultation fee and laboratory cost. The total average cost found to be Rs.2,800/- per patient.
- **Loss of man-days due to Illness:** Infection and hospitalisation lead to loss of man-days, affecting the wages of employees to a great extent. The average man-days lost were found to vary between 8 to 15 days.

Preventive Cost Analysis

The most common method employed for prevention of illness due to water-borne diseases was boiling water before consumption. Most of the residents who responded to the survey boiled water for almost 6 months during a year. Different fuels used for boiling water were LPG and kerosene. The average preventive cost was Rs.1,800/- per annum.

Willing to Pay Analysis

The survey revealed that more than 90 percent of the sample groups were willing to pay higher water charges. 30 percent of respondents were ready to pay additional charges of up to Rs.25/- per month; 18 percent were willing to pay Rs.50/- per month, and 10 percent were ready to pay Rs.150/- per month additional charges if the quality of drinking water supplied by Kolhapur Municipal Corporation was improved.

Alternative Treatment Technology

The cost of the scheme suggested by the Kolhapur Municipal Corporation would be Rs.820 million, while the alternative options suggested here would cost Rs.386 million. The proposed Kolhapur Municipal Corporation scheme for treatment of municipal wastewater envisages treatment conforming to river discharge standards. Since these standards are more stringent warranting more elaborate treatment, the cost of treatment is higher. Moreover, the treatment does not include disinfection of sewage to destroy pathogens. The risk of illness therefore, remains.

Alternative options of the present study envisage less expensive treatment of sewage conforming to irrigation standards, not requiring disinfection, and with zero river pollution.

Comparative Cost Analysis

Our study adequately reveals that the proposed alternative wastewater treatment plant is comparatively cheaper cost-wise as treatment of municipal wastewater to irrigation standards is cheaper than treatment conforming to river discharge standards. The cost-wise estimate of the proposed Kolhapur Municipal Corporation sewage treatment plant and the cost of the alternative treatment of this study are as follows:

Treatments options	Sewage Treatment Plant Cost Rs. in millions	Operation And Maintenance cost Rs. in millions
Kolhapur Municipal Corporation proposed	820	55
Alternative treatment method of this study	386	105

Farmers in the demand area with availability of irrigation water can shift over to a cropping pattern. The survey undertaken adequately demonstrates this.

Changed Cropping Pattern

The sample farmers were asked what their proposed cropping patterns, tentative cost yield per acre and farm incomes would be if water was available round the year. Data collected reveals the following main conclusions.

- Cropping Pattern: All the 20 farmers surveyed revealed that they would bring about a shift in their cropping pattern and move over to cultivation of commercial crops like sugarcane and wheat. They would practice mixed farming with wheat and sugarcane on part of their land, while wheat, jawar and groundnut would be grown on another part. Sugarcane would be a 12-month standing crop.
- Average total cost of production of sugarcane per acre would be Rs.12,000/- to Rs.15,000/- per year, while cost of production of groundnut would be Rs.5,000/- per acre per year and that of Jawar/vegetable Rs.3,000/- to Rs.7,000/- respectively.

Total yield per acre would be 40 tonnes for sugarcane.

- Gross farm income crop-wise per acre would be:
  - Sugarcane: Rs.50,000/- per acre
  - Wheat: Rs.12,000/- per acre
  - Jawar: Rs.10,000/- to Rs.12,000/- per acre
  - Vegetables: Rs.16,000/- per acre
- Net profit per year per crop per acre would be:
  - Sugarcane: Rs.38,000/- to Rs.40,000/- per acre
  - Wheat: Rs.6,000/- to Rs.9,000/- per acre
  - Jawar: Rs.7,000/- per year per acre
  - Vegetables: Rs.10,000/- to Rs.15,000/- per acre per year

Thus, our sample survey of farmers in Girgaon reveals that

- Farmers are ready to accept irrigation water
- Supply of water assures wage availability year round for farmers
- With assured water supply, shift in cropping patterns develops commercial crop cultivation.
- Shift is also seen towards mixed cropping pattern.
- All farmers are not moving towards sugarcane cultivation on all land. But the trend is to cultivate sugarcane on some land and in the remaining holdings, to move towards cereal and vegetable cultivation. Shift to cultivation of cereals and vegetables is a low cost- high income yielding cropping pattern, while a shift to sugarcane is a high cost - high income yielding cropping pattern.
- Shift in cropping pattern with assured water supply raises farm productivity and farm income levels of beneficiary farmers.
- Assured irrigation water supply could also lead the farmers to undertake diversified crop production. Possibility of mixed cropping pattern and inter-crop pattern are more feasible. The farmers in villages around Kolhapur city know the economic feasibility and higher income gain from cultivation of vegetables, which can be cultivated as inter-crop along with the yearlong standing crop, sugarcane. In addition, cultivation of maize and sunflower are also possible along with sugarcane cultivation. Mixed farming techniques can also be progressively increased so that farm incomes are augmented along with sugarcane cultivation. This change in cropping pattern is possible with assured water supply.

Cost Benefit Analysis of Cleaner Production Technologies in India

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Introduction

The environmental protection policy in India has traditionally relied on pollution control technology that treats waste according to the end-of–pipe solution, which involves disposal through dilution or burial. But in recent years, the limitations of this approach have become increasingly evident due to rising awareness of global environmental risks, growth of waste volumes, and the limits of waste disposal to land, sea and air. At the same time, there is a realisation that the end-of-pipe solution to pollution simply displaces the problem elsewhere, or creates entirely new environmental hazards. This has prompted leading firms and researchers to look for new models of industrial activity based on minimisation of waste, energy saving and reduction of resources used in production. This could be achieved through the concept of Cleaner Technology (CT), which is an integrated pollution control and prevention approach that conserves resources, minimises waste generation and energy use, and is based on the comprehensive analysis of process and product impacts on the environment.

Objectives

The objectives of the study are to:

- Carry out a cost-benefit analysis of cleaner production technologies, including the related spill-over/spin-off effects.
- Evaluate the impact of cleaner production technologies in some selected Indian industries like agrochemicals, pharmaceuticals, electroplating and chemicals & dyes.
- Identify the background and driving forces for the development and use of cleaner technologies as well as the barriers to them.
- Infer the implications of this study for corporate (and also new industries) and macro policies, including the local economy.
- Identify the types of training and sources of training relating to cleaner technologies.
- Identify the characteristics of organisational citizenship.

Scope of the Study

The study covers agrochemicals, electroplating, pharmaceuticals and dyes &chemical industries in Maharashtra and Gujarat.

In a majority of cases studied, the pollution abatement is carried out on an incremental basis involving retrofitting, recycling, recovery and fuel/raw material substitution. In a few cases however, the generically new plant or new automatic packing/filling units are installed. These are mentioned in each case under the head “Cleaner Technology” (CT).

Methodology and Data Sources

For the purpose of the study 17 firms were chosen, forming a cross section of agrochemicals, electroplating, pharmaceuticals and dyes & chemical industries in the two states of Maharashtra and Gujarat. The analysis was attempted at three levels:

- The micro level or the level of the firm, to ascertain economic rationality in terms of the direct costs and benefits associated with CT.
- Indirect or spin-off effects by way of merit goods to immediate environment.
- The public goods level, where perceptions of population in the surrounding area were expressed through contingent valuation.

The tools of *Cost Benefit Analysis* like payback period and net present value (NPV) were employed to assess CT. However, the NPV method was used only in cases where the payback period exceeded three years to ascertain the returns making due allowance for the time value of money discounting. This was carried out on the assumption that the life of the equipment is 10 years and that the cost of the capital is 15 percent. Also, a *Waste Measurement Index* (WMI) was computed wherever relevant and possible. All these were based on both quantitative and qualitative data gathered with the help of a detailed questionnaire and interviews. Respondents were asked to assign ranks to specific aspects like driving forces and barriers. The rankings were then weighted on the basis of scores assigned by three independent experts. In certain cases, the firms were asked to assign scores ranging from very low to very high.

This was supplemented by an analysis of *Merit goods,* such as an improvement or otherwise in health, demonstration effect, awareness of workers, quality of air and water, noise, and organisational citizenship.

An evaluation of public goods, as relevant to a better environment through cleaner technologies, was attempted with the help of the *Contingent Valuation Method* (CVM). *Willingness to Pay* (WTP) was assessed via this technique. The CVM survey covered population in the surrounding area to gauge the willingness to pay for better environment as a result of CT adoption and implementation.

Results

Cost benefit analysis:

In most cases where cleaner production technologies were implemented, the cost benefit analysis shows that the firms have benefited by and large, both quantitatively and qualitatively. The quantitative benefits are reflected in the short payback periods; in some cases even as short as a few days to few months. Even in cases where the discounting method of NPV was used, the CT implementation yielded positive NPVs, except in two cases namely Knoll Pharma and Gujarat Insecticides, with marginally negative NPVs [– Rs.9.53 lakhs (B/C being 0.93) and – Rs.7 lakhs (B/C being 0.91) respectively]. The results are summarised in table 1.

Table 1. Economic implications of CT.

Industry	Range of Pay Back Periods	NPVs and Range of Benefit Cost Ratios
Electroplating - Incremental CTs	3.6 month to 18 months	N.A.
Fertilizers - Incremental CTs	8 months to 23 months	N.A.
- Generic CTs	4 years to 5 years	NPV = Positive; B/C Ratio = 1.04
Pesticides - Incremental CTs	17 days to 54 days	NA
	5.5 years	NPV = Negative; B/C Ratio = 0.91
- Generic CTs	3 to 5 years	NPV = Positive B/C Ratio = 1.03
Pharmaceutical Incremental CTs	2.6 years	N.A.
- Generic CTs	5.4 years	NPV = Negative B/C Ratio = 0.93
Dyes and Chemicals - incremental CTs	2 days – 8 months	N.A.

There is every likelihood that these may also turn out to be positive if a lower cost of capital is assumed, which sounds reasonable in the emerging context of declining interest rates. Besides, there are some concessions and soft loans made available for eco-friendly and energy conservation measures.

Switch Over

There have been no production interruptions in the adoption and implementation of cleaner technologies. In all the cases, the firms implemented CT during a shutdown period. Adequate inventory was built up in a few cases where extended shutdown was anticipated. Therefore, nil adjustment costs were incurred during the switchover to CT measures. The best efforts were made to obtain imputed values, wherever it was found relevant e.g. fabrication, use of land, manpower, etc.

In respect to *Corporate Citizenship*, it is heartening to note that most of the firms studied fare reasonably well. In some cases, the responses have been very encouraging with high scores. Of the 17 firms studied, 10 firms scored high to very high, 5 firms scored good and only 2 firms scored low.

In terms of *Merit Goods* of qualitative benefits and spin-off/spill-over effects, there have been positive impacts on the quality of air, water, and demonstration effect, and employee attitudes. Of the 17 firms studied, 8 scored in the high to very high category, 4 firms scored in the good category and 5 firms scored in the low category.Positive health impacts have been perceived and reported in very few cases. In many other cases, there may have been health benefits as a result of reduction in dust, emissions, effluents, and odour, and yet the firms have not been able to link it to the CT measures or health records.

Driving Force

The major driving forces behind adoption of CT, as revealed by the study are:

- Top management commitment
- Better safety and health
- Efficiency drive, and
- Corporate image

However, in respect of small-scale industrial units studied in Gujarat, market forces or related factors such as efficiency and quality considerations scored high. While it is reasonable to expect that market forces should primarily drive the adoption of CT, top management commitment appears to play a decisive role when it comes to implementation. This perhaps, may have been the reason why the ranking pattern did not essentially change, even after weighting it on the basis of scores obtained from independent experts. Nevertheless, if top management commitment were to precede market forces in adoption and / or implementation of CT, then it leads to an entirely different policy framework with eco-labelling and higher credit rating at the centre stage.

Barriers to CT

Most companies covered in this study did not experience any significant barriers while implementing CT measures. In some cases however, the lack of funds for long-term investments amidst pressure to obtain quicker returns has been viewed as a problem while adopting CT.

The study also reveals that training has received due attention in most of the large-scale units. Greater attention however, seems to be focused on in-house training, especially on on-the-job training. Among the sources of training and information, in-house staff has been found to be very useful, followed by journals/media, universities/R&D organisations and industry associations.

The study also reveals that in most cases, the CT implemented are not only environmentally friendly, but also less hazardous. The example of Gharda Chemicals in Maharashtra has been studied to further explain this point. All the five changes studied have led to better environmental conditions, which are less hazardous than before.

- The recovery of TCSA with the help of a distillation unit is less hazardous, as in the present system, the release of TCSA vapours is minimised.
- The second modification reported is the recovery of DMA reffinate, which is less hazardous and environmentally friendly.
- Recovery of organic waste, which was earlier being incinerated, is less hazardous as incineration is a process that can lead to the release of various toxic gases if carried out without proper secondary air pollution control devices like scrubbers.
- Recovery of unreacted isobutylene and hexane, which were earlier let off into the atmosphere, has been minimised, as these gases are now recovered with a compressor and purification system.
- CMA recovery is less hazardous as the recovery is done by cyanide destruction and pH adjustment. Cyanide is one of the most hazardous substances.

In some cases the new technology's main benefit is energy conservation and has no influence on the hazardous nature of the process.

The attractive payback period/return should have shown market forces as the major driving force, but instead the top management commitment has taken its place in our findings. This apparent contradiction may perhaps be explained by the fact that only a few progressive firms have implemented CT. The attractive returns may be a post-facto realisation. If the former were true, most of the industries would have adopted CT, but the reality seems to be very different.

The CVM survey was confined to the area around the Thane-Belapur Industrial belt. The evidence in general, supports the theory and experience obtained in other countries, that larger proportions of the higher income groups display willingness to pay in comparison to their ‘poorer’ counterparts. However, in certain specific locations that are comparatively ‘better-off’ areas in terms of income earned, evidence to the contrary is also obtained, where one does not see any real positive correlation between higher incomes and higher WTP. At the very lowest end of the income spectrum, the WTP is negative, perhaps indicating that the environment does not figure in their priorities at the subsistence level. Although the income is not related to WTP, the higher the education level, the greater is the proportion expressing WTP across the entire region. This implies that a positive correlation exists between education and WTP. However, irrespective of one’s income or educational qualifications, the overriding view that prevails is that “the polluter should pay”. In other words, they feel that it is polluters’ responsibility to pay first. A pressing need for more effective governmental intervention and control is also stressed. All in all, the Contingent Valuation exercise has proved to be worthwhile as it gives an indication of WTP being subject to certain riders, as well as an insight into people’s perceptions about the environment, roles of the industry and the government. It should be noted that CVM implies valuation of social damages, and the willingness to pay has been based on such overall considerations as perceived by the respondents.

Concluding Remarks and Recommendations

Cleaner production technologies are not only desirable from the environmental point of view as a pre-emptive strategy, but also make good economic sense. Such a transition adds to the bottom line by conserving resources like energy, raw materials and manpower, improving yield and reducing treatment/disposal costs.

- Efforts should be made to promote cleaner technologies through suitable incentives and setting up of state-wise information clearing houses on CT. This is especially important given that many firms have indicated the lack of funds for long-term investment, and lack of information on tested technologies.
- There are no laws encouraging waste minimisation, recovery and recycling. The Government of India can make cleaner production a major focus area by amending the existing Environment Protection Act – (1986).
- Industry Associations need more strengthening, and the emphasis should shift more towards facilitating CTs and Green Rating, rather than mere abatement to meet regulatory requirements.
- Industry Associations should network with their counterparts - government agencies and other organisations like the Global Reporting Initiatives. This is necessary to move closer to the creation and development of a clearing house for speedier exchange of information on CT and accelerate the demonstration effect.

Implications for Regional Development in Maharashtra and Gujarat

In order to promote CT and eventually establish eco-industrial parks, an integrated approach is needed by the state governments, their various agencies dealing with industrial development and Industry Associations. This should begin with proper planning at the initial stage of siting /location of industries, which would facilitate better sharing of resources i.e., sharing of wastes, byproducts, and waste energy, etc. between various industries, leading to minimal wastage and optimal resources use.

Also, awareness programs/training programs and demonstration projects should be conducted for clusters of small-scale industries on a continuous basis.

Limitations of the Study

It is important to note that no generalisation can be attempted, as the study is not based on statistical representation of the sectors/industries covered, but is confined to case studies.

In the CVM survey, the differing pattern based on *relative proximity* to polluting industries and *gender* could not be ascertained. Here too, there was a lot of resistance to spare time for face-to-face interviews with the enumerators.

Scope for Future Work

The study could be extended to other major energy/ resource intensive industries like power, refineries and iron & steel, as well as to other states. Further, efforts can be made to obtain time series data wherever possible, so that internal rate of return and external rate of return can be estimated. Besides, recourse may be made to normative costs if available in cases where actual data is not forthcoming.

Lastly, to supplement surrounding area population surveys, a repertory grid analysis can be attempted with the help of community workshops. This would give a better picture of the relative importance assigned to environmental quality by different social strata of people at different locations.

An Environmental Assessment of Oil and Gas Exploration

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Introduction

The exploration of energy resources has played an important role in generating and sustaining development and economic growth in India. In recent years, increased importance has being given to the exploration and development of conventional energy resources like oil and natural gas, locally referred to as refinery outputs. Petroleum generally occurs in sedimentary deposits in a complex mixture of hydrocarbons, which exist naturally under the ground in the form of gaseous (natural gas), liquid (crude oil), and solid (asphalt or coal) states.

The oil and gas exploration activities have an impact on air, water and soil environments. The environmental impact on air is in the form of air emissions at the time of production. It also contains pollutants due to controlled flaring and venting, which are necessary for safe operations. There are occasions where air pollutants are released accidentally due to discharge from well blowouts. It contains gases such as sulphur dioxide (SO_2), carbon monoxide (CO), hydrogen sulphide (H_2S), and the other oxides of nitrogen, as well as particulates containing partially burnt hydrocarbon and metals. All of these are potentially hazardous to human health and vegetation growth. Principal gaseous emissions from oil and gas operations may include carbon dioxide, carbon monoxide, methane, volatile organic carbons (VOC), nitrogen oxides and halons.

Aquatic ecosystems are a major concern due to the pollution arising out of oil and natural gas production, as it involves various activities that affect the normal functioning of water ecosystems. The potential effects due to pollution on water resources include both ground and surface waters. There is a need to evaluate any major impact by the operations, particularly where water is used by local people, fisheries and wildlife.

The extent of disturbance on soil will depend on the soil type and the geology of the area. Soils have a low resistance to degradation and are vulnerable to changes in temperature and chemicals introduced by various human activities.

Exploration, development and production of oil and gas is a complex activity, where drilling operations have a major impact on the environment. During drilling, hydrocarbon and heavy metals found in the mud additives get accumulated in the waste pits, posing a serious threat to the aquifer in the region.

Objectives

The main objectives of this study are to:

- Assess the effluents and other substances discharged in the area surrounding the drilling site.
- Quantitative assessment of the type of drilling – depth, type of substances discharged in air, water, and soil.
- Linkages of the drilling activity with environmental degradation.
- Identify regulatory waste management mechanisms and guidelines in India in relation to similar regulations in other countries.
- Suggest policy guidelines for reduction in environment damages.

Methodology

The scope of work includes:

- Collecting data from the secondary sources.
- Analysing water samples in the water column to monitor hydrographical, chemical and biological characteristics, including pollutants like petroleum hydrocarbons and heavy metals.

- Analysing sediment samples to quantify hydrocarbon depositions, heavy metal concentrations and benthic biota.
- Analysing a few samples of zooplankton and fishes in the vicinity of oil fields to understand and estimate the possible bioaccumulation of pollutants.

The next step involves field visits to gather primary information on selected indicators. Observations are made on in-site operations to examine the cause and effect relationships. Some additional data, by way of Techno-Economic Survey, were collected regarding the reservoir characteristics, rate of production, and levels of associated gas, geological formation, and equipment used at the site. However, the focus was on the waste disposal and management at the site – on shore and off shore. In order to quantify the environmental impact of drilling activity, both primary and secondary sources of data were used. A quantitative assessment of this data includes depth, types of substances discharged in the air, water, and soil in the drilling activity. In order to assess economic cost or social cost, a primary door-to-door socio-economic survey has been conducted to examine the perceptions of the households (stakeholders) during the drilling operations.

The environmental impact of oil and gas exploration provides an important aspect of socio-economic activities of the community in the villages surveyed. This socio-economic survey was conducted at three different geographical locations to assess the impact of oil and gas drilling on the living conditions of the people in the neighbourhood of the exploration activity. Since the drilling sites are very large and are spread across a wide area, a sample coverage of some of the areas representing the total system was ensured. Three geographically and environmentally different locations were chosen to assess the impact of exploration activities in the country as a whole. A total of six villages covering different locations within the country were selected. The three geographical locations considered are onshore activities of Krishna Godavari basin and Assam area, and offshore activities related to the costal Maharashtra region. Through a field survey, data was collected from three villages - Karavaka, Kesanapalli, and Ethakota in AP, two villages - Hatipati and Kanwareur in Assam, and one, Jangir in Maharashtra. A random sample of 20 households was collected from each of these villages. Besides the household survey, a Techno-Economic survey was conducted to solicit the views of the decision makers at the drilling.

Results

The major findings of the study were categorised under the heading of Socio-economic impact, blowout, and social and economic costs of oil and gas exploration.

Socio–Economic Survey of Households

A uniform number of households were chosen as the sample size in each village. 60 households were chosen in Andhra Pradesh, and 40 in Assam. Basic features like location, educational details, occupation, income levels, livestock parameters, land holding patterns, crops grown and yield, among others, were covered for various sampling locations in AP and Assam.

The data revealed that the male population is more in the study area than female population. This is due to the fact that the drilling operations are done by either skilled or semi-skilled individuals, for which manpower is more important. In Assam, this difference is narrowed due to the long duration of drilling activity that takes place. Here, women also work along with the men to make their livelihoods.

The next important factor is the impact assessment on agriculture and flora and fauna in the neighbourhood. Less than half the households indicated some impact on the agricultural yield. This cannot be confirmed because the respondents are those who posses either irrigated land or unirrigated land. The changes that were noticed are: change in soil structure, increased hardness, less yield, increased operational costs, more input consumption, change in cropping pattern, etc. This needs more probing at a micro level. The general impression however, is that the ONGC is taking care to see that irrigated lands are not contaminated. There are some instances where coconut trees have been affected but the proof is yet to be established. Similarly, there is no significant impact on flora and fauna.

The second aspect involves medical / health factors due to water contamination. The commonly identified diseases are viral, protozoal, helminthic, and leptospiral. Here, the respondents, distribution and frequency of occurrence indicate that 80 percent of households do not experience any of the above diseases.

Air Pollution

Overall, only 25 percent of the sample surveyed expressed that air pollution was a problem. However, about 45 percent of those questioned from Hatipati expressed that drilling operations were a major concern with regard to air pollution.

Water Pollution

Surprisingly, respondents stated that in comparison to surface water pollution, ground water pollution was more on account of the drilling operations. This perception was high in the villages of Assam.

Soil Pollution

The extent of environmental impact of Group Gathering Stations (GGS) is more persistent and acute as compared to drilling sites. The extent of damage at drilling sites is limited and the nature of damage is transient, except the damage to the topsoil which is irreversible.

The Effect of Blowout

A major blow out in the village of Pasarlapudi in Andhra Pradesh in 1995 majorly impacted the local inhabitants, destroying crops, especially coconut trees and paddy fields. On 8 January 1995 at 6.50 pm, a sudden increase in gas pressure pushed the casting out and the well caught fire. For about 30 days, only the vertical spread of the flame was noticed. Later, due to damage in BOP, the fire increased in the horizontal direction at the BOP site.

The villagers of Pasarlapudi were evacuated to a safe place, thus disturbing their normal life. Though they were paid compensation, it offered very little in terms of the suffering they had to undergo such as shifting homes, disorganisation and displacement of cattle, and the loss of livelihood because of a break in their work (especially for people who were involved in dairy and poultry farming).

The Social Benefits and Costs of Oil and Gas Exploration

Based on the socio-economic survey, it is evident that there are more benefits than the costs due to the exploration activities of ONGC. The income levels of the sampled respondents have improved and there is a shift from below the poverty line to above the poverty line. For example, the survey indicated that the median level of income is above Rs.11,000 per year. The associated costs are in the form of social costs, either due to depletion of livestock population or loss of economic returns from the livestock held by the respondents. In this study, this has been quantified in terms of milk yield as well as the morbidity of the livestock.

Most of the damage is observed during the drilling operations season, which lasts about three months. During these three months the respondents indicated certain health damages either due to minor headache or nausea, which accumulated into cost estimates in terms of wages lost and ill health. This is quantified in the study in the form of number of mandays lost due to ill health and converted indirectly into Rupee terms. On an average, the study revealed that the direct costs, in the form of medical expenses, were Rs.462, and indirect cost were Rs.518 per household per year.

The damage due to soil erosion for agriculture crops is not significant. However, the health hazards due to water contamination that lead to water bound diseases cost the households total medical expenses of Rs.626 per household per year. The major impact was on coconut trees which experienced a decrease in the yield at the time of the blow out due to smoke from gas flaring. Finally, the cost of living has increased by 65 percent in Assam and by 60 percent in AP.

Not much information is available on the economic cost as a result of the blow out as it occurred only once in the study area. However, it affected normal life significantly, and the indirect costs are measured according to rehabilitation of the affected people. Similarly, with respect to offshore operations the respondents in Jangir village indicated some reduction in their livelihood due to the oil sleek on the beache around the village. In this case, farmers, labourers and fishermen who depend on tourismhave indicated an economic loss of about Rs.10,000 per year.

Policy Recommendations

On the basis of the case studies, certain policy guidelines are suggested for qualitative improvement in the environmental management scenario so a harmonious relationship can exist between drilling and production of oil and gas industries, and the environment.

- Water based drilling systems must be used. These are generally not toxic in nature, as is evident from the analysis carried out by various studies. Presently, there is no Centralised mud processing or recycling facility at the studied drill sites. Once the drilling operations are completed, the rig moves to another location. This process generates vast amounts of waste, which is normally left behind. Sites must be restored to the condition before drilling by practicing strategies followed by international companies.

Role of Oil Companies and the Government

Oil and gas production is one of the most important contributors to pollution in the coastal areas of India. To counter this, the Government of India has regulated various measures, besides initiating both national and international responsibilities to protect and preserve the coastal marine environment.

India is also a signatory to the ‘Law of the Sea’ which envisages protection of the sea.

Besides this, the Coastal Ocean Monitoring and Prediction Systems (COMPAS) Programme, was initiated by the Department of Ocean Development (DOD), Government of India in 1990-91. This programme seeks to assess the health of our oceans in environmental terms.. Under this programme, 25 parameters are used to study pollution-related data, which is collected and analysed, and the results are published in annual reports and made available to both the Central and State Government Pollution Control Boards for required action.

Limitations of the Study

The limitations of the study are as follows:

- The data for the study of the technical analysis of environmental pollution caused by oil and gas exploration was mostly confined to one single site in Andhra Pradesh. Data from multiple sites would have enabled a comparative analysis of impact levels.
- In the case of the socio-economic survey, the sample sizes were small. This prevented us from attempting a rigorous statistics / econometric analysis based on the existing data.

Even though the co-investigator is associated with ONGC, the main organisation involved in exploring production activity, its role was confined to gathering appropriate information on the identified parameters. These results have been examined and discussed at a focal theme workshop held at Network for Preventive Environmental Management (Net PEM).

Pollution Prevention and Cleaner Production

Measures with regard to operational aspects of drilling range from planning considerations to integration of environmental issues and engineering design. The application of on-site procedures aimed at reducing the risk of pollution. Pro-active, preventative techniques are often more effective and efficient. Therefore, ‘Pollution Prevention’, is a very useful concept endorsed by the international oil and gas exploration and production industry. The term ‘Cleaner Production’ is used by many international and national organisations. Clean Technologies are important to provide improved combustion performance. For example, dry low NO_x combustion (DLN) technology, selective catalytic reduction (SCR) technology, as well as water and steam injection, all aim at reducing NO_x emission. Similarly, other preventive measurers include providing injection systems and pre-combustion in diesel engines, which also have the potential to reduce NO_x emissions.

Oil Spill Contingency Planning

One of the mandates of the study is to apply systems approach to environmental planning. In case of oil spills, various risk factors have to be addressed as a part of contingency planning.

All operations should properly examine the risk, size, nature and potential consequences of oil spills and develop appropriate contingency plans, including informing the community of any hazards involved. The basics of contingency planning are:

- Identification of risk
- Planning and implementation of actions to manage risks
- Procedures for reviewing and testing of preparedness
- Training of personnel

A wide range of international, regional and national legislation regulates the decommissioning of offshore structures.

Environmentally-Sensitive Areas

The framework presented in this study would allow operators and stakeholders to understand the development and practice of environmental management, and to appreciate the ecological, social and cultural sensitivity related to operations.

However, not all measures discussed in this framework document will necessarily be appropriate for implementation in all geographic areas or under all conditions. The reader is referred to existing guidelines for activities in sensitive environments – Arctic and sub-Arctic, mangroves, tropics, tropical rain forests, coastal water, and geophysical operations.

Other environments also have peculiar sensitivities and may warrant special approaches: for example, temperate woodlands, boreal forests, wetlands and marshes, freshwater and inland seas, coral reefs, arid areas.

Environmental Economics

The objective of this study is to provide an environmental assessment for the exploration of oil and gas. This activity mostly consists of Engineering and Geological applications. The role of Economics is recently identified in this particular field. Unlike other industries, it is difficult to provide a cost and a price - value for production of oil and gas. The price of oil and gas represent the actual cost of production (direct cost), but also include many indirect costs such as depletion, exhaustibility, discount prices, type of competition, social and environmental costs. This study successfully quantifies certain indirect costs and benefits. It is necessary to conduct an exhaustive analysis to account for the other parameters for the upstream activities of the oil and gas industry. Environmental economics concepts such as willingness to pay, willingness to accept for an environmental commodity can be obtained with an integrated econometric model based on authentic data / information.

Environmental Life Cycle Analysis: Measuring Consumer and Manufacturers' Response to Environmental Pricing of Automotive Gadgets

Anand Samuel and Suganthi L. *Anna University, Chennai*

Introduction

Sustainability is the key area of focus in the 21st century. Measures are to be developed to combat environmental degradation to ensure a sustainable future. Correction and prevention are the techniques adopted in such issues. As the adage goes, prevention is better than cure, and therefore, the present work has been initiated to provide a preventive measure for environmental degradation caused by the automobile sector. A method to levy environmental tax is analysed in this work that would be acceptable to public, manufacturers as well as the government. It is hoped that the results of this work will help in the formulation of environmental taxes in India.

Objectives

The main objectives of the study are to:

- Conduct Life Cycle Analysis (LCA) of an automobile air conditioner.
- Develop a data base for LCA calculations.
- Formulate a methodology for Entropy Added Taxing based on environmental damage.
- Simulate the response of automobile consumers and manufacturers to environmental taxing.
- Recommend a policy framework for implementation.

Life Cycle Assessment Based Tax

In Life Cycle Assessment (LCA), the environmental effects of processes and products are evaluated from raw material extraction through post use of disposition. It is also referred to as the "cradle to grave" approach or "womb to tomb" approach. The comprehensive environmental impact of a product or process can be assessed only by the LCA method.

The Life Cycle Assessment method has four components:

- Definition of system boundaries
- Inventory analysis
- Impact analysis
- Improvement analysis

The system boundaries can be fixed depending upon the accuracy one needs. The boundary can be extended to any limit, but beyond a certain level the incremental environmental effects are very marginal. One of the advantages of the LCA methodology is that it incorporates improvement analysis, which makes the process of making systems environment friendly possible.

In LCA of any equipment, the following phases are considered:

- Raw material acquisition
- Processing of materials
- Manufacturing and/ or assemble
- Use or service
- Re-use
- Re-manufacturing
- Material recycling
- Treatment and disposal

For each of these phases, the direct and indirect environmental effects need to be estimated. The energy consumption details are also to be collected. This will be helpful in finding the indirect environmental impact. The LCA results can be used as the base for levying environmental tax.

Entropy Added Tax

In every process of a system, entropy is added i.e., exergy or useful energy is lost. We cannot go for complete elimination of exergy loss. We have to reduce the exergy loss to the maximum extent, so that better utilisation of energy can be achieved. Further, energy is conserved by identifying and correcting the process that unnecessarily destroys exergy. To reduce exergy loss we should go for complete analysis of exergy in the system.

The exergy analysis is based on evaluating the work that is available at every point in the system. From the analysis of available work throughout the system, the quantity and location of lost work and useful work can be determined. This is the information required to make the complete exergy analysis of the system and to locate inefficient processes, equipment and operating procedures.

Exergy is calculated on the basis of the final temperature reference that is taken as the surrounding environment. In an energy analysis, based on the first law of thermodynamics, all forms of energy are considered to be equivalent. The loss of quality of energy is not taken into account. For example, the change in the quality of thermal energy as it is transferred from a higher to a lower temperature cannot be continuous. An exergy analysis, based on the first and second law of thermodynamics, shows the thermodynamic imperfection of a process, including all quality losses of materials and energy.

An energy balance is always closed as stated in the first law of thermodynamics. There can never be an energy loss; however, energy transfer to the environment amounts to irreversible loss of useful energy. In order to pinpoint and quantify the irreversibilities, an exergy analysis is performed. This can be used as the basis for Entropy Added Tax.

Study Area

Various industries in Tamil Nadu and Andhra Pradesh producing automobile air conditioners were contacted to collect data on energy consumption and effluent release for different processes. For conducting the Delphi study, the consumers and manufacturers in and around Chennai were contacted.

