MANAGEMENT OF WETLANDS OF NON-PROMINENCE FROM THE PERSPECTIVE OF BENEFIT-DEGRADATION RELATION

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Abstract

Wetlands of non-prominence discussed here are some water bodies in the lower-gangetic floodplains of India. People surrounding these wetlands earn their livelihood and derive many direct and indirect benefits from them. To acquire benefits, often stakeholders subject them to environmental degradation. This study tries to identify the socio-economic activities in and around these wetlands to estimate the value of the benefits derived out of these activities, to measure the degradation of physical component of the wetlands, and to estimate the benefit-degradation relations for these wetlands. For the purpose of this study, ten wetlands in Bardhaman district in West Bengal, India were surveyed. The benefit and degradation were measured, and then the benefit-degradation relations have been estimated using regression models. From the benefit-degradation relations some alternatives for uses of wetlands have been worked out in an eco-friendly manner to find the conflicts that might emerge among the stakeholders.

1. INTRODUCTION

Wetlands play a pivotal role for ecology. But apart from the ecological value, wetlands have significant contribution to the economic development both at the micro and macro levels. The interaction of wetlands with the surrounding population generates multifarious benefits through its different functions, uses and attributes (James, 1991). The ecological services provided by this ecosystem are considered as its functions (Table 1). Important wetland functions are ground water recharge and discharge, flood mitigation and wildlife habitat (Adamus et al., 1991). The well-known function of wetlands is as a provider of year-round dwelling place, breeding ground, refuge and wintering sites for migratory birds and a wide range of vertebrates and invertebrates. Various uses of wetland ecosystems are agriculture, aquaculture, forestry and water withdrawal for irrigation. The use value of wetlands also includes benefits like recreation, tourism, education and transport corridor that are being prioritised in recent times. A range of valuation techniques exist for assessing the economic value of the wetland ecosystem (Table 2). But estimation of the aggregate value of a wetland is complex since the component parts of the ecosystem are contingent on the existence and continued proper functioning of the whole (Turner et al., 2000). The value of wetland as a natural resource is embodied in its attributes. These values are largely aesthetic. Nowadays these values are also gaining greater attention worldwide (IPCC, 1995). The attribute incorporates its biological diversity, historic value, cultural value and aesthetic value. Thus the significant role of wetlands is well understood, but in many cases they are under serious threat. In some countries legal measures have been announced in recent years to tackle the problem of wetland degradation. However, this recognition is aimed to safeguard only the prominent wetlands (The Environment Protection Act in India, 1986).

Apart from these prominent wetlands there are a large number of isolated wetlands, which play a significant role in the wellbeing of the surrounding community. The existence of these wetlands is not so important ecologically and their relevance becomes insignificant with reference to the macro-level discussion in an economy. But with respect to the micro-context, their contribution is irrefutable because the population surrounding these wetlands earns their livelihood and derives various benefits from them. The socio-economic

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Table 1: The main functions, products and attributes associated with wetlands

Benefits	Wetlands associated
Functions	
Groundwater recharge	Marshes, Swamps, Lakes
Groundwater discharge	All
Flood Control	Most of the wetlands
Nutrient retention	All
Water Transport	Estuaries, Mangroves, Lakes
Recreation and tourism	All
Products	
Forest resources	Mangrove, Swamps
Fisheries	Most of the wetlands
Forage resources	Estuaries, Mangroves, Marshes
Agricultural resources	Waterlogged, Marshes
Water supply	Lakes, Ponds
Attributes	
Biological diversity	All
Uniqueness to Culture/Heritage	All

life is closely associated with the existence of these ecosystems. However, among all the benefits derived from these wetlands, some activities are not eco-friendly. For example, drawing water for irrigation lowers the water table of these wetlands and hampers the smooth functioning of its ecology. The agricultural activity in seasonally drained wetlands is another activity, which disrupts the ecological balance of wetlands. Such utilisation enhances the benefit from the wetlands but subsequently degrades the ecosystem. It is essential to identify and then quantify their degree of influence. Such quantification can help policy makers and planners to enforce legal measure on unrestricted utilization of the wetlands (Adger, 2000).

Table 2: Wetland values and valuation methods

Values	Valuation methods
Direct use value	Market analysis, productivity loss, hedonic pricing, travel cost, replacement and restoration costs, contingent valuation
Indirect use value	Damage costs, production functions, hedonic pricing, relocation, replacement and restoration costs, contingent valuation
Nonuse value	Contingent valuation

