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AGRICULTURAL ACTIVITIES AND THEIR IMPACTS ON THE ECOLOGY AND BIODIVERSITY OF THE SUNDARBANS AREA OF BANGLADESH

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Summary: A study was conducted through survey and monitoring to examine the impact of agricultural practices and forest resources collection on the ecology and biodiversity of the Sundarbans area of Bangladesh during May to December 2001. The study was conducted in three villages adjacent to Sundarbans, namely Mongla, Dacope and Shyamnagar in the Bagerhat, Khulna and Satkhira districts, respectively. Two major agricultural activities were highlighted, of which brackish water shrimp cultivation has been identified as a major land-use practice that is gradually replacing traditional agricultural systems in the region. Shrimp cultivation along with its associated activities emerged as the practice that most adversely influenced the ecological and socioeconomic setup of the region as well as its biodiversity. Over exploitation of forest resources such as timber, fuel, goalpata, honey and fish is common. The major ecological problems were increased soil and water salinity, deterioration of soil fertility and productivity, pollution of soil and water ecosystems and loss of biodiversity. Biodiversity issues included the depletion of rice genetic resources, homestead plantations, livestock and poultry, other natural vegetation, forest flora and fauna including trees, animals, birds, fish and other forms of aquatic life. Ecological changes as well as depletion of these resources have resulted in secondary issues such as the biomass fuel crisis, food security problems, malnutrition, increased cost of living, poverty and social disharmony among the rural communities. The study further revealed that major intervention is urgently needed to prevent further ecological damage and biodiversity depletion, as well as to improve the socioeconomic situation in the region.

Rationale of the Study

The Sundarbans is the largest natural mangrove forest in the world, and it has a unique ecosystem with diversified natural resources. It is located in the southwestern part of Bangladesh, and offers coastal protection to the Southwest of Bangladesh. The forest area is comprised of parts of the Bagerhat, Khulna, and Satkhira districts of Bangladesh. The total area of the Sundarbans is around 6,017km^2 of which 62% falls under the territory of Bangladesh and the rest lies in the West Bengal of India. The total forest area is around 4.2% of the total land area of the country as well as 51% of its total forest area.[4] This mangrove biotype has been considered a highly

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productive ecosystem, and it provides a wide range of valuable forest products and plays a crucial role in the life cycle of many important species. It is the most diverse and the richest of the natural resources of Bangladesh, and is also a dynamic, fragile and complex ecosystem. The mangrove ecosystem serves as a good habitat for offshore fishing and onshore shrimp cultivation. It is a component of the global wildlife heritage, a recreational resort and a major source of government revenue as well as income to the surrounding inhabitants. Sundarbans is rich in floral as well as faunal biodiversity. A total of 334 species, representing 245 genera of plants thrive in the Sundarbans.[12] As many as 120 species of fish, 59 species of reptiles, over 300 species of birds, and 42 species of mammals have been recorded in the Sundarbans.[13] Having taken into account its unique structure, scenic beauty and biodiversity, the UNESCO declared three wildlife sanctuaries of the Sundarbans as World Heritage Sites in 1997.

The mangroves play a significant role in the lives and economics of the coastal communities. Population growth and economic development have resulted in the mangroves and its ecosystems being increasingly exploited for their various resources. At present around 500,000 families are dependent on the Sundarbans for their livelihood. A total of 200,000 fishermen are also dependent on this forest. Thus the Sundarbans support almost a million household members.[4] Human activities have severely affected the mangrove areas. Consequently, the mangrove forest area has reduced, resulting in worsening the condition of the coastal environment. In the recent past, newer dimensions were added by the introduction of modern rice cultivation as well as shrimp cultivation in the region. These practices have also involved the indiscriminate use of agro-chemicals, which in turn has affected the ecological balance of the forest. However, the impact of modern agriculture as well as its historical trends on the ecology and biodiversity of the Sundarbans has not been well understood or documented. Having regard to the above mentioned views this study was undertaken to (i) identify recent agricultural activities which have contributed to the deterioration of the ecosystems of the Sundarbans; (ii) evaluate the impact of agricultural systems on the ecology and biodiversity of the Sundarbans; and (iii) formulate management strategies incorporating ecological, economic and social parameters for the conservation of the natural resources of the Sundarbans.

Study Area and Methodology

The study was conducted during May-December 2001, with financial assistance from the United Nations Education, Cultural and Scientific Organization (UNESCO).

Study Area

The study was conducted in the selected areas of Mongla, Dacoupe and Shyamnagar Upazillas, in the Bagerthat, Khulna and Satkhira districts, respectively (Figure 1). The selected areas were adjacent i.e., within 0-5km of the Sundarbans Reserve

Forest under three coastal districts of Bangladesh. Topographically, the study areas of the Sundarbans Reserve Forest were of the medium land category. The soil was largely non-calcareous floodplain but a considerable portion of the Shyamnagar Upazilla contained acid sulfate soil. The pH of the major areas ranged from 5.5 to 7.3 (moderately acid to neutral). However, a considerable portion of the Dacoupe Upazilla had a pH of 7.3 to 8.4 (moderately alkaline). The entire region included in the study represents the saline zone of Bangladesh. Of the study areas, Dacope and Mongla represent the areas where salinity was in the S2 category, which meant that over 70% of the Upazillas is affected by salinity. In contrast, the Shyamnagar area was in the S2+S3 category, which meant that over 60% of the Upazilla is affected by salinity together with the dominance the of S2 category.