Methodology

A literature survey on different environmental taxing methodologies was conducted. As LCA based taxing and entropy added taxing were found to be better methodologies in terms of sustainability, work was focused on these. Data on energy consumption and pollution levels of different processes involved in the making of an automobile air conditioner was taken. Detailed analysis was carried out and the pollution caused in three different phases was found out - raw material acquisition, manufacture and service or operation. Exergy analysis of an automobile air conditioner was then carried out to quantify the entropy addition. After establishing the fact that LCA based taxing and entropy added taxing are possible, computer programmes were written to carry out exergy loss calculation and LCA for auto air conditioners. Then a Delphi study was conducted among manufacturers and consumers of automobile gadgets to find out the response for environmental taxing in India. The survey was conducted to

- Study the environmental awareness among public.
- Seek the justification for environmental tax.
- Formulate the accepted method of levying environmental tax.

In the first round, 500 questionnaires were sent to consumers and manufacturers of automobiles to which 298 responses were received. The results were then analysed and a policy framework was drawn.

Data Analysis

In the first round the survey Delphi was administered to respondents and the feedback obtained was analysed. The analysis was performed to determine the level of confidence with which participants answered the questions. The characteristics of Delphi are anonymity, iteration, controlled feedback and statistical aggregation of group response. Two rounds of Delphi were conducted. The statistical analysis was performed which gives the mean, median and extent of spread of participant’s opinion, helping to identify whether a consensus has been arrived at. The Delphi helps the participants to come to a common understanding. Stability and consensus are achieved through the Delphi analysis, and hence can be used for policy decisions.

Stability

To check whether Delphi rounds and response categories are independent i.e., group stability, the two hypotheses used in the chi square ($\times^2$) test were as follows:

Ho: The Delphi rounds are independent of the responses obtained in them

H_1: The Delphi rounds are not independent of the responses obtained in them

The calculated and the Chi square (x^2) values along with their degrees of freedom (DOF) for group stability and individual stability were determined. It was found that the computed value was less than the critical value at the 0.05 level of significance in most of the cases. Hence, the null hypothesis was accepted, and group stability was present in almost all cases.

The individual stability was checked next. For individual stability to be present, the respondents who selected a certain option in the first round would have chosen the same option in the second round. The two hypothesis to test whether there were significant differences between individual responses in the different rounds were as follows:

Ho: Individual responses of rounds i and i+1 are independent

H_1: Individual responses of rounds i and i+1 are not independent

Comparing the calculated and the critical ($\times^2$) values, it was found that in almost all cases the calculated value was higher than the critical value. This indicated that the null hypothesis was rejected at 0.05 level of significance. The null hypothesis "that the individual responses in the two rounds were dependent" was rejected. We accept the alternative hypothesis, indicating the presence of individual stability in all cases. The reason why both individual and group stability were checked was because although individual stability implies group stability, group stability does not imply individual stability. The reason for this is that there may be major switching of individual responses with no significant variation in the overall group response.

Consensus

The variation of standard deviation and confidence in the two rounds were determined. The distance of the point from the origin indicates the amount of change in deviation and confidence.

Results

Life Cycle Assessment

The total pollution caused for the *ACQUISITION OF RAW MATERIAL* for an air conditioner is summarised below:

Carbon dioxide	1720.8 kg
Nitrogen dioxide	694.6 x 10-3 kg
Sulfur dioxide	1048.5 x 10-3 kg
Carbon monoxide	186.0 x 10-3 kg
Hydrocarbons	327.6 x 10-3 kg
Suspended particulate	538.7 x 10-3 kg
R12	30 gm

The total pollution causing emission due to the *MANUFACTURE AND ASSEMBLY* of an auto air conditioner was as follows:

Carbon dioxide	8.0 kg
Nitrogen dioxide	0.2 kg
Sulfur dioxide	0.2 kg
Carbon monoxide	0.01 kg
Hydrocarbons	0.007 kg
TSP	0.12 kg
R11	150gm
R12	650 gm

The total emissions caused during the lifetime *SERVICE* of an auto air conditioner.

Carbon dioxide	9070.5 kg
Nitrogen dioxide	22.00 kg
Sulfur dioxide	21.84 kg
Carbon monoxide	1.98 kg
Hydrocarbons	1.03 kg
TSP	11.9 kg
R12	110 gm

Exergy Analysis

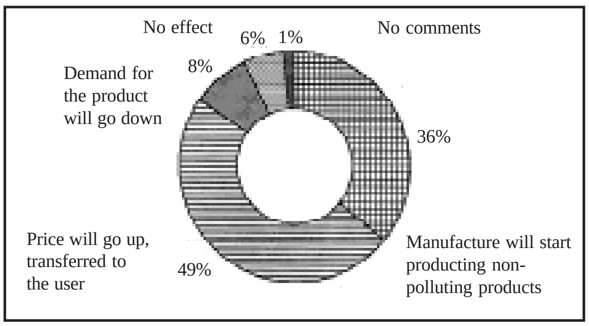
The Exergy loss values

Components	Exergy loss in kW	Exergy Destruction in kW	Total in kW	% of Loss
Compressor	0.0	0.5724	0.5724	9.2699
Condenser	45.7459	-41.8711	3.8748	62.7497
Throttling device	0.0	1.7771	1.7771	28.7783
Evaporator	-39.5709	39.5216	-0.0493	-0.7979

Survey Results

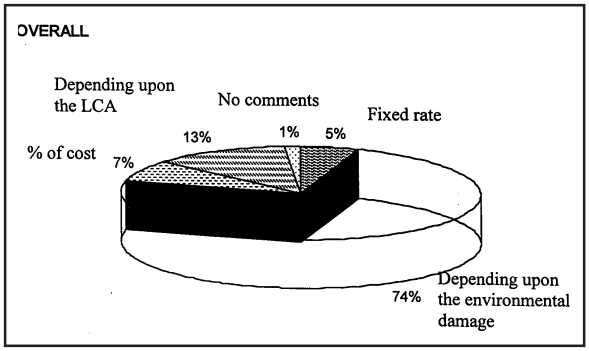
It is known that environmental taxing is followed in different countries to combat pollution. It is the experience of many nations that, in addition to fulfilling its prime objective of reducing pollution, levying environmental taxes also brings about side effects. As the environmental tax is levied, the demand for the product may go down. The manufacturer may either become environment friendly or the tax burden may be transferred to the public by way of higher prices. When asked to give their opinion about what will happen in India, majority of the consumers as well as the manufacturers (46% and 55% respectively) stated that the tax burden will be transferred to the users. This is not desirable. The government has to take steps to curb the habit of increasing the price by the manufacturers. Unless this is done the environmental tax will not do its job of abating pollution. Fig. 1 shows the responses of the consumers as well as the manufacturers.

Fig.1 Effect of Environmental Taxing



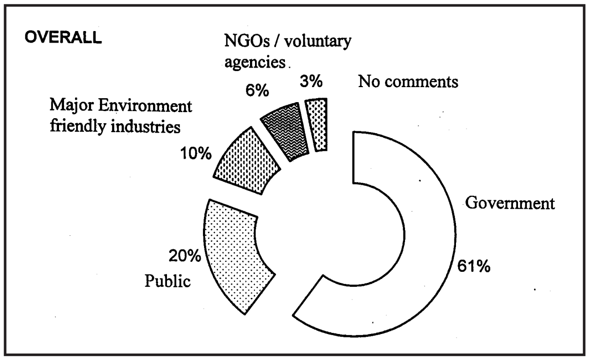
In the question related to the basis for environmental taxation, the focus was on either fixed rate or depending upon the environmental damage done. On an average, 74 percent of the respondents opted for damage based taxing. Only 5 percent of the respondents opted for fixed tax rate. Hence, it is concluded that some taxing methodology based on environmental damage has to be evolved. The responses are shown in Fig. 2.

Fig.2 Basis of Environmental Taxation



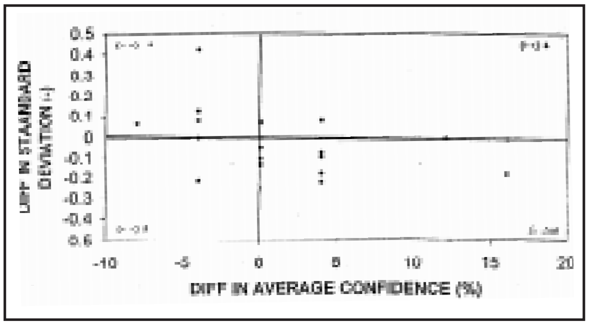
Having gone thus far in environment taxing, the next question is about who should play a major role in introducing environment tax. Majority of the respondents felt that the government should take the initiative. About 61 percent opted for this, followed by initiative taken by the public, as shown in Fig. 3.

Fig.3. Major Player In Introducing Environmental Tax



The differences in standard deviation and confidence were determined, and the points are plotted in Fig.4. The distance of the point from the origin indicates the amount of change in deviation and confidence. It was found that a majority of the points lie in the fourth quadrant, which is that of increasing confidence and decreasing deviation. In total, 15 lie in the acceptable (+ -), 4 in the (+ +) quadrant, 2in the (- -) quadrant and 5 in the (- +) quadrant. It was hence found that consensus has been achieved in a majority of cases.

Fig. 4. Confidence Level and Standard Deviation for Delphi



Overall Results and Outputs of the Study

- Environmental taxing is needed.
- If Carbon tax is sidelined, the other tax forms such as LCA based Tax and EAT (Entropy Added Tax) need to be investigated.
- EAT is the best in terms of sustainability. However, it is cumbersome, and would be difficult to introduce at present.
- LCA based tax is appropriate for the Indian context, and would also help industries to seriously adopt ISO 14000.
- The database for conducting LCA was collected in the study. A life cycle index was formulated that could be useful to compute tax, if such a decision was taken.
- The impact of different stages of the life cycle such as raw material acquisition, manufacture and assembly, service and maintenance and disposal on ozone depletion, acidification and green house gas accumulation for automobile air-conditioner were estimated.
- LCA for an automobile with the secondary data, for the different materials used in the car was done. It was found that the air-conditioner pollution is about 2 percent of the total pollution associated with the entire car.
- Exergy analysis was carried out for air-conditioners of different capacities that predict the percentage loss of exergy taking place in the air-conditioner. This percentage loss can be used directly to fix the EAT.
- The Delphi study revealed that there is a lack of awareness regarding the environmental degradation among people, both manufacturers and users. More than 60 percent of the people are aware of environmental degradation taking place in our country.
- The survey revealed that the best method to prevent pollution is to create greater awareness among the public. More than 50 percent of the people felt this way. About 25 percent of the respondents felt that heavy penalty for polluters would help prevent pollution.
- About 36 percent of the respondents felt that manufacturers would start producing non-polluting equipment if an environmental tax was levied.
- More than 46 percent of the respondents welcomed the idea of an environmental tax.
- According to 74 percent of the respondents, the basis for environmental taxation should be the environmental damage caused by the equipment.
- About 46 percent of the respondents felt that the taxes should be as low as 5 percent of the total cost.
- When asked about the choice between taxing the component and taxing the system, 36 percent of the respondents were in favour of taxing individual components, and 60 percent of the respondents favoured taxing the whole system.
- To prevent the transference of tax burden onto the public, the preferences of respondents for different options were:
    - Fixed pricing policy by 25 percent of the respondents.
    - Low tax with disincentives was suggested by 28 percent of the respondents.
    - Low tax was suggested by 30 percent of the respondents.

- A majority of the respondents felt that the major player in introducing environmental tax should be the government.
- The stability and consensus study conducted on the Delphi results revealed that around 2 results gave the accurate results.

Policy Recommendations

- To combat environmental degradation, Environmental Tax as a strategy is acceptable to the manufacturers and users of goods.
- Among the three different environmental taxes - Carbon tax, LCA based tax and Entropy Added Tax - it is recommended that the government enforce LCA based tax as Carbon tax has already been proved to be unacceptable, and Entropy Added Tax is quite cumbersome to calculate.
- Steps should be taken by the government to prevent the tax burden from being passed on to consumers by the manufacturers. In the present open economy, as the competition is high if 'low environmental tax with disincentives' for polluters is levied, then manufacturers will be forced to change this and go in for Environmentally Friendly Technologies.
- Life Cycle Assessment should be made mandatory for all products. Eco-labeling should be enforced and granted only for products for which LCA is done.

Internalisation of Wastes in Industrial Plants

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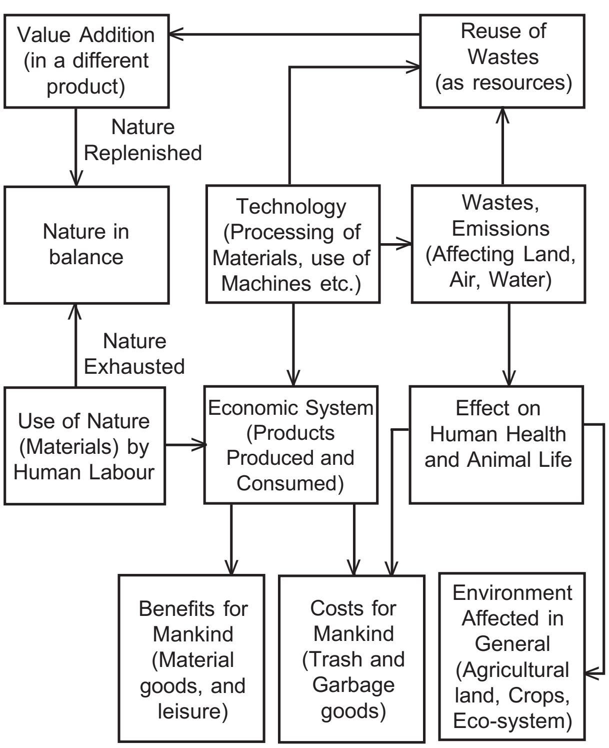
Introduction

Conventionally, an economic system links inputs with outputs. The environment is the physical domain that offers the economy the scope to develop. Waste is produced by industries depending on the type of inputs used or technology applied for production of output.

We assume that the industry itself takes on the role to internalise wastes, either within the plant where it is generated, or in an inter-industry frame to reduce wastes as shown in Flowchart 1.

Fly ash is generated by all coal-based power plants. The fly ash that the plant piles up imposes environmental costs on society. Our analysis rests essentially on the reuse of wastes. This reuse can convert a liability into an asset.

Flow Chart 1: Management and Use of Wastes



Objectives

The objectives of the study are to examine:

- How generation of fly ash by the chosen industrial plants can be reduced per unit of final output.
- How fly ash generated in one industrial plant is transformed into a final product within or in another industrial plant.
- How fly ash affects adjoining human settlements, crop fields, etc.
- What alternative products and technologies can ensure long-term internalisation of fly ash.

Study Area

Two industrial plants located in two districts of Uttar Pradesh, Allahabad and Ghaziabad, were studied. The plants selected used coal as the basic input for production of their respective final products. Burning of coal leads to generation of fly ash. The techno-economic possibilities of converting fly ash into economic 'goods', through internalisation of fly ash within the industrial plants was examined.

One of the two plants selected was the Phulpur unit of the Indian Farmers Fertilizer Cooperative Ltd. (IFFCO) in Allahabad district. The second plant was the Dadri unit of the National Thermal Power Corporation (NTPC) in Ghaziabad district.

The Phulpur unit of IFFCO is a fertilizer plant that uses coal as one of the physical inputs and produces fertilizer as the final output. In the production process, fly ash is generated. We examined how far this Unit internalises 'fly ash'.

The Dadri unit of NTPC generates electricity with an installed capacity of 840 MW. The thermal unit of the Dadri power plant generates fly ash as a by product. We examined the scope of ash utilisation by the Dadri Unit.

In both cases, we examined the nature and cost of disposal of fly ash, and the net benefits from utilisation of fly ash. We also examined the cost-benefit implications of utilisation of fly ash.

Methodology

We studied the methods that the selected plants have been using to control and reuse fly ash. In addition to collecting data from the reports and records of these units, we collected primary data from the R&D personnel of the selected plants.

Actual and techno-economic possibilities of utilisation of fly ash in products of use were examined. For this, we selected plants that produced bricks and cement based on information on utilisation of fly ash in India from secondary sources (Table 1). At present India uses only 3 percent of total fly ash generated in all thermal power plants. In 1995 the generation of fly ash in all thermal power plants in India stood at 75 million tonnes. Of this, as much as 93.0 percent was used in production of bricks and Portland Pozzolana cement.

Table 1: Utilisation of Fly Ash in India (Product-specific utilisation as a percentage of total utilisation of fly ash)

Areas of Use	% Utilisation of Fly Ash
Fly Ash Bricks	70.2
Portland Pozzolana Cement	23.0
Asbestos Products	6.41
Others*	0.57

Note: * *Include Underground Fills, Hydraulic Structures, Ash Ponds and Dykes, Agriculture and Soil Amendment.*

Structured schedules were adopted for collection of information from the brick and cement plants, located adjacent to the selected IFFCO and NTPC plants, in accordance with the Notification of the MOE&F, GOI, 1999. Structured schedules were also used to interview people affected in the areas adjoining the selected industrial plants that generate and dispose fly ash. A questionnaire was used to get ideas from experts on the utilisation of fly ash.

Data Analysis

Fly Ash generation, management, utilisation, and reduction of ash content in coal used

IFFCO supplies ash regularly to cement manufacturers. Since April 2000 the plant shifted from wet ash disposal in the ash pond formed in the adjoining area to supplying dry ash. The rate of utilisation of fly ash exceeds the rate of generation, so in a span of less than 10 years, the plant will be able to utilise all fly ash generated. This utilisation covers both internal and external uses.

NTPC has formed an ash mound inside the plant premises for storage of fly ash. In addition, it supplies dry fly ash that it generates to cement and asbestos industries.

Since the beginning of commercial production in August 1992 till the end of March 2001, around 22 percent of fly ash generated by the unit has been utilised. Almost 16 per cent of this has been used to fill low-lying areas and embankments. The remaining 6 percent has been used to manufacture bricks, blocks, cement, and asbestos. Thus, around 78 percent of the accumulated ash generated is dumped on the ash mound.

IFFCO can utilise 100 percent of the fly ash generated because of zero transportation cost when it supplies fly ash to cement manufacturers. On the other hand, NTPC does not attempt to utilise fly ash above 20 percent on average as it already incurs huge fixed costs for carrying fly ash from the boiler to the ash mound.

Conventional Clay Brick Plants (located within 50-km. radius from IFFCO and NTPC)

Reasons for Non-Utilisation of Fly Ash

- The R&D laboratory of IFFCO has developed a project for the utilisation of fly ash in brick manufacturing. These bricks are both internally and externally used.
- NTPC produces fly ash bricks on a regular basis primarily for internal use.
- No record was found of the number of conventional clay brick plants within a radius of 50 km from IFFCO and NTPC.

Ten clay brick plants within the 50 km radius from IFFCO and NTPC were selected to capture the major problems and possibilities of utilisation of fly ash.

Non-Utilisation of Fly Ash in Conventional Clay Bricks: General Reasons

- Land for conventional clay brick plants are easily available (purchase or lease-in) in Allahabad and Ghaziabad.
- The price of land is within reach (purchase or lease-in) of the brick plant owners in both districts.
- The technique of production of conventional clay bricks is known.
- Conventional clay brick plant owners do not know the technology of mixing fly ash in clay bricks.
- The transportation cost of fly ash from ash generating plants is high compared to the cost of land leased.
- There are no problems of marketing conventional clay bricks.
- Strong reliability of conventional clay bricks in the market.
- Clay bricks ensure stable benefits for conventional brick plant owners.

Fly Ash-Sand-Lime-Gypsum Brick Plants located within 50 km radius from IFFCO and NTPC

Observations on Actual and Possible Use of Fly Ash

No fly ash-sand-lime-gypsum brick plants were found within the radius of 50 km from IFFCO. Upto seven functioning fly ash-sand-lime-gypsum brick plants were located within a 50 km. radius from NTPC, which use fly ash generated by the latter. There is no supply constraint so far as availability of raw materials for manufacturing fly ash bricks in these plants are concerned. All the seven fly ash brick plants reported that they got technology for manufacturing fly ash-sand-lime-gypsum bricks from NTPC, which is ready to provide technological support to any potential entrepreneur willing to set up a fly ash brick plant.

Since the market price of fly ash-sand-lime-gypsum brick is higher than the cost of production per unit, the producers of such bricks can market them, even with positive transportation cost of fly ash. There is also a positive price differential between clay bricks and fly ash bricks. Manufacturing and marketing fly ash bricks requires steps for relative cost reductions.

Cement Plants that receive Fly Ash from IFFCO and NTPC: Utilisation of Fly Ash

Cement Plants as Users of Fly Ash from IFFCO

The permissible percentage of fly ash that can be used in Portland Pozzolana Cement (PPC), as reported by the users of fly ash varies from a minimum of 25 percent to a maximum of 35 percent. Based on the survey of a number of cement plants, it was observed that there is no dearth of demand for fly ash from the cement manufacturers. Neither IFFCO nor the cement manufacturers incur any transportation cost to carry fly ash from IFFCO to cement plants.

Cement Plants as Users of Fly Ash from NTPC

The cement manufacturers are the main external users of fly ash supplied by NTPC. The technical ratio in which fly ash is mixed in identified cement plant is Fly Ash: Clinker: Gypsum as 38:55:07 to produce Portland Pozzolana Cement. NTPC can increase its supply of fly ash to cement plants, if it bears the transport cost.

Effect of Spread of Fly Ash in the Areas Adjoining IFFCO and NTPC

Areas Adjoining IFFCO

IFFCO is reported to take care of areas within a radius of 3 km from its own location. Following the pilot survey, seven villages and 65 households settled within 2,000 meters from the plant were studied and households within each village were selected in a dispersed manner. Almost all the households from all the villages reported to have been experiencing adverse effect of spread of fly ash disposed by IFFCO on agricultural land. They also reported about the air and water-borne diseases because of spread of fly ash.

The Directorate of Environment, UP, and the Pollution Control Board, Government of UP do not keep any record of the quality of air and water in the areas inhabited by people adjoining IFFCO. We did not find any registered medical practitioner who could confirm the health-related problems conveyed by the people in the adjoining area.

Areas Adjoining NTPC

Seven villages and 65 households were selected in the areas adjoining NTPC following a pilot survey. The households reported adverse effects of the spread of fly ash on agricultural land. They also complained about air-borne diseases because of the spread of fly ash. We did not find any registered medical practitioner staying in the areas adjoining those that we surveyed. The Directorate of Environment, UP, and the Pollution Control Board, Government of UP do not keep any record of the quality of air and water in the areas inhabited by people adjoining NTPC.

Reduction of Ash Content in Coal Combustion: Possibilities in IFFCO and NTPC

In India, at present 70 percent of extraction of coal comes from open cast mines and the underground mines contribute the balance. Both the quality of coal and the method of combustion determine the effluents produced during combustion of coal. The heat value of the fuel is determined by

UHV = 8900 – 138 (A+M),

where,

UHV = Useful Heat Value,

A = Ash Content in percentage,

M = Moisture Content in percentage.

Coal available from different sources is graded in terms of the UHV.

Use of clean coal also leads to higher useful heat value (UHV) because it generates lower ash content by percentage and total quantity per unit of generation of electricity. NTPC reported using clean (washed) coal since 1998 for reduction of ash content. The source of coal has remained unchanged. The coal used by IFFCO has an ash content of 40 percent at the minimum and 48 percent at the maximum. IFFCO has no plan to change the source of coal that it receives and its R&D laboratory does not plan to use clean (washed) coal to reduce ash content.

Results

Cost (Fixed and Recurring) for Disposal of Fly Ash by IFFCO and NTPC

The fixed cost for dry ash disposal (on setting pipelines, etc.) for IFFCO was around Rs.2.5 crores. If accounted, the recurring cost would not exceed Rs.0.15 per tonne of ash.

The distance of the ash mound from the ash generating point at NTPC is 4 km. To carry the ash from the boiler to the ash mound, the fixed cost incurred was Rs.137 crores. The recurring cost (ash handling cost per MT) is Rs.30. Quantity of dumping of ash per day is 3,556 MT for the Dadri Unit, for which average handling/ dumping cost per day amounts to a little more than Rs.1 lakh.

Land Cost for Land Leased-in: The case of Brick Plants Adjoining IFFCO and NTPC

Most of the brick plant owners within a 50km radius of IFFCO and NTPC use lease-in land for digging purposes. Of the total land being used by the brick plants adjoining IFFCO, around 80 percent is on lease, while of the total land being used by the brick plants adjoining NTPC, around 60 percent is on lease.

The average land price per acre at the market for brick plant owners who leased-in land within a 50 km radius of IFFCO, is Rs.89,000. The average land price amounts to Rs.1,41,000 for the brick plants located within a 50 km radius of NTPC.

The availability of abundant and low cost topsoil helps in using clay as and when required. Absence of initiatives and incentives from the government help in continuing production of clay bricks without mixing fly ash by any percentage.

Land Saving (Area, Volume and Value) by Replacing Clay with Fly Ash

The soil cutting area (sq. metre) in any year for all the brick plants in Allahabad district is 316.84 acres, of which agricultural land constitutes 73.48 percent. Assuming soil cutting destroys the topsoil, the total value of the land destroyed comes to around Rs.3 crores for the entire district covering all clay brick plants (on the basis of average land price at present value). Given the quantum of soil cutting per year, we calculate the quantity of fly ash that can replace 30 percent (maximum) clay. Thus, we calculate maximum agricultural land that can be saved by using fly ash (maximum 30 percent) as replacement of clay (weight-to-weight basis).

Table 2: Projections Based on Major Observations of Brick Plants Projections for Allahabad district)

Sl. No.	Projections	Indicators
1.	Conventional brick plants in the district of Allahabad (2000-01)	356
2.	Soil cutting area per year (in acre)	317
3.	Agricultural Land destroyed by soil cutting per year (in acre)	233
4.	Total value of destroyed land (in Rs.)	2,81,98,760
5.	Soil cutting in volume per year (in MT)	26,34,841
6.	Fly ash in volume that can be used per year (in MT)*	7,90,452
7.	Agricultural land per year that can be saved by using fly ash (in acre)*	70

Note: * *Calculations based on use of fly ash replacing clay by 30*

Source: *Field survey.*
- *Information on conventional brick factories of Allahabad, provided by District Board, Allahabad.*

The soil cutting area (sq. metre) in any year for all the brick plants in Ghaziabad district is 1,155.6 acres, of which agricultural land constitutes 100 percent. The total value of land that is destroyed by soil cutting amounts to more than Rs.16 crores for the whole district covering all clay brick plants (on the basis of average land price existing in 2001). Given the quantum of soil cutting per year, we calculated the quantity of fly ash that can replace 30 percent (maximum) clay. Thus, we calculated maximum agricultural land that can be saved by using fly ash (maximum 30 percent) as replacement of clay (weight to weight basis).

Table 3: Projections Based on Major Observations of Brick Plants (Projections for Ghaziabad district)

Sl. No.	Projections	Indicators
1.	Conventional brick plants in the district of Ghaziabad (2000-01)	360
2.	Soil cutting area per year (in acre)	1,155
3.	Agricultural land destroyed by soil cutting per year (in acre)	1,155
4.	Total land value of destroyed land (in Rs. million)	162
5.	Soil cutting in volume per year (in MT)	2,10,61,965
6.	Fly ash in volume that can be used per year (in MT)*	63,18,589
7.	Agricultural land per year that can be saved by using fly ash (in acre)*	364.6

Note: * *Calculations based on use of fly ash replacing clay by 30%.*

Source: *Field survey.*
NTPC guide for users of coal ash, October 1999.

Cost-Benefit Projections for Conventional Clay Bricks and Fly Ash Mixed Clay Bricks

In both Allahabad and Ghaziabad districts, encompassing IFFCO and NTPC, bricks are more or less similar by quality (size and weight). In Allahabad, the total number of conventional clay brick plants at the time of survey was 356, while in Ghaziabad, it was 360. We selected ten such brick plants located within the 50 km radius of each of the ash generating plants. There is no record of the number of conventional clay brick plants within the specified radius. Thus, we relied on district level data.

For Allahabad, the average digging depth for clay bricks is much higher. Average land price for Ghaziabad is much higher compared to that of Allahabad. The average distance of the clay brick plants from the ash generating plant is the same for both the districts. The average transportation cost for carrying fly ash (per 16 MT) is much higher for Ghaziabad. Both the average cost of production per 1,000 bricks and average market price for Ghaziabad are higher compared to those of Allahabad. There is a variation in quantity of soil that is exhausted (used) between the districts for brick manufacturing because of variations in digging depth. The quantity of soil used (in cubic metre) is more in Allahabad as compared to Ghaziabad. Naturally, the number of clay bricks that can be manufactured per acre (sq. metre) of land is much higher for Allahabad compared to Ghaziabad. On the assumption of 25 percent clay replaced by fly ash (on weight-to-weight basis), the quantity (volume) of fly ash that can be used thus, is higher for Allahabad as compared to Ghaziabad. For this ratio-specific utilisation of fly ash (75:25), the transport cost of fly ash from the ash generating plant is lower for Allahabad.

The cost of production of fly ash mixed clay bricks per 1000 is marginally more when 25 per cent of clay is replaced by fly ash for both the districts. For every 1,000 bricks, the cost-difference is Rs.27 in Allahabad and Rs.42 in Ghaziabad. As a percentage of cost of production of clay bricks in the respective districts, these are 3.33 and 4.47.

Net Benefits (Total Benefits – Total Cost) for utilisation of Fly Ash in Conventional Clay Brick Plants and Fly Ash-Sand-Lime-Gypsum Brick Plants

While production of conventional clay bricks increasingly exhausts agricultural land, production of fly ash bricks saves agricultural land (by both area and volume). However, both cost of production per unit and market price per unit are higher in case of fly ash-sand-lime-gypsum bricks. While net surplus (Revenue – Cost) is positive for both types of brick plants, it is much higher for clay bricks per plant based on annual production level. Since plant size is much higher (by capacity production) for clay bricks, clay brick plants record higher net benefits on an average. Based on calculations for over 1,000 pieces of bricks, fly ash-sand-lime-gypsum brick plants show more net benefits. Thus, there are reasons to promote fly ash brick plants.

Policy Recommendations

The purpose of this study is to prevent and minimise generation of waste, and maximise reuse and recycling. The study also aims at the production of reusable goods from waste, and saving scarce resources assisted by the participation of government authorities and other stakeholders. The study concentrates on fly ash as a waste generated in coal-using industrial plants. Saving topsoil by the utilisation of fly ash in possible value-added goods requires a number of measures. These measures include:

Measures Recommended for Ash Generating Plants

- Planned disposal and dumping of ash by the ash management/utilisation cell of the ash generating plant.
- Identification and selection of the site for dumping fly ash in advance so that human settlements are not displaced, nor is there any adverse effect on agricultural land.
- Transparency in disclosure of fly ash generated per plant per year, and accountability of fly ash generators.
- Public announcements regarding the quality of ash being generated, the receivers of fly ash who utilise the ash generated by the plant, and the quantity of accumulated ash up to date.
- Shouldering of transportation cost of fly ash from the ash-generating unit to the ash utilisation unit.

Measures Recommended for Government

- Announcements through Notification or government order on the measures to be adopted by ash generating plants regarding dumping and disposal of fly ash before the units are given license to set up their plants.
- Locate ash generating plants at a safe distance from existing human settlements and plantation areas.
- Free soil testing of the brick plants by MOE&F and GOI, to examine its possible mixing with fly ash generated by the coal-based plants within a 50 km radius.

- Circulating notifications including amendments if any, regarding the utilisation of fly ash among micro level public bodies and public administration.
- Maintaining a record of quality of soil, air, and water within a reasonable area adjoining ash generating plants by the Pollution Control Board, GOI, and also by the State Pollution Control Board and Directorate of Environment.
- Impose tax per unit (volume on weight basis) on fly ash stored by the ash generating plant.
- Reduce rate of tax per unit or total tax exemption on fly ash mixed clay bricks, so that it has an encouraging effect on production of fly ash mixed clay bricks.
- Reduce/exempt tax on fly ash users for productive purposes.
- Document quality of fly ash products and their dissemination by the government/ appropriate authorities.
- Eco-label fly ash bricks by fixing logos on environmentally safe fly ash bricks.
- Maintain a record of the number of conventional clay brick plants within the radius of 50 km from major fly ash generating plants.
- Fix the price per unit of fly ash bricks, both clay-mixed fly ash bricks and fly ash-sand-lime-gypsum bricks on the basis of input cost.
- Announce the price of fly ash bricks fixed per unit for both the buyers and producers of such bricks.
- Fill mine and land, keeping in mind transportation cost of fly ash from the point of generation to the site.

General Recommendations

- Supply technology to the potential users of fly ash for manufacturing value-added goods.
- Provide cost-free training to the managers and workers engaged in utilising fly ash in value-added goods.
- Provide information on alternative products and technologies through public media for the utilisation of fly ash.
- Circulate/publicise the results of soil testing to the actual and potential users of fly ash.

The suggestions that we have offered centre on brick plants. We found no problems for the cement plants so far as utilisation of fly ash in clinker and gypsum for manufacturing cement is concerned. The alternative products where fly ash can be utilised for value-addition of products have also been explained in this study.

Water Pollution from Chemical Industries in Gujarat

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Introduction

Gujarat produces many chemicals, which include Petrochemicals, Agro-chemicals and Pharmaceuticals, dyes, especially – organic and inorganic alkalis and sulphur. Gujarat contributes to 42 percent of total exports of dyes, chemicals, and color chemicals in India. This group of industry consumes a higher amount of water than any other industry, and hence disposes the highest amount of wastewater in drainage -creek or river - than any other group of industry. As such, 40 percent of total chemical units are chlorine-based, and hence water pollution by these industrial units is a threat to the workers of the industry.

In the post-liberalization period, the profile of industries has changed from textile based to petrochemicals in Gujarat. Gujarat attracted sizable investment in these groups of industry.

Such industrialization changed the nature of industrial pollution in the state.

Therefore, there is a case to examine industrial wastewater pollution by leading chemical industries, especially in the estates in Gujarat developed by the Gujarat Industrial Development Corporation (GIDC). In this study, an attempt is made to assess the problem in the industrial estates located at Ankleshwar, Panoli, Dahej, Villait and Bharuch.