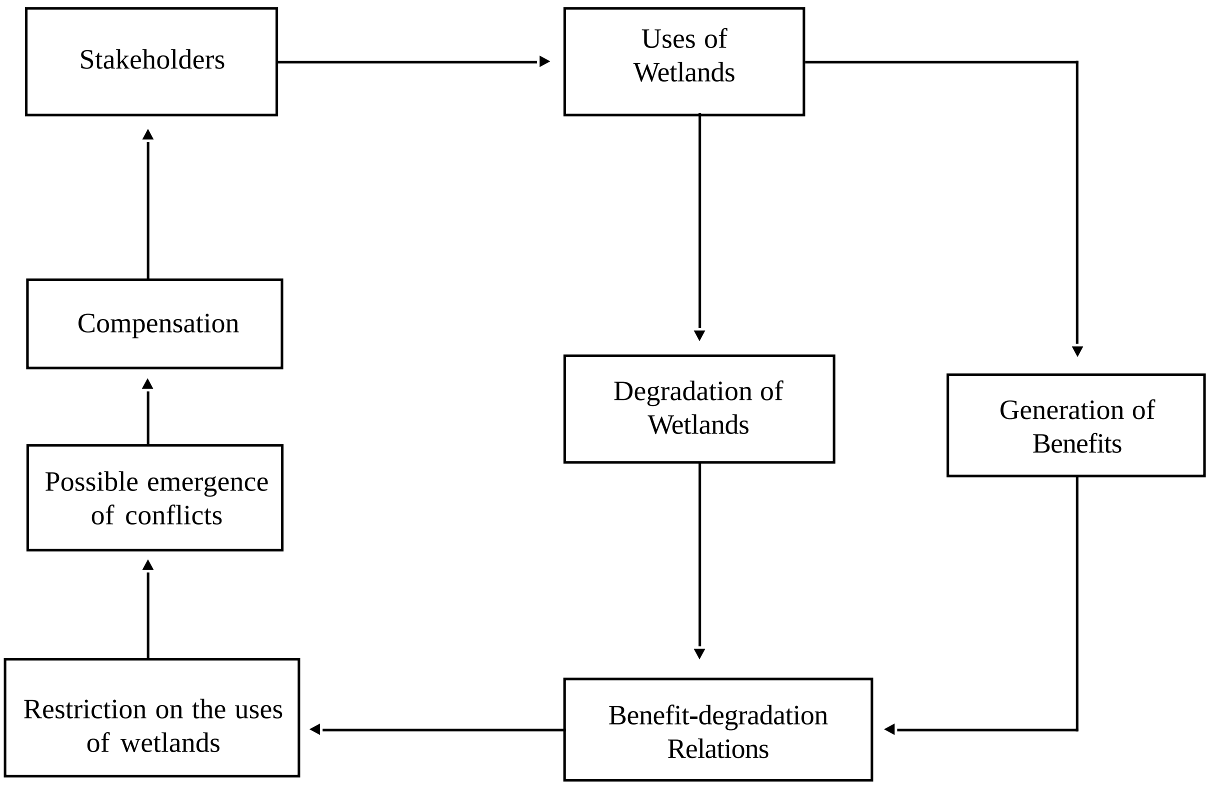
In the Indian context, a number of studies have captured the relevant impacts on wetland ecosystem under different management options (Verma et al., 2001; Singh, 2001). This study estimates the mathematical relationship between economic interaction of wetlands (through its various uses) and the subsequent environmental impact so that appropriate management strategies can be formulated to conserve them. In general, to conserve any natural resources, it is always beneficial to reduce human pressure on them. However, limited admittance to a natural resource like wetland will invariably mean financially displacing some stakeholders, which may lead to conflicts among beneficiaries[1]. This study also looks at the kind of conflicts, which may emerge of if unrestricted utilization of wetlands is no more permitted.

[1] These types of conflicts have been captured through "social cost " by Coase (1960). Coase pointed out that if legal action were taken, there would be loss to someone. Under such circumstances the negotiating parties would interact among themselves to minimise the loss, provided such negotiation is costless.

2. PLAN OF THE WORK

Some isolated wetlands in rural region were selected, and the utilization pattern of these wetlands by the surrounding community was identified. Where possible, the benefits generated and the degradation caused from these wetlands were quantified. Then we tried to established a functional relation between these economic benefits derived and their resultant degradation to arrive at the positive or negative influence of such usage its ecology. To evaluate the economic conflict between various stakeholders if unrestricted utilisation of the wetlands is no more permitted, a pay-off matrix for alternative uses of wetlands was prepared. A schematic diagram of the plan is presented in figure 1.

Figure 1: Schematic plan of the present study



3. METHODOLOGY

To work out the tasks as shown in the schematic diagram of figure 1 the following methodologies have been adopted at various steps.

3.1 Selection of wetlands

This study is confined to the lower-gangetic floodplains, which lie in West Bengal[2]. These wetlands play a very important role in the rural and urban life of the beneficiaries. Most of these wetlands are under increasing pressure for conversion to other forms and vulnerable to degradation as they are not adequately protected. They receive the least consideration or value in conservation plans. In spite of this, a number of wetlands still exist but they are exploited potential without regard to the consequences of such exploitation. They are undergoing steady deterioration due to overutilisation, pollution and lack of scientific conservation effort.

[2] West Bengal has the largest number of wetlands in India

The number of wetlands in West Bengal is largest in Bardhaman district. This district is important in terms of agricultural yield with substantial development in the application of high input-high output technology in agriculture like high yielding variety (HYV) seeds, chemical fertilizers and pesticides. However, the high input modern technology cannot yield fruitful return if controlled irrigation facility is not available in form of ground water irrigation in summer. About 63% of the total sown area in this district is covered by canal irrigation, which is considered to be inadequate (Economic Review, 1999-2000). Farmers extensively use ground water for cultivation during the dry season. The presence of wetlands is vital for maintaining ground water.