Methodology

The study was conducted through survey and monitoring of the selected areas. The selected farmers were interviewed with regard to the present situation of land-use and agricultural practices. Farmers were also interviewed regarding resource collection from the Sundarbans and to help identify the impact of such collection on the ecology and biodiversity of the forest. Homesteads in the study areas were monitored to assess tree resources and productivity. Focal group discussions were made in each survey area to get to know community feelings about agricultural practices, as well as their impact on the forest ecosystem. Discussions were held with several eminent persons, including public representatives, former government officials and old farmers on a whole range of issues, from resource depletion in the Sundarbans forest to means of overcoming the problems. Discussions were also held with several government and non-government organizations.

Fertilizer and insecticide dealers and fuel traders were surveyed from each study area, to get to know the marketing chain of fuelwood from the Sundarbans forest, as well as to know the extent of the use of agro-chemicals in and around the forest area. Moreover, local markets in each study area were also surveyed to monitor the price of rice, vegetables, livestock products, and fish. Secondary information was collected from different government and non-government organizations. Tree species of the three locations in the Sundarbans were monitored to know the floral diversity of the study areas. In each location, three sampling plots where tree species were counted were selected.

Results and Discussion

The results of the present study and relevant discussions are documented for convenience under the following sections:

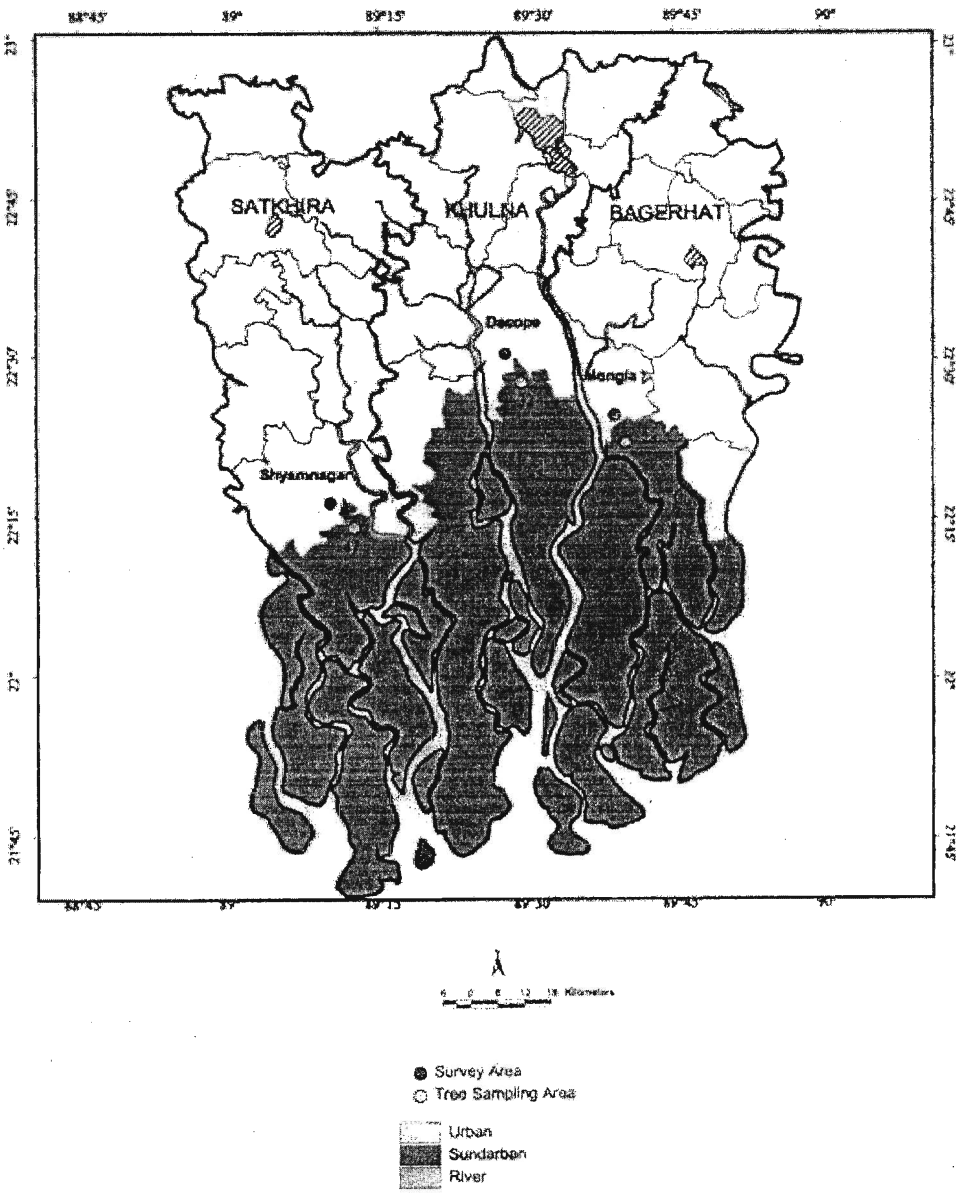

Figure 1: Location of the Study Areas

Socioeconomics and Land Utilization

Socioeconomic Profile of the Sample Survey Population

The age of the respondents ranged from 25 to 75 years and family size varied from 3 to 8. There were 85,771 farming communities in the three Upazillas. In Mongla,