Table 1: Sector-wise Distribution of Industrial Units in Some Important GIDC Chemical Estates

No.	Name of Industrial Estate	District	Industrial Sector											
			Chemical	Engineering	Textile (dying and printing)	Textile (spinning and weaving)	Rolling mills	Plastic rubber and packaging	Bulk drugs and Pharmaceuticals	Iron and steel	Refinery	Electroplating	Miscellaneous	Total
1	Naroda	Ahmedabad	86	18	28	0	6	42	14	0	0	0	162	419
2	Odhav	Ahmedabad	150	310	10	90	55	180	11	0	0	0	360	1166
3	Vatava	Ahmedabad	368	497	22	25	97	41	0	0	0	0	205	1280
4	Ankleshwar	Bharuch	203	152	0	147	0	67	47	0	0	0	104	720
5	Panoli	Bharuch	109	7	0	119	0	21	1	0	0	0	7	264
6	Pandesara	Surat	32	45	71	370	0	0	0	0	0	0	50	568
7	Sachin	Surat	60	380	70	0	0	0	0	0	0	0	0	860
8	Makarpura	Vadodara	27	425	0	0	0	75	10	0	0	14	394	945
9	Nandesari	Vadodara	200	22	0	1	0	4	15	0	0	0	5	247
10	Petrofil	Vadodara	9	0	0	0	0	0	1	2	1	1	0	14
11	Sarigam	Valsad	320	445	0	23	0	317	4	0	0	0	32	1141
12	Vapi	Valsad	325	400	0	76	0	172	105	0	0	0	122	1200
	Total		1889	2764	201	1201	86	975	249	2	1	15	8824	

Source: GIDC, Gandhinagar August 1999.

Objectives

The major objectives of the study are to:

- Study the water supply and wastewater disposal arrangements of industrial units located in the Narmada valley area of Bharuch District.
- Assess the degree and extent of pollution load in GIDC industrial estates.
- Study the economics of Common Effluent Treatment Plants (CETP) in chemical estates in Gujarat.
- Offer policy options for industrial wastewater disposal, river and ocean pollution in the Narmada valley area and environment policy options.

Methodology

The present study is based on both primary and secondary data.

Nature and Sources of Secondary data

The secondary data such as water pollution load on Narmada River; characteristics of water of Narmada and geographical area covered under the basin are collected from the Central Pollution Control board (CPCB). Data regarding quality of wastewater from the Ankleshwar estate was collected from the National Environmental Engineering Research Institute (NEERI), Nagpur. From an empirical study for the year 1999, secondary data pertaining to water and wastewater characteristics, pollution load, development and location of industrial groups, existing water supply and abatement measures was collected from various sources.

Primary Data

In order to study micro-level management of wastewater and point level pollution, a Four-Tier Questionnaire was used. A brief discussion of the questionnaire is given below:

Questionnaire No.1: This attempted to know point level water pollution at the industry level with reference to the type of products, water and power consumption, supply cost of fresh water, characteristics of effluent generated (Table 3) and discharged, abatement cost of wastewater, cost of treatment, problems with GIDC, GPCP, and their suggestions for wastewater disposal at the estate level. Data was collected from selected units, which are in operation for the last five years.

Questionnaire No.2: This deals with the GIDC estate located in the Narmada basin and covers estate level information, such as main activities, water supply, common wastewater treatment facility provided by the GIDC, infrastructure facilities provided at special chemical and allied group of industries.

Questionnaire No.3: This deals with the GIDC estate association level information regarding group efforts to manage wastewater and solid waste pollution, and collects suggestions of the leaders of the association with regard to the management of wastewater pollution. It also covers problems of the associations, pollution regulating authority, other NGOs and so on. Data on various costs of common effluent treatment plants was also collected.

Questionnaire No.4: This deals with role of NGOs in water pollution awareness and efforts for abatement of water pollution measures. The questionnaire covers main activities of NGOs in the Narmada River basin, their programmes on awareness of industrial pollution, their liaison with government machinery and regulating authorities and their suggestions for abatement of wastewater pollution in the area.

Table 2: Selection of Sample Industrial Units

Name of the Estate/ Group of the industry	Chemicals	Petro-chemicals	Pesticides	Pharma-ceuticals	Total
Ankleshwar	13	2	4	4	23
Bharuch	2	2	1	1	6
Dahej	1	1	-	-	2
Jhagadia	2	-	1	1	4
Panoli	3	3	2	2	10
Total	21	8	8	8	45

Tools of Data Analysis

The collected statistical data is classified and processed in the light of objectives, to analyze the problem in time series and cross-section order. Percentage analysis, frequency scroll, growth rate techniques are used and average per unit cost is measured for pollution abatement.

Cost function is used to measure treatment cost at each sample industry level for cleaner production as under:

Treatment cost = f (Volume, COD, BOD, etc)

Cost = A. Volume. COD. BOD. SS

Treatment cost is compared with value added, employment generated by the industrial units to know affordable cost for cleaner production.

Costs to run and manage an effluent treatment plant were estimated in order to know the cost per tanker of wastewater in monthly time series data.

The following formula is used to know the cost of wastewater treatment as per quality of wastewater:

CETP Treatment cost = f (Volume of Wastewater, average acidity and average COD, Capacity Utilization of CETP)

Total operational charges = f (Volume. Average acidity. Average COD. Capacity utilization of CETP)

Results

An extensive inquiry of 20 sample units is shown in Table No. 4. The table indicates the importance of the chemical group of industry in the area. Average output per unit is Rs.232 million, value added is Rs.74 million and employment is 200 persons . Average output per employee is Rs. 9,14,000, whereas value added is Rs. 4,71,000.

Regression analysis results reveal that both in the case of common effluent treatment plants and individual treatment plants, the cost of wastewater treatment is largely affected by the supply and characteristics of wastewater. According to respondents, wastewater treatment cost appears to be 20-22 percent of total production cost. Considering the very high value additions and employment per unit, it may be prudent to find effective pollution control means rather than closing down the polluting industries.

This study was done in 1999-2000 for only organized industries. Unorganized industries were not covered. Despite cost variation among areas, time and units, the study provides cost production for the chemical and petrochemical group of industries.

Table3: Representative Characteristic of Liquid Effluent in Chemical Estate in Gujarat

Parameter (Units)	Vapi Estate	Ankleshwar Estate	Nandaseri Estate	Vatva Estate	Odhav Estate	Naroda Estate	Panoli Estate	Sarigram Estate	Sachin Estate
Flow (MLD)	55	45	4	16	3.5	3	20	0.2	20
pH	7	4.8	6.5	5.5	6.8	6	4.2	7.4	3
BOD (Mg/L)	400	1000	750	500	325	300	405	1125	150
Suspended Solid (Mg/L)	300	700	1100	300	250	250	312	60	350
COD (mg/L)	1000	2000	1500	5000	840	900	970	4621	395
Chlorides (Mg/L)	1000	2500	1700	2100	1100	1000	760	800	2500
TDS (Mg/L)	5000	4500	5000	3500	4100	3500	3380	9202	6000

Table 4.Output, Value added and employment in sample Units

Sample Code No.	Products	Output Value Rs. Millions	Value Added Rs. Millions	Employment in person	Per employee output in '000 of Rs.	Value added per employee in '000 of Rs.
s1	Ranitidine	51.5	23.5	85	606	276
	Arigeofulvin					
s2	Manocratophos	520	270	220	2364	1227
	Trying Mithile phosphad					
	Mangozab					
s3	D V Acid chloride	30	18	90	333	200
	1.2.4 Triazoil					
s4	Toluene Di locy	190	80	60	3167	1333
	T.D.I. (Toluene Di Isocynonet)					
	Aniline					
	Nitobeusene					
	HCL					
s5	Colour Dyes	16.6	5.6	45	369	124
	Chemicals of eight types					
s6	16 different pesticides	24.3	15	160	152	094
s7	Quinnolphos	770	420	220	3500	1909
	Carbondazine					
	fenwelcred					
	cypermetrim					
s8	Antibiotics	19	13	80	238	163
	Ampicline					
	Curpnzin					
	Cepreroksin					
s9	Different kind of Paints	16.6	9	60	277	150
s10	Ammonia	1165	124.2	1800	647	69
	Urea					
	Steam					
	Methanol					
	Electric Power					
	Frmic Acid					
	Concentrated Nitric Acid					
	Weak Nitric Acid					
	Calcium Ammonium Nitrate					
	Ammonium Nitrophosphate					
	Acistic Acid					

contd on next page...

Sample Code No.	Products	Output Value Rs. Millions	Value Added Rs. Millions	Employment in person	Per employee output in '000 of Rs.	Value added per employee in '000 of Rs.
	Synthesis Gas					
s11	Concentrated Nitric Acid	1207.6	161.7	75	568	2.29
	Gymsum					
	NPJ					
	Supho	66	38	85	776	447
s12	Supho-J					
	Armstrings					
s13	PES	82	50	65	1262	769
	Coustic Soda					
	Clorine					
s14	HCL	32.4	22.4	250	130	90
	Hydrogen					
	Sodium Hypoclorite					
	Captafol					
	Captan					
s15	Hexaconanazola	20.2	12.2	35	577	1017
	Acephase					
	GBC					
	Oil Red					
s16	Oil Orange	57	29	55	1036	527
	Metal complexes					
s17	Pigments powder	7.8	4	122	64	33
	Pigments Intermediate					
	Costic soda					
s18	Chlorine	233.3	100.3	370	631	2.71
	HCL					
	Gama Acid					
s19	G/soft	6.1	4.1	45	136	91
	K/Acid					
	Liquid					
s20	Tablets	120	74	83	1446	892
	Capsule					
	Total	**4635.4**	**1474**	**4005**	**18279**	**9416**
	Average per unit	**232**	**74**	**200.25**	**914**	**471**

ENVIRONMENT, HEALTH AND ECONOMICS

Economic Analysis of Rural Pollution and Health Impacts in Northern India: A Multi-institutional Project

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Introduction

The rural population of India, and many other developing countries, suffer from serious problems of indoor air pollution due to kitchen smoke, unsafe water and lack of sanitation. These problems are critical to local environment. The World Bank estimates that improvements in local environmental conditions faced by the poor could lower incidences of the major killer diseases by up to 40 percent.

Much of the previous research on environment and health issues facing rural areas of developing countries is fragmented and contains only partial analysis. Causal links between symptoms and rural conditions have not been convincingly established. For example, disease analysis may be done, but pollution levels are not measured; or in some surveys, pollution levels are recorded, but socio-economic data is not collected. Wide-ranging and coherent studies are needed to address the problems prevalent in rural areas. It was with this objective in mind that the survey on *Energy, Water, Sanitation and Health Issues in Rural North India* was undertaken. The *comprehensive* and *multi-disciplinary study* was conducted in three states of rural north India; namely Uttar Pradesh, Rajasthan and Himachal Pradesh. It has a large random and representative sample population and incorporates a number of other relevant factors. It investigates the links between health and household fuel use, *indoor* air pollution, water safety and sanitation; concentrating in particular, on the role of and effects on *women*. A focus on economic aspects such as "willingness to pay" for clean fuels or infrastructure improvements and the health costs incurred due to illness are also key features included in the survey. A number of questions were addressed within each of these areas.

Objectives

The major objectives of the study are to:

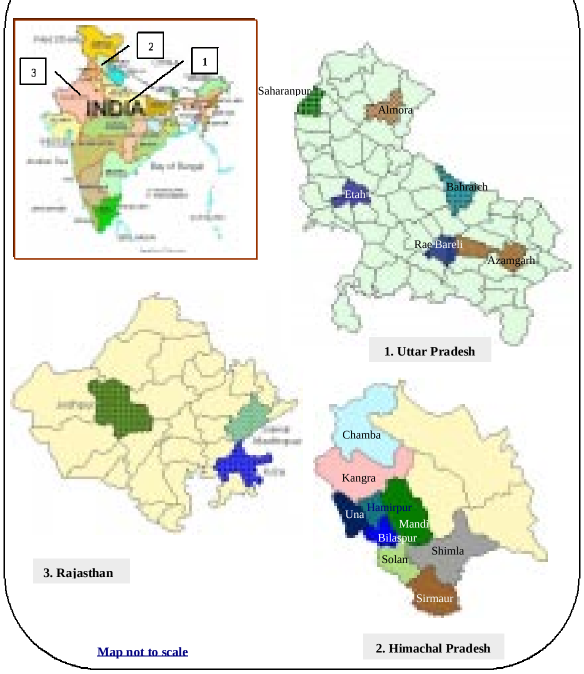
- Analyse energy consumption pattern, its procurement and energy transition.
- Factors affecting the use of clean fuels.
- Find out the levels of indoor air pollution due to cooking.
- Analyse water and sanitation issues.
- Record health impacts due to lack of clean energy, water and sanitation facilities.
- Assess willingness to pay to improve energy, water and sanitation facilities.
- Assess economic burden of using dirty fuels, unsafe water and inadequate sanitation facilities.
- Assess people's environmental priorities.

The Integrated Survey

To understand the impact of lack of energy, water and sanitation on health and human resources, an integrated survey was conducted covering 10,265 rural households (HHs) from 118 villages of 18 districts in three states of Rural North India (RNI) namely: Gangetic plains of Uttar Pradesh (UP includes Uttaranchal), dry desert zones of Rajasthan and the mountainous ecosystem of Himachal Pradesh (HP). These states were selected because of their geo-ecologic, socio-economic and locational conditions that represent Rural North India (RNI). Location of these states is given in Figure 1. The three sampled states represent a large share of many attributes of RNI. They cover over 87 percent of the inhabited villages, 83 percent of rural households, 82 percent rural population (187 million of 226.23 million people) and 69 percent of the land area in RNI. These three states constitute 63 percent of net domestic product at current prices (1998-99).

Data was collected from households and individuals relating to use of different fuels, access to clean water, sanitation facilities, symptoms of diseases, expenditure on health, demographic and socio-economic information. At the same time, measurements of air quality in the kitchen and outside the home were carried out in UP. Health surveys were carried out for 58,768 individuals. Indicators for lung functions (Peak Expiratory Flow) were measured for most of the adult individuals present at the time of the survey. Doctors examined a sub-sample of individuals for presence of diseases. Village level data on health centres, water related and other infrastructure facilities was also collected.

Figure 1: Schematic Map Showing Sampled Districts in Uttar Pradesh, Rajasthan and Himachal Pradesh



Methodology

Selection of Villages and Households: The survey was designed in such a way that it represented various socio-economic and geo-ecological and location zones. Accordingly, three states namely UP, Rajasthan and HP were selected from northern India. The households were selected by using multistage stratified sampling design to have a representative sample. At ***stage one***, stratification of each state was done on the basis of its broad socio-cultural regions (SCRs). A representative district from the median population was selected from each SCR. At ***stage two,*** stratification of districts was done by village population sizes. The villages were divided into four strata on the basis of population data available from Census 1991. In stratum 1, villages with population less than 1000 were included; stratum 2 had villages with population 1000-3000, whereas in stratum 3, villages with population between 3000-5000 were included. The 4th stratum with village population more than 5000 were excluded from the sample because these villages resemble semi urban areas. At ***stage three,*** the selection of the villages from each stratum was done using probability proportional to size (PPS) sampling method. Selection of households (***stage four***) within selected villages was done using systematic random sampling. The number of sample households in each district were in proportion with the universe distribution of rural households in these selected districts.

Survey Coverage: The survey was conducted at two levels, viz. individual level and household level. Pollution survey was conducted to record indoor air quality at household level and water quality analysis was done at village level. Additional surveys were carried out at village and health centre level, to get an overall picture of the village and health centre facilities.

Individual level survey: The individual level survey included physiological characteristics. viz. age, sex, height, weight, health related data and behavioural characteristics such as smoking habit, literacy, occupation, time activity pattern and cooking behaviour. The household level data was collected to get a comprehensive picture of socio-economic conditions, energy use pattern, water and sanitation related facilities, housing characteristics, cooking behaviour, environmental priorities of women, willingness to pay to reduce kitchen smoke and to improve water and sanitation facilities.

Health Survey: At the individual level, the Medical Research Council (MRC) questionnaire, 1986, UK, for respiratory symptoms was followed, which included questions regarding six symptom categories. The inquiry was made *direct*ly from those who were present during the survey for analysis, according to the MRC protocol. In addition, proxy responses for those who were absent during the survey were obtained from the main respondent and mostly mother's responses for children below 15 years. According to the MRC protocol, only the *direct* responses can be analysed for the respiratory diseases. Therefore, the information collected for absent members and children are analysed separately. This gave us a picture of overall prevalence of respiratory diseases for the adults and also for the children. Measurement of PEF rate, an indicator of airways obstruction, which reflects lung function and the extent to which it is impaired, was conducted for direct cases. Information regarding pregnancy and childbirth related problems were also recorded from women.

Household level Survey:

Survey of energy use pattern and practices: Data on energy use patterns included information on the use of biofuels and commercial fuels for cooking, sources of procurement of cooking fuel, time, distance and effort involved in procurement, progress along the energy ladder of increasingly more convenient fuel, etc. Housing characteristics included information on the number of rooms, type of house and type of kitchen, location of kitchen and number of doors and windows in the kitchen. Further data collected on cooking behaviour, number of meals cooked using different fuels in a day, time spent for cooking, cooking involvement of different groups of individuals and type of involvement. Time activity pattern of the members of household was also recorded. Data collected to assess people's willingness to reduce the impact of indoor air pollution included information on people's choice of type of intervention, reason for not using clean fuels, willingness to pay for additional amount of clean fuel and additional demand for kerosene.

Survey of water and sanitation facilities and health: Data on water availability, source of collection, efforts required to fetch water, problems faced in collection, type of problems, water quality, water storage and purification practices, etc, was obtained. The occurrence of water related diseases such as worms in stool, diarrhoea and jaundice, and associated health expenditure and days lost due to suffering were recorded. Data on availability of sanitation and sewerage facilities and willingness to contribute to improve water, sanitation and sewerage facilities was also collected.

Additional Surveys

Measurement and monitoring of indoor air quality: (IAQ) were carried out in 519 households of UP. Kitchens were categorised into four types- i) inside living room; ii) separate kitchen - inside the house, iii) separate kitchen - outside the house, and iv) no kitchen - open air cooking. Locations of the personal samplers were decided based on the type of kitchen and layout of the house. To assess the personal exposure, one sampler was attached to the chief cook during the cooking period. One sample was collected at a distance of about 2m away from the stove but inside kitchen/room to assess exposure of other family members. One sample each was collected from the living room and one from the open space of house i.e. veranda, etc., where people spend most of their time, to assess the effects of cooking operations in these areas. In addition to Respirable Suspended Particulate Matter (RSPM) observations, measurements for SO_2, NOx and CO were taken during the cooking operation at these locations. Indoor air pollution monitoring was carried out during the cooking period extending upto 3 hrs.

Water quality tests were performed in all the selected villages across the three states. Water samples were taken directly from the sources accessed by the villagers. A total of 137 samples were tested for dissolved oxygen, biological oxygen demand (BOD), nitrate, total coliform and fecal coliform.

Village level surveys were done to corroborate the data acquired at the household and individual level, and also to get an overall picture of the village. The distances of a village from the nearest road, bus stop and railway station, as well as the distance from any air polluting industry were also recorded.

The *health centre survey* established the type of health facilities available to village residents in terms of number of beds, medical equipment and sanitation standards. Through the use of a questionnaire (that differed in content from the household questionnaire), facts about patient numbers and prevalence of respiratory and water borne diseases including information about seasonal variations were gathered.

The data was analysed and then extrapolated for RNI to gain some macro level understanding and to get some policy insights. For energy and water related issues, extrapolations based on sample proportions were applied to the total rural households in RNI, whereas health related extrapolations were based on sample proportions applied to rural population in RNI.

The states wise break up of the sample is given in Table 1.

Table 1: State wise break up of the Sample

Coverage level	State			Total
	Uttar Pradesh	Rajasthan	Himachal Pradesh	
Districts	6	3	9	18
Villages	51	13	54	118
Households	7564	1989	712	10265
Individuals	42713	11955	4100	58768

Demographic profile of the individuals and socio-economic profile of the sample households are given in the Annexure.

Results

Highlights of the Energy Scene in Rural North India

A large proportion of households in RNI, as shown in Box 1, depend on biofuels, which are gathered by spending 8 billion human hours annually. Such a high amount of human labour, if put to better use, can bring prosperity in the region. In spite of high willingness to pay to purchase kerosene even at *higher than market price*, the kerosene supply is not adequate. If the demand of 49 percent of the households, who are willing to pay *more than market price,* to purchase kerosene for cooking is met, it can reduce pressure on human and forest resources substantially and also provide better living conditions. Twenty seven percent of the non-electrified houses, if electrified, could help divert kerosene (which is currently used for illumination) for cooking. This would also give relief to women from exposure due to kitchen smoke that cause serious health impact.

BOX 1: HOUSEHOLD ENERGY – Rural North India

- 96.6% of households (HHs) use biofeus, 4.9% use kerosene and 4.95% use LPG for cooking. Most of them however use multiple fuels.
- Forests contribute 39% of the fuel wood need.
- 56 million tonnes of biofuels (of which 37 million tonnes of fuel wood) are gathered annually.
- 23 million households spend 8 billion hours annually in fuel wood gathering.
- 35 million households use 1.74 million tonnes of kerosene per annum for cooking and lighting.
- 34% of HHs (out of the HHs using kerosene for cooking) procure kerosene form open market and 97% procure it from fair price shops.
- 49% of HHs are willing to pay more than market price to purchase kerosene for cooking.
- 0.2% HHs use Biogas for cooking.
- 63% of HHs are electrified.

Exposure to Indoor Air Pollution and its Measurements

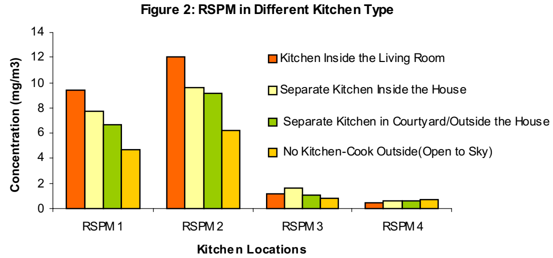
- When the kitchen is inside the living room or inside the house, the chief *cook* and other family members are exposed to a significant level of pollution during cooking hours (~ 3 hrs per day).
- *Cooks* are exposed to an average of 6.8 mg/m^3 of respirable suspended particulate matter (RSPM) while burning biofuels during cooking hours.
- While cooking with biofuels, RSPM concentration in the kitchen (about 2 meters away from stove) has a mean value of 9.2 mg/m^3. This shows that *those* who assist or

are in close proximity to the stove are exposed to even higher level of pollution than the *cook,* especially if they are in the direction of the plume of smoke.

- When the kitchen is located outside the house RSPM concentration inside the house reduces significantly.

- *Cook's* personal exposure to CO, SO_2 and NO_x are higher than the National Air Quality Standards. However, the concentration of SO_2 and NO_x reduce significantly below the NAQS as the *sampler* moved away two or more meters from the stove. Outside the house, SO_2 and NO_x levels sometimes drop below the detection level. RSPM concentration for different kitchen types is given in the Figure 2.

Figure 2: RSPM in Different Kitchen Type



Respirable suspended particulate matter (RSPM) in Different Kitchen Types

RSPM 1 = Personal exposure, RSPM 2 = Concentration at 2 meter away from the stove,

RSPM 3 = Concentration in the living room, RSPM 4 = Concentration outside the house

Highlights of Water and Sanitation Coverage in Rural North India

Sixty two percent of the households (Box 2) do not have water supply in their homes; so they spend 32 billion hours annually, for water collection. Perhaps the same hours could be used to improve water supply in the region. The low economic development is both a cause and effect of low accessibility to clean drinking water, sanitation and sewerage facilities. However, some households are willing to contribute financially to avail clean drinking water, better sanitation and sewerage facilities, which could improve these facilities, if supported and integrated with other government programmes.

BOX 2: WATER and SANITATION : Rural North India

- 62% of HHs do not have water supply in or near their homes.
- 22.8 million HHs spend 32 billion hours per year to collect water from outside home.
- Only 5% of HHs are connected with sewerage facility.
- 10% of HHs have toilet facility inside the house
- 1 % of HHs use community toilets

Proportion of households *willing* to pay for:

- Clean drinking water: 7 %
- Community based drinking water supply: 25 %
- Sewerage facilities: 28 %
- 'In-home' toilets: 29 %
- Community toilets: 25 %

Water Quality Report

Water Quality data from 137 samples revealed that:

- Dissolved oxygen was in the range of 1.9 mg/l to 17.5 mg/l.
- BOD was above the drinking water/human use standard of 2 mg/l in 105 samples. In UP, all the 100 samples had BOD above the standard.
- Total coliform count was above the standard of 50 MPN/100 ml in 76 samples, whereas the fecal coliform count was found in 73 samples.
- In Rajasthan, all the water samples had fecal coliform, which as per standard should be nil in potable water.

Toll on Human Health

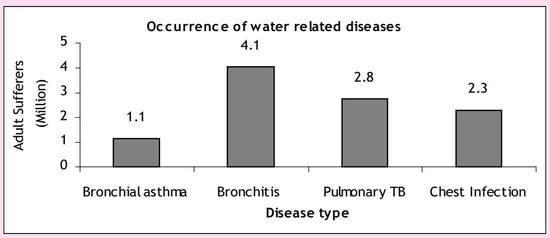
Analysis of prevalence of respiratory diseases (Box 3), shows that 17 percent of rural adults (24 million adults) have some respiratory symptoms. Nearly 13 percent (17 million adults) have serious respiratory symptoms and 7 percent (about 10 million adults) may have respiratory diseases. Prevalence of respiratory diseases works out as follows:

- 4.3 percent (6 million rural adults) suffer from Bronchitis
- 2.9 percent (4 million adults) suffer from Pulmonary TB
- 2.1 percent (3 million adults) suffer from Chest infection
- 1.45 percent (2 million) suffer from Bronchial asthma.

While the former two are strongly associated with indoor air pollution, the latter two are possibly triggered by indoor air pollution.

BOX 3: RESPIRATORY AND EYE DISEASES

- Respiratory symptoms are prevalent among 24 million adults, of which 17 million have serious symptoms
- Adults suffer from various respiratory diseases as given in the figure below:



LRI/ ARI prevalence among **children below 5 years:** 4.4 million (15.4%)

Expenditure on Respiratory Diseases

- Total private expenditure on health:
  - Rs. 15 billion per year for respiratory diseases
  - Rs.6 billion per year for eye related diseases
- Of the total expenditure incurred on:
  - **Respiratory diseases:** 56% is spent on medicine, 19% on special diet and doctor's fee each and 6% on hospitalisation
  - **Eye related diseases:** 70% is spent on medicine and 30% on doctor's fee.

Only about 20 percent of sufferers (adults and children) took some treatment and spent about Rs.15 billion$ on doctors' fees, medicines, hospitalisation and special diets. Similarly, on eye related diseases, sufferers spent about Rs.6 billion on doctors' fees and medicines. This is a huge loss to this deprived community. Though all the health aliments leading to monetary loss are not due to exposure to indoor air pollution, it has a significant impact on health.

About 15.5 percent of children below 5 years of age (4.4 million rural children in RNI) suffer from Lower Respiratory Infections (LRI)/ Acute Respiratory Infections (ARI).

Risk Factors for Respiratory and Eye Diseases

Odd ratios* for respiratory and eye diseases among female adults for several important variables are given in Table 2.

Table 2: Odd ratios for respiratory and eye diseases among female adults

Variables	Splitting Criteria	Respiratory Disease				Eye Irritation
		Bronchitis	Asthma	Chest Infection	TB	
Age	More than 30 Yrs/ Upto 30 Yrs	**3.99**	**4.05**	**2.64**	**2.85**	**2.53**
Smoking Habit	Smokers/ Non-smokers	**3.22**	**2.94**	**2.66**	**1.66**	-
Illiteracy	Illiterate/ Literate	**3.95**	**6.43**	**3.97**	**3.00**	**1.95**
Fuel index~	>15.56/ Up to 15.56	**2.53**	**2.47**	**2.08**	**1.94**	**1.99**
Asset index*	<0.25/>= 0.25	**1.88**	**3.51**	**3.01**	**1.93**	**1.53**
Type of Fuel used	Biofuel/Both fuel or Clean fuel	**1.99**	**2.55**	**1.83**	**2.36**	1.37
Number of rooms	<2/>2 rooms	1.39	**1.81**	**1.64**	1.43	1.39

Number in bold represents statistical significance

~ A composite indicator based on multiple variables such as age, type of involvement (such as chief cook, assisting in cooking, etc), number of years spent cooking and fuel type used.

*Asset index has negative impact on respiratory diseases

$ Rs. 44 = 1 US Dollar in 2000

** Commonly used in epidemiological studies to describe the likely harm an exposure might cause. It is calculated by dividing the odds in the more susceptible group by the odds in the less susceptible group. Higher the odd ratio, higher is the chance of a symptom.*

Table 2 shows that:

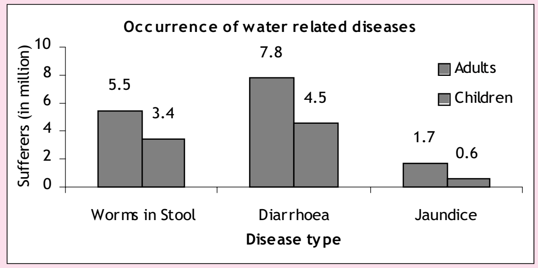
- Women above 30 years are at higher risk than younger women by a factor of 3.99 for Bronchitis, 4.05 for Asthma, 2.64 for chest infection and 2.85 for TB.
- Smoking is a high risk factor for all respiratory diseases but not for eye irritation.
- Illiterate women are at 3 to 6 times higher risk compared to literates for *all respiratory diseases*. Most benefits of literacy occur at the primary level education itself. i.e. odd ratios sharply fall with primary education.
- Fuel index was constructed to capture lifetime exposure. Higher index is associated with high lifetime exposure and risk for all respiratory and eye diseases.
- Asset index (used as a proxy for income or economic status, as enquiry on income is usually less reliable) shows negative impacts on respiratory and eye related diseases.
- Biofuel users have higher risk of respiratory diseases as compared to clean fuel users.
- Number of rooms has significant impacts only on Asthma and chest infection.
- Water and sanitation related diseases (Box 4) occur in 13 million rural adults and 7.7 million rural children as recorded in the survey for water related diseases in the past. Diarrhoea and worms in stool in the past one month and jaundice in past 2 years were recorded. These diseases lead to an expenditure of Rs.13 billion per year (by adults and children in RNI).

Risk Factors for Water Related Diseases

- Water storage in an open bucket or drum has 3 times higher risk for diarrhoea and 2 times for worm in stool, compared to safe water storage practices such as *pot covered with a lid.*
- Adults from the households not using any *purification methods* have high risk by a factor of 1.5 for diarrhoea and 4 for worm in stool.

BOX 4: WATER RELATED DISEASES *

- 13 million adults (9.7% of total adults) and 7.7 million children (8.7% of total children) in RNI suffered from *some water related diseases* in the past. Occurrence of major diseases are as given in the figure below:



- Prevalence of diarrhoea is high among children below 5 years (in 9% children).

Expenditure

Total expenditure for water related diseases for adults and children: Rs. 13 billion per year.

- Of the total expenditure incurred, 37% is spent on special diet, 33% on doctor's fee, 17% on hospitalisation and 13% on medicine.

Total Medical Expenditure

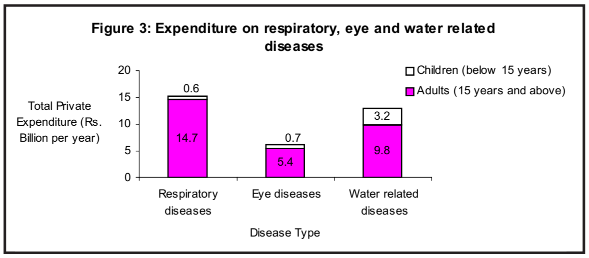
Rs.29.9 billion per year is spent for adults and Rs.4.5 billion for children in RNI towards healthcare related to inadequate energy and water facilities. Disease-wise expenditure is as given in Figure 3. Improved medical care facilities with a reach to all the villages and improved energy, water, sanitation can help reduce the expenditure substantially.

Total Economic Burden

Total economic loss due to lack of energy, water and sanitation and its impact on health and human resources is summarised in Box 5, which shows that, 4,815 million days per year are spent or lost, due to inadequate facilities and resources. The total *economic loss* due to the health impact of dirty fuel, unsafe water and time spent in their procurement is over Rs.323 billion per year in RNI. Availability of clean energy and water sources, accessibility to

**** Notes:***

1. *Worms in stool was taken for an individual where worms were passed any time during past one month*
2. ***Diarrhoea** was taken for an individual when it lasted for more than 2 days during past one month*
3. ***Occurrence of Jaundice** was considered any time in past 2 years*



better sanitation and health facilities can improve economic and social conditions of the rural poor. Also, better access to energy and water resources could improve efficiency of agriculture and allied activities, which can create opportunities for better employment and better livelihood. When such a large human resource is spent, just to meet the basic survival need, how can people improve their living conditions and participate in economic growth process? An integrated approach and participation from various ministries, government departments, NGOs and village communities are required to achieve the sustainable economic development of Rural North India.