The total area under wetlands in Bardhaman district is 6441.77 hectare out of which lakes and oxbow lakes, waterlogged (seasonal) and swamps and marshes occupy 3415.94 hectare (Raha, et al., 1997). The rest are reservoirs, tanks and abandoned quarries. Since the former group of water bodies occupies a significant position in the total water bodies present in the district, they have been chosen for study.[3] Altogether ten wetlands, which are water logged seasonally, swamps and marshes covering an area of 680 hectare (20% of the area) were selected for the study. These wetlands have been selected from similar agro-climatic zone in the same area to avoid significant variation in biodiversity and benefits. While selecting the wetlands for survey, special emphasis was given to those wetlands, which have substantial interaction with the surrounding economy. These wetlands are used for net fishing and withdrawal of water for irrigation. The huge economic benefits obtained from net fishing have caused part of these wetlands to be converted to aquaculture ponds (Das et al., 2001). All the wetlands are used for storage of water, which are accumulated either from runoff or from drenched water of nearby rivers. This water is used for irrigation in periods of water scarcity.

Table 3: Wetland Profile

Sr. no.	Name of wetland	Area of wetland (hectare)	Average depth of water (meter)	
			Pre-monsoon	Post-monsoon
1.	Haruabhanga	10	4.12	6.86
2.	Kalobaur	40	3.36	8.39
3.	Lakshmipur	15	1.07	5.34
4.	Chakkobla	60	1.07	4.12
5.	Barokobla	25	6.86	9.91
6.	Bara Beel	56	1.07	2.74
7.	Jalanga	75	1.67	3.81
8.	Srikhanda	80	0.38	6.86
9.	Bater Beel	275	0.46	2.14
10.	Padma Beel	20	0.23	2.14

Among ten selected wetlands, seven wetlands are perennial and three are seasonal. These seasonal wetlands are converted temporarily in the post monsoon season by draining water to derive fertile agricultural land for harvesting food crops especially, rice. These wetlands are filled up again and return to their original state in monsoon. Some of these wetlands are also being used for jute retting.[4] Thus the major economic benefits from the selected wetlands derived by the surrounding population are fishery, irrigation, jute retting, and drained off fertile farmland for cultivation (Table 4). These specified wetlands are used for various domestic

[3] Among various definitions of wetlands given by different institutions, the most accepted definition was put forward in Ramsar Convention held in Iran (1971) which define wetlands as “areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six meters.” (Raha et al., 1997). In this study, the selected wetlands under survey are in accordance with the Convention, and these are mainly lakes, and oxbow lakes while some are seasonally waterlogged wetlands (Table 3).

purposes like bathing, washing clothes and utensils and rearing ducks. By grazing cattle in the wetlands, herders save 15-35% of total annual cost of cattle feed. However, due to lack of relevant information and presence of non-quantifiable variables these uses of wetlands are not included in the analysis of benefits derived from wetlands. Instead we just mention these advantages available to the surrounding households due to the presence of these wetlands.

Table 4. Number of households deriving benefits across different wetlands

Sr. No.	Name of wetland	Fishing		Irrigation		Jute retting		Agriculture	
		Population	Sample	Population	Sample	Population	Sample	Population	Sample
1.	Haruabhanga	125	10	125	10	0	50	0	0
2.	Kalobaur	200	25	100	10	60	0	0	0
3.	Lakshmipur	90	10	20	3	0	0	0	0
4.	Chakkobla	20	3	200	15	0	0	0	0
5.	Barokobla	60	5	50	3	0	0	0	0
6.	Bara Beel	400	35	800	75	0	0	0	0
7.	Jalanga	100	10	300	32	0	0	0	0
8.	Srikhanda*	200	22	0	0	200	25	1000	100
9.	Bater Beel*	150	15	0	0	100	12	600	55
10.	Padma Beel*	75	5	0	0	20	4	75	10

*Seasonally drained

4. SELECTION OF SAMPLE OF STAKEHOLDERS

Initially the list of beneficiaries was collected from the office of the Gram Panchayat (village council) and fishermen's co-operative society. Among the total beneficiaries of each category about 12% were selected by random sampling. These beneficiaries were surveyed through personal interviews. Questions were asked questions related to their socio-economic profile - family structure, income level, education and occupation. Information regarding their interaction with the wetlands was captured by asking questions like conversion of the surveyed wetlands, benefits generated, annual income accrued, operational land holding, amount of land cultivated within the wetland, land area generated, area of land irrigated by water from the surveyed wetland, descriptions of biotic abundance found in and around the wetland at present and fifteen years back. The interviewees were also asked to put suggestions regarding any desirable conversion of the wetlands.

About eight percent of the selected households, i.e., approximately ten percent of the total beneficiaries, responded by giving answers to the preformatted questionnaire.

4.1 Estimation of Benefits

The wetlands are often altered to satisfy economic needs with no consideration to the values associated with them in their unaltered state. They represent a resource of high value and their role in the economy should be considered with due care. In the absence of a proper valuation technique, misallocation of wetland resources will occur which might have long-term consequences.

[4] In the process of jute retting, the stems of matured jute plants are collected and bunched together. These bunches are dipped into the wetlands and they are kept drowned completely into water by putting heavy mass on them for a period of about one month. After required interval of time, the fibers are taken out of the stem while the jute stick remains. These fibers are then thrashed and rinsed thoroughly to get pure jute.

Fishing benefit is derived from the entire surveyed area. The value of average annual fish catch from these wetlands has been estimated by market price method, as reliable market prices are available for the fish caught from these wetlands (Winpenny, 1991). We have measured the fishing benefit in two ways:

(i) Fishing benefit per household as FS_{hh} by the formula

$$FS_{hh} = \left(\sum_{i=1}^{n_f} \text{Value of fish catch by ith household}\right) / n_f \qquad (1a)$$

(ii) Fishing benefit per hectare as FS_{ha} by the formula:

$$FS_{ha} = (FS_{hh} \text{ X } N_f) / A \qquad (1b)$$

Where, n_f is the number of surveyed households engaged in fish catching, N_f is the total number of households engaged in fish catching around that wetland and A is the area of the wetland in hectare.

The water from the wetland is being used for irrigation in the surrounding agricultural fields. Seven surveyed wetlands render this benefit. The value of water used for irrigation cannot be estimated by the market price method because this wetland product is not sold in the market or no acceptable price is available for this benefit. But some cost is incurred to get this benefit through uses of pump-sets for lifting water from wetland to the farmland which has been observed to be less than that incurred for lifting water from alternative sources. Here the net benefit method is used for its estimation.[5] However, a true value of water could be obtained through the Household production function (HPF) approach. The underlying assumption in most HPF models is that a household allocates some of its available labour time, and possibly its income, i.e., the household combines its labour and other goods to "produce" a good or service, only for its own consumption and welfare (i.e., household utility). But here we stick to the cost based method, in spite of the superiority of the HPF over the former, mainly due to insufficient data. In the same way as fishing benefit, the benefits from irrigation has been measured in two ways,

(i) Irrigation benefit per household as IRR_{hh} by the formula:

$$IRR_{hh} = \left(\sum_{i=1}^{n_i} \text{Saving from irrigation by the ith household}\right) / n_i \qquad (2a)$$

(ii) Irrigation benefit per hectare as IRR_{ha} by the formula:

$$IRR_{ha} = (IRR_{hh} \text{ X } N_i) / A \qquad (2b)$$

Where, n_i is the number of surveyed households deriving the irrigation benefit, N_i is the total number of households procuring the same benefit around that wetland and A is the area of the wetland in hectare.

The surrounding households are deriving the benefit of jute retting from four of the surveyed wetlands. Ponds can be hired on rental basis for jute retting. But if wetlands are used for this purpose no such rent is charged. Substitute price is used for this use value of the wetlands and the rental charges of the ponds hired for jute retting has been considered here as the value of jute retting benefit. As before, the benefit of jute retting has been calculated in two ways:

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[5] If groundwater is extracted instead by privately owned shallow tube-wells or submersibles, it costs higher for the farmer due to the fact that volume of water extracted per hour from the surface of a wetland is much more than that of a non-wetland source like ground water (using a pump-set of the same horse-power). The difference between these two costs of water required for irrigation of one acre of land is being considered to be the value of this wetland use.

(i) Jute retting benefit per household as JR_{hh} by the formula:

$$JR_{hh} = (\sum_{i=1}^{n_j} \text{Jute retting benefit derived by the ith household}) / n_j \qquad (3a)$$

(ii) Jute retting benefit per hectare area as JR_{ha} by the formula:

$$JR_{ha} = (JR_{hh} \times N_j) / A \qquad (3b)$$

Where, n_j is the number of surveyed households deriving the jute retting benefit, N_j is the total number of households obtaining the same benefit around that entire wetland and A is the area of the wetland in hectare.

The seasonally drained off wetlands generate productive land for cultivation of food crops, especially rice. (Obviously, this agricultural benefit by draining off wetland is received at the cost of other benefits, viz. fishing, irrigation, etc. Therefore, the agricultural outcome may be regarded as cost and should be deducted form the total benefit. But one of the objectives of this paper is to find the "individual benefit" (i. e., use) – degradation relation (Table 5), so we term it as "benefit" instead of "cost".) The agricultural benefits obtained from three wetlands have been quantified by the monetary value of their production through household survey. The net average annual benefit from cultivation has been estimated per hectare. On this basis the agricultural benefits have been computed from three wetlands. So here, the same market price method has been employed for the value estimation. The two measurements of agricultural benefit are,

(i) Agricultural benefit per household as AG_{hh} by the formula:

$$AG_{hh} = (\sum_{i=1}^{n_a} \text{Monetary value of the agricultur al output produced by the ith household}) / n_a \qquad (4a)$$

(ii) Agricultural benefit per hectare area as AG_{ha} by the formula:

$$AG_{ha} = (AG_{hh} \times N_a) / A \qquad (4b)$$

Where, n_a is the number of surveyed households deriving the agricultural benefit, N_a is the total number of households obtaining the same benefit around that entire wetland and A is the area of the wetland in hectare.