BOX 5: Economic burden due to energy, water, sanitation and health problems (per year)

	Energy (a)	Water (b)	Total (a + b)
Days spent/ lost (Million)			
• Days+ spent in collection	822	3,212	4,034
• Days lost due to diseases	260	521	78
TOTAL	1,082	3,733	4,815
Monetary value* of working days spent/ lost (Rs. Billion)			
• Fuelwood gathering and water collection	49	193	242
• Due to diseases	16	31	47
Direct expenditure on health (Rs. Billion)	21	13	34
Total economic loss (due to improper energy and water facilities and due to health impacts of their procurement and use)	86	237	323

Notes:
1. Days spent in fuel wood gathering and water collection are given in column (a) and (b) respectively
2. Diseases includes: respiratory and eye related diseases under energy column (a) and water and sanitation related diseases under water column (b)

+ Taking 10 hrs as a standard working hours per day

* Includes imputed cost per working day taken at Rs. 60 per day (approx. wage rate)

Transportation Burden

Collection of fuel wood and water require transporting them. While the number of hours are accounted, physical strain from carrying heavy loads is not. It leads to headache, neckache, backache and also bruises, injuries and dangers of snakebites etc. Box 6 shows that on an average, members of a household walk 325 km per year for fuel wood collection and 2,774 km per year for water collection.

BOX 6: Transportation burden (per year per households) due to due to lack of energy and water facilities

	Fuelwood	Water
Proportion of households collecting (%)	62	62
Average distance walked per trip (km)	2.6	0.8
Average number of trips	125	3468
Total distance walked (km)	325	2774
Average quantity collected (tonnes/Kilolitres)	1.3	73

Conclusions and Recommendations

Access to energy, water, sanitation and health need to be stressed for social and economic development. They also concern poverty - gender - environment linkages and need a holistic view so as to reach a consensus to achieve the common goals. In addition to current status of energy, water, sanitation and people's priorities, health impacts of exposure to pollutants due to cooking with biofuels and lack of clean drinking water are also recorded.

In Himachal Pradesh, which has good access to clean fuels and water, one notices a sharp difference in all socio-economic indicators such as literacy, female/male ratio, health, income levels and other infrastructure. Could this be due to the decision taken to give them clean fuels to prevent deforestation in the hilly areas 10 years ago? If so, this decision has had many unintended benefits beyond preventing deforestation. One wishes that such a decision was taken for all the states in India. Almora district, which is a hilly district and was under UP at the time of the survey, also is well ahead of the other districts in UP, where the same government prevails.

A comprehensive policy and programme is needed that could integrate energy, water, sanitation and health with development goals such as employment generation, poverty alleviation and sustainable livelihood so as to bring about cohesive development in all arenas of life of the rural people. This requires focused linkages, participatory, collective and coordinated efforts of different ministries such as the Ministries of Education, Environment and Forests, Petroleum, Rural Development, Health, Agriculture, Non-conventional Energy Sources and the Central Water Commission along with local government and non-government organisations. Multipronged approach is needed as suggested below.

Energy Supply and Utilisation:

Biofuels:

- It is clear from the survey that substantial proportions of households have developed their own fuel wood supply (60% in UP, 47% in Rajasthan and 64% in HP). In spite of this, large proportions of households procure fuel wood from forests (36% in UP, 40% in Rajasthan and 49% in HP). To reduce this pressure on forests and to ensure fuel wood supply, afforestation on common lands, village lands and wastelands should be promoted. The Wasteland Development Board, Forest Department, Rural Development Department and MNES should come together to improve the fuel wood supply, by either supplying it as it is or converting it into clean fuel by means of biogasification.

- There are many factors that hinder the use of clean fuels, the most important being affordability and availability. Government intervention plays a crucial role in promoting any technology, but lack of effective financial and institutional mechanisms have proved to be the barriers. Therefore, we need to invent new financial and institutional mechanisms, which would help people to avail of better fuel sources and other facilities and services of their choice.

- *Reduce biofuel use* for cooking either by improving efficiency of usage or by replacing it with available alternative fuels such as kerosene, LPG or renewable energy technologies such as biogas, solar cookers and so on.

- *Biomass gasification:* Huge quantity of biomass available in rural areas is currently used inefficiently. This can be brought to productive and efficient use if it is converted into electricity by *biogasification*. Afforestation and energy plantation programmes can be connected with this initiative so that supply of raw material is ensured. However, this would require a feasibility study before it is taken up. This programme can generate large employment, satisfy local needs with local resources and avoid transmission and distribution loss that is currently incurred by state electricity boards.

Kerosene:

- Kerosene is an inferior lighting fuel compared to electricity, but is still used in majority of the households in the absence of regular electrical supply. Even the minimum allocated quantity of 3 to 5 litres per month does not reach the target households regularly, due to its diversion to other *lucrative* uses such as transportation. The quota was fixed as per lighting needs several decades ago. It has not been revised except in hilly areas. It is easy to adulterate or use subsidised kerosene for adulteration of other petroleum products. Therefore, it is necessary to streamline kerosene supply and direct it to the targeted users below the poverty line.

- However, kerosene can be a cleaner cooking fuel compared to biofuels, if burned with a blue flame in a pressured stove. Moreover, it is the most preferred cooking fuel in the energy ladder after fuel wood, even in low-income households due to the convenience of turning on and off as and when required.

- To strengthen kerosene supply and to ensure that the subsidy is given to the target population, we suggest the following policy options:

  - Restructure subsidy pattern and deliver it directly to the consumer. It could be done by issuing *coupons* to the poor households, instead of the subsidy at the supplier level. *IT Enabled Electronic Card (ITEE-Card)* can be issued to each household. This concept, which was suggested by Reliance Ltd. during a meeting at IGIDR in September 2001, where petroleum minister Shri. Ram Naik presided. This can be explored further to understand the pros and cons of such *technology*. This could assure accountable and assured benefits to the target consumers.

- If 49 percent of the households are willing to pay a price for additional quantity of kerosene, which is much higher than the subsidised price, the open market needs to be improved. Open market can take care of some share of demand of the households that are economically better off and in a position to pay a higher price. This would help to reduce pressure on fuel wood sources and associated impacts.

<u>*LPG:*</u>

- LPG (liquefied petroleum gas) is the *best available* cooking fuel, but access to LPG is very low in the rural areas of Uttar Pradesh and Rajasthan. The situation in HP however, is far better. Therefore, it is important to improve access to this fuel. Currently available cylinders are heavy and difficult to carry to remote areas due to inadequate transportation facilities, and require a large investment upfront. LPG, if available in small containers, would be convenient even for poor people located in remote villages.
    - Bottling of small cylinders (Union Minister for Petroleum and Natural Gas, announced during a discussion in a seminar at IGIDR in September 2001 that 5 kg cylinders of LPG would be introduced for domestic purpose). These cylinders are targeted at low-income group households in the rural and hilly terrain areas due to ease of transportation, compared to the existing 14.2 kg cylinder. Every town or village with a population of 10,000 or more would be given an LPG distribution agency (as against 20,000 now) for easy transportation and affordability. This initiative can play a crucial role in breaking the barriers of affordability and availability of LPG in rural north India. This programme would also have a social impact on people's lives.

<u>*Biogas:*</u>

- Biogas is another feasible option available in rural areas of north India. The government, with support from NGOs and the community, has a crucial role to play if this potential is to be tapped.
- The survery shows that about 3.7 percent of the households have more than 3 to 5 animals, which is sufficient to install a biogas plant of 2 cubic meter capacity that can satisfy cooking energy needs of 5 to 8 individuals. These households fall into the economically *better off* class and therefore, with strategic promotion it is possible to install biogas plants.
- The survey showed that over 24 percent of households have less than 3 animals per household, but together they can install family size biogas plants if '*sharing mechanism for dung, slurry and cost'* can be developed.
- Apart from family sized biogas plants, there is a large potential for community biogas plants. In fact, in many cases community size biogas plants would be beneficial in many ways. The advantages community biogas plants provide are:
    - Cater to the energy needs of the households who do not possess livestock
    - Generate employment
    - Remote villages without access to electricity are best suitable for community biogas installation, which can also be used to generate electricity
- Training programmes can be initiated in industrial training institutes with the emphasis on installation, management and service of biogas plants. This would ensure better functioning of biogas plants.

Conservation, Technology and Institutions:

- For illuminating homes, night schools, etc, solar lanterns are suitable in rural areas, where, power supply is erratic. Servicing and perhaps assembling of these lamps, can be initiated in some villages so that employment is generated and people have access to such products and services

- Promotion of energy conserving systems, where integrated choices of fuels, improved stoves and appropriate pots and lids have to be made. Improved cooking stoves and pressure cookers can save large quantities of fuel wood. It is a less expensive and feasible option to save biofuels. However, the survey showed lack of awareness about the advantages and functioning (though simple) of improved stoves. It is therefore, necessary to initiate community awareness programmes.

- Improved and accessible financial mechanism: Initial investment is the main constraint in promotion of most technologies in rural areas. Therefore, financial support through Self Help Groups (SHGs) formed in villages across these states can be very effective in their promotion.Due to their financial strengths, SHGs can generate and use money for such purposes.

Water and Sanitation Facilities

Water scarcity is the most important issue that leads to all other related problems. Availability of safe drinking water, upon which, health of individuals and welfare of the people depend, requires an integrated approach for comprehensive and sustainable solutions.

The aim of the policy should be to provide safe sources of drinking water within people's reach, and to minimise the hardships faced by people in collecting water. Priorities in sanitation should be to provide people with sanitation facilities so that water does not get contaminated and does not harm health. We recommend the following policy measures and interventions:

- In many villages people use surface water sources such as ponds and lakes. These sources are prone to contamination from poor sanitation, agriculture run off, etc. that contains harmful disease causing agents, which affect human health. Therefore, such open sources should be restricted from use and alternative water sources should be strengthened. If these sources are used, water testing and monitoring should be practiced regularly at delivery point.

- On an average, 2,774 km is walked per year per households to collect 73 kilolitres of water. This takes substantial time and hard work. Therefore, it is necessary to improve local water resource base by various methods:

  - Improving ground water resource and rain water harvesting and storing water for use during scarcity seasons

  - Tapping rainwater by various rainwater harvesting techniques can minimise water shortage. The advantages of rainwater harvesting are that it provides safe water supply and helps in groundwater recharge. Therefore, area-specific rainwater harvesting should be promoted with community, government and NGOs participation.

  - Watershed management programmes can also play a crucial role in improving water resource base

- It is observed that water is contaminated further in households, due to poor storage and unhygienic conditions, especially in poor households. Contamination occurs mainly due to lack of awareness about simple methods, which, if practiced, can influence health outcome in a positive way.

  - Covering water storage pots, use of pots with long handles (this would avoid contamination of water by dirty hands and dirt in the air) and other hygienic storage methods need to be popularised

  - *Water pots should be kept* above the ground level so that dust does not enter into the pots

  - Simple cloth filter can avoid many diseases

- Boil water before drinking

- Awareness programmes (especially for women) on these *simple* techniques should be popularised in villages so that people practice these methods. NGOs could play a crucial role in this endeavour.
- Development of village level information systems on various aspects of water resources: As stressed in India's National Water Policy document of 2001, a village level information system need to be developed so that information about various water related issues is easily available to people.
- Human excreta are the most important disease-carrying agents due to defecation in open spaces. In some villages, community toilets can be popularised with awareness programmes about keeping them clean. The survey suggests that people are willing to contribute to the construction of in-home and community toilets. This contribution can reduce the burden on the government funds and provide the required facility.

Health Care Facilities

- Training of healthcare professionals is needed to spot the problems relating to pollution and to sensitise them to be alert. Many villages do not have convenient health facilities. In many cases, in spite of having health centre facilities, the centres are not equipped with basics instruments/ infrastructure required for simple treatment.
- Many diseases spread due to negligence, lack of awareness of their origin and lack of measures to check them. Such diseases can be avoided by simple precautions such as cleaning hands and utensils properly and avoiding delay in treatment. Awareness about such techniques can be promoted with the support NGOs, the Health Ministry and Rural Development Ministry.
- Exposure to air pollutants can be minimised by structural changes in housing e.g. by improving ventilation of the kitchen and house, and having a separate kitchen or installing chimanys.
- The study shows that with improvement in female literacy, adverse health impacts of respiratory and water related diseases could be reduced.
- Health centres should be networked with information systems to communicate with each other for better implementation of public health policy.
- It is reported that sick people and pregnant women suffer as they travel long distances to reach to health centres, due to lack of medical facilities nearby. To minimise their drudgery and to support them with health care access, mobile vans can be introduced that go around villages to provide medical aid.

Transportation Facilities

- As the results suggest, over 822 and 3,212 million days are spent in fuel wood and water collection respectively, which impose hardship and loss of productive time on the rural poor. This also creates physical strain and health damage. To reduce this damage:
    - Village level cooperative transport facility such as trolleys or wheelbarrows to carry water pots and fuel wood loads could be made available.
    - Alternatively, small motorised vehicles can be provided to communities to carry fuel wood and water on a cooperative basis. This would substantially reduce the physical burden on women and children if collectively financed.

Annexure

Household and Population of Northern India, 2001 (Million)

	UP	Rajasthan	HP	Total (Rural North India)
Total number of households	22.27	7.10	1.00	36.73
Total Rural Population	137.85	43.27	5.48	226.23
• Male	72.24	22.39	2.75	118.42
• Female	65.61	20.87	2.73	107.81

Socio-demographic profile of the sample (percent)								
	All		UP		Rajasthan		HP	
Gender	Female	Male	Female	Male	Female	Male	Female	Male
Base: All individuals	28,560	30,208	20,921	21,792	5,552	6,403	2,087	2,013
Proportion (%)	49	51	49	51	46	54	51	49
Age								
Up to 15 years	42	45	42	45	43	46	30	32
16 – 40 years	40	36	40	36	41	38	48	44
> 40 years	18	19	18	19	16	16	22	24
Literacy *(adults)*	26	59	24	56	17	59	69	84
Occupation (adults)								
Farm based	2	40	2	42	3	35	4	30
Industry/Service	2	20	2	16	2	26	4	35
Home based/Housewife	85	4	88	4	83	4	69	3
Unemployed/Others	10	36	8	38	12	35	23	32
Base: All adults (above 14 yrs.)	17,417	17,410	12,583	12,346	3,325	3,662	1,509	1,402

Socio-Economic profile of the sample households (percent)				
Land holding	All	UP	Rajasthan	HP
Landless and non-farm households	48	53	27	60
Marginal & small (up to 5 acres)	42	41	48	35
Medium & large (more than 6 acres)	10	6	25	5
Annual household income (in Rs)				
Up to Rs. 20,000	58	61	50	43
More than Rs 20,000	42	39	50	57
Kitchen appliances				
Kerosene Stove	22	21	18	49
Pressure Cooker	17	14	5	86
Gas Stove	9	6	4	57
Water Filter	1	1	0.2	5
Livestock				
Buffalo	46	46	49	43
Cow	37	33	44	58
Bullock	24	26	13	31
Sheep / Goat	25	21	42	17
Number of rooms				
1 Room	35	36	34	18
2 Rooms	32	32	30	26
3 or more rooms	33	31	34	55
Kitchen location				
Inside living room (No separate kitchen)	26	28	23	9
Separate Kitchen: Inside home	39	44	12	57
Separate Kitchen: Outside home	14	9	29	31
No kitchen room: Open air cooking	21	18	36	3
Base: All Households	10,265	7,564	1,989	712

Economic Valuation of Health Damage in North Chennai using a Comparative Risk Assessment Framework

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Introduction

The general objective of the project was to rank a set of environmental problems faced by a municipality within an industrial zone of Chennai city using a comparative risk assessment framework (CRA). The CRA approach originally developed by the United States Environmental Protection Agency (USEPA), has been applied for aiding resource allocation for environmental management in several states of USA as well as in many cities of developing countries including Ahmedabad in India and Asansol in Bangladesh. One of the biggest impediments to the successful application of the CRA framework in developing countries is the lack of information about quantitative exposure and health effects. The project demonstrates the usefulness of the CRA approach by addressing many of these deficiencies through rigorous primary and secondary data collection on environmental, health and economic parameters. The study is one of the first studies in India to use a quantitative health risk assessment framework to address environmental health concerns at a municipal level with direct stakeholder involvement.

Objectives

The objectives of the study are to:

- Assess human health risks associated with particular environmental exposures using both previously established dose – response information and cross-sectional epidemiological information collected during the course of the study.
- Evaluate the economic costs associated with these health risks using local economic information to enable ranking of the particular environmental concerns on the basis of both the health and economic risks.

Study Area

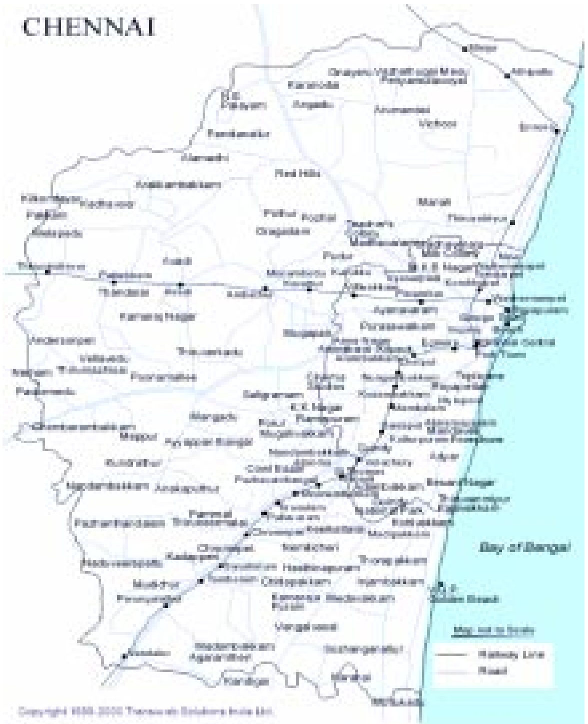
The geographic focus of the project was the Thiruvottiyur Municipality in North Chennai. Since even within a single zone, there are a multitude of environmental concerns, the project sought to analyse only an identified set of problems as listed below.

List of Environmental Concerns

Air	Water	Solid Waste
Particulates (Total / respirable)	Microbial contamination	Access to sanitation
Indoor air pollutants	Heavy metals	Proximity to solid waste dumps
SO2		
NO2		
Lead		

Methodology

- Population exposure to selected air and water pollutants were assessed using a combination of secondary data sources as well as primary sampling.
- Health risks were then assessed using dose-response information established specifically from developing country studies.
- Primary data on the prevalence of respiratory, gastro-intestinal and vector-borne diseases within the resident population of the study zone was collected through the administration of a health assessment questionnaire.

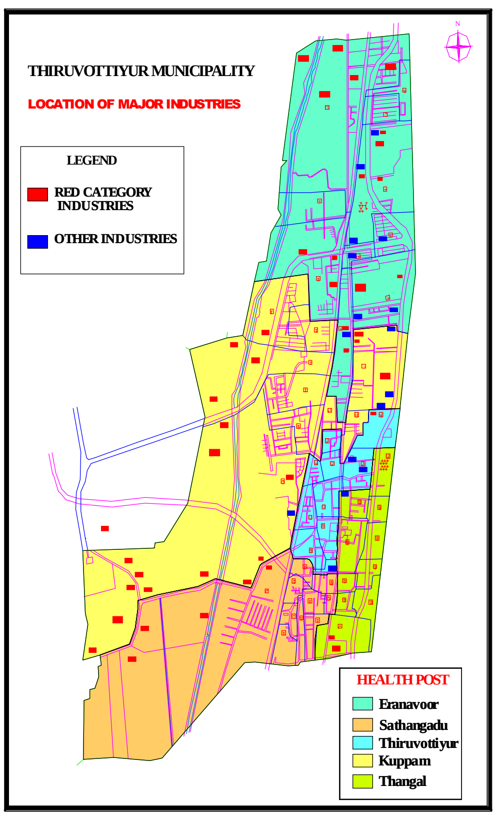


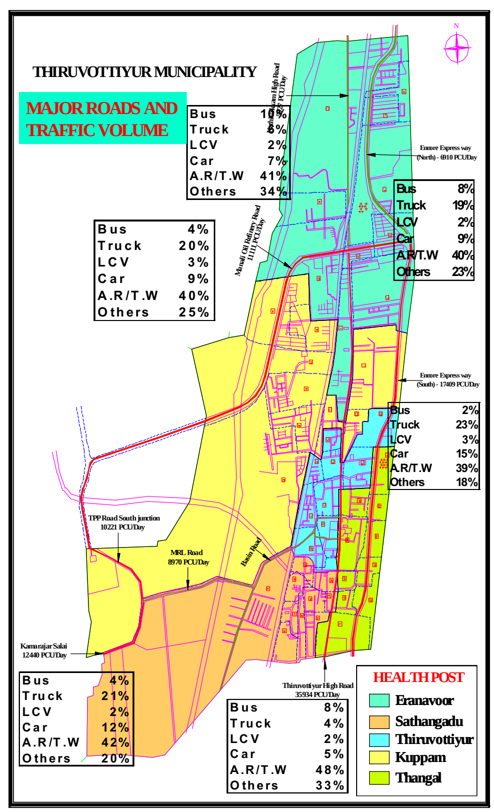
- Local information on costs of hospital visits, treatment and work-loss days specifically attributable to environmental exposure were collected to assess economic costs of the health damage.
- Health and economic risks associated with each environmental problem were assessed on the basis of data collected from the preceding steps as well as on the basis of public perceptions and ranked accordingly.

Results

Air Quality

Air quality information was collected from secondary sources as well as through primary sampling. Secondary sources included the National Ambient Air Quality Monitoring Database (NAAQM) and Environmental Impact Assessment (EIA) reports of area industries done over a period of the past five years. Primary





Maps showing location of study area in Thiruvottiyur Municipality in North Chennai, along with industry and vehicular traffic profiles and organisation of health posts for health data collection.

sampling was carried out for PM10 (Particulate matter less than 10 mm), CO, SO2, NO2, lead and indoor air-pollutants (in houses using bio-fuels) through a combination of personal sampling and area sampling techniques.

The environmental air quality data analyses revealed that levels of PM10 are the single biggest concern. The results of limited primary sampling show that a significant fraction of the population is exposed to PM 10 levels not adequately reflected in the area average reported by the NAAQ database. Populations that use bio-mass fuels in homes for cooking or live in slums adjacent to high traffic corridors, commuters, traffic police all represent categories that are exposed to concentrations well in excess of the standards. Population exposure profiles show that nearly 95 percent of the population is exposed to concentrations in excess of the World Health Organisation (WHO) guideline values for PM10.

Annual 24-hour averages of lead in air as established through high volume sampling were below the prescribed standards. However, blood lead levels were higher than the action level of the USEPA. Since the relative contribution from air borne lead could not be ascertained, risks from elevated blood lead levels were separately calculated. Although the annual 24-hour averages of CO, SO2 and NO2 were below the standards, the short-term exposure limits were exceeded significantly during bio-mass burning while cooking or burning of open refuse. The limits were also exceeded during sporadic releases by the industry. Based on the above results, health risk calculations were done only for PM 10 and for lead. Although the short-term exposure limits were exceeded for other pollutants, the consequent health risks could not be quantified due to the uncertainty in the dose - reponse relationship data for such exposures.

Water Quality

Data on physico-chemical and microbiological parameters was collected predominantly from the Ground water Cell of Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB). EIA reports of area industries were additional sources of information. Some primary data was also collected, by sampling drinking water in select households. Secondary data collected over a period of the last five years revealed that microbiological contamination with faecal coliforms was the most significant concern within the municipality. The data showed the presence of faecal coliforms in almost all sampling locations spread across the municipality over multiple time frames.

Data on heavy metals including lead, chromium, arsenic, copper, iron and zinc showed that levels were predominantly below the prescribed standards. Limited data on pesticides showed no significant contamination of drinking water sources. Since the available data did not show significant presence for any of the major chemical contaminants, health risk calculations for water contaminants were limited to the assessment of prevalence of gastro-intestinal disorders attributable to microbial contamination.

Solid Waste and Access to Sanitation

Qualitative information on solid waste was collected both from municipal sources and from household level surveys. Nearly 35 percent of the population did not have access to a private toilet and made use of open grounds or public toilets. In slum populations nearly 80 percent did not have access to private toilets. Around 55 percent of the population reported being severely affected by rain - water stagnation. 30 percent lived in houses that were less than 100m meters from solid waste dumps. The municipality was operating three of the solid waste dumps. Most of the dumps were also found to contain large quantities of chemical and other hazardous wastes. The access to these dumpsites was unrestricted. Rag pickers included many children from the neighbouring slums. Improper solid waste disposal and lack of access to private sanitation was cited as the most important environmental health concern in community perception surveys. Quantitative health risk assessments were not performed for solid waste concerns, as quantitative exposure information was not available. Prevalence of vector borne and water borne infectious diseases was collected from area hospitals as well as from study households.

Health Risk Assessment and Economic Valuation of Health Damage using Previously Established Dose-response Information

PM-10

Health End point	Estimated Impact on study population*	Unit costs** (in rupees)	Total costs (Lakhs of rupees)
Pre mature deaths	202	393,879	797
Respiratory hospital admissions	285	1713	4
ERV (Emergency room visits)	5598	228.3	12
RAD/1000(Restricted activity days)	1367	41	563
RSD/1000(Respiratory symptom days)	4352	20	870
COPD (Chronic obstructive pulmonary disease)	1455	69,997	1018
LRI (Lower respiratory infections) in children	16,078	346	55
Asthma attacks	54275	200	108

TOTAL: 3432 LAKHS

* Study population (covering an industrial municipality in North Chennai) - 211,000

** All costs are annual costs

Indoor Air Pollutants

Indoor air pollutants monitored included respirable particulates, carbon monoxide, SO2 and NO2. Biomass combustion made the greatest contribution for exposures to these pollutants in households (where in it was being used for cooking). The health risks from respirable particulates were taken into account while reconstructing PM 10 exposures for the population. Short term exposure guidelines for carbon monoxide were exceeded in 67percent of homes during cooking with bio-mass fuels while the guideline values for SO2 and NO2 were exceeded in about 15 percent of the homes. Although gas exposures exceeded prescribed standards, the consequent health risks could not be quantified due to the lack of definitive dose- response relationships for short-term exposure.

Blood Lead

Although lead levels in air and water were below the permissible standards, the blood lead levels were still higher than the action level set by the USEPA. The mean blood lead levels in children were 22ìg/dl while in adults it was 16 ìg/dl. Applying dose response information cited in the main report, the calculated health risks for the study zone population were as follows.

Blood lead

Mean Blood lead levels	Health End point	Estimated Impact on study population
Children- 22mg/dl	Loss of IQ points	2 points/ child
	Increase in infant deaths	4.5 deaths /year
Adults - 16 mg /dl	Increase in Blood pressure Men Women	 2.6 - 3.2 mm Hg 1.6 - 1.8 mm Hg
	Heart Attacks	114/year
	Strokes	14/year
	Premature deaths	110/year

The economic costs associated with these health end points have not been computed. Unlike PM10, studies on lead have come only from the developed country settings wherein the doses are nearly an order of magnitude less than what has been observed in this study. These risk calculations are therefore uncertain. Also, the cost of these health endpoints could not be ascertained in this study and as there are no national figures available, a cost estimation for these risks was not carried out.

Microbial contaminants in water and sanitation related issues were not examined using the dose- response framework. Instead their contribution to health impacts was assessed from the cross-sectional health and economic information gathered through the household survey and the health information available at the local health care facilities.

Health Impact Assessment and Economic Valuation from Cross-sectional Epidemiological Information gathered through the Household Survey

The prevalence of respiratory, gastrointestinal and vector borne illnesses was assessed in the study zone through the administration of a household level questionnaire that collected both health and economic information. Treatment costs, wage loss days and defensive expenditure attributable to specific health end points associated with air, water or sanitation related issues were assessed to evaluate the associated economic loss. Although, this method was media specific (i.e. air/ water/solid waste) and not pollutant specific , it allowed comparisons to be made between estimates that were obtained from applying previously established dose-response functions and those obtained through direct assessment methods.

The economic costs of respiratory illness as determined from the house - hold survey is in broad agreement with the economic costs for respiratory illness calculated using the dose-response information for PM 10 exposure. Also the preceding calculations show that while the health costs associated with air pollution are high, they are outweighed by water and sanitation related concerns in the municipality.

Health End point	Prevalence (Lakhs of Rs.)	Treatment Costs (Lakhs	Wage Loss (Lakhs of Rs.)	Defensive Expenditure costs for of Rs.)	Total annual study zone (Lakhs of Rs.)
Respiratory illness	12%	710	942		1652
Gastrointestinal disorders	16%	1167	1111	85	2363
Vector-borne illness	5%	1175	338	243	1757

Relative Ranking of Environmental Concerns on the Basis of Health and Economic Risks.

The health and economic risks obtained from the preceding steps were ranked relatively as follows after taking into account the uncertainties surrounding these estimates as well as people's perception (that was assessed as a part of the household survey).

High risks	Microbial contamination of water
	PM 10
	Sanitation and solid waste disposal
Medium risks	Lead
	Indoor air pollutants from biomass combustion
Low risks	NO2
	Volatile organics
Uncertain risks	CO
	SO2
	Chemical contaminants in drinking water
	Hazardous wastes

Conclusions

The study has been one of the first exercises within the city of Chennai, to use the quantitative health risk assessment framework to value environmental health damage. Exposure assessment is one of the most crucial components to conduct environmental health risk assessments and the present study through a combination of primary and secondary data collection has generated a large database of population exposure information for several key pollutants in the study zone. Although uncertainties still surround the application of the dose-response information as well the use of cross sectional epidemiological information, the study has clearly identified the need for initiating remedial action for environmental concerns listed in the high risk category. The scheme of relative ranking of risks allows one to prioritise between the concerns without the need to be concerned about the absolute value of these risks. The economic valuation of health damage assessed in this study can easily be used in subsequent cost-benefit analyses to choose between alternate methods for reducing population exposures.

Most importantly the study has been executed with significant stakeholder participation including members of the Tiruvottiyur Municipality, the Tamil Nadu State Pollution Control Board and Chennai Metropolitan

Development Authority. The involvement of these members will greatly facilitate the subsequent design and implementation of an environmental management plan for the region. Institutional capacity building exercises in the form of training in health risk assessment methodologies were carried out twice during the course of this study. This would serve to further strengthen the local network of professionals to refine these estimates for this zone as well as undertake similar exercises that would cover the entire Chennai Metropolitan Area.

Finally the study has identified areas, where the largest gaps in data accuracy are likely to be present. Recognition of these areas will contribute to refining the framework for conducting of subsequent longitudinal environmental health studies. This will in turn ensure that the actual health and economic costs are captured with the least degree of uncertainty for local policy interventions. In that sense, it is hoped that the study will serve as good proto- type for other studies in the region to recognise the importance of environmental health risks and initiate action plans aimed at protecting the health of the public.

A Study of Environmental Exposure to PAHs in Economically Underprivileged Population of Urban/Rural Areas of Uttar Pradesh

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Introduction

Polycyclic Aromatic Hydrocarbons (PAHs) are one of the most hazardous (carcinogenic) contaminants of the present ambient air environment. These are a well-known class of carcinogens emitted largely due to emissions from auto-exhaust or fuel biomass combustion. Ambient and indoor air pollution due to PAHs, both in rural and urban areas, is an environmental health hazard. The gasoline/ diesel exhaust emissions constitute the most important source of PAH pollution in urban India. Busy traffic channels are one of the worst polluted sites. Several subjects such as roadside vendors, traffic constables and controllers, cycle-rikshaw or trolley pullers and daily commuters in these areas are exposed to PAHs everyday.

Emission from fuel biomass is the source of PAH pollution in rural India. Biomass is a common type of traditional fuel, viz. fuel wood, crop waste and endurable animal dung, which is used frequently as an inexpensive source of energy for cooking food in rural parts of India. In winter months, it is also used to warm the houses. Emission from biomass burning is the single largest source of PAH pollution in rural ambient/indoor air. The women folk get relatively more exposed to PAHs, especially while cooking food for extended periods of time particularly due to low energy value of the biomass fuel.

No available study has reported on the site-specific environmental load of pollutants and the exposure assessment of population dwelling specifically in PAH polluted urban traffic channels, rural huts and the vicinal areas in India. There is a complete paucity of information on the exposure and health risk assessment of Indian urban/rural subjects exposed to PAHs in India.

Herein, we report (a) total PAH content and its profile in ambient/indoor air of urban/rural areas in Lucknow district, (b) PAHs exposure assessment in subjects living/working near PAH polluted sites, and (c) prevalent morbidities in PAH exposed destitute subjects. There is a lack of human data on these aspects.

Objectives

The objectives of the present study are to:

- Determine PAH concentrations in urban ambient/rural indoor air environment.
- Assess the potential risk of adverse health effects in the PAH exposed subjects.
- Evaluate the health damages caused by exposure to PAHs in economic terms.

Methodology

Ambient Air Monitoring

The rural parts of Lucknow were monitored for the ambient/indoor air of High Traffic Density (HTD) and Low Traffic Density (LTD) sites of urban and biomass/fossil fuel.. The sampling was done both in summer (March through June) and in winter (November through February). The ambient air was sampled using respirable dust sampler. Sampling was done at three different locations and in two seasons. Two HTD sites (site 1 Charbagh and site 2 Hussainganj) with idling/slow moving traffic and one LTD site (Janakipuram) with relatively fast moving traffic were monitored (Annexure I). The HTD sites were among the busiest traffic channels of the city. The LTD site was scarcely busy. The parameters monitored were SPM, RSPM, SO_2, NO_x and PAHs. The study was done for a total of 384 adult subjects dwelling specifically in PAH polluted traffic channels in urban areas or the PAH polluted huts in rural areas. The study was limited to the 100-km radius of Lucknow.

Indoor Air Monitoring

The indoor air was sampled at locations in Village-Mall (Tehsil-Malihabad, District-Lucknow), approximately 40 km north west of Lucknow City (Annexure II). Rural huts with single room accommodation and of similar volume were selected. The types of fuel used in this area were wood, Cow Dung Cake (CDC) and Liquefied Petroleum Gas (LPG). Kerosene and electric heaters were not prevalent in these areas. Agricultural waste was also not found in use during the survey. The cooking areas and the smoke-less non-cooking areas were monitored. The sampling was done at the time of cooking approximately for one hour using both Personal/Area Samplers. RSPM, SO_2, NO_x and PAHs were monitored in indoor air. For active or passive exposure, only RSPM and PAHs were monitored.