5. ASSESSMENT OF DEGRADATION

The degradation of wetlands can be assessed by looking at the deterioration in their biotic and abiotic parameters (IWMED, 1999). Biotic parameters include bio-geographical zone of the wetland, its habitat type and nature of distribution of the aquatic flora and fauna. The abiotic parameters are site area, topographic configuration, water regime and water quality. Degradation in biotic parameters may result in reduced biotic diversity (Dugan, 1993), eutrophication (Jana et al., 2002) and infestation of exotic species (Murty et al., 1998 and Muraleedharan et al., 1997). The degradation of the abiotic parameters may result in loss of wetland area (IPCC, 1995), encroachment (Dogra, 1993), drainage (The CEERA team, 1999), reclamation for agriculture, siltation (Sridhar et al., 2002), reduction in dissolved oxygen content and pollution (De et al., 2002). To assess the degradation of wetland resources in the surveyed area each of the biotic and abiotic parameters were selected.

The wetlands nurture a wide range of flora and fauna. The conversion and other human activities around the wetlands lead to decline in abundance of several flora and fauna. The surrounding population of the surveyed wetlands reported that both varieties and number of fish and other aquatic animals have reduced severely in the last 15 years due to excessive withdrawal of water for irrigation and net fishing. According to them, reduction in biotic abundance is highest for seasonal wetlands (where water is drained out). Also, the bird population is dwindling every year mainly due to (i) unsustainable fish catch distorting the food chain, and (ii) noise of diesel pump-sets (used for lifting water from the wetlands to adjacent agricultural lands) disturbing the serenity of the area. In order to measure the decline in biotic abundance, data have been collected from fisherman community and surrounding farmers, related to the numbers and types of fish, aquatic animals and birds that have disappeared from the wetland. For this study, the reported reduction in biotic abundance is one of the biotic indicators to estimate the degradation of wetlands. Non-sighted or non-available species in the survey area may not be endangered elsewhere but are not longer found in the surveyed wetland areas and may be viewed as local depletion. The reduction in biotic abundance (denoted by $BA_{\text{reduction/ha}}$) has been calculated per hectare area of each wetland in the following way:

$$BA_{\text{reduction/ ha}} = \frac{\text{Total reduction in biotic abundance in a particular wetland}}{\text{Area of the wetland}} \qquad (5)$$

The decline in biotic abundance is taken per unit area because a wide range of observations were found to justify that the number of species traced in an area increases with the size of that area (Groombridge, 1992). This increase follows an anticipated pattern known as the Arrhenius relationship.

One key measure of water quality is dissolved oxygen level in it and this is one of the important habitat factors for the aquatic abundance within the wetland. Usually the level of dissolved oxygen stands at 8 mg/l in fresh water at 25°C (Ramachandra and Murty, 2002). Since the highest level of dissolved oxygen level among the surveyed wetlands is close to 7 mg/l and all these surveyed wetlands have extensive interaction with the surrounding population, 7 mg/l is taken as the standard level of dissolved oxygen. The deviation of the actual value of dissolved oxygen of the surveyed wetlands from the assumed standard level of 7 mg/l, denoted by DO_{dev} is considered as the degradation of wetlands in the analysis. Hence,

$$DO_{dev} = 7 - \text{the actual value of the dissolved oxygen} \qquad (6)$$

6. ESTIMATION OF BENEFIT - DEGRADATION RELATION

Every economic action can have some effects on the environment and every environmental change can have some impacts on the economy. There exists a relationship between the benefits derived from the wetlands through various economic activities and the degradation of the wetlands. After the estimation of benefits and degradation through the aforesaid indicators the following linear regression model has been framed to identify these benefit-degradation relations:

$$BA_{\text{reduction/ha}} = a_0 + a_1 FS_{ha} + a_2 IRR_{ha} + a_3 JR_{ha} + a_4 AG_{ha} \qquad (7)$$

and

$$DO_{dev} = b_0 + b_1 FS_{ha} + b_2 IRR_{ha} + b_3 JR_{ha} + b_4 AG_{ha} \qquad (8)$$

Where a_0 and b_0 can be interpreted as the degradation of the wetland when it is left aside, and a_i and b_i, (i= 1, 2, 3, 4) are the parameters associated with the explanatory variables. Here the structural factors, which exert explanatory power to the relationship between benefits and degradation, include specific benefits derived per unit area of wetlands. Since there is wide variation in the total commanding area under the surveyed wetlands, it will be commensurate to take into account the value of benefits derived from these wetlands in terms of benefits per unit area.

7. IDENTIFICATION OF THE CONFLICT

Assuming the existence of a close association between benefits derived and resultant degradation, a reduction of benefits might occur while conserving the wetlands. This may have a negative effect on the stakeholders, as some of the beneficiaries would lose in the course of preservation of these fragile ecosystems. As a result a conflict will spurt up, which has been portrayed through a pay off matrix (Frank, 1997). In this pay off matrix method, the possible outcomes of different strategies employed for preservation have been are. From all these feasible outcomes, choosing the socially optimal one would be justified (Coase, 1960).