Health Effects and Exposure Estimates

Representation of economically underprivileged users of biomass fuel (especially in rural areas) and other demographic variables that may have a bearing on PAH exposure like smoking, etc. were ensured. Informed consent was taken from each study subject before their inclusion in the study. The study subjects were interviewed for details about personal, occupational and clinical history, which were noted on a pre-tested schedule. A complete clinical examination (viz. general health physical examination, respiratory, cardiovascular, gastro-intestinal, musculo-skeletal and central nervous system) of each subject was done and recorded by a medical doctor.

Exposure Assessment

Urine samples were collected from each studied subject after the verbal consent. Following enzymatic digestion, clean up and the enrichment of sample, 1-pyrenol was isolated and quantified over HPLC with fluorescence detectors. The results were corrected for the percent recovery and expressed as mmol1-OH-pyrene/mol urinary creatinine, which is an index biomarker for PAH exposure.

Economic Valuation

The purpose was to make a rough estimate of the total magnitude of economic cost associated with health damage due to PAH exposure in Lucknow. These costs measured the economics of health impacts. In valuing the costs of morbidity, three types of costs were considered: (a) medical expenses; (b) lost wages, and (c) individual disutility (discomfort, suffering, and the opportunity cost of time). The questions pertaining to sickness during the last one month and one year for each subject were recorded. The total expenditure incurred on medical treatment was recorded. Loss of earnings in Rupees due to absence from work (days with symptoms) and due to poor quality / less work (restricted study with days) due to illness were also recorded. A rough estimate of the total magnitude of economic costs associated with PAH exposure was calculated. These costs were calculated only in terms of health damage. The calculation is as follows:

Total cost = (Incidence of deaths x value of life) + Incidence of sickness due to PAH exposure x (cost of treatment + cost wages)

Considering that sources of PAH exposure include transport, industry, energy, smoking, exposure to bio-mass fuel burning and food, etc., no attempt was made to differentiate the health impacts by the sources of PAH exposure. The cost due to death in the family was excluded as the design of the study was cross-sectional, and hence death could not be attributed to PAH exposure. The overall limitations of this “back-of-the envelope” approach to value environmental costs were very clear. The methodologies, data and estimates of ‘average’ costs and values are all subject to extensive refinement.

Data Processing and Statistical Analysis

The data generated was compiled and transferred to the personal computer through the use of Lotus, MS Excel and EPI INFO. Analysis was done using software EPI INFO and Systat

9.0. The significance of the mean value of different parameters in different exposure groups were analysed using analysis of variance techniques after ascertaining the assumptions of normality and homogeneity of variance. Significance of prevalence of different signs and symptoms in different exposed and control groups were analysed using Chi square or Fisher exact test depending upon the expected cell frequencies. Odds ratio for exposed (Urinary pyrene excretion µmol/mol >0.5) in comparison to non- exposed (Urinary pyrene excretion µmol/mol =0.5) for different explanatory variables were calculated and the significance tested using Mental Hanzel's procedure.

Results

Ambient Air Pollution

SPM and RSPM levels at all the monitored locations in summer were close to or within the permissible limit of the residential area (Table 1). The results were compared with National Ambient Air Quality Standard (NAAQS) values. The SPM and RSPM levels at all the monitored locations in winter exceeded the permissible limit for residential area.

SO_2 and NO_x levels at all the monitored locations in both summer and winter were within the permissible limit for residential area. Results were compared with NAAQS values.

PAHs

In Summer

The analysis of PAHs profile revealed the presence of all the examined types (both auto-exhaust/biomass emission specific PAHs) in the sampled air (Figure 1). The mean values of SPAHs (20.97 & 24.76 ng/m3) at HTD sites and at LTD site (9.44 ng/m3) were much greater (Table 1) than the guide value of 1ng/m^3 set for PAH by the World Health Organisation (WHO). PAHs are not included in the Indian National Ambient Air Quality Standard (NAAQS). The mean values of SPAHs were more at HTD sites than the LTD site by a factor of 2X. The range of SPAHs (92.67, 48.06) at HTD sites was more than the same (29.65) at the LTD site. Benzo(ghi)perylene, chrysene and acenaphthylene registered maximum at the monitored sites, whereas anthracene registered the minimum (Figure 1). Each type in the PAH profile at HTD locations registered an excess over its LTD site value and the increase was 1-2X. The two HTD sites when compared together, showed a dissimilar pattern in their PAH profile. Acenaphthylene, acenapthene, anthracene, fluoranthene and chrysene were higher at Site 2 whereas benzo(ghi)perylene was highest at Site 1. Levels of benzo(a)pyrene at HTD Site 2 were <1ng/m3 and were surprisingly similar to that of the LTD site. The unusually low levels of benzo(a)pyrene at the HTD site in summer may be related to meteorological and topographical conditions at the monitored sites. A percent composition study of the PAH profile at the investigated sites revealed that benzo(ghi)perylene alone constituted 50 percent of all the investigated PAHs at HTD Site 1. At other monitored sites the percent composition was similar and evenly distributed.

In Winter

The analysis of PAH profile revealed the presence of all the examined varieties (both auto-exhaust/biomass emission specific PAHs) in the sampled air (Figure 1). The mean values of SPAHs (106.08 and 100.33 ng/m^3) at HTD sites and at the LTD site (26.64 ng/m^3) were much greater than the guide value of 1ng/m3 set for PAH by WHO (Table 1). PAHs are not included in the Indian National Ambient Air Quality Standard (NAAQS). In winter, very few types of PAHs registered <1ng/m^3 levels at the LTD site (Figure 1). The mean values of SPAHs at HTD sites increased by a factor of 4X over the LTD site mean value. The range observed at the HTD site (78.87, 220.81), was more than the same (80.20) observed at the LTD site (Table 1). Mean PAHs concentrations at the same monitoring locations hiked by a factor of 2-4X in winter. Benzo(ghi)perylene, benzo(a)pyrene and chrysene registered a maximum level at the monitored locations whereas anthracene registered a minimum, as it did in summer (Figure 1). Each type in the PAH profile at HTD locations registered an excess over its LTD value and the hike was 2-10X. Unlike summer, the two HTD sites showed a similar pattern in PAHs profile. Levels of acenaphthylene, anthracene, chrysene, phenanthrene, benzo (a) pyrene and benzo(ghi)perylene were higher but similar at both the sites. Levels of benzo(ghi)perylene were surprisingly similar at all the locations. The unusually high ambient air levels of PAHs in winter may be related to meteorological and topographical conditions viz. low wind speeds and relatively shorter cold-air columns of SPM/RSPM at the monitored sites. Chrysene, benzo(a)pyrene and benzo(ghi)perylene together constituted 60-70 percent of the sum PAHs levels. Chrysene alone constituted 20-40 percent among the examined ones. A moderate but statistically insignificant ($p<0.05$) correlation between RSPM and benzo(a)pyrene level was noticed in winter.

Rural Indoor Air Pollution

RSPM during Passive Exposure

RSPM levels at all the monitored locations, save the LPG site, exceeded the permissible limit for rural areas both in summer and winter season. The results were compared with NAAQS values. The mean concentration in summer was found to be 6.35 mg/m^3, 9.53 mg/m^3, below detection limit (BDL) and 0.44 mg/m^3 at the cooking sites using wood, CDC, LPG, and at non-cooking site respectively (Table 2). Similar mean concentrations were found for the monitored sites in winter. RSPM levels at the fuel biomass using-site were 5-10X greater than the LPG or non-cooking site in both the seasons.

RSPM during Active Exposure

RSPM levels at all the monitored locations, including the LPG site, far exceeded the permissible limit for rural areas both in summer and winter season. The results were compared with NAAQS values. The mean concentration in summer was found to be 12.86 mg/m^3, 13.85 mg/m^3, 0.95 mg/m^3 and 1.01 mg/m^3 at the cooking sites using wood, CDC, LPG and at non-cooking site respectively (Table 2). Similarly mean concentrations were found for the monitored sites in winter. RSPM levels at the fuel biomass using-site were 10X greater than the LPG or non-cooking site in both the seasons. The results were compared with NAAQS values.

Sulphur Dioxide (SO_2) during Passive Exposure

Mean SO_2 levels monitored at all the locations were more than the permissible limit for rural areas in both summer and winter. Results were compared with NAAQS values. The mean concentrations in summer were 39.58 µg/m^3, 49.07 µg/m^3, 7.97 µg/m^3 and 7.11 µg/m^3 at the cooking sites using fuel wood, CDC, LPG and at the non-cooking site respectively (Table 2). Similar mean concentrations were found for the monitored sites in winter. SO_2 levels were 5X higher at fuel biomass using sites.

Oxides of Nitrogen (NO_x) during Passive Exposure

Mean NO_x levels monitored at all the locations were more than the permissible limit for rural areas in both summer and winter. Results were compared with NAAQS values. The mean concentrations in summer were 51.08 µg/m^3, 61.28 µg/m^3, 11.47 µg/m^3 and 10.47 µg/m^3 at the cooking sites using fuel wood, CDC, LPG and at the non-cooking site respectively (Table 2). Similar mean concentrations were found for the monitored sites in winter. NO_x levels were 5X higher at fuel biomass using sites.

PAHs during Passive Exposure

All the examined varieties of PAHs were present in the indoor air sampled during passive exposure to biomass/fossil fuel combustion in summer. The mean values of SPAHs (19.98mg/m^3, 27.83mg/m^3) at the cooking sites using fuel wood, CDC were more than the LPG using sites (7.42mg/m^3) and the non-cooking sites (6.18 mg/m^3) values in summer (Table 2). Similarly, mean values of SPAHs in winter were more at the cooking sites using fuel wood, CDC than the LPG using sites and the non-cooking sites ,and were greater by a factor of 2X than summer. The range (44.49, 54.01, 12.73) of SPAHs values at biomass/fossil fuel using-sites in summer was more than the same (3.71) at the non-cooking site. Similarly, the range (99.79, 39.04, 27.94) in winter was also more than the same (20.58) at the non-cooking site in winter, but it was greater than in summer. These values were far more than the guide value of 1ng/m^3 set by the WHO for ambient air PAH. Compared to occupational exposure standard of 0.2mg/m3 (TLV) recommended by NIOSH, the obtained mean values were quite low. Mean SPAHs values at the non-cooking site and at the site using LPG fuel type appeared similar in both the seasons. Levels of all the examined PAHs at these sites ranged between 0.06 to ~5 mg/m^3 in summer and between 0.12 to ~16 mg/m^3 in winter. In both the seasons, acenaphthylene registered a maximum level at the monitored sites, whereas anthracene registered minimum (Figure 2). At the biomass using sites in summer, acenaphthylene, acenapthene and fluoranthene were major components and constituted >75 percent of all the investigated PAHs. Acenaphthylene and acenapthene, the volatile PAHs, alone constituted a total of 60 percent at the site using biomass fuel. In winter, acenaphthylene, acenapthene, fluoranthene, pyrene and chrysene were the major components and constituted >90 percent of all the investigated PAHs. Acenaphthylene and fluoranthene were the major components at sites using fuel LPG. At non-cooking sites, only acenaphthylene was the major component.

PAHs During Active Exposure

All the examined varieties of PAHs were present in the indoor air sampled during active exposure to biomass/fossil fuel combustion in summer and winter. The mean values of SPAHs (40.83 mg/m^3, 77.01 mg/m^3) at the cooking sites using fuel wood, CDC were more than the LPG using site and the non-cooking site value (11.10 mg/m^3, 11.36 mg/m^3) in summer (Table 3). Similarly mean values of SPAHs in winter were more at the cooking sites using fuel wood, CDC, than the LPG using or the non-cooking site and were than summer. Range (167.71, 206.44) of SPAHs at biomass/fossil fuel using-site in summer was more than the same (13.72, 14.45) at the LPG using or non-cooking site. Similarly, the range (150.27, 109.94) in winter was also more than the same (21.02, 32.09) at the LPG using or non-cooking site in winter but it was greater than in summer. These values were far more than the guide value of 1ng/m^3 set by W.H.O. for ambient air PAH. But considering cooking as an occupation and comparing it with occupational exposure standard of 0.2mg/m3 (TLV) recommended by NIOSH, the obtained mean values were quite low. Mean SPAHs values at non-cooking site and at the site using LPG fuel type appeared similar in both the seasons (Table 3). Levels of all the examined PAHs at these sites ranged in between 0.01 to 17.5 mg/m^3 in summer and between 0.25 to ~19 mg/m^3 in winter. At sites using bio-fuels, mean levels registered a hike over sites using LPG or non-cooking sites by a factor of 2-20X. In both seasons, acenaphthylene and acenapthene registered a maximum level at the monitored sites, whereas anthracene registered minimum (Figure 3). At the biomass using sites, acenaphthylene, acenapthene fluoranthene and pyrene were the major components and constituted >75 percent of all the investigated PAHs. In winter, chrysene showed more in the list of the major components, and together constituted >90 percent of all components. In both the seasons, acenaphthylene and acenapthene, the volatile PAHs, alone constituted a total of 50 percent at the site using biomass fuel. The percentage profile changed at non-cooking sites or at sites using LPG. In summer, only acenaphthylene and phenanthrene were the major components whereas the acenaphthylene, acenapthene and fluoranthene were the major components in winter.

Adverse Health Effects and Exposure Estimates in PAH Exposed Subjects

The general profile and 1-hydroxypyrene excretion pattern of the study population was recorded. Urinary hydroxy pyrene (UHP) is known to be a good exposure marker for PAH exposure. In our study we selected = 0.5umol/mol creatinine as the cut-off upper limit for computations. A higher percentage (82.8%) of population excreting more than normal levels of UHP was observed largely in congested areas. Mean pyrene levels in different PAH exposed population groups were not statistically significant. Factors affecting UHP excretion were found to be gender, vehicular emission exposure, non-vegetarian diet and smoking. Females excreted 1-hydroxypyrebne more than males in both rural and urban non-congested areas. In congested areas, males excreted more compared to females. The proportion of subjects excreting more than normal levels of UHP (> 0.5 µmol/mol) was significantly higher in the group exposed to vehicular emission (OR = 2.32, $p < 0.001$) compared to the proportion of subjects in the group less exposed to vehicular emission in low traffic density areas. Similarly, the proportion of rural subjects excreting more than the cut-off limit of UHP was higher in the group exposed to biomass emissions compared to the group not exposed to biomass emissions.

PAHs carcinogenic potential is often reported but the short-term clinical effects are hardly known. In our study, we detected a group of symptoms related to eye, ear, cardiovascular and respiratory systems that were significantly more in groups excreting greater than normal levels. Subjects with this symptoms-cluster who were excreting more than normal levels of UHP were observed to be 29.4 percent compared to 17.3 percent, who had the symptoms-cluster but excreted normal levels of UHP. Differences were statistically significant. As such this cluster of symptoms are effects of exposure to different air pollutants. But in subjects with high UHP excretion, exposure to PAHs could be an attributing factor for a proportion of these clinical symptoms-clusters. No statistical association could be observed in subjects with specific morbidity or specific affected organ system and high UHP excretion. No links of mortality with UHP could be detected. Average Year Life Loss (00) for deaths in the family of the groups excreting less than or above the cut-off limit were scored and found to be 15.9 years (below cut-off limit) and 21.3 years (above the cut-off limit), considering 63 years life expectancy at 0 age. Subjects excreting more UHP experienced more days of sickness and lost more money in the form of lost earnings. More than 20 percent of subjects both in low and high UHP excreting groups spent money on treatment. Total money spent on treatment and that spent on consultation and drugs was more in subjects with more excretion of UHP. This is also true for lost earnings due to sickness and poor quality work/less time devoted to work. *A population of 16.4 lakh (1.64 million) persons is estimated to excrete higher than the cut-off levels of UHP in Lucknow, and is thus exposed to PAHs. A sizeable population of 3.84 lakh (0.38 million) of these suffers form a symptoms-cluster that is attributable to PAHs.* The cost of PAH exposure related symptoms-cluster is estimated to range between Rs.20.0-163.3 crores for Lucknow with an average estimated cost to be Rs.91.9 crore.

Conclusion

PAH concentrations in ambient/indoor air in Lucknow are far greater than WHO prescribed limits. The source is petrol/diesel exhaust and biomass combustion. A substantially higher percentage of population is exposed to PAHs and faces the risk of short-term clinical symptoms related to cardiovascular, respiratory, ear and eye systems that are attributable to PAH exposure. The estimated cost of health damage in the PAH exposed population (1.64 million) on an average is Rs.90 crore (Rs.900 million) per annum for Lucknow.

Policy Recommendations

- Studies on a larger scale (e.g. National Coordinated Program) are needed in India to characterise more PAH polluted areas and PAH exposed subjects, especially for the health risk assessment plus health-damage cost evaluations vis-à-vis PAH pollution. It will establish a large database, not only to link the PAHs emissions exposure with prevalence of cardiovascular and respiratory system specific ailments, but also to compute a dose response relationship.
- A site investigation plan should be developed in the country that addresses the issues of potential sources, local hot spots or the geographical spreads of PAHs contamination and its affiliation with the prevalence rate of PAH exposure related health hazards.
- The PAH exposure assessment of urban/rural Indian subjects (by monitoring urinary exposure marker level as done in our project for the first time in the country) should be a priority, as it would help define areas where exposure point concentrations exceeded the levels of health concern.
- The site investigation plan should include environmental monitoring, exposure assessment, residential history information and health survey. The work-plan should be validated in various areas of the country to distinguish between the least and the most polluted areas, and for comparison of the environment and health in India. This will help to study the size and geographical spread of the population at risk.
- There is a paucity of data on the prevalent types of morbidities or cancer risk in PAH exposed Indian subjects, which needs to be met.
- The National Ambient Air Quality Standard for PAHs should also be prescribed with immediate effect.

- Widespread publicity on environmental levels of toxic air pollutants and the associated health risk for increased public awareness and political sensitivity to curb the PAHs levels, exposures and related health effects is recommended through various means, including web notice boards.

To contain the PAH pollution in ambient/ indoor air in urban/rural areas in India, the following aspects should be prioritised:

Technology

- Low PAH emitting vehicles.
- Change in fuel policy to limit the environmental levels of PAHs.
- Phasing out of the combustion engines with outdated designs.
- Discouraging gasoline/diesel-powered transport by suitable alternatives of mass transport.
- Biomass substitution with safer fuels e.g. LPG.
- Ventilated housing and work environment.
- Raise the current speed limits on well-protected highways.
- Increase the number of high-speed roads and the high-speed fly-overs in PAH polluted cities.

Environment

- Geographical spread and intensification of Green Belts.
- Regular monitoring of the ambient/indoor air PAH levels to contain it within the limit or the targetted value.

Medical

- Exposure assessment of PAH exposed subjects to study the pattern and change in the prevalent rate of associated morbidities by environmental or technological interventions.
- Lung cancer (target tissue) risk assessment particularly in view of extraordinarily high levels of benzo(a)pyrene & RSPM content of ambient air environment.
- Study mortality rate association with ambient air PAHs/RSPM content.
- Study PAHs burden in body tissues.

The main objective however, is to bring down PAHs environmental levels, exposure levels and the frequency of related adverse health effects to normal values.

Table 1: Ambient Air Pollutant Level at Low Traffic Density & High Traffic Density Sites in Urban Lucknow in 2001- 02

Pollutant	Permissible Limit in India	SUMMER			WINTER		
		LTD Site	HTD Site 1	HTD Site 2	LTD Site	HTD Site 1	HTD Site 2
SPM[a]	200	137.54	159.6	153.35	222.61	361.86	332.82
RSPM[a]	100	72.98	100.37	96.37	165.22	288.67	264.32
SO_x [a]	80	15.21	16.12	16.71	15.10	17.33	18.46
NO_x [a]	80	17.34	23.63	21.54	20.61	23.36	24.45
?PAHs[b]	*Not specified*	9.44	20.97	24.76	26.64	106.08	100.33
Range		29.65	92.67	48.6	80.2	78.87	220.81

a: μg/m^3 b: ng/m^3

Table 2: Indoor Air Pollutant Level during Passive Exposure in Rural Lucknow

Pollutant	Permissible Limit in India	SUMMER				WINTER			
		At cooking site			At non-cooking site	At cooking site			At non-cooking site
		Wood	Cowdung	LPG		Wood	Cowdung	LPG	
RSPM[a]	0.1	6.35	9.53	BDL	0.44	9.71	9.91	0.86	0.89
SO_x [b]	*Not specified*	39.58	49.07	7.97	7.11	64.98	69.18	8.84	9.53
NO_x [b]	*Not specified*	51.08	61.28	11.47	10.47	88.80	91.44	12.04	11.85
?PAHs[b]	*Not specified*	19.98	27.83	7.42	6.18	37.5	42.3	20.2	19.06
Range		44.49	54.01	12.73	3.71	99.79	39.04	27.94	20.58

a: mg/m^3 b: $\mu g/m^3$

Table 3: Indoor Air Pollutant Level during Active Exposure in Rural Lucknow

Pollutant	Permissible Limit in India	SUMMER				WINTER			
		At cooking site			At non-cooking site	At cooking site			At non-cooking site
		Wood	Cowdung	LPG		Wood	Cowdung	LPG	
RSPM[a]	0.1	12.86	13.85	0.95	1.01	15.79	15.18	1.02	0.81
?PAHs[b]	*Not specified*	40.83	77.01	11.10	11.36	69.23	90.50	26.78	23.73
Range		167.71	206.44	13.72	14.45	150.27	109.94	21.02	32.09

a: mg/m^3 b: ug/m^3

Figure-1: PAHs Profile in Ambient Air of Urban Lucknow during 2001/02

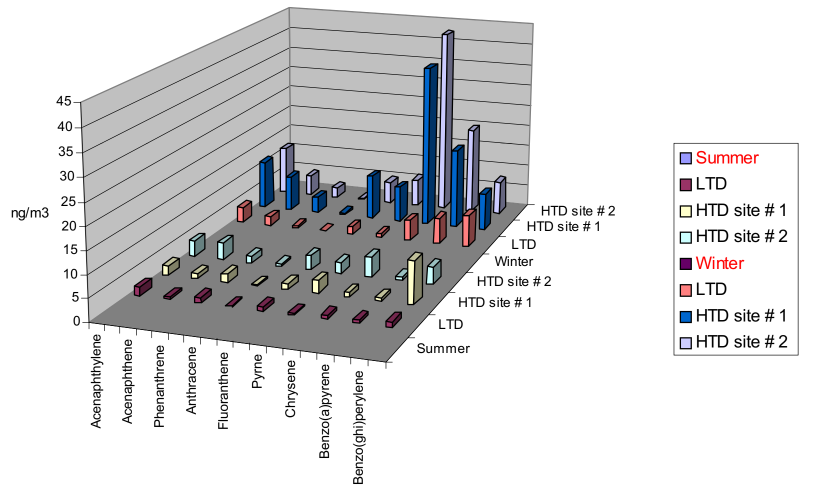


Figure-2: Indoor PAHs Profile during Active Exposure at Rural Lucknow

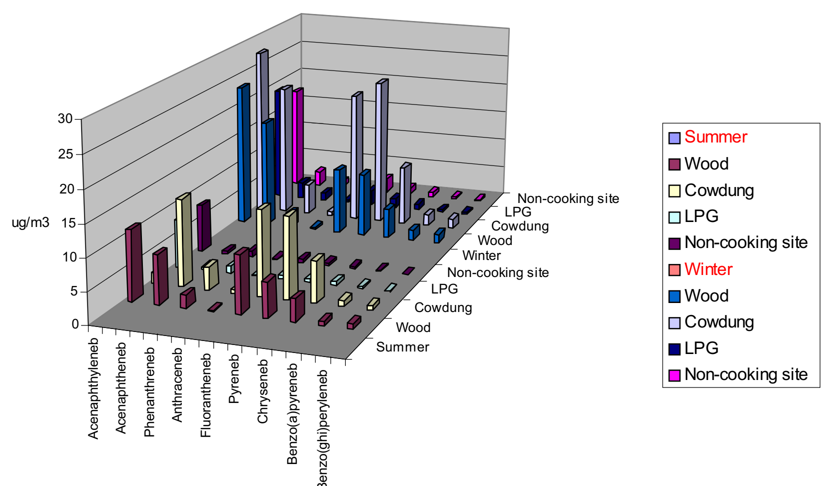
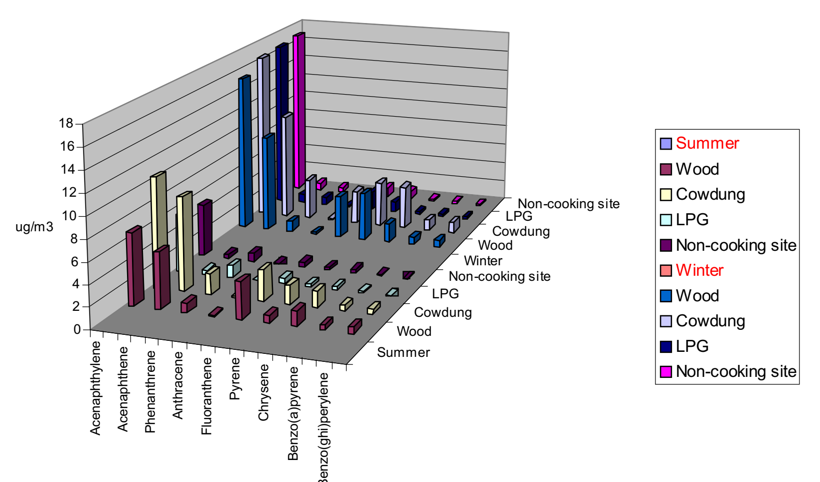


Figure-3: Indoor PAHs Profile during Passive Exposure at Rural Lucknow



Estimating the Environmental Cost of Industrialisation in Gujarat: A Case Study of Ankleshwar GIDC

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Introduction

Industrialisation is considered to be one of the factors leading to growth. The Government of Gujarat (GOG) has repeatedly offered many concessions to attract capital. Gujarat tried to encourage industrialisation by offering infrastructural facilities for small and medium scale industrial units by establishing the Gujarat Industrial Development Corporation (GIDC) in 1962. Thus, Ankleshwar Industrial Estate (AIE) was established by the GIDC with a view to develop a backward tribal belt of Gujarat and place it on the industrial map of the country. As a result of the efforts of the GOG, Gujarat did emerge as one of the most industrialised states in India.

Presently, the AIE ranks second among all the 122 fully developed estates in terms of employment, investment and production. AIE has been the subject of study by quite a few researchers, but these have not addressed the environmental economic issues of industrialisation.

Objective

The objectives of this project are to:

- Estimate the environmental cost of industrialisation taking Ankleshwar GIDC as a case study, and focus on a relatively neglected area of study viz; cost in terms of loss of property value.

It is expected that property in a cleaner environment would fetch a higher price than a similar property in a polluted environment. This price differential can be taken as willingness to pay for clean air. One can directly estimate people's willingness to pay by using contingent valuation. In our study both methods have been used, viz. direct as well as indirect, to calculate this element of environmental cost. In a poor economy like India, it is expected that the real estate market is not very developed. Further, in a situation of severe unemployment and underemployment people may not put a high value on clean environment. This should not lead us to a situation where we do not even attempt to estimate environmental costs.

Study Area

This study concentrates on Ankleshwar GIDC, which falls in the Golden Corridor of Gujarat state. AIE is strategically important for the industrial scene of Gujarat. It is strategic because of the following locational advantages:

- Its proximity to urban industrial conglomerates of Bharuch, Valsad, Vadodara and Ahmedabad.
- Availability of subsidies under the special backward area upliftment programme promoted by the state.
- Availability of oil and natural gas in and around Ankleshwar.
- Existence of a convenient outlet for effluent disposal due to its proximity to the sea as well as to the Narmada River. The AIE has two creeks - Amlakhadi and Sarangpur Khadi - that carry treated wastewaters to the Narmada River.

The Ankleshwar Industrial Estate houses mainly dye factories, chemical and allied industries, paper and pulp producers, pesticides, textiles, pharmaceuticals, paint manufactures and engineering companies. To get a comparative picture of real estate price behaviour between two different areas - one polluted and another non- / less polluted - we selected Ankleshwar town along with Ankleshwar GIDC. Ankleshwar town is close to Ankleshwar GIDC and is supposed to be non-polluted or less polluted. People residing in Ankleshwar town commute to Ankleshwar GIDC for work.

Methodology

The Behaviour Linkage Method, which is a combination of revealed preference methods, particularly the hedonic pricing method and the stated preference method of contingent valuation for estimating the environmental cost as expressed in property / real estate value, has been used in this study.

An attempt is made to measure environmental externality through the housing value method. Hedonic Property Value [HPV] method tries to capture the value of clean environment by comparing the value of similar properties near a polluted site and a cleaner site. We have to bear in mind the fact that property values also depend, besides pollution levels, on income, size of the house, size of the family, quality of construction / fixtures, etc. To use this method, we need data on property values, pollution levels by different sites, income, family size, etc. This data is not readily available. In fact, there are only two monitoring centres in Ankleshwar GIDC, for which we get data on air pollution. We have therefore, considered the perceptions of the people regarding the value of their property and the pollution existing in their area. We have also gathered information on maintenance cost of property. The cost is to be estimated in terms of fall / not increasing the value of a given property as well as in terms of frequency of painting the house, changing of pipes, etc. The relationship between housing values and air pollution, in other HPV studies, did not turn out to be large. Thus, this relationship is observed to be small but significant in other studies. The HPV method is expected to give us the direction, rather than the magnitude of air quality's influence on residential property values.

In this study we have used the following techniques:

- Revealed preference method by estimating the Willingness To Pay (WTP) and Willingness To Accept (WTA), elasticities of WTP with respect to income for property owners and for tenants by zones (i.e. North or South) of GIDC.

- Hedonic Price Functions are estimated using Ordinary Least Squares (OLS) method. Four dependent variables –. Purchase Price, log of Purchase Price, Rent, and log of Rent – are used one after the other. Independent variables finally selected include annual income, distance from residence to school, number of children, number of rooms, Dummy for maintenance on account of discolouration, and concentration of SO_2.

- A new dependent variable is created named Relative value, which is defined as a Ratio of Purchase Price per average square feet of built-up area. Using OLS, its relation with SO_2 and age of the building is observed.

- 'Residualisation' has been done to take care of multi-collinearity between income and number of rooms. Hedonic Price Functions have been estimated using the residualised variable as well.

- Using a different Hedonic Price Function, we have estimated Marginal Rent / Marginal Purchase Price. In these functions five independent variables, - number of rooms, distance from residence to workplace, people's perception about pollution in their area, concentration of SPM/SO_2, and dummy for zone (i.e. North or South of GIDC) - are used. These estimated marginal rent / purchase price variables are then used to estimate the Marginal Willingness To Pay using OLS.

Total number of respondents in our sample is given below for Ankleshwar GIDC, Ankleshwar Town and Real Estate Agents.

Area	No. of Respondents	
Ankleshwar GIDC	1253	includes Residential + Commercial + Residential cum Commercial property owners / tenants.
Ankleshwar Town	667	households
Real Estate Agents	30	

Results

As noted earlier, Contingent Valuation Method (CVM) and Hedonic Pricing Method (HPM) were used in this study. Since data on property prices, and on other important variables was not available, we used the survey method to collect primary data. A sample of 1,253 people were surveyed in Ankleshwar GIDC. The findings of this study are discussed below:

- Ankleshwar GIDC is divided clearly into two zones, viz. North and South, characterised by different socio-economic backgrounds of the respondents. Respondents residing in the north of GIDC had, on an average, much lower annual income (lower than Rs.58,000/-) as compared to residents of the south of GIDC (slightly more than Rs.1,00,000/-). Further, on an average, residents of the north of GIDC had a marginally larger size of family with more children. There was a considerable concentration of single room houses in the north. The residents of the north complained about severe problems of air pollution at night, particularly after midnight when the industrial units released gases illegally. This finding indicated that relatively poor people resided in areas that were more polluted.

- Residential / Commercial properties located in the north zone of GIDC suffered from higher incidence of decolourisation, greater corrosion of iron fittings like grills on the windows, and greater chipping of the paint. All these show that these were the outcomes of higher levels of pollution.

- About 64 percent of the respondents were forced to keep their doors/windows closed on account of air pollution. 66 percent of the respondents expressed that their property prices have fallen in recent years,, but the reason for this was industrial recession, not air pollution. Presently, a situation exists where air quality has improved (on account of closing down of some industrial units) and properly prices have fallen. This should not lead us to believe that air pollution has no influence on property prices and this component of environmental cost should be treated as zero.

- An overwhelming majority (81%) of respondents were not ready to accept any monetary compensation for a 50 percent increase in levels of air pollution. As against this, a relatively smaller proportion (48%) of the respondents registered zero (nil) willingness to pay. These zero responses are mainly ‘protest zeros.’

- From amongst the three socio-economic variables, viz. annual income; size of the family, and, number of children, used here, it was annual income that turned out to be significantly and positively correlated with each one of the four dependent variable, viz. purchase price, log of purchase price, rent and log of rent.

- Purchase price and log of purchase price were significantly correlated with all the six independent variables labelled as Structural Variables. From amongst these six independent variables, five, viz. built-up area, number of rooms, number of bathrooms, number of toilets and expected price of the property, were positively and significantly correlated with purchase price and its logarithm.

- From amongst the seven accessibility variables, it was the travel expenditure incurred by the respondents to reach the workplace that was positively and significantly correlated with purchase price and its logarithm. The same independent variable had a negative and significant relation with log of rent. The other two, viz. distance from residence to garden and distance from residence to theatre, had negative and significant correlation with purchase price and log of purchase price. These two independent variables were not significantly correlated with rent and its log.