6. RESULTS AND DISCUSSION

The numbers of households deriving various yields from the surveyed wetlands are presented in Table 4. This table reveals that the average number of households deriving agricultural benefit is highest. Average number of households getting fishing benefit is less than the average number of households receiving irrigation benefit. The average number of households receiving the benefit of jute retting is even smaller because only four out of ten surveyed wetlands render this benefit.

Table 5. Average benefits derived from the surveyed wetlands (in rupees) per annum

Item	Statistics	Fishing	Irrigation	Jute retting	Agriculture
Average benefits derived per household of the stakeholders per annum	Sample mean	2643	823	206	1258
	Standard deviation	2876	969	302	2437
	Coefficient of variation	108.81	117.73	146.60	193.72
Average benefits derived per household of the stakeholders per annum	Sample mean	3280	6313	3770	213
	Standard deviation	3884	5647	5191	292
	Coefficient of variation	118.41	89.45	137.69	137.08

The resulting benefits per household and benefits per hectare separately for each wetland are computed using the formulae (1) - (4). Table 5 shows that the average income per household from fish catch is highest, as all the surveyed wetlands render this service to the neighbouring population. Moreover, this fishing benefit has a lower coefficient of variation than irrigation, jute retting or agriculture benefit. This implies that fishing income per household among the surveyed sample is more consistent than income from other benefits. More or less the same trend has also been observed in case of benefits per hectare.

It is apparent from the descriptive statistics in Table 6 that the average number of fish variety that were not found in abundance, is highest and its variability is least among all the species. In other words, fish are the more threatened species in these wetland ecosystems as compared to aquatic animals and birds. It is also observed from the table that DO levels of the wetlands varied considerably. Except for a few water bodies like

Table 6. Average reduction in abundance of number of species and average water quality

Statistics	Average reduction in abundance of #			Total reduction in biotic abundanceper hectare	Average dissolved oxygen (mg/l)
	Fish	Aquatic animal	Bird		
Mean	1.60	0.90	0.80	0.09	2.62
Standard deviation	1.17	0.74	0.92	0.08	1.87
Coefficient of variation	73.36	81.98	114.87	91.63	71.48

Reduction in abundance means reported numbers of types of fish, aquatic animals and birds that were not being sighted during the reference year in the particular wetland.

Bater Beel, Chakkobla Beel and Jalanga, the DO levels were above 2 mg/l. Its highest was observed at Barokobla (about 6.94 mg/l).

In the first approach of identifying the benefit-degradation relation, degradation has been considered from an ecological point of view i.e., using relation (7). Results of the Multiple Regression analysis in Table 7 show that all the anthropogenic activities derived per unit area though enhance benefits from the wetlands, aggravate the problem of reduction in biotic abundance (Table 7, Model 1a). Human interference is responsible for almost 50% of the total reduction in biotic abundance. However, Stepwise Backward Regression shows that among all the activities performed in and around the wetlands, irrigation and agriculture are most harmful for sustenance of the wetland ecology. They are responsible for 40% of the total reduction in biotic abundance (Table 7, Model 1b).

In the second approach, the water quality is used to indicate the degradation of wetlands i.e., using relation (8). Model 2a of Table 7 shows that the water quality has deteriorated by 85%. Irrigation and agricultural activities cause the deterioration by reducing the dissolved oxygen level in the water whereas fishing and jute retting improve water quality. The Backward Stepwise Regression with the same set of variables in Model 2b of Table 7 shows that fishing and irrigation activities alone exert comparatively strong illustrative power to this relationship with 68% explanation. In the absence of these activities, the deviations from standard DO level would be substantial as is evident from the constant, b_o, of Model 2a and 2b. This would aggravate the situation

Table 7. Multiple Regression Results

Model	Dependent Veriable	Parameters associated with the Explanatory variable					
		Intercept	Fishing benefit per ha	Irrigation benefit per ha	Jute retting benefit per ha	Agriculture benefit per ha	R^2
1a. Linear Multiple Regression	Reduction in biotic abundance per ha abundance per ha	- 0.02508	0.0003616 (0.862)	0.0003381 (0.829)	0.004606 (0.632)	0.0002490 (0.918)	0.496
1b. Backward Stepwise Regression	Reduction in biotic abundance per ha abundance per ha	0.02019	-	0.0005477 (2.058)	-	0.0002930 (1.617)	0.402
2a. Linear Multiple Regression	DO_{dev}	6.346	- 0.02469 (- 4.840)	0.02010 (4.051)	- 0.214 (- 2.413)	0.005762 (1.747)	0.858
2b. Backward Stepwise Regression	DO_{dev}	5.693	- 0.02238 (- 3.931)	0.02007 (3.241)	-	-	0.689

Note: Figure in the parenthesis indicates the t-value.

as observed in many cast aside wetlands. So comprehensive management techniques along with appropriate utilisation should be adopted for better maintenance of these precious ecosystems.

Finally, pay-off matrices were constructed for both perennial and seasonal wetlands for their different uses. Alternative strategies were assumed for preservation and better maintenance of the existing non-converted wetlands. The various optional strategies along with their resultant outcomes in case of Bater Beel - a seasonally drained wetland are shown in Table 8. It is observed that from seasonal conversion the agricultural farmers in Bater Beel can retrieve a 256-hectare of land from which they can procure an amount of rupees 42,17,650 approximately.[6] They also incur an input cost of rupees 35,71,900 approximately, which includes labour, irrigation and fertilizer cost for the recovered land. So the net gain to the farmers is about 6,45,750 rupees. This earning

[6] Total return from agriculture = IRR_{hh} x N, where N is the total number of beneficiaries deriving the agricultural benefit.

is of immense importance to their survival and would not accrue to them had such conversion not taken place. This earning is secured in six months before the beginning of monsoon. On the other hand, during the harvest period if the water would not be drained out fishermen could earn an amount of nearly 1,78,400 rupees in total.[7] But due to conversion they have to stop fishing in the wetland during the six months harvest period. The pay-

Table 8. Outcome and pay-off summary (seasonal wetland)

Case	Legal/social/political regime	Outcome	Net benefit (rupees)		
			Fishermen	Farmer	Total
1.	Agricultural farmers not Liable	Agricultural farmers convert and fishermen stop earning. Ecosystem is disturbed	0	6,45,750	6,45,750
2.	Agricultural farmer liable	Agricultural farmers convert and employ fishermen as agricultural labourer Ecosystem is disturbed.	4,65,750	6,45,750	11,11,500
3	Seasonal draining	Fishermen's income from fishing increases and agricultural farmers stop earning. Lesser disturbance in biotic diversity is stopped	>1,78,400	0	>1,78,400

off matrix for the fishermen and the agricultural farmers are summarized in Case 1 of Table 8. It is assumed that farmers are not liable legally or socially.

If the agricultural farmers had to pay compensation for six months to the fisherman it would have been at least 1,78,400 rupees. This is the amount the fishermen could earn from the perennial wetland if the process of conversion were not permitted for the said six months. But in this case, the fishermen are reimbursed through employment as agricultural labourer in the cultivation process. They earn rupees 69 per day per person in the harvest season. They can find employment for 45 days, thereby earning on average an amount of rupees 4,65,750 in total during the entire season. Since their fishing income is far less than their wage receipts, they have no objection to the seasonal conversion of this wetland. So from societal point of view the net benefit is highest when farmer compensates the losers by providing alternative employment opportunities to them (Case 2 in Table 8). This is probably the most efficient pay-off outcome if the impact of environmental degradation for the process of draining is not taken into account.

However, to preserve the wetland ecosystem, seasonal draining should no more be allowed. This would augment the fishermen income and enable biotic diversity to flourish. Agricultural farmers will be displaced, face financial hardship and a conflict would arise. The question arises whether fishermen can be made liable to compensate agricultural farmers. Since, fishermen's income is lower compared to that of agricultural farmers, it is not possible to impose such burden on them. The option then is to rehabilitate the displaced agricultural farmers elsewhere. Such strategy is discussed in Case 3 of Table 8. Through this strategy, not only can we maintain biodiversity but recharge water table in the adjacent upland areas from the resultant perennial wetland.

Alternative strategies along with resultant outcomes in case of the perennial Bara Beel wetland are presented in Table 9. There is a conflict between interests of fishing and irrigation. Due to withdrawal of water from the wetland the agricultural farmers gain and fishermen lose.[8] On the gainers side, agricultural farmers use

[7] Total return from fishery = FS_{hh} x N, where N is the total number of beneficiaries deriving the fishing benefit.

[8] The beneficiaries from this wetland include 800 agricultural farmers who draw irrigation benefit and 400 fishermen drawing fishing benefit (Table1). Among them 200 households are common benefit holders. While calculating the gain of farmers and loss of fishermen these common beneficiaries have been excluded from our analysis to counterbalance because they are gainers on one side and losers on the other.

this water for irrigation in their fields and avoid the cost of ground water lifting by submersible pump sets or tube-wells. This reduction in input cost is their indirect gain. The total value of this indirect benefit to the farmer community was estimated at rupees 2,79,300 per annum. On the other hand, withdrawal of water for irrigation

Table 9. Outcome and pay-off summary (perennial wetland)

Case	Legal/social/political regime	Outcome	Net benefit (rupees)		
			Farmer	Fishermen	Total
1.	Agricultural farmers liable	Agricultural farmers draw water and compensate the fishermen	69,300	2,10,000	2,79,300
2.	Agricultural farmer not liable	Agricultural farmers draw water but not compensate the fishermen and fishermen's income reduces	2,79,300	0	2,79,300
3	Restricted withdrawal of water from the wetland by agricultural farmers	Fishermen's income augments and farmers benefit decreases. The wetland ecosystem sustains	>0	>2,10,000	>2,10,000

lowers the volume of water in this wetland and reduces potential fish catch. The immediate sufferers are the fishermen who suffer a loss of about 2,10,000 rupees per annum due to the water withdrawn for irrigation.[9]