- Data on air pollution was not available for different areas of GIDC as there are only two monitoring centres in GIDC. The respondents were asked to state whether they perceived air pollution in their area to be unbearable, bearable or moderate. We observed a negative regression coefficient between pollution being perceived as unbearable and the purchase price of the property / log of purchase price / rent / log of rent. These coefficients turned out to be statistically not significant. The perception of people that pollution is moderate was significantly and positively correlated with purchase price, log of purchase price and log of rent. This means that people did not mind paying a higher price / rent for areas that they thought were moderately polluted. It was the concentration of nitrogen oxide that was negatively and significantly correlated with rent. The same variable had a negative but a weak correlation with other three dependent variables.

- A strong positive correlation existed between income and distance from workplace, implying that people who can afford to stay in a cleaner environment did not mind commuting a longer distance to work and incurring higher transport cost.

- To estimate Hedonic Price Function, we used four dependent variables, viz. Purchase Price, log of Purchase Price, Rent, and log of Rent. Five independent variables, viz. annual income, no. of children, no. of rooms, distance from residence to school and dummy for maintenance cost on account of discolouration and corrosion, explained together about 31 percent, 42 percent, 34 percent, and 22 percent of variations in purchase price, Ln purchase price, rent and Ln rent, respectively. From amongst the five independent variables, only two - annual income and number of rooms - turned out to be significantly and positively associated with all the four dependent variables. Distance from residence to school was significantly and negatively associated with rent and Ln rent. The dummy for maintenance had negative and significant association with log rent. The results for respondents residing in the south of GIDC were similar.

- Incorporating variables on air pollution, i.e. SO_2 and SO_2^2, did not change our results significantly in terms of explanatory power of the equations. The explanatory powers of regression incorporating these two variables, along with other variables were lower than what they were without the pollution variables. But, with the introduction of SO_2 and $(SO_2)^2$ as additional variables, annual income and number of children lost their significance in explaining variations in purchase price. Annual income continued to be significant for explaining variations in Ln purchase price, rent and Ln rent. Number of rooms continued to be a significant variable in explaining variations in all the four dependent variables.

Given below is a table showing correlation between different variables.

Table 1: Correlation Matrix of GIDC Ankleshwar for Purchase Price, Ln Purchase Price, Rent, Ln Rent with Socio-Eco, Structural, Accessibility and Environmental Variables

	Purchase Price	Ln Purchase Price	Rent	Ln Rent
(I) Socio-Eco. Variables				
Annual Income	.139**	.201**	.178**	.125*
Size of Family	-.006	-.103*	.145**	.100*
No. of Children	-.118*	-.204**	-.070	-.048
(II) Structural Variables				
Built-up area sq.ft.	.329**	.433**	.152**	.140**
No. of Rooms	.564**	.573**	.469**	.360**
Age of House	-.224	-.327**	-.082	-.102
Bathroom	.541**	.460**	.419**	.272**
Toilets	.520**	.420**	.366**	.238**
Expected Price of house	.710**	.547**	.362**	.174**
Maintenance cost	.202**	.178**	.167**	.068
(III) Accessibility Variables				
Dist. from residence to work place	-.006	.022	.036	.064
Travel Expenditure	.125**	.154**	.010	-.160**
Time taken to reach work place	-.007	-.015	.019	.095*
Dist. from residence to School	-.061	-.088*	-.014	-.068
Dist. from residence to Market	-.041	-.077	-.044	-.049
Dist. from residence to Garden	-.142**	-.211**	.040	-.019
Dist. from residence to Theatre	-.142**	-.220**	.019	-.035
(IV) Environmental Variables				
Dup1=1 if perception of pollution is unbearable	-.065	-.076	-.051	-.029
Dup2=1 if perception of pollution is moderate	.115**	.098*	.057	.119*
Due2=1 if forced to keep doors/windows closed	-.018	-.004	.013	.070
Due3=1 if maintenance is for discolouration & corrossion	-.031	.003	-.104	-.155**
Due4=1 if rank of air pollution is ranked one	.022	.043	.028	-.018
SO_2	-.082	-.101	-.091	-.086
No_x	-.027	-.008	-.118*	-.097
SPM	.002	.041	-.078	-.059

Note: ** Correlation is significant at 0.01 level (2-tailed)

* Correlation is significant at 0.05 level (2-tailed)

- Since the annual income and number of rooms were majorly correlated, we used residualisation. Thus, from the effect of the number of rooms on purchase price / Ln purchase price / rent / Ln rent, we have taken out the effect of annual income on the number of rooms. The explanatory power of our regression equations is not expected to change, but the regression coefficient for income is expected to change as its effect captured in number of rooms is corrected for. With this correction, annual income turned out to be a more significant variable. The rest of the regression coefficients did not change.

- None of the four dependent variables mentioned above had significant association with environmental variables. A new dependent variable called Relative Value of the real estate was introduced. This variable is derived from the two variables of purchase price and built-up area. Thus,

  Relative Value = Purchase price per square feet of built-up area Average price per average square feet of built-up area.

Regressing this variable on two variables using step-wise regression, we got the following result.

Relative Value = 0.586 + 0.376 (age)* - 0.235 (SO_2)*

(Adjusted R^2 = 0.155) * significant at 1% level.

This indicates that the age of the building had a positive and significant relationship with the relative value of the real estate – as defined above. In this model SO_2 emerged as a strong negative effect on relative value of the property. The effect that was not captured in actual purchase price got reflected in the *relative* value of the real estate.

Our findings and results show that rigorous statistical exercises did not help us to indicate any effect of air pollution on property prices. One of the reasons for this is that our data was not robust enough to withstand such rigorous exercise. In spite of this, we did succeed in establishing the adverse effect of air pollution on property prices by using people's perceptions regarding levels of pollution and property price behaviour. Further, even when people residing in GIDC and working there had fear of unemployment, they were willing to pay for reducing air pollution. There were large numbers of respondents who registered a 'protest zero'. In sum, people did have a fairly clear idea about the relationship between air pollution and property prices.

Our study clearly brought out the fact that income is negatively, though weakly, correlated with SO_2, NO_x and SPM. We have also observed a strong positive effect of income on purchase price, Ln purchase price, rent and Ln rent. These two observations taken together indicate the existence of an inverse relationship between air pollution and property prices. The government should try to protect the value of properties in industrial estates by monitoring air quality of industrial units that are expected to start production when the economy comes out of industrial recession. The government should not allow growth of industrial output, ignoring the loss of property value whose existence this project has brought out.

Concluding Remarks and Recommendations

The present study is an attempt to estimate the environmental cost of industrialisation as expressed in terms of loss of property value on account of air pollution resulting from industrial development. Based on our experience and findings, the following recommendations are put forward:

- Reliable data on air pollution and property prices should be collected. The foremost requirement is establishment, of a number of monitoring centres for air/water quality. Mandatory auditing of industrial units in terms of pollutants emitted per unit of output, total volume of output, etc. should be introduced and records must be maintained. The data should be made available in the public domain.

- To encourage citizens' awareness and action, industrial units should be classified according to the type and quantity of pollutants they emit. A colour code should be adopted to identify the units that cross the permissible limits of different pollutants. Those that emit less than the acceptable quantity of given pollutants may be allotted a green colour, while those crossing limits and creating hazards may be given a red colour. These colour codes should be made public, and after a few warnings, the colour given to an industrial unit should also be made public. This would exert pressure on these units, emerging from fear of adverse public opinion. This knowledge will make it possible for people to select a site for their house where they are not forced to keep the windows and doors closed.

- The effect of air pollution on property price can be indicated by looking at the average purchase price per average built-up area between north and south of GIDC. The north-east area of GIDC falls in the wind direction and suffers air pollution more intensely as compared to the south. The ratio of average purchase price to average built-up area for the south and north turned out to be 1:9, implying that on an average, property price per square feet in the south was almost twice that in the north.
- Illegal release of gases at night must be stopped. Industrial units dumping wastes illegally at night and releasing harmful gases should be severely punished and heavy penalty should be imposed.
- Even poor people were willing to pay for an improvement in air/water quality, and were not willing to accept even a marginal deterioration in air quality. These costs do not get incorporated in our cost calculations while planning our industrial strategy. Unfortunately, the price for cleaner air was also not captured by our hedonic price function as all the regression coefficients for air pollution turned out to be statistically insignificant. This is so because for these people, having an employment, saving on transport and benefiting from other infrastructural facilities available in GIDC was more important than staying away and paying higher real estate prices in cleaner environments. However, it was observed that relatively poor people lived in areas that fall in the wind direction for most of the time during a year. Their property prices were lower, and as per their perceptions these prices did not increase as much as in other areas in the south of GIDC.
- Intense efforts should be made to monitor air and water quality, and the assistance of research institutes, university departments and NGOs should be sought by the GOG.
- The government should have a clear-cut policy on housing in industrial estates.

NATIONAL AND INTERNATIONAL POLICY ISSUES

Trade and Environment: Conflicts and Prospects — A Case Study of Leather Goods, Tea and Cut Flowers

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Introduction

Environmental regulations cover a variety of facets, from global to national, from national to regional and local issues, from sectors to products, from awareness to law. They include, inter-alia, charges and taxes for environmental protection, requirements relating to products including standards and technical regulations, eco-labeling, packaging and recycling requirements, laws regarding deployment of labour, and laws to deal with hazardous substances, and endangered species. Some of them act as non-tariff barriers.

Major Linkages between Environment and Trade

Three distinct links between trade and environment are: environmental policies affecting trade flows; trade flows affecting environments and environmental policies; and trans-boundary environmental externalities due to trade. A related issue is relocation of industries in 'pollution havens' away from environmentally sensitive regions. This can reverse the direction of trade. Of these three major links, only the first one is addressed in this study with three major exportable commodities as case studies, namely tea, cut flowers, and leather and leather goods.

The choice of products is deliberate. Tea is one of the oldest and most prominent export commodities from India (with strong competition from Sri Lanka and Kenya). Its production is highly dependent on land and water, and it is hence considered a primary product. Therefore, it was thought to be appropriate to study it vis-à-vis land and water related environmental regulations (e.g., pesticide control, water pollution etc.). Cut flowers belong to a category of young and emerging export products from India. Its production depends on land, and substantially on modern capital such as cold storage, cold chamber transport facilities, and packaging requirements. Therefore, there are possibilities of environmental regulations affecting them both positively and negatively. Once again, it has links with both primary (i.e., horticulture) and tertiary sectors (i.e., transport, packaging, cold storage, shipping etc.). Leather and leather product sector is based on tanning, which is known to be one of the most water and soil polluting, and odor producing activity. There are a number of water pollution related as well as packaging and eco-labeling regulations (e.g., regulations on PCP control, azo dyes, eco-labeling etc.) that affect the export performance of the industry. Belonging to a processing industry, leather is a secondary level industry.

Review of Literature

Going by the available empirical and theoretical studies, no strong evidence in favour of a negative effect of stringent environmental regulations on exports has been found so far. Either environmental cost is not significant, or pollution abatement subsidies have come in place. There are some studies to show (with gravity models) that more stringent environmental regulations have increased the levels of exports. Other studies have also established that effects of environmental regulations can be either small or too difficult to detect. Its effect on trade, growth and productivity all seem to be insignificant. Rather, as argued by Porter and Linde in 1995, all such industries that move to more cost-effective abatement processes, including reduction of emissions, can become more competitive via innovations and adaptations.

A major countrywide study on environmental regulations on trade performances in developing countries, came to the following conclusions:

"To conclude, the evidence from these case studies on 'how foreign environmental regulations impact on a developing country or transition country' is mixed. Many of the larger exporting countries claim that the effects have been small, and in most cases manageable for the exporters. In several cases the adoption of the stricter standards not only decrease environmental damage, it also increases efficiency and profits for firms."

Analysis of Indian Trade Pattern

The export trade performance of the three products is studied in detail. Time series data for 20 years are analyzed in terms of (a) changing direction of trade among major importing countries; (b) shifts in the shares between different countries; (c) the demand pressures (e.g., income, volume of their imports), dependency ratios and terms of trade as applicable to the importing country; d) Indian market share (again, depending upon the domestic production and terms of trade.

Tea is the primary export commodity for India, although its share in over-all Indian exports is only 1.27 percent in US $ value terms, which has been declining over the years. Tea exports accounted for 6.34 percent of India's total exports in 1980-81 in Rupee terms, which gradually declined to around 3 percent between 1987-91, and witnessed a further decrease to around 1 percent in the years 1992-99. It touched a low of 1.12 percent in 1999. As seen in Chart 1, the importance of Indian tea in relation to world exports has been declining since 1989. However, there has been a fair amount of stability in the major markets for India's tea exports. Two indicators that are relevant here are India's dependency ratio and market share. Indian dependency on the Russian market was at a steady growth from 30 percent in 1980 to 60 percent till the year 1989; then it decreased to 36 percent by the year 1999. Indian dependency on the UK showed a decrease from around 19 percent in the 80s to 10 percent in 1999. Similar is the case with Egypt. The loss of market share with these major customers was made good by new customers like the United Arab Emirates. There are also year-to-year fluctuations in these export indicators over the years.

Chart 1: % Share of Indian Export of Tea in world's Total Export (Based on Value of Export)

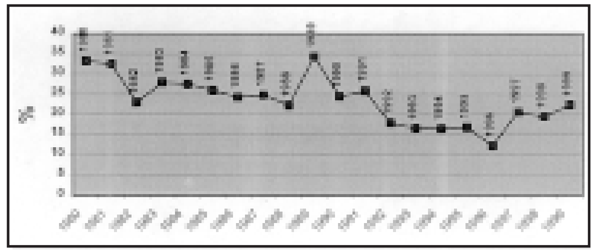
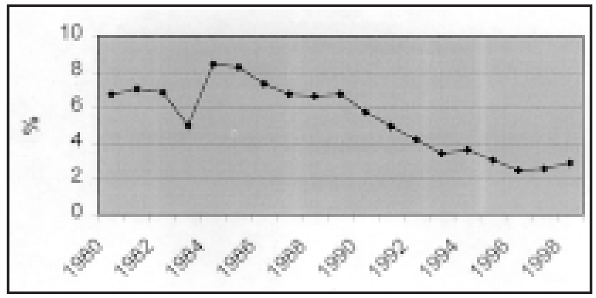


Chart 1: % Share of Indian Export of Leather in world's Total Export (61)



India is one of the major exporters of leather and leather products. Nearly 65 percent of its exports are destined for the European Union. Germany, among the EU countries is the largest importer of India's leather products, accounting for about 20 per-cent of trade. A steady shift in the direction of trade has been observed, possibly due to liberal environmental regulations and easy market accessibility in UK, USA and France. India's dependency (as per the dependency ratio), on the erstwhile centrally planned economies has drastically come down. For the UK and USA, the dependency ratio has gone up. The importance of the remaining countries as a source for India's exports has either declined or remained the same during the period of 1980s. The data confirms a steady shift in the direction of leather products' exports, particularly towards the U.S.A. and U.K.

Analysis of Environmental Regulations

Environmental regulations the world over have evolved significantly over time, especiallly during the last three decades. There are a variety of regulations, ranging from voluntary and informatory, to prohibitory and mandatory. They have emerged in some instances, at the initiatives of country themselves, or as a result of group or trading bloc initiatives. They have also flowed from multilateral environment agreements (such as SPS and TRIPS regulations under WTO, or CITES). There are also Indian (domestic specific) environmental regulations. Indian regulations follow from the Water Act of 1974, Air Act of 1981, Environmental Protection Act of 1986, and Pollution Control Board's standards and list of sectors and products in the categories of major polluting industries for priority action. All such components of environmental regulations are reviewed, and the time series information on them has been indexed using (a) multi-criterion and (b) factor analysis.

Starting from tanning to packaging, a number of environmental regulations come into play for leather and the leather product industry. This is one sector, in which Indian domestic regulations affect the industry as much as international regulations. Effluents are to be treated before they are discharged into rivers or open land. Exports of cut flowers governed by strict regulations on packaging, preservation during transit, eco-labeling, and restrictions on the use of pesticides and fertilizer at the horticultural stage. The tea industry also has to comply with water and land related environmental regulations, as well as regulations related to packaging. Environmental regulations vary from country to country. They also differ, in terms of introducing stringency over time. For an exporting country such as India, it is therefore, necessary to take a close look at a variety of such regulations over time in different importing countries.

Methodology

The methodology of this study is briefly described here. First, the trade patterns of all the three products are reviewed using time series data from 1980 onwards. Both the volume and direction of trade are analyzed. The major breaks and shifts in the trade patterns are noted. Then, time series information on environmental regulations in various countries (mainly Germany, USA, the Netherlands, UK, and European Union) is analyzed. They are grouped as precautionary, prohibitory, mandatory, informative, and transparency types. They have been indexed, based on the information about their stringency. Time series of aggregated indices of environmental regulations and restrictions are compiled and analyzed. For this, Multi-criterion analysis as well as Factor analysis was carried out. Subsequently, a trade model is formulated, using terms of trade, trade related pull and push factors (i.e., demand and supply), and with and without environmental regulation indices. The model is estimated econometrically.

Porter and Linde in a major study in 1995 argue about the long-term benefits of the regulation forcing and motivating process innovations and production efficiencies, thereby enhancing trade and welfare. But what will be the effect of such regulations in the short run? A related question is: how does the export sector adjust itself over time? Will it converge to the long run path as indicated by them? In order to answer some of these questions, it may be necessary to add indices of environmental regulations or the cost of the regulations as explicit variables in a trade model.

A specific hypothesis is formulated in this study. Environmental compliance costs are severe on the primary export commodities, because of which export levels are affected. One can notice that for higher and higher order of processed product exports, the environmental compliance costs tend to become low and insignificant. Hence, they seem to be capable of internalizing the burden of such costs and emerging with improvements in technology and innovations to gain from trade.

The hypothesis is stated precisely as:

'As one moves from lower to high value added product exports or from primary to higher and higher levels of processing and manufacturing, the impact of environmental regulations turn to become positive from being negative'.

This hypothesis is tested using an econometrically estimated trade model.

Experience of Indian Exporters

Tanneries

In the case of tanneries, the small-scale units bear the burden of high cost of treatment and lack of financing, technology, and sometimes, even lack of knowledge about the regulations. They also find it difficult to set up Common Effluent Treatment Plants(CETP) because of spatial dispersion of the units. Small-scale tanneries therefore, continue to have individual effluent treatment plants, however inefficient they may be. Pollution abatement costs of producing one kg of processed hide and skin vary between 0.41 to 1.48 percent, whereas the same under a common effluent treatment plant technology would be between 0.41 to 0.81 percent. In 1998, there were as many as 1000 small-scale tanneries in India, against just about 75 large units.

However, the tanneries, which have complied and taken measures for Pentachlorophenol, pH, biological and chemical demands on Oxygen, total dissolved solids, several other chemical regulations etc., have gained better access to world exports. There is a general feeling in the industry that in the long run, regulations are good for the industry. There are some variations in the standards between different countries. Some countries like Italy and USA insist only on pH value regulations. The total dissolved solids (TDS) regulations are not very important for them. But the Tamil Nadu Pollution Control Board insists strictly on the TDS at 2100 ppm limit and reverse osmosis plants. The compliance costs at the Common Effluent Treatment levels is very small. At best, it goes up to 2 - 4 percent of total product costs. But during the last 6 - 8 years, the compliance costs have been rising. Secondly, almost all producers are aware about the relevant regulations. Thirdly, the regulations did not make the exporters change their importing partners or change the direction of trade. Finally, more than the environmental costs, the overall trade recession has affected the leather exporters from India. Recession in Germany in particular, has affected the exports quite significantly.

Tea

Tea gardeners and exporters in India feel that this is one plantation activity, that is environmentally friendly above all. Tea means green biomass. There is no direct foreign investment in this industry so far. Since almost 8 years, the industry has been complying with multiplicities of environmental regulations, such as EU, CODEX, US Food Regulations, German packaging and eco-labeling regulations, and Russian Gosstandart regulations (on the residuals of heavy metals such as cadmium, nickel, etc.). Considerable research has also been carried out by the Tea Research Authority and United Planters Association of Southern India.

The most important environmentally sensitive issues relating to tea plantation are the use of pesticides and land use pattern. The choice before the tea gardens is either to comply with pesticide control levels as stipulated by EU, or opt for organic farming. The gardeners say that organic farming will involve an additional cost, of even up to 100 percent extra. If the cost of regular Darjeeling tea is Rs.200-250 per kg, it would be as high as Rs.400-500 per kg using organic farming. Many German importers are willing to pay this higher price. Initially, when the German importers provided some incentive capital and paid for environmental and social auditing, some of the major Indian exporters switched to organic farming in parts of their tea gardens and continue to maintain these parts. Most others however, comply with EU pesticide regulations, at much lower levels than the said limits. Yet, there are currently about 11 major planters in the Darjeeling area who practice organic farming.

Most tea exporters find these environmental regulations such as pesticide controls, maintaining ground water quality, afforestation, soil replenishment, preventing biodiversity loss, etc., costly, but because of the worldwide compliance, they have had to implement them. It is also learnt from the exporters that there are no major scale effects (advantages) in the cost of environmental compliance. The costs on account of these reflect in their pricing, depending upon the composition of organic and regular gardening. Added to these are the Eco-labeling and packaging regulations. Therefore, on the whole, environmental regulations seem to have affected the cost and price patterns of tea exports.

Cut Flowers

As far as cut flowers are concerned, the pesticide control, regulations on harvesting, cold storage and transporting, as well as packaging regulations add to the cost build-ups. The three major environmentally relevant costs are use of farmyard manure (ranging from 5-8%), plant protection costs (ranging from 3-5%) and transport and handing costs (ranging from 3-5%). The cost of cold storage and refrigeration vans is about 18-19 percent of the total cost of production. The packaging and freight costs are about 35 percent of total cost. About 35 percent of marketing and about 2 percent of production costs are environmentally related. Since the sector is in its initial stages, there is a lack of knowledge about regulations and recommended practices (based on almost 55 to 75 percent of respondents' mixed views). Furthermore, they also lack advanced technology in packing and handling (as expressed by over 75 percent of respondents).

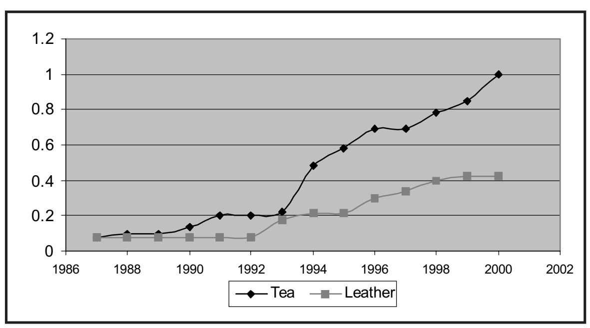
Econometric Models on the Effects of Regulations on Trade Pattern

As against standard methods of formulating Gravity models linking trade and environment (e.g., with 'year specific' dummies in the case of time series analysis, or 'country specific' in case of cross-section analysis), specific econometric exercises were carried out. They are: econometric models to (a) identify the shifts or breaks in trade pattern attributable to environmental regulations, (b) link trade with such breaks along with alternative specifications of the dependent variables (variants of gravity models), (c) construct time series composite indices of stringencies in environmental regulations, and finally, (d) link trade patterns with those composite environmental regulations, along with other explanatory factors.

First are the usual gravity type models with exports in value as the dependent variable with explanatory variables such as volume of world trade (demand factor), Indian production (supply factor), terms of trade (price factor), and the year of stringent environmental regulation as a dummy variable. The exercise revealed that the time dummy variables for the years 1984, 1991 and 1996 coincided with some of the major environmental protection moves world over in those years. They suggest links between declining trends in exports with such regulations. As far as terms of trade for leather goods and tea are concerned, it seems to act in two different ways. For the former, it is a supply price factor, whereas in the case of tea it is a demand price factor (i.e., dominated by the London price, rather than at Kolkata). This is understandable as Indian leather goods have a larger share in world exports, and have been in the business for quite a long time. The world level export is a major demand pull factor for Indian exports.

The composite index of stringency of environmental regulations in importing countries with respect to tea and leather and leather goods exports can be viewed in Chart 3 below. For both tea and leather, environmental regulations in the aggregate have followed a positive stringency path. Though they followed roughly the same trend till about 1993, in more recent years the strictness of leather-specific regulations seem to be leveling off, whereas the same on tea appear to be increasing. It is likely that such a growth pattern of the relative strictness of environmental regulations on a primary product such as tea, as compared to regulations on manufactured leather goods, is mirroring the greater success of producers of manufactured goods in internalizing the economic costs of environmental regulations, but not the primary commodity producers.

Chart 3: Stringency Paths of Composite Indices of Environmental Regulations for Tea and Leather



Tea

To analyse the effects of environmental regulations on the export of tea, an econometric model was estimated in which the ratio of Indian tea exports to developed and developing countries is taken as a dependent variable. A-priori, one would expect a switch in Indian exports away from countries with stringent environmental regulations (i.e., developed countries) to those that having less stringent regulations (i.e., developing countries). A composite index of stringency was derived from four different types of environmental regulations-maximum residue levels of pesticides, packaging regulations, Sanitary and Phyto-Sanitary standards and general stringency. Other independent variables used in the model are: the indices of dependency of India's exports on developing countries and on the EU countries, a dummy variable for major shifts in environmental regulations since the Rio conference (with a value zero before 1992 and 1 after that), relative per capita income of developed to developing countries, and the terms of trade defined as the price in Kolkatta (i.e., a producer price) relative to that in London (i.e., a consumer price).

The major finding is that the stringency of environmental regulations reduces the share of India's exports going to the developed countries. The terms of trade effect is such that a higher relative price in Kolkatta means a smaller gap between consumer and producer prices and has a stimulating effect both on demand and supply. The shift of trade pattern around 1992 (as viewed from the significant dummy variable) is a reflection that most exporters who had experienced some difficulty in meeting the environmental standards initially till 1992 have been able to withstand the global competitiveness with compliance.

The main finding that follows is about the relevance of environmental regulations. Tea is a primary export commodity. It has revealed the impact of regulations negatively. In terms of elasticities, however, more than environmental regulations, the trade dependency ratios, relative prices and income factor are dominant. Hence, one can see the long-term effect to be one of slowly moving towards improved efficiency, environmental transparency and better environmental conditions in the tea garden sectors in India.

Leather And Leather Goods

Major buyers of Indian leather products are from European Union. The regulations are also dominated by these countries. Therefore, the ratio of exports to EU to that of non-EU is considered as the dependent variable for the econometric model. The explanatory variables used are,: Indian dependency on European Union, Terms of Trade defined as the ratio of World price of leather and leather goods exports to Indian price of exported goods, several dummy variables such as dummy variable for the year 1994, index of stringency of environmental regulations, GDP of European Union, Market share of Indian exports in European Union, and several others.

On the basis of the econometric exercise, the following major observations can be made on the export of leather and leather goods from India. First, one can clearly say that environmental regulations seem to enhance Indian trade prospects. Clearly, this is an indication that the Indian leather and leather goods sector, being one of the oldest in the export profession, has already taken a sufficient leap in complying with the European environmental regulations and has been maintaining the competitiveness. Second, this is also due to very attractive terms of trade, which have a positive effect on Indian exports. Third, Indian dependency on European demand is very important. Therefore, India cannot ignore the environmental regulations from EU countries.

Towards policy formulation

The policy implications that follow from this study can be summarised as follows:

- It is necessary to treat small scale and large scale producers separately while designing the environmental regulations.
- The primary commodity exports such as agricultural products (e.g., cut flowers, and to some extent tea) do reveal a higher burden of environmental regulations in the short run. They require additional time to adjust their

cost burden, learn new technologies, and collect information regarding such regulations, among other activities that will help boost exports.

- Training is required in packaging, handling, environmental auditing etc., Such personnel need to be provided more training and information to graduate to becoming competitive.
- Small-scale primary product units require higher doses of subsidies in setting up of combined effluent treatment plants, or cooperative cold storage, packaging units etc.
- Environmental regulations need to be ranked in terms of their negative effects on society. The industry specific rankings also need to be worked out (e.g., severity index for each environmental hazard and the rank of it for each industry, say textile, leather tanning, chemicals and so on).
- As one moves from lower levels of manufacturing to higher levels of processing and mechanization, the environmental compliance costs per unit of output are declining. Such industries should set up training centers for their own ancillary units, that are either in the small-scale sector, or they will find the cost impact of environmental regulations to be quite high. More thrust needs to be given to set up R & D centres by large-scale manufacturing units to develop eco-friendly inputs, techniques and awareness.
- Finally, there is a need for a geographically widely spread out set up of testing centres by the Pollution Control Boards, to enable the small and medium scale units to get their products certified for environmental clearance.

Vulnerability and Adaptation to Climate Change: Agriculture and Coastal Resources in India

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Introduction and Motivation

Accumulation of trace gases such as carbon dioxide (CO_2), methane (CH_4) etc. in the atmosphere, caused mainly due to anthropogenic activities such as burning of fossil fuels, is believed to be altering the Earth's climate system. The third assessment report of the Intergovernmental Panel on Climate Change (IPCC) has concluded that "there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities".

Analysis of various pollution abatement strategies is well documented in the field of environmental economics. However, the study of climate change problem poses a special and formidable challenge due to a variety of reasons. These are global and inter-disciplinary, that the problem is long time periods involved. There are associated uncertainties and so on. Also, the differences among world nations in terms of their historic, present and future contributions to greenhouse gas (GHG) emissions, and their respective vulnerabilities to potential changes in the climate makes it a complex problem to resolve.

The available evidence from various climate change impact studies suggests that the developing countries are likely to get more adversely affected than the developed countries. Most of the available impact estimates do not account for impact due to extreme climate events such as cyclones and droughts, whose frequency and intensity could increase following climate change. These natural disasters cause significant damages in developing countries. Asia, for example, accounts for almost 38 per cent of hydrological and meteorological disasters that occurred between the period 1991 and 2000 all over the world. Of those reported killed by natural disasters, 83 percent lived in Asia, while 67 percent lived in nations with low human development indicators.

Thus, from the developing country perspective, the present day vulnerability due to natural disasters, the possibility of increase in frequency and intensity of such events under climate change regime, and the potential high impact of climate change on the performance of climate sensitive sectors make a strong case for focus on adaptation options as part of climate change policy.

A fundamental input necessary for formulating adaptation policies is knowledge of climate change induced impact and vulnerability of climate sensitive sectors. This study focuses on this aspect through an analysis of two climate sensitive sectors in India.

Objectives

Among a large number of climate sensitive sectors, agriculture and coastal resources have special significance in the Indian context. Agriculture plays a vital role in Indian economy by providing employment to more than 60 percent of the total labor force and accounting for about 27 percent of gross domestic product (GDP). Despite significant strides made in food grain production since the advent of the green revolution, growing population and increasing biotic and abiotic stresses are likely to widen the supply-demand gap in the future. Climate change induced pressure is expected to further worsen the situation. India has more than 6500 km of coastline (excluding the coastline of the islands); spread over 53 coastal districts and six union territories. With high population density, these coastal districts account for nearly 50 percent of the country's total population. Rise in sea level coupled with storms is likely to cause devastating effects on the coastal areas.

Impact assessment studies in India were done using predictions on mean climate changes. Climate change impact studies worldwide are now focusing on analyzing impact due to changes not only for mean climate but also for variation at extreme points and manifestation of climate change. It is widely believed that the climate change manifestation could be through extreme climate events such as cyclones and droughts.

Thus, the main objectives of the present study are to:

- Assess the vulnerability of Indian agriculture and coastal resource sectors to climate change by specifically incorporating the climate variability and extreme events in the assessment
- Identify various adaptation strategies specific to these two sectors

Methodology

Vulnerability assessment constitutes an extension of a climate impact assessment as it explicitly considers climate variability, climate extremes and non-climatic factors. Vulnerability assessments can be further refined by considering the feasibility of adaptation through the concept of adaptive capacity – which takes into account the requirements for, and limitations to, implementing adaptation measures.

Agriculture

The study extends the net-revenue approach done earlier, developed in previous studies which use the cross-sectional evidence from farms facing a wide range of climatic conditions, to examine the impact of climate variation on Indian agriculture. The present study specifically explores the impact of including inter-annual and diurnal variation in climate variables on the farm-level net-revenue. As climate change is also likely to be associated with change in the climate variation, inclusion of climate variation terms in the model is expected to improve the model specification and take the analysis closer to vulnerability assessment.

In previous analyses, it was demonstrated that both long-run averages of temperature and precipitation have quadratic relationships with farm level net-revenue. Hence, the present study adopts similar specifications for the model, but extends it to specifically study the influence of climate variation terms as shown below:

$$R = f(T_j, T^2_j, P^2_j, T_jP_j, DT_j, YT_j, YP_j, SOIL, BULLOCK, TRACTOR, POPDEN, LITPROP, HYV, LAT, ALT)$$

where, R is the farm level net-revenue per hectare;

T_j and P_j are the normal temperature and precipitation respectively, and j denotes the seasons;

DT_j denotes the diurnal variation of normal temperature;

YT_j and YP_j denote the yearly variation of temperature and precipitation;

SOIL represents the soil characteristics such as soil types and topsoil depth classes;

CULTIV, BULLOCK, TRACTOR are the number of cultivators, bullocks and tractors respectively in per hectare terms;

POPDEN is the population density;

LITPROP is the proportion of literate people;

HYVFR is the proportion of area under high yielding varieties (HYV);

LAT and ALT are the latitude and altitude of the cross-sectional unit.

For accurate assessment of impact on agriculture, it would be necessary to perturb both the average climate variables and their variation variables. Even if one were not to incorporate the possible changes in the climate variation variables for impact assessment, inclusion of these variables is expected to improve the model specification. In the above equation, variable *DT* represents the diurnal range in temperature, which is the difference between the maximum and minimum daily temperature; and *YT* and *YP* represent the standard deviation of temperature and precipitation over a period of time.

Coastal Resources

Given that the impact due to sea level rise is not likely to be uniform across different parts of the country, a regional level composite vulnerability index is developed to identify the most vulnerable regions. Also, the vulnerability index would take both climate and non-climate factors into consideration, and hence the analysis is a step forward from impact assessment. The vulnerability index is expected to be useful in prioritizing the response strategies. For the purpose of index calculation, vulnerability is hypothesized to be a function of *impact* on the region, and *resistance* and *resilience* of the region in responding to the impact it experiences.