Now if the farmers are liable for withdrawal of water from this wetland, they have to compensate the fishermen for their loss. Thus the compensation for the fishermen ought to be as much as 2,10,000 rupees, so that their losses are outweighed (Case 1 of Table 9). If the farmers repay this amount from their indirect benefit of input cost reduction, the farmers' net benefit will reduce by the amount they have to reimburse to the fishermen i.e., 2,10,000 rupees. Their net gain would turn out to be 69,300 rupees in total. The net benefit to the society is thus 2,79,300 rupees. But if the agricultural farmers are not accountable for extraction of water (which is currently happening), they will not reconcile with the fishermen to compensate their losses. In that case the farmer would draw water, thereby gaining through reduction in their input cost and fishermen's income would be curtailed. However, the net benefit to the society would be the same as in the previous case (Case 2 in Table 9).

In the above two cases, it is assumed that the two negotiating parties interact to pursue their own interest in deriving the best from the wetland resource. But unrestricted withdrawal for a prolonged period will augment agricultural income on one hand and degrade wetland resource on the other. In the long run the species abundance will be severely reduced. This will invariably take a heavy toll on the fishermen community and they have to be compensated for this damage. It would be wise, under such circumstances, to allow the agricultural farmers to draw water up to a certain extent beyond which they must opt for alternative sources of irrigation, if needed. The fishermen's income would augmented by at least 2,10,000 rupees, and farmers incur an additional establishment cost for drawing water from alternative sources if required. The net benefit might be less than the first two alternatives, but would be the best option from ecological point of view as environmental damage is least as is figured in Case 3 of Table 9. Moreover, curbing of environmental damage implies enhancement of the

[9] On an average, the fishing benefit per household from all the ten selected wetlands under study stands at 2,650 rupees per annum, while that from this particular water body is at a lower value of 1,600 rupees per annum. The loss of the fishermen has been estimated assuming this average amount of 2,650 rupees to be the minimal possible earning.

potential income of the fishermen as restriction on withdrawal keeps the habitat place intact and biotic abundance to flourish in and around the wetland.

7. CONCLUSION

The wetlands under study are mainly lakes and oxbow lakes with some being seasonally waterlogged. They contribute greatly to the surrounding population by way of the various values they provide. Their utilization generates benefits in the form of fish catch, irrigation water, jute retting and derived agricultural land. But the utilization pattern is not environmentally benign in many cases and consequently the wetlands degrade. The extent of damage in some cases is beyond sustainable limits. Anthropogenic activities are somehow responsible for this degradation with varying degrees. But the policy makers are not aware of the degradation of wetlands of this type. For example, the government has emphasized in West Bengal Town and Country Planning and Development Act, 1979, (Kundu et al., 1997), that no permission for filling of tanks, ponds, water body, 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, and (e) pisiculture. However, these policies either overlook or ignore the degradation of existing wetlands due to anthropogenic activities, which cause deterioration of water quality and reduction of biotic abundance.

A comprehensive policy should be framed for preservation and better maintenance of existing non-converted wetlands. If all the anthropogenic activities cannot be curbed due to economic pressure, only those activities should be encouraged which cause the least damage. But these activities should also be allowed within permissible limits. For example, overfishing in wetlands should be stopped, water lifting for irrigation purposes should be restricted to a predetermined level for the sustenance of existing species habitat, and seasonal draining should not be encouraged, as is supported by the regression results in Table 7.[10] However such restriction on resource utilization will adversely affect some beneficiaries and a conflict may arise.

In case of seasonally drained wetlands the optimal solution would be one where the monetary benefit is apparently the most. This is presented in case 2 of Table 8 when the agricultural farmer converts the wetland to cultivable field by draining the water in the post-monsoon season and employs the displaced fishermen as agricultural labourer. Again in case of the perennial wetland the optimal solution would come forth when the agricultural farmers draw water and compensates the fishermen adequately for lower value of their fish catch. Thus, in both perennial and seasonally drained wetlands, the socially optimal situation is the case where income is highest and consequently the environmental damage is the most. Now, any environmental measure obviously implies conflict among different beneficiary groups as the short-term total net benefit decreases significantly in the micro-economy. But the emerging conflict could be mitigated if they are compensated properly. One such way is to provide alternative employment opportunities to the losers. But these alternative employment opportunities should be planned in such a way that the villagers would get no more incentives from the wetland utilization after being employed elsewhere. Otherwise, the process of wetland preservation would go in vein. Thus, policy makers must have a two-fold strategy to reduce environmental degradation: (i) to find the critical level for sustainable uses of wetlands, and (ii) to find alternative employment opportunities to the losers to reduce pressure on these fragile ecosystems.

[10] The problem of overfishing arises due to the open accessibility of wetland resources. Anyone can harvest from wetland resources because these are common property. The extent of overfishing can be estimated with the help of Maximum Sustainable Yield (MSY), which refers to the stock corresponding to the maximum harvest, or yield that can be sustained indefinitely (Fisher, 1981). Generally, MSY can be estimated using a method involving catch-effort data, the aspect of which has not been incorporated in our field survey (Clark, 1976).

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