The composite vulnerability index was developed using the following characteristics of various coastal regions across India: (a) demographic characteristics – such as population density, annual population growth rate; (b) physical characteristics – such as coast length, insularity, frequency of cyclones, probable maximum surge height; (c) economic characteristics – such as agricultural dependency, income; (d) social characteristics – such as literacy, spread of institutional set up. The composite index is calculated by taking an average of all the standardized observations of each region over all the components. The averaging procedure implies that equal weights are assigned to each component. The procedure is similar to that followed in the construction of Human Development Index by the UNDP. The index computations are made for a range of combinations of the parameters listed above to check robustness of the index.

The study also attempts to model storm induced damages. However, given the data limitations, a two-pronged approach has been adopted. In the first approach, the concept of 'surge influence factor' is used to estimate the loss of human lives due to cyclonic storms. Broadly, the loss of human lives would depend on the risk level of the region, warning time and compliance to the evacuation plan. The loss of human lives due to a storm in any region is estimated as:

$$+H = \sum_i P\, C\, a_i\, r_i$$

where, P is the population of the region;

C is the non-compliance factor, measured based on historic evidence of storm warning and compliance;

a_i is the fraction of the region's area related to a given hazard level; and r_i is the risk coefficient for the hazard level.

The second approach attempts to develop a functional relationship between human loss and surge using econometric methods. The choice of human loss as the end-point of analysis is due to non-availability of reliable data on economic damages.

Data

Agriculture

The net-revenue model specified above is estimated using pooled cross-sectional and time-series data for 271 districts covering most of India[1]. The farm-level net revenue is estimated using agricultural production data for as many as 20 major and minor crops. The climate data is based on a recent publication of the India Meteorological Department (IMD) on climate normals for about 391 meteorological stations spread across India. The data on climate normals corresponds to the period 1951-1980. The data on yearly climate variation also matches with the above time period. As the climate data is available at the level of meteorological stations and the analysis is attempted at the district level, surface interpolation technique is used to transfer climate data from the meteorological station level to the district level. The interpolation technique uses geographical parameters such as latitude, longitude, altitude, and distance from the nearest seashore as independent variables. The procedure also takes into account differences between high and low altitude regions. The climate and climate variation variables corresponding to the months January, April, July and October are used in the analysis to represent the four seasons respectively.

Coastal Resources

For vulnerability index calculations, district level data on various characteristics of the coastal districts is assembled from a range of sources such as census, IMD, vulnerability atlas (developed by the Ministry of Urban Affairs and Employment, Government of India) and center for monitoring the Indian economy. Data on coast length is estimated using geographic information system (GIS) software. Similarly, district level income is generated

[1] *It may be noted that the 271 districts used in the analysis correspond with the 1961 census definitions.*

using a simple procedure based on allocating state income.

For storm induced human loss estimations, data on district specific areas in different hazard levels is assembled from the vulnerability atlas, while data on corresponding risk coefficients and non-compliance factors are collected from disaster management literature. The analysis uses four hazard levels: Very High *plus* Surge, Very High, High, and Moderate. The surge influence factor is calculated for two different scenarios of surge penetration – 10 km and 30 km. Three different scenarios for non-compliance factors have been used: 0.004, 0.008 and 0.08 to reflect different levels of preparedness.

For estimating the storm damage model, data on human loss, surge height, time and duration of the storm, and location and period of its occurrence are used. The data set corresponds to the period 1952 to 1996 and covers all the major storms that have hit both east and west coasts of India.

Results

Agriculture

An F-test comparing the model with and without the climate variation terms showed that the climate variation variables together are significantly different from zero. The t-statistic showed that barring a few, all the climate variation variables are significant in improving the model specification.

To gain insight about the effect of climate variation terms in the model, the climate change induced impact is estimated for a few representative scenarios. The climate change induced impact is measured through changes in net revenue triggered by expected changes in the climate variables. The impact is estimated at individual district levels and is then aggregated to derive the national level impact.

As the net-revenue approach uses the cross-sectional evidence from farms facing a wide range of climatic conditions to estimate the response function, with farms differing not only in terms of their average climate, but also in terms of the climate variation they experience, not incorporating the climate variation variables in the model could lead to bias in the estimated climate coefficients. Hence, impact estimated based on the model without the climate variation terms could be upwardly biased. The results presented in the table below capture this aspect. The impact calculated using the model with climate variation is uniformly lower than those calculated using the model without climate variation. The last column in this table reports estimated impact under a climate change scenario that incorporates higher climate variation along with changes in mean climate. The reported estimates are for a 5 percent increase in climate variation and the impact is uniformly more. Thus, the results show that changing climate -involving increases in both mean and variation, would lead to significantly more impact on Indian agriculture. Temperature changes – both mean and variation – have significantly more adverse impacts on Indian agriculture than the precipitation changes.

Net-revenue Estimates with Climate Variation

DT/DP	Impacts as Percentage of Net Revenue		
	Without Climate Variation Terms	With Climate Variation Terms	With Climate Variation Terms and 5% Higher Variation
2°C/7%	-7.8	- 6.8	-9.5
3.5°C/14%	-24.0	- 17.8	-28.1

Note: The figures represent percentage change in net-revenue (1990 value).

Among various adaptation strategies, special mention could be made of insurance. The new-generation micro-insurance schemes, by attempting to achieve financial viability at the design stage itself, could not only cover the future risks such as those expected under the climate change conditions, but also avoid moral hazard and adverse selection problems that commonly plague insurance schemes.

Coastal Resources

Vulnerability index estimations have been carried out for different specifications of the index. The results based on the rank correlations show that the vulnerability rankings across districts are significantly robust. The vulnerability index estimated for the Indian coastal districts indicate that (see Map):

- The districts along the eastern coast are relatively more vulnerable than those on the western coast
- The coastal districts in the states West Bengal, Orissa, Andhra Pradesh and Tamil Nadu are only marginally different from each other in terms of their vulnerability
- The districts that are frequently affected by cyclonic storms are relatively more vulnerable – these include districts like 24 Parganas, Baleshwar, Krishna

The table below shows the estimated casualties due to storms in various coastal districts under different scenarios of surge penetration and non-compliance by the population to the storm warning.

Expected Casualties due to Storms

District \ NCF	Surge Penetration - 10 km			Surge Penetration - 30 km		
	0.004	0.008	0.08	0.004	0.008	0.08
N 24 Parganas	470	940	9399	1053	2105	21052
Medinipur	310	620	6204	562	1124	11245
S 24 Parganas	286	571	5710	580	1160	11604
Srikakulam	218	436	4361	476	952	9520
Baleshwar	192	384	3836	441	882	8824
Cuttack	186	372	3720	390	780	7804
East Godavari	167	334	3337	374	747	7473
Krishna	105	211	2109	224	448	4483

Note: NCF – non-compliance factor

Comparison of district-wise expected casualties due to storms with district-wise vulnerability index shows that the relative ranking of districts remains more or less similar between the two analyses. This is an important result because the two analyses address vulnerability from two related, but different perspectives, and their similarity shows robustness of the finding.

The estimated storm damage model is as follows:

$$\text{lnloss} = \underset{(8.51)}{6.19\,(sd1)} + \underset{(5.95)}{4.37\,(sd2)} + \underset{(7.06)}{4.56\,(sd3)} + \underset{(4.09)}{3.46\,(sd4)} + \underset{(3.34)}{0.439\,(seasurge)}$$

where, lnloss – human loss (in log)

sd1, sd2, sd3, sd4 – state dummies for AP, TN, Orissa & WB, Gujarat

seasurge – interaction dummy of season and surge height

Model estimates show:

- Storm surge has positive and significant influence on human loss
- Storm induced vulnerability is more for AP followed by Orissa & WB, TN and Gujarat
- Storms in the winter season are more destructive than those occurring in summer season
- Storm duration and its period of occurrence (i.e., 60s, 70s, 80s, or 90s) are not significant

Given that human loss as an end-point of analysis is prone to criticism, the impact of storm surge on human lives and storm induced normalized damages has been studied. Based on the data corresponding to the storms of comparable intensities that had hit the Andhra Pradesh coast during 1977 and 1998, the study showed that human loss has better correlation with various storm characteristics, compared to normalized damages.

A prudent adaptive response to the threat of climate change may be to improve adaptation to existing climate and its variability, including extreme events such as cyclones. As argued in the case of crop insurance, insurance to natural disasters should have little or no government subsidy to avoid moral hazard and adverse selection problems. For instance, in insurance schemes operated through cooperatives, peer monitoring of claims could defend against moral hazard and peer pressure could weed out bad risks. New approaches like index-based or area-based contracts to insure natural disasters should be attempted, and these approaches in conjunction with developments in micro-finance, could make insurance an increasingly viable proposition for poor people to better manage risk.

Policy Implications

A number of policy relevant conclusions can be derived based on the results of the study:

- When increase in Indian agriculture as well as in mean variation takes place, impacts are significantly higher. The estimated reduction in net-revenue is of the order of 10 percent for a 2°C rise in temperature and 7 percent increase in precipitation coupled with a 5 percent higher variation

- Even with 'autonomous' adaptation, the impacts would be significant on agriculture, and hence make the sector highly vulnerable to climate change

- Relative rankings of Indian coastal districts based on an integrated vulnerability index indicate that districts on the Eastern coast are relatively more vulnerable than those on the Western coast

- Relative rankings of the coastal districts based on predicted storm induced casualties are similar to the rankings based on integrated vulnerability index, indicating the robustness of the finding

- Storm surge has significant influence on human casualties resulting due to cyclonic storms. As a rise in the sea level could lead to higher surge, the potential impact of cyclonic storms in the future could be more devastating

The scope of the study does not warrant policy suggestions that feed directly into climate negotiations. However, a few policy recommendations that can be made on the basis of results obtained from this study include:

- Adaptation to climate change is an issue of considerable interest to India, given its high vulnerability to climate change. The results of this study for two climate sensitive sectors, agriculture and coastal resources, highlight this. Equal emphasis, if not more, should be placed on adaptation policies in the climate change negotiations

- Vulnerability indices, such as those developed for the coastal districts of India in this study, could provide insights on prioritising adaptation strategies for specifically vulnerable regions

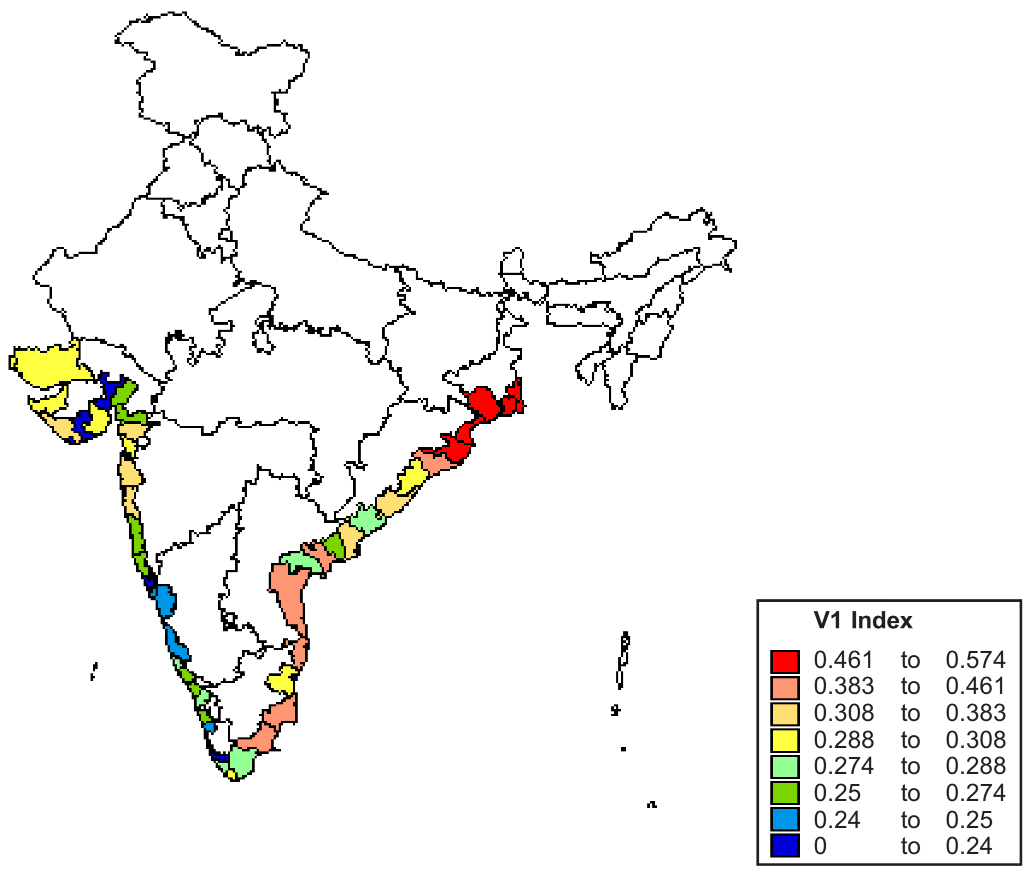
- Understanding vulnerability to present day climate extremes such as cyclones would provide a useful insight about the adaptive capacity of a region. Such knowledge could be useful in formulating adaptation strategies

- Immediate benefits can be gained from better adaptation to climate variability and extreme atmospheric events. Immediate benefits also can be gained by removing maladaptive policies and practices

- India could benefit by ensuring that its legal and economic structures and price signals encourage the private sector to take adaptive measures. Insurance, and more specifically micro-insurance, should be encouraged to help people adapt to the climate change conditions

- Even though the impact, and hence the adaptation needs are local in nature, given the global nature of the climate change problem, responsibility rests on all the countries. The developed countries should shoulder bulk of the cost of adaptation in developing countries on the basis of the fairness principle

- Governments in developing countries could legitimately press the strategy and earlier commitment to reduce GHG using such results.



Vulnerability Index for Indian Coastal Districts

Environmentally Accounting for Indian Industry

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Introduction

This study deals with some aspects of environmental and economic accounting and provides a case study of accounting industrial pollution in the estimation of environmentally corrected net national product (ENNP) for India. The study deals with :

- Conceptual issues about the definition and measurement of ENNP.
- Estimation of environmental values using the maintenance cost method in the context of industrial pollution in India.
- Effect of environmental regulation on the productive efficiency of industry,
- Environmental and economic accounting and the design of environmental policy.

The empirical analysis is carried out using mainly the primary data collected through a survey of water polluting industries in India.

Sustainable income is defined as the maximum income obtained in the economy, currently guaranteeing the same level of income in the future given the constraints on labor, man-made capital and natural capital. Environmentally sustainable income is the maximum producible income within environmental and other services in the economy by guaranteeing the current levels of environmental services in the future. There are many definitions of environmentally sustainable income depending on assumptions one makes about the substitution between man-made capital and environmental or natural capital, and requirements for maintaining the quality of environmental services at a certain threshold level. Measurement of environmentally corrected net national product (NNP) requires the extension of conventional national accounts resulting in integrated economic and environmental accounting. It requires the description of the environment in physical terms and the valuation of natural assets.

The net national product (NNP) could be shown as the nation's sustainable income as well as a measure of welfare. Environmentally corrected net national product (ENNP) could be estimated by deducting the value of decrease in stocks of environmental resources at their shadow prices from the conventional net national product. Models for deriving shadow prices are provided with alternative specifications about the technology of polluting firms. Given the environmental regulations, industry considers waste disposal services offered by the environmental media as productive inputs along with the conventional inputs, since it has to pay the price for them in the form of pollution taxes. Industry uses pollution abatement technologies, comprising end-of-pipe treatment, process changes in production, and changes in the use of inputs and products for reducing pollution loads as per the environmental regulation. In this type of situation, the assumption of free disposal of pollution is not appropriate in describing the technologies of firms generating pollution. For a firm having the resource constraint, reduction of pollution leads to a fall in the production of output. The description of the technology of a polluting firm as one of producing jointly good and bad outputs with the assumption that there is a disposal cost, makes it possible to account for the loss in the production of good output to reduce the bad output, pollution. The output distance function in the theory of production describes the technology of a polluting firm in this way. The shadow prices of environmental resources are derived in a general framework of overall planning problems for the economy, in which environmental inputs are productive inputs in the industry, use of environment by the industry affects the utility of people, and industry uses abatement technologies to reduce pollution. It is shown that in case there is a fall in the environmental quality with the economic development, the maintenance cost at shadow prices have to be deducted from NNP to arrive at ENNP. It is shown that a pollution tax levied on the firms, equal to the marginal cost of abatement at optimum, guarantees market efficiency in the inter-temporal or dynamic setting. In a sub-optimal or second best economic programme, effects of an investment project on the NNP can be evaluated using local or second best prices. The second best prices are suitably adjusted market prices for private goods and the estimated prices using data collected through specially designed survey methods for public goods or environmental services.

A review of theory of production in dealing with the problem of measuring the pollution abatement cost is attempted. Application of methodologies of production, cost and profit functions in explaining the firm's behaviour in making the choices of inputs, outputs, and pollution loads is discussed. The limitations of these methods in describing technologies of polluting firms, and the data requirement for estimating the cost of pollution abatement are highlighted. A review of methodology of distance functions has shown that the technologies of polluting firms could be explained as one of joint production of good and bad outputs. The distance function methodology is free from many limitations of the conventional methods in estimating the cost of pollution abatement. The output and input distance functions could be used for estimating the shadow prices or marginal costs of abatement for a vector of pollutants or bad outputs. The estimates of shadow prices of bad outputs are needed to estimate ENNP, and for designing pollutant specific taxes for controlling pollution.

Data

Primary data is used in this study, which has been collected through a survey of water and air polluting industries in India. The questionnaire used in the survey has four parts. Part I asks for the general production and cost details of the factory . The information obtained in this part of the questionnaire consists of data about products and byproducts produced by the factory, turnover, number of employees and wage bill, quantity and value of raw materials and fuel inputs used, and the capital stock of the plant, apart from other details. Part II deals with the water pollution abatement. It asks for the technological details of water pollution consisting of volume of wastewater, capacity of effluent treatment plant, nature of effluent treatment, and characteristics of treated and untreated wastewater in terms of concentrations of Bio-oxygen demand (BOD), Chemical oxygen demand (COD), Dissolved solids (DS), Suspended solids (SS), and pH. It also asks for the economic or financial details about effluent treatment, consisting of capital stock, number of people employed and the wage bill, and material and energy input cost. Part III deals with environmental regulations faced by the factory. It seeks information about representations to the factory by NGOs and local people, court cases about air and water pollution faced and won by the factory, and the legal expenses incurred by the factory.

Methodology

The methodology of distance functions is used to estimate shadow prices of a vector of pollutants for water polluting industries in India. The data collected for a large number of polluting firms in India through two surveys, one conducted in 1995 and another in 2000, is used to estimate the output distance function.

Results

The estimates of shadow prices show that on an average, the cost to the Indian industry for reducing one ton of BOD, COD, and SS are respectively, Rs.18,696, Rs.45,104 and Rs.27,044. Large differences in the estimates of firm specific shadow prices of pollutants reflect the use of inefficient water pollution abatement technologies. The relationships between firm specific shadow prices or marginal costs of abatement of BOD, COD, and SS, and the index of compliance (effluent concentration ratio) show that there is an increasing marginal cost of pollution abatement. Using the taxes-standards approach to pollution control, the taxes necessary for making the firms comply with the national standards of water pollution are estimated. The estimated taxes for making the firms realise the standards of 35mg/l for BOD, 250mg/l for COD, and 100mg/l for SS are respectively given as Rs.20,157, Rs.48,826, and Rs.21,444 per ton. Physical and monetary accounts are developed for industrial water pollution in India. The estimates of net pollution loads of the industry and their monetary values are made.

These estimates provide inputs for developing environmental and economic accounts using the United Nations' Methodology of Integrated Environmental and Economic Accounting. The monetary value of net additions to stocks of BOD, COD, and SS are estimated as Rs.87,780.289 million for the year 1997-98. Given the estimate of net national product for India for the year 1997-98 as Rs.11,731,393 million at 1996-97 prices, the environmentally corrected NNP for India, corrected for industrial pollution is estimated as Rs.116,436,133 (11,731,393- 87,780.289) millions for the year 1997-98.

The possibility for the firms subjected to environmental regulations (Porter hypothesis) in the Indian water polluting industry to have win-win opportunities is examined. Using three-year panel data for 92 water-polluting firms, the stochastic output distance function and the equation explaining the relationship between technical inefficiency and the indices of environmental regulation (RI) and water conservation (CI) are jointly estimated. The coefficients of RI and CI are significant at one percent level, but the coefficient of time variable is not significant even at 10 percent level. A positive (negative) sign for the estimated coefficients of RI and CI shows that the lower (higher) the value of the variable, the higher (lower) the value of the technical inefficiency. The positive (negative) sign of the coefficient of time implies increase (decrease) of technical inefficiency over time. The signs of estimated coefficients of RI and CI in the model of technical inefficiency are positive, implying that the lower the RI and CI, the lower the inefficiency. In other words, the more the industry complies with the regulations, the more efficient it becomes. This result supports the Porter hypothesis. Water conservation results in the saving of costs to the industry, and thus contributing to an increase in productive efficiency. There may be potential complementarities between production of conventional output and reduction of pollution loads. With the abatement technologies involving process changes as opposed to the end–of-pipe treatment, the cost of jointly producing conventional output and a clean environment may be lower than the cost of producing them separately. Such complementarities might arise, for example, from cost savings associated with recovered or recycled effluents and reuse of wastewater. The proponents of Porter hypothesis argue that complementarities between environmental activities and conventional production, combined with the induced innovations associated with environmental requirement, can partially offset or actually exceed the direct expenditures associated with environmental protection.

Case Study: Indian Sugar Industry

A detailed study of the Indian sugar industry shows that the estimates of technical efficiency, scale economies, and the shadow prices of bad outputs for a sample of firms in the Indian sugar industry are sensitive to the specification of technologies and environmental regulation. The output and input distance functions with the assumption of weak disposability of bad outputs (a multi-product firm could not reduce one of the outputs without affecting the production of other outputs) account for the effect of environmental regulation on the productive efficiency of firms. In this context, the models of the firms' behaviour with the strong disposability assumption (a firm could dispose one of the outputs with out affecting other outputs) of bad outputs or relaxed environmental constraints could not accurately explain the input and output choices of firms. The estimates of indicators of firm's performance like technical efficiency, and scale economies could be sensitive to the assumptions about the environmental constraints they are facing. In the case of both output and input distance functions, the technical efficiency estimates made with the binding environmental constraint are found to be higher than those made with the relaxed environmental constraint. There are output losses due to binding environmental constraint relating to water pollution in the Indian sugar industry in the range of 3 to 5 percent. In the case of specification of technology of firms by the production functions, the environmental regulation in the form of pollution taxes for instance will make them to consider the waste disposal services as productive inputs for which they have to pay. The generalized production function with the environmental inputs as productive inputs will explain the firm's behaviour accurately. The cost of abatement of firms could be accounted and the shadow prices of bad outputs could be estimated using output and input distance functions with the assumption of binding environmental constraints. The output distance function assumes that there is a binding resource constraint on the firm making the reduction of bad output possible only by reducing the production of good output. However, the input distance function allows the firm to obtain additional resources to reduce pollution loads for a given level of good output.

The detailed analysis of a polluting firm's behaviour in taking decisions about outputs, inputs and pollution loads as attempted in this study provides inputs for designing an environmental policy. As shown, it provides inputs for estimating ENNP, and for the design of economic instruments. This study provides some guidelines for future research in the design of environmental policy in India.

Policy Implications

There is an urgent need for more research in Applied Environmental Economics to provide inputs into policy making.

- Generalised national accounts have a long way to go before they are designed along the lines of the UN methodology of 'Integrated Environmental and Economic Accounting', and before economic instruments, pollution taxes and marketable pollution permits are designed and implemented.
- In the absence of a reliable database about environmental economics in India, researchers have to rely on data from primary sources collected through specially conducted surveys. Hence, there is an urgent need to develop a strong and reliable database on environmental economics in India, which would require the coordinated efforts of relevant officials from government and private sectors as well as academia.
- Similar types of studies should be carried out in natural resource accounting for forest and agricultural sectors in India, and should aim at measuring the cost of sustainable use of forests for development purposes, and land and water for agriculture. The cost of sustainable use is the cost of shadow projects and abatement activities. To estimate the cost of environmentally sustainable use of land and water in agriculture, one can use the distance function methodology in the theory of production. The farmers may be facing regulation in terms of limits on ground water extraction, mining of soil nutrients, and avoiding water logging. In this case, output distance function can be estimated for the agricultural sector by describing the technology of farms as one of producing the good output (farm produce) and the bad outputs (salinity, water logging and nutrient loss). The estimated shadow prices for the salinity, nutrient loss, and water logging can be used to estimate the incremental cost of degradation of environmental resources due to agricultural production. By deducting this incremental cost from NNP, one can estimate ENNP corrected for agriculture.
- Detailed research studies about water and air pollution by the industrial and transport sectors are needed. A database for carrying out these studies has to be created by making it mandatory for the polluters to supply data on a regular basis as asked for in the questionnaire sent to them by the regulator. In that respect, the present study is limited as it deals with only the problem of water pollution because of poor responses in the survey from firms about air pollution related data. Even for water pollution, only 15 percent of surveyed firms could provide the detailed data needed.

Subsidies and the Environment: With Special Reference to Agriculture in India

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Introduction

Subsidies are a potent means of raising the consumption of a commodity or service, and thereby augmenting welfare. Besides commodity specific effects, subsidies also have macro effects and indirect effects arising from the interdependence between sectors or markets. The indirect effects of subsidies arise because of the inter-linkages in the production process. Several of these indirect effects may be harmful and unanticipated. The case of the environment being adversely affected by excessive subsidisation is a prime example. Excessive use of a subsidised product like fertilisers may do long term damage to the fertility of the soil. Similarly, subsidy-induced excessive use of water affects the fertility of land due to soil erosion and salinity. As in most countries, environmentally perverse subsides are common in India in many sectors as well. In the context of the global economy, perverse (both economically and environmentally) subsidies in six sectors namely energy, road transport, agriculture, forestry, fisheries and water have been estimated to be 5.3 percent of the global economy, and constitute about 80 percent of the total subsidies (estimated to be 6.8 %of the global economy) (Myers, et al, 1999). This is a serious indictment of the current subsidy regimes worldwide. Thus, perverse subsidy reform, so far an underplayed instrument of government policy, has a critical role to play in addressing environmental concerns.

This is not to say that all subsidies are bad and they cannot serve any useful purpose. There are many cases however, where subsidies can benefit the environment. Such subsidies include subsidies for reforestation projects, farming techniques or crops, which raise soil fertility. Similarly, expenditures on wetland protection, subsidies to encourage environment friendly technologies, to promote windmill farms and subsidies for the promotion of public transportation and to help reduce the use of private cars are some of the examples of subsidies beneficial to the environment.

Objectives and Scope

The objective of this study is to examine the interface between subsidies and the environment with a view to highlighting both the positive and adverse roles that subsidies may play in affecting the environment. While subsidies are interpreted in a broad way, our focus has been on subsidies that emanate from government budgets in India. The environment is affected by subsidies in a variety of ways. On the one hand, there are subsidies specifically designed to promote or benefit some aspect of the environment, e.g., subsidisation of an afforestation programme. On the other hand, there are subsidies that, while promoting some other economic objective (like agricultural output), have an indirect, and sometimes unanticipated effect on the environment. Often these effects may be adverse or harmful. In this study, an endeavour is made to identify and quantify budgetary subsidies that have a bearing on the environment, whether direct or indirect. While attempting to examine the nature and impact of the subsidy-induced effects on the environment, we especially focus on subsidies that often have a dual impact, positively affecting some aspect of the economy, and adversely affecting the environment during some phase of the life cycle of the subsidisation process.

Thus in the context of the environment, subsidies can be divided into two groups: environment-promoting subsidies and environment-degrading subsidies. It is quite likely that the volume of environment-promoting subsidies is small, and its impact is limited. On the other hand, the volume of the environmentally detrimental subsidies is large, although its environment degrading impact remains unrecognised, unmeasured, and unmonitored.

In analysing the environmentally perverse subsidies, this study focuses on three agricultural inputs – power, irrigation and fertilisers, in which, such perverse subsidies are reported to be pervasive. In so far as environmentally friendly subsidies are concerned, this study attempts to cover all such subsidies which emanate from the government budgets. In particular, the following may be listed: soil and water conservation, forest conservation, development and regeneration, afforestation and ecology development, flood control, anti-sea erosion projects, drainage, non-conventional sources of energy, environmental research, prevention and control of pollution, and sewerage and sanitation.

The specific objectives of the study are to:

- Provide an analytical framework for identifying the role and impact of subsidies on the environment — distinguishing, in this specific context, between positive and perverse subsidies
- Identify and measure the volume of environmentally friendly budgetary subsidies in India, both explicit and implicit, and analyse their inter-regional distribution
- Focusing on agriculture and degradation of natural resources in India, develop a framework to assess the implications of subsidies like those relating to irrigation water, power and fertilisers on environmental degradation, and identify the key indicators to be used for assessing the impact of subsidies on the environment

In this context, some critical issues that have been raised and examined in this study are:

- What may be the volume of the two types of subsidies?
- What are the areas where the budget supports an environment-promoting activity? In such cases what may be the volume of subsidy involved?
- Are we under-subsidising the promotion of the environment?
- Are we over-subsidising activities that damage the environment?
- What policy changes may be introduced in terms of modifying our subsidy regime for protecting and promoting our environment?

Methodology

A: In measuring the volume of budgetary subsidies in India that have a bearing on the environment, both the Central budgets and State budgets are covered. Subsequently, these environment-related subsidies are divided into two categories: one group where the subsidies are designed to have a positive impact on the environment, and another group where, as a result of subsidising some other aspect of the economy, the environment may get adversely affected.

In the case of some subsidies, there may be *prima facie* grounds to believe that these will have a positive impact on environment. For example, subsidies for sewerage and sanitation, or subsidies for non-conventional sources of energy are likely to have a beneficial effect on the environment. Subsidies like environmental forestry and wildlife, soil and water conservation and fisheries can also be considered as necessary for environmental protection.

However, there are several budgetary heads where subsidisation may have a mixed or adverse effect. For example, in the case of 'irrigation', subsidisation may lead to both positive and negative effects. It is important to note that it is not the *activity*, but the *subsidy* that may be classified as perverse. Irrigation as an activity is extremely beneficial to agriculture. In fact agricultural land covered under irrigation in India is about 35 percent, which is quite poor. So, apparently any subsidy targeting irrigation should have a positive effect. But excess use of water due to excess subsidisation of irrigation may damage the fertility of soil, having an adverse impact. When subsidy is given in excess, it leads to problems that may sometimes be unanticipated. The environment may be adversely affected by the overuse and inefficient use of resources due to improper pricing engendered by the subsidies. It is therefore important that, while framing a subsidy policy and determining agricultural prices, the shadow price of environmental resources be properly taken into account.

The volume of subsidies has been estimated for these budgetary heads for all the Indian states and the Central Government for the years 1994-95, 1995-96 and 1996-97. All the basic data is drawn from the Finance Accounts of the Central and State governments.

Subsidies are measured as unrecovered costs of governmental provision of goods and services that are not classified as public goods. The unrecovered costs are measured as the excess of aggregate costs over receipts from the concerned budgetary head. The main elements of the methodology are described below.

Measurement of subsidy requires (i) identification of budgetary heads that can be interpreted as other than pure public goods, (ii) estimation of costs, and (iii) estimation of receipts. Costs themselves have two components: current or variable costs and annualised capital costs. The current (revenue) expenditure on a budgetary head is taken as the variable cost. The capital cost is worked out as the expected annual return on the stock of capital in the form of equity, loans or ownership of capital assets.

Costs:

Aggregate costs may be written as:

$C = RX + (i+d^*) K_0 + iZ_0$

Here, RX = Revenue expenditure

i = Effective interest rate

d* = Depreciation rate

K_0 = Aggregate capital expenditure at the beginning of the period pertaining to the budgetary head

Z_0 = Sum of loans and equity investment at the beginning of the period pertaining to the budgetary head

Receipts:

Aggregate receipts may be written as:

$R = RR + (I + D)$

Here, RR = Revenue Receipts

I = Interest receipts

D = Dividends

Subsidy is defined as:

S = C – R, where S is the calculated subsidy.

Estimation of Capital Cost:

Since estimates are made with respect to a financial year, annualised cost of capital needs to be estimated. In this context, two rates are important: the depreciation rate and the effective interest rate.

In estimating the depreciation rate, the average life of a capital asset is taken to be 50 years. The depreciation rate is worked out as a function of the parameters, viz., the rate of growth of nominal investment (z) and the long term rate of inflation (p). This methodology is relevant in the case of investment data given in Finance Accounts, which are accumulated as stock in the terms of the nominal values prevalent in the year of acquisition of the asset. The depreciation rate is given by d* as indicated below.

$$d^* = \frac{1/50.\{1 + w + w^2 + \dots\dots + w^{49}\}.(1 + p)}{\{1 + x + x^2 + \dots\dots + x^{49}\}}$$

with $w = (1+p)/(1+z)$

and $x = 1/(1+z)$

Here, p is the long term rate of inflation and z is the growth rate of investment. ‘p’ has been taken to be 7.98% and ‘z’ has been calculated to be 12.35%. d*, the depreciation rate, was calculated to be 0.05247, that is 5.25%, by the above method.

Apart from depreciation, we also require the effective interest rate to indicate the opportunity cost of funds. This is to be used in the case of all categories of capital expenditure, i.e. loans and advances, equity investment and own capital expenditure on the functional head.

The effective interest rates, calculated as interest payments as percentage of total borrowing by the concerned government (Centre/State), were obtained state-wise and year-wise from the interest and loans data given in the *Finance Accounts.*

B. Next, the study provides a framework to identify the impact and assess implications of environmentally perverse subsidies on the environment. This section also provides a framework to identify the environmentally optimal levels of input use to derive the price changes needed in order to move the consumption towards optimum. It then presents a dynamic framework for obtaining an environmentally optimal nitrogenous fertiliser price regime.

Results

A.

- Subsidies identified as having a bearing on the environment account for less than 1 percent of the GDP, Centre and States considered together. Of these, subsidies having a clear positive impact on the environment are only a small fraction.
- Division of subsidies between centre and states shows that Environment-related (ER) subsidies emanate relatively more from the state budgets.
- Centre has a relatively higher share in some of the Group B subsidies. Inter-state comparisons of per capita ER subsidies indicate that:
    - Per capita subsidy is higher for states with higher per capita incomes
    - A substantial share of ER subsidies pertains to irrigation
- A positive relationship is seen when per capita revenue expenditure on environment promoting schemes is plotted against per capita income of the state, indicating that the propensity of a state to invest in environmental subsidies depends largely on the financial condition of the state.
- Subsidies relating to major and medium irrigation, minor irrigation and soil and water conservation had the largest share in ER subsidies for most states.

Table 1:Group A and Group B Subsidies of Centre and States (1994-95 to 1996-97) (Rs. crore for agg. & Rs. for per capita)

		1994-95	1995-96	1996-97
Group A Subsidies (Aggregate)	Centre	333.89	664.76	624.18
	States	2831.96	2986.45	3596.76
Group B Subsidies (Aggregate)	Centre	4986.85	5714.27	5847.11
	States	13718.96	15228.34	17484.72
Group A Subsidies (Per capita)	Centre	3.64	7.24	6.80
	States	30.92	32.61	39.28
Group B Subsidies (Per capita)	Centre	54.32	62.24	63.69
	States	149.81	166.29	190.93

Note: Per capita estimates for Centre are for the national population

Table 2: Environmental Subsidies: Inter State Comparison (1996-97)

State	Group A Subsidies		Group B Subsidies	
	Aggregate (Rs. Crore)	Per Capita (Rs.)	Aggregate (Rs. Crore)	Per Capita (Rs.)
Andhra Pradesh	167.69	23.44	1879.12	262.63
Arunachal Pradesh	23.43	241.16	22.45	231.08
Assam	163.22	67.18	178.31	73.39
Bihar	201.48	21.69	946.60	101.89
Delhi	37.17	34.16	6.30	5.79
Goa	12.06	92.04	52.43	400.34
Gujarat	191.43	42.76	1746.72	390.18
Haryana	81.51	45.25	532.43	295.54
Himachal Pradesh	46.79	82.33	56.91	100.15
Jammu & Kashmir	97.61	115.36	96.32	113.84
Karnataka	209.67	43.11	1482.84	304.86
Kerala	198.60	63.91	322.47	103.77
Madhya Pradesh	416.81	57.67	1167.80	161.56
Maharashtra	551.17	64.58	3312.85	388.14
Manipur	41.07	199.34	63.46	307.99
Meghalaya	27.75	139.40	10.60	53.22
Mizoram	14.86	191.58	2.84	36.62
Nagaland	21.80	159.75	8.47	62.04
Orissa	137.40	40.31	672.69	197.37
Punjab	97.25	44.25	591.52	269.17
Rajasthan	117.22	24.30	1128.40	233.96
Sikkim	12.31	269.71	3.16	69.20
Tamil Nadu	152.28	25.54	431.03	72.28
Tripura	26.09	84.36	30.22	97.72
Uttar Pradesh	377.08	24.76	2298.63	150.91
West Bengal	173.02	23.50	440.14	59.79
Total	3596.77	39.28	17484.71	190.93

Table 3:

(Rs.)

Average GSDP Per Capita	States	Per Capita Environment-Related Subsidies (Avg. 94-95 to 96-97)	
	General Category	Group A	Group B
4753	Bihar	20.09	96.47
6615	Orissa	37.47	175.7
6763	Uttar Pradesh	20.01	138.8
7925	Madhya Pradesh	48.44	149.01
8337	Rajasthan	33.00	209.29
9422	West Bengal	20.26	52.68
9484	Himachal Pradesh	79.70	96.28
10292	Andhra Pradesh	18.03	215.84
10308	Kerala	53.26	97.24
10575	Karnataka	37.34	260.91
11535	Tamil Nadu	22.93	66.25
14998	Gujarat	39.24	339.46
15934	Haryana	40.64	327.28
17438	Maharashtra	50.07	326.71
18392	Punjab	39.76	226.82
21609	Goa	83.83	334.06
	Special Category		
5593	Tripura	78.10	92.69
7551	Assam	65.85	70.14
7934	Manipur	158.24	292.22
8915	Meghalaya	129.75	45.04
10201	Mizoram	189.80	39.04
10352	Sikkim	209.79	64.18
11861	Nagaland	123.46	51.04
11871	Arunachal Pradesh	230.76	210.56
24257	Delhi	22.19	4.76

B.

The analytical framework presented in Chapter 3 allows one to identify the impact of input use on environmental quality and crop yield. The model incorporates the environmental variables directly into the farm production function. The strength of the framework lies in its straightforward applicability. From the framework, environmentally optimal levels of input use can be identified, which also serve to derive the input price changes needed in order to move the farmers towards the social optimum.

The study also addresses the issue as an optimal control problem to obtain a price structure for the given input that will address the problem of overuse and will be environmentally optimal. This is done for nitrogenous fertilisers where the control variable for the social planner is the price of the fertiliser.

It is shown that given the initial nitrogen fixed in the system No, the environmentally optimal solution is to choose an initial price P0, such that the ordered pair (N0, P0) lies on a stable branch, then the dynamic forces of the model, represented by the solution of simultaneous equation system, lead to an inter-temporal equilibrium. This gives the environmentally optimal price of nitrogen fertiliser , and the stable branches give the environmentally optimal time path of the nitrogen price. If the system is not on one of the stable branches, the dynamic forces of the model lead to a situation of either (i) ever-increasing N accompanied by ever-decreasing P, or (ii) ever-increasing P accompanied by ever-decreasing N. Clearly, none of these is sustainable.

Assessment and Conclusion

The Indian scenario with respect to environment today seems mixed. On the one hand, we have states investing in agricultural input subsidies for short-term increases in agricultural output, which may potentially harm agriculture itself through a degeneration of the environment in the longer run. On the other hand, we also find that adequate environmental protection is missing in states where it is most desirable. The environmental problems of the country today call for appropriate and reliable data generation, which would help in truly analysing the existing conditions and in framing related directives and policies.

Conventional economic analysis obscures the degradation of the natural resource base that supports the economy including the agriculture of a country. Changes in the productivity and availability of natural resources simply are not taken into account. Economic research documenting the relationship between farm practices and environmental degradation is scanty.

The following points need to be taken into consideration:

- Apart from increasing environmental awareness, correct pricing of environmental resources needs to be brought about and sustainable agriculture encouraged.
- The fact that environmental resources cannot be exploited indefinitely needs to be realised and steps need to be taken to ensure their optimal usage.
- Distortionary and environmentally harmful subsidies should be reduced appropriately so as to curb their harmful effects on the environment. For this, the cost of the environmental resources has to be incorporated in the market price of the agricultural inputs to induce its correct usage. The revenue that would be generated from such a policy would be two-fold: first, through the reduction of the subsidy itself, and secondly, via the increased market price.
- Subsidisation programmes should not be thought of as static exercises. Rather they should respond to their past history and the user charges that are levied in the concerned sector. Viewing subsidies in terms of a life cycle where they may grow in importance initially or in an expansion phase, reach a maximum and then are rolled back in the contraction phase may be the best method of promoting relevant objectives in a sector. When appropriate changes do not take place in response to the history of the subsidy and the external environment, the expansion phase may be over stated and contraction may prove to be very difficult. Subsidy programmes that are not scrutinised with respect to their desired life cycle pattern may prove to be more harmful than beneficial. Recognising a suitable life cycle is especially important in the context of environment.

Delineation and Dissemination of Corporate Green Accounting: Procedures with Case Studies in Medium Sized Textile, Pharmaceutical and Chemical Industries

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Introduction

Corporate Environmental Accounting or **Green Accounting** is a method of improving business decision-making with recognition of the increasing environmental challenges and opportunities posed to businesses today. It does this by identifying misallocated internal and external environmental resources and allocating them to particular products or processes. Environmental accounting provides firms with true costs of their products and processes, thus leading to better business decisions and sustained profitability, over the entire life-cycle of the product/services.

Business corporations need to internalise environmental issues in their decision- making. Corporate environmental accounting serves as a tool in the hands of management in that direction. Currently, a structured framework for the inclusion of environmental costs in corporate accounts is not available. Therefore, the present study has been undertaken to help delineate a framework for explicit inclusion of environmental costs and benefits in the accounting practices, and its validation through case studies in medium sized industries.

Four medium sized industries, viz. Indian Oil Blending Ltd. (Petrochemical), Paithan Silk Mills Ltd. (Textile), Kedia Chemicals Ltd. (Chemical), and Eskay Fine Chemicals Ltd. (Pharmaceutical) have been identified as case studies to validate the proposed framework for Corporate Environmental Accounting.

Objectives

The objectives of the project were:

- Delineation of a Corporate Green Accounting framework appropriate for accounting practices in India incorporating environmental costs and benefits of production processes in vogue.
- Validation and dissemination of the framework for usage in medium sized chemical, textile and pharmaceutical industrial units.
- Monetization and demonstration of cost-effectiveness of pollution prevention and waste minimisation practices with recourse to corporate green accounting framework in four industrial units.

Methodology

The methodology followed consisted of the following procedures:

- Establishing an evaluation team comprising representatives from production, engineering, accounts, stores, and R&D divisions.
- Studying manufacturing process, and material and energy balance in the industry.
- Identifying waste generating (Environmental Cost) centres.
- Identifying process emissions and effluents, their location, quantification and categorisation.
- Identifying pollution prevention and waste minimisation opportunities.
- Evaluating the economics of pollution prevention programmes.
- Evaluating social costs.
- Studying accounting practices in the organisations.
- Listing out environment related activities after discussion with the evaluation team.

- Identifying entries in the account books for the following:
  - Capital expenditure for procuring and installing pollution prevention equipment.
  - Depreciation for the above equipment.
  - Operating and maintenance cost (labour, power, consumables, and spares).
  - Monitoring and Pollution Control (compliance costs).
    - § Pollution Control Board fees.
    - § Cost towards emissions and effluents monitoring.
    - § Penalties and fines paid, if any.
    - § Training of employees for ISO 14000.
    - § Record keeping for characteristics of emissions and effluents.
  - Cost towards ISO 14000 implementation and any other environmental management systems.
  - Green belt development and maintenance cost.
  - Collect information regarding benefits from pollution prevention activities.
    - § Quantify operational and maintenance requirements, material and power consumption.
    - § Quantify emissions and effluents reduced/recycled.
    - § Monetization of benefits.
  - Identify accounting codes/ heads.
  - Discuss how and who will maintain the identified accounting heads.
  - Generate data for quarter/annum, and review.

Delineation of Green Corporate Accounting Framework

Environmental cost has to be accounted in the same manner as in the case of other costs, as it also affects the bottom line considerably. Green Accounting describes how goods and services should be priced to reflect their true costs (including environmental and social costs). In Green Corporate Accounting, the natural resources are redefined as assets in company ledgers, and the environmental costs are built into a product's cost.

A standard Green Accounting framework is presented in *Table 1a & 1 b*. This framework has been delineated with special reference to Indian corporate sectors. It is fluctuating in nature and could be easily used in different industrial sectors, whether they are large or medium scale. For its validation and its effective dissemination to Indian corporates, four sample industries each from different sectors viz. Petrochemical, Chemical, Textile and Pharmaceutical have been identified as case studies.

The method for evaluating Cost-of-Pollution to Society was delineated (*Table 2*).

One of the case studies, Green Accounting Framework for Paithan silk Mills Ltd. (Textile) is presented in this summary report.

Table 1a: Green Accounting Framework for Corporate Sector

Cost elements			Units of measure	Consumption	Unit cost (Rs.)	Total cost (Rs.)
Fixed Cost	Depreciation on pollution control equipments					
	Expenditure for implementing ISO 14000 / EMS					
	Expenditure saved due to installation of equipments and/or through technology upgradation for Cleaner Technology					
	Other Tax exemptions and Benefits					
	Sub total					
Waste Management	Solid waste	Handling				
		Treatment				
		Recycle / Reuse / Sold as scrap				
		Disposal				
		Sub total				
	Liquid waste	Handling				
		Treatment				
		Recycle / Reuse / Sold in market				
		Disposal				
		Sub total				
	Air Emissions	Handling cost				
		Treatment cost				
		Recycle / Reuse / Sold in market				
		Disposal cost				
		Sub total				
Environmental services	Compliance/Surveillance Audit					
	Environmental Monitoring & Reporting					
	Environmental facility O & M	Water				
		Chemicals				
		Energy				
		Labour				
	Sub total					
Social costs	Damage caused by Air Pollutants to Health and Vegetation					
	Damage caused by Wastewater Pollution to Health and Vegetation					
	Damage caused by Dumping of Solid waste to Health and Vegetation					
Safety Aspects	First Aid Facility					
	Safety Measure's Expenses					
	Medical Compensation					
	Routine Diagnostics					
	Sub total					
Grand Total						

Table 1b: Green Corporate Accounting Framework Integrated with General Accounting

Cost elements				Units of measure	Consumption	Unit cost (Rs.)	Total cost (Rs.)
Raw Materials		A					
		B					
		Sub total					
Utilities	Energy	Electrical					
		Thermal	Fumace Oil				
			LDO				
			Diesel				
	Water	Process use					
		Others					
		Sub total					
Fixed Costs		Packaging					
		General services & Admin.					
		Labour	Direct				
			Fixed				
		Divisional overhead					
		Depreciation					
		Sub total					
Waste Management		Solid waste	Handling				
			Treatment				
			Disposal				
			Sub total				
		Liquid waste	Handling				
			Treatment				
			Disposal				
			Sub total				
		Air Emissions	Handling				
			Treatment				
			Disposal				
			Sub total				
Packaging material inventory		Sold as scrap					
		Reuse					
		Disposal					
		Sub total					
Environmental services		Compliance/Surveillance Audit					
		Environmental Monitoring & Reporting					
		Environmental facility O & M					
		Sub total					
Social costs		Total Damage caused by Air Pollutants to Health and Vegetation					
		Total Damage caused by Wastewater Pollution to Health and Vegetation					
		Damage caused by Dumping of Solid waste to Health and Vegetation					
Safety Aspects		First Aid Facility					
		Safety Measure's Expenses					
		Medical Compensation					
		Routine Diagnostics					
		Sub total					
Grand Total							

Table 2. Identification of Stressors and their Potential impacts for the manufacturing process of a product

Stressors	Potential Impacts
Emission / Burden on air: Hazardous chemicals	
Inorganic	Human health
Metals	Human health
Organic	Human health
Emission / Burden on air: Gases	
CO	Human health
SO_2	Human health, Human welfare, Environmental resources
Nox	Human health, Human welfare, Environmental resources
Oxidants	Human health, Human welfare
GHG	Global climate
Aerosols/Particulate (PM-10)	Human health, Human welfare
Particulate (>PM-10)	Human health, Environmental Resources
Electro Magnetic Radiation	Human health, Environmental Resources
Noise	Human health, Aesthetics
Potential Emission / Burden to Water: Hazardous chemicals	
Inorganic(non metals)	Human health
Metals	Human health, Environmental resources
Organic	Human health, Environmental resources
BOD/COD	Environmental resources
Exotics	Human welfare, Environmental resources
Acids / Bases	Environmental resources
Waste products	Environmental resources
Acid deposition	Environmental resources
Suspended solids	Environmental resources
Water diversion / withdraw	Environmental resources
Thermal alteration	Environmental resources
Potential Emission / Burden to Land: Hazardous chemicals	
Inorganic (non metals)	Human health
Metals	Human health, Environmental resources
Organic	Human health, Environmental resources
Waste products	Environmental resources
Acid deposition	Environmental resources
Soil erosion	Environmental resources
Land use	Human welfare

Identification and Classification of Pollution Damages

The major impact can be summarised as follows:

- Impact on Human Health
- Impact on Human Welfare
- Impact on Aesthetics
- Impact on Environmental Resources
- Impact on Global Climate

The identified potential Stressors and impacts are then screened and categorised into four categories to estimate the cost of pollution to society:

- The impact that could be mitigated (*C1*)
- The impact that is relatively low (*C2*)
- There is not enough scientific information available for a quantitative assessment of the impact (*C3*)
- A quantitative assessment of the impact can be completed (*C4*)

Based on the screening classifications (C1-C4), the impacts of category C4 are assigned full or partial economic valuation; category C3 impacts are qualitatively assessed and analysed separately; C2 impacts are deleted from ith mitigation of C1 impacts are included in calculations of pollution prevention cost.

Case Study - Textile Processing Industry

- Paithan Silk Mills Ltd (PSML) is a small-scale textile-processing unit that dyes and finishes pure cotton, polyester-cotton, bright polyester and nylon fabrics.
- Paithan Mills has a built-up capacity for processing 5,00,000 m of cloth per month, but were operating at 50 percent of its installed capacity during the study.
- Stake holder analysis was performed (*Table 3*)
- Environmental Cost Centres of the industry were identified (*Table 4*)
- Thermal energy audit revealed that reducing the stack temperature could enhance the efficiency of the Boiler and Thermic Fluid Heater. The cost benefit analysis of fuel savings that accrue through adopting remedial measures was made (*Table 5*)
- Implementation of Effluent Treatment Plant was suggested to PMSL for possible recycling of treated wastewater, and the effluent treatment plan was monetized (*Table 6*)
- The Environmental Costs for 1997-2000 were evaluated (*Table 7*)
- Waste minimisation options and recommendations for reducing environmental costs were delineated and disseminated to PSML

Table 3: Stakeholder analysis of PSML

Stakeholders	Expectations from PSML
Paithan Silk Mill Ltd.	• Excellent quality product • Maximization of contribution towards profit while keeping the expenditure to minimum
Customers	• Excellent quality product • On time delivery • Minimal prices
Suppliers	• Continual demand for raw materials • Timely payments
Employees	• Job satisfaction and security • Satisfactory wages
Pollution Control Board	• Industry abiding by the Pollution Control board standards for emission and effluent discharge at all times
Neighbouring industries	• Healthy relations • No nuisance causing actions
Society	• Non-polluting industry • Generation of jobs • Improvement of the infrastructure of the surrounding areas
Environment (Air, Water, and Land)	• Zero emission or disccharges to the environment • Optimum use of water and electricity • Development of green belt in the surrounding areas
Maharashtra Industrial Development Corporation	• Continual purchase of water
Maharashtra State Electricity Board	• Continual purchase of electricity
Packaging materials suppliers and disposers	• Continually increasing demand
Shareholders	• Increase in share value
Government	• Payment of taxes

Table 4. Environmental Cost Centres and details of wastes generated a PMSL

Environmental Cost Centre	Operation / process	Composition
a. Nylon parachute processing		
Stenter	Water Wash	Suspended solids
Scouring Jigger I	Water Wash	Suspended solids
Jigger II	De-rusting	Oxalic acid
Jigger II	Peroxide treatment	Sodium carbonate
Wash trough	Cold & Hot wash	Suspended solids
Wash trough	Acidification	Acetic acid
Stenter trough	Silicone treatment	Silicone
b. Bright polyester goods processing		
Jet scouring machine	Water wash	NaOH, Scouring agent
Scouring machine	Sc. Agent treatment	NaOH, Scouring agent
Jigger	De-rusting	Oxalic acid, HCl
Wash trough	Cold & Hot wash	Suspended solids
Jet machine	Peroxide treatment	Sodium carbonate
Wash trough	Cold & Hot wash	Suspended solids
Squeezing machine	Squeezing	Suspended solids
c. Polyester-Cotton Fabric Processing		
Desizing jigger	Desizing	Wastewater
Wash trough	Cold & Hot wash	Wastewater
Wash trough	Hac wash	Acetic acid
Jet dyeing machine	Polyester dyeing	Acetic acid
Jet dyeing machine	Cotton dyeing	NaOH, Dye
Bleaching	Peroxide transfer	Wastewater
Wash trough	Soap wash	Soap
d. Steam generation and Thermic fluid heating		
Boiler	Steam generation	Flue gas
Thermic Fluid Heater	Heating thermic fluid	Flue gas

Table 5. Cost:Benefit Analysis of implementing remedial measures in the Thermal Energy sector

Items			Values
Total oil consumption			3,49,000 litres per annum
Fuel cost per annum			Rs. 38,39,000
Total annual monetary savings on fuel cost			Rs. 2,45,495
Through reduction in stack temperature of the boiler	Rs.	61,776	
Through recycling of steam condensate	Rs.	98,841	
Through insulation of valves	Rs.	84,842	
Cost of implementing the necessary modifications			Rs. 2,62,000
Tilting of fuel storage tanks, relocation of the drain valve	Rs.	5,000	
Insulation of valves	Rs.	1,32,000	
Piping for redirection of steam condensate	Rs.	1,00,000	
Miscellaneous expenses	Rs.	25,000	
Investment Payback Period			**13 months**

Table 6. Monetization of suggested treatment plan

Capital investment for suggested treatment plant	**:**			**Rs. 3,50,000**
• Machineries	:	Rs.	3,00,000	
• Construction	:	Rs.	50,000	
Operating Cost (per annum)				**Rs. 2,66,915**
• Chemicals (@Rs. 686/day)	:	Rs.	2,16,090	
• Power (@ Rs. 61/day)	:	Rs.	19,215	
• Labour (315 Man days, @ Rs.60/d)	:	Rs.	18,900	
• Miscellaneous (@10% O&M cost)	:	Rs.	12,710	
Savings				
• Present expenditure on water supply and disposal (60 cum/ per day)	:	Rs.	1200/day	
• Total O&M cost for suggested treatment	:	Rs.	847/day	
• The savings by reuse of treated water:				
◆ Daily Savings (1200- 847)	:	**Rs.**	**353 per day**	
◆ Yearly savings	:	**Rs.**	**1,11,195**	
Capital Expenses Pay Back period				**38 months**

Table 7. Environmental costs for 1997-2000

Description	1999-2000	1998-99	1997-98
Production (m)	2,50,000	2,66,000	2,48,000
Expenditure (Rs. Lakhs)	1,38,75000	1,46,83,200	1,36,64,800
Income (Rs. Lakhs)	1,03,75000	1,05,33,200	1,02,86,800
Profit (Rs. Lakhs)	-35.00	- 41.50	-33.78
Capital investment for pollution prevention system (Rs. Lakhs)	16.83	19.80	23.30
Environmental cost (Rs. Lakhs)			
Depreciation	2.52	2.97	3.45
Environmental Monitoring & Reporting (MPCB)	0.05	0. 05	0. 04
Effluent treatment cost	0.84	0.84	0.79
CETP costs	0.10	0.10	0.09
Environmental services (MIDC)	0.25	0.25	0.20
Green belt development and maintenance	0.96	0.75	0.60
Total Environmental costs (EC) (Rs. Lakhs)	4.72	4.96	5.17
EC per meter of product (Rs)	1.89	1.86	2.08

A Study on the Effect of Pollution Control Scheme on Output and Prices of Different Goods and Services of the Indian Economy

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Introduction

Air pollution, water and solid effluents and thermal pollution from industries are assuming importance with the rapid population growth of the country. There is an increasing demand for water in irrigation, human and industrial consumption. The available water resources are getting depleted and water quality has deteriorated.

There are only a few studies on quantitative analysis involving interdependence between water pollution and economic activities. This study attempts to present an in-depth quantitative analysis with detailed and current data linking the economy and water pollution in different sectors of the Indian economy.

Objectives

The objectives of the present study are to:

- Study the total amount of water pollution generated directly and indirectly in different sectors of India
- Develop a water quality index
- Study the effect of pollution abatement scheme on the output and prices of different goods and services
- Suggest some policies and also study the implications of such policies on pollution generation and pollution management in India

Methodology

The input-output framework has been extended here to account for water pollution generation.

Model I

To study water pollution generation associated with inter-industry activity, let us consider a matrix of pollution output coefficient, denoted by W [W_{kj}]. Each element of this is the amount of water pollutant type 'K', (for example, chloride, sulphide) generated per Rupee's worth of industry 'J's output. Hence, the level of water pollution associated with a given vector of total outputs can be expressed as

$$R = WX$$

where R is the vector of pollution level. Hence by multiplying the traditional Leontief's inverse matrix $(I-A)^{-1}$, we can compute $R^{/}$,that is, the total pollution of each type generated by the economy directly and indirectly by different sectors.

$$R^{/} = W (I - A)^{-1}$$

Here

$R^{/}$ is the direct and indirect water pollution coefficient matrix of different sectors (K x n)

W is the direct water pollution coefficient matrix of different sectors (K x n)

$(I - A)^{-1}$ is the Leontief matrix multiplier of different sectors (n x n).

Model II

Model II a

The model has further been extended to incorporate pollution abatement cost, in a straightforward manner by introducing a sector of clean water instead of pollution producing sector with negative entries, and a anti - pollution sector. This can be presented in the matrix form as formally described below:

$$\begin{bmatrix} I - A_{11} & - A_{12} \\ -A_{21} & I - A_{22} \end{bmatrix} * \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} = \begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix}$$

or,

$$\begin{bmatrix} X_1 \\ X_2 \end{bmatrix} = \begin{bmatrix} I - A_{11} & - A_{12} \\ -A_{21} & I - A_{22} \end{bmatrix}^{-1} * \begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix}$$

A_{11} is the original input-output matrix (without abatement)

A_{12} is the input structure coefficients of 'clean water' sector.

A_{21} is the matrix of direct clean water output coefficients

A_{22} is the clean water output coefficient matrix for clean water production

X_1, Y_1 are respectively the original output and final demand vectors (without abatement).

X_2, Y_2 are respectively the total output and final demand for the clean water sector.

Then from the model the impact of the abatement cost on the output can be studied.

Model IIb

To express the effect of pollution abatement cost on prices of different goods and services, the original input-output model has similarly been extended to account for the 'clean water' sector, as described above in case of the output model, and formally presented below:

$$\begin{bmatrix} P_1 \\ P_2 \end{bmatrix} = \begin{bmatrix} I - A_{11} & - A_{21} \\ -A_{21} & I - A_{22} \end{bmatrix}^{-1} * \begin{bmatrix} n_1 \\ n_2 \end{bmatrix}$$

where,

P_1 is the prices of different goods and services

P_2 is the prices of producing one unit of clean water

n_1 is the value-added coefficients of different products

n_2 is the value added in clean water sector per unit of clean water produced.

And A_{11}, A_{12}, A_{21}, A_{22} have the same interpretation as discussed earlier in the case of the output model.

Data

The present study is based on the secondary data. The major data used for the work are:

- The Input-Output table.
- The different types of water pollutants generated by the different industries of India.
- Cost data

Input-Output Data

The study has used the latest input-output table of India (1989-90) prepared by the CSO. This table consists of 115*115 sectors. For the sake of convenience the input-output table has been aggregated into 32 sectors.

We have obtained 10 types of water pollution data. Water pollutants generated by the different Indian industries are mentioned below:

- Suspended solids (SS)
- Dissolved solids (DS)
- Chloride, Sulphide, Zinc
- Phenol, Oil and Grease
- Biochemical Oxygen Demand (BOD)
- Chemical Oxygen Demand (COD)
- Other pollutants such as nitrogen, chromium, cyanide, Alkalinity, etc.,

Cost Data

In the present study we dealt only with the operational (or running / recurring) cost aspects of the pollution abatement measures. Running cost of the treatment plant includes cost of power, salaries of the staff, chemicals used, maintenance, repairs and depreciation. The main emphasis is given only on BOD removal. Of the running cost items, cost of power and chemicals (inorganic) used have been treated endogenously into the system and the salaries of the staffs, cost of operation and maintenance exogenously as components of Gross Value Added.

Results

Experiments with Model I

The direct water pollution coefficient represents the direct effect of pollution generation within a sector and the total coefficient (direct plus indirect) represents the indirect effect of pollution generation among other related sectors.

The results show that the amount of total pollution generation per unit of the output of the product is significantly higher for all industries compared to direct pollution generation. For example, direct pollution coefficients of leather industries are found to be 0.0015, 0.0071, 0.0023, and 0.0007 for SS, DS, Chloride, and Oil, Grease and others respectively per million Rupees of output. Whereas the total pollution coefficient of this industry is 0.0030, 0.0094, 0.0030, 0.0002, 0.0038 for the same pollutants respectively, which is much higher compared to direct coefficients. Thus one cannot simply look at the size of the direct water pollution coefficients, but must also consider the size of the total coefficients (direct plus indirect). In case of Livestock industries indirect pollution generation is found to be insignificant.

Experiment with Model II and Results

This model dealt with the pollution abatement activities including abatement cost in production, which, in turn, will affect the price and output of different industries. The analysis shows that the demand for all the output of different sectors has changed and the prices of all the sectors have increased. It is evident from the study that the Inorganic Chemicals industry experiences a higher percentage increase in output (13.5%) followed by Construction (3.2%) and Mining and Quarrying (2.6%). It is also observed that the percentage price increase is higher for Livestock's (11.4%) followed by Leather Products (1.9%).

Conventional national accounts focus only on the market transaction and indicators that reflect important factors in welfare generation, but they do not measure welfare itself. By not accounting for the private and social costs of the use of natural resources (water resources) and the degradation of the environment, conventional accounts may send wrong signals of progress to decision makers. So, EDP (Environmentally Adjusted Domestic Product) must be done along with NDP (Net Domestic Product) annually. In this study, NDP is Rs. 3835789.6 million, while we arrive at a EDP of Rs. 3700704.1 million. Based on our study, considering only "water resources", we observed that in India (1989-90) EDP falls back by 3.52 percent of GDP. If other natural resources could be accounted for then the situation could be much worse. Further research in this field is needed.

Conclusions

The direct water pollution coefficient counts the direct effect of pollution generation within a sector and the total coefficient (direct and indirect) counts the indirect effect of pollution generation among other related sectors. The results show that the amount of total pollution generation per unit of the product is significantly higher for all industries compared to direct pollution generation coefficient. Thus one can not simply look at the size of the direct water pollution coefficients, but must also consider the size of the total coefficient (direct and indirect).

It is observed from the study that the whole economy will be affected due to pollution control measures. The government can use a variety of regulatory and economic instruments to reduce water pollution. Some contributions have been made in the form of policy suggestions incorporated in this study. Through these, it is evident that the price system would also differ if, instead of voluntary action or obeying a special law, each industry under takes to eliminate pollution at its own expense, and as a result, pays off an appropriate proposed tax for pollution generation. The present study has considered: (1) the pollution taxes charged per ton of BOD generation; (2) taxes imposed on those sectors that have no Effluent Treatment Plant (ETP), and subsidies given to the sectors that have ETP; (3) taxes on sectors that make use of pollution generating inputs in their production process, and (4) the effect of water cess on prices @ Rs. 0.05 and 0.25 per kilo of water consumed. From the study, it is apparent that the price of the product will be more if sectors are taxed than if the pollution control schemes have been undertaken. Further, the product will be cheaper if subsidies are given to those sectors that have ETP. In the latter case, price also increases, but this increase is very negligible.

Recommendations

- There is a need to generate detailed adequate and recent data on water pollutants.
- Detailed break-up of the total cost of pollution abatement activity was available and possible to analyse for only 10 industries, and only for one or two units of a particular industry. For more effective and socially useful results, however, the study requires a detailed, complete and recent data set on the cost of abatement of all the industries within the economy.
- Finally, note should be made of the non-availability of the effluent character of the wastewater and solid waste coming out from any Effluent Treatment Plant (ETP), as required for proper and complete construction of Water Quality Index.

India: Environmental Management Capacity Building Project

The Ministry of Environment & Forests (MoEF), Government of India implemented a programme with assistance from the World Bank, titled "India: Environmental Management Capacity Building (EMCaB)".

The programme ran from 1998 to 2003. Its purpose was to enhance the capacity for the application of economic principles and tools for environmental management in India across a full range of issues such as priority setting, cost-benefit analysis of alternative policies for pollution control, resources management and biodiversity conservation. These objectives are achieved through curriculum development, preparation of text books and teaching materials in environmental economics, programmes for faculty upgradation through short courses in India, and supplementing them with a few overseas fellowships, training for practicing non-academic economists and non-economists in environmental economics, supporting research on priority areas in environmental economics and providing library support. Four core institutions were identified to lead the project keeping in view their expertise and the desired regional spread of the programme. These were:

- Madras School of Economics (MSE), Chennai
- Institute of Economic Growth (IEG), Delhi
- Indira Gandhi Institute of Development Research (IGIDR), Mumbai, and
- Indian Statistical Institute (ISI), Kolkata

MSE provided overall coordination. An Expert Committee on Environmental Economics (ECEE), under the Chairmanship of Professor Raja Chelliah, acted as the overseeing committee that reviewed and coordinated the programmes of different core units. Professor U. Sankar from MSE was the National Project Coordinator for the programme.

Professor Jyoti Parikh, Senior Professor at IGIDR, chaired the Environmental Economics Research Committee (EERC) that facilitated the environmental economics research component of the EMCaB programme. It helped the researchers with inputs from experts to refine their proposals and monitored the progress through periodic workshops and reviews. It sponsored projects spread across 30 universities, 23 research institutions, and a few NGOs all over India.

IGIDR was established by the Reserve Bank of India to study national and global issues relating to economic development, to promote and conduct research, to teach and train professions and to promote national and international collaboration. IGIDR is a deemed university and conducts M.Phil / Ph.D. programmes in development policy. From 2003, the institute is offering an M.Sc programme in Economics.