the landless category was the dominant category comprising 40% of the respondents, followed by marginal (25%), medium (15%), large (10%) and small (10%) farm categories. In Dacope, the small farm category was the major group, comprising 35% of the sample population, followed by marginal (30%), landless (25%), and medium (10%) farm categories. No large farm was found within the sample population. In Shyamnagar, once again the small farm category was dominant (35%), followed by medium and marginal (20%) farm categories. The literacy rates in Mongla, Dacope and Shyamnagar were 42.8, 37.6, and 28.2%, respectively.

Agriculture was the principal occupation of farmers in all the survey areas. About 45, 55 and 60% of the respondents in Mongla, Dacope and Shyamnagar, respectively, were engaged in agricultural activities. Seven secondary occupations of respondents were identified in the study areas. These were shrimp cultivation, fishing, shrimp fry collection, fuelwood collection, honey collection, golpata collection, working as labourers, and engaging in business/trading. In Mongla, fuelwood collection was found to be the dominant secondary occupation, whereas in Dacope and Shyamnagar, fishing appeared to be the dominant secondary occupation. In all of the locations, shrimp cultivation appeared to be the second most important secondary occupation.

Land Utilization

Historically, the region was dominated by a single crop farming system with the local Aman rice, which was cropped in the cropping pattern: 'Fallow-Rice-Fallow'.[1] This major farming system is still the dominant cropping pattern with only the addition of a modern variety of rice in the mid 1980s. But in the early 1980s, brackish water shrimp cultivation emerged as a vital land-use, leading to the emergence of a new farming system e.g. Fallow-Shrimp-Rice. In a few areas of Shyamnagar, however, shrimp cultivation was the sole land use activity, with a rotational shrimp-fallow cycle. In the case of the former, shrimp cultivation was done during January to June - July, followed by T. Aman rice cultivation on the same land. In the latter pattern, only shrimp was cultivated year round with no rice crop in the pattern. However, it was reported that every year more and more lands were used for shrimp cultivation and less and less lands for rice cultivation due to increased salinity and other constraints, as was the case particularly in Shyamnagar.

Agricultural Activities

Rice cultivation

The study areas as well as the entire region was dominated by a rice-based farming system; in particular, Aman rice was identified as the main and single most important field crop.

Traditionally, farmers in this region cultivated local/indigenous varieties of rice. However, with the increase in population and the growing demand for food, modern varieties of rice with high yield potential, have been gaining popularity in the region since the mid 1980s. In the study areas, BR22, BR23, BR30, BR31 and BR32 varieties were popular among the farmers in particular, the former two for their salt tolerance characteristics. During the study, a total of 40 local rice varieties were identified from across the region. Among the local varieties, only 4-5 varieties were found to be under normal cultivation and the majority of the local varieties were at the stage of near-elimination or extinction. About 19 varieties were reported to be already extinct from the region. The principal reasons behind the elimination of local varieties were the adoption of modern rice varieties as well as the rapid expansion of brackish water shrimp cultivation. The other reasons for loss/extinction of the local varieties were due to the increase in salinity, as well as a lack of a suitable salt tolerant crop variety and poor yield.

Management Practices in Rice Cultivation

Fertilizer use and pest management were two major practices in rice cultivation. However, weeding which is necessary in the cultivation of modern varieties of rice, was another important management practice in the region.

Fertilizer use

Introduction of modern varieties of rice in the region has led to the increased use of chemical fertilizers. Among the chemical fertilizers, Nitrogen (N) and Phosphorus (P) were the two fertilizers most commonly used by rice growers. However, the use of Potassium (K) was not so common. It was revealed that the use of $ZnSO_4$ and Gypsum were also common in Dacope and Shyamnagar. Fertilizer doses, particularly of N and P, were much higher than the doses recommended by BARC (1997) for this region. Despite increases in fertilizer use, a reduction of yield potential in rice was revealed. It was a common opinion across the study areas, that expected yield levels could not be maintained if fertilizer dose was not increased incrementally.

Pest Management

Introduction of modern methods of rice cultivation has led to the use of insecticides for controlling insect pests in the region during the last two decades. However, in recent years shrimp cultivation has also resulted in the widespread use of insecticide. Expansion of the land area for shrimp cultivation has led to a reduction in the area used for rice cultivation. This has resulted in insect pests attacking the fewer rice fields more aggressively. Even local rice varieties have been attacked in recent years, which is very unusual. It was found that farmers usually applied lower doses of insecticide than recommended but in higher frequencies. This meant that they

applied excessive quantities with lesser efficacy, eventually increasing insect resistance against insecticide in recent years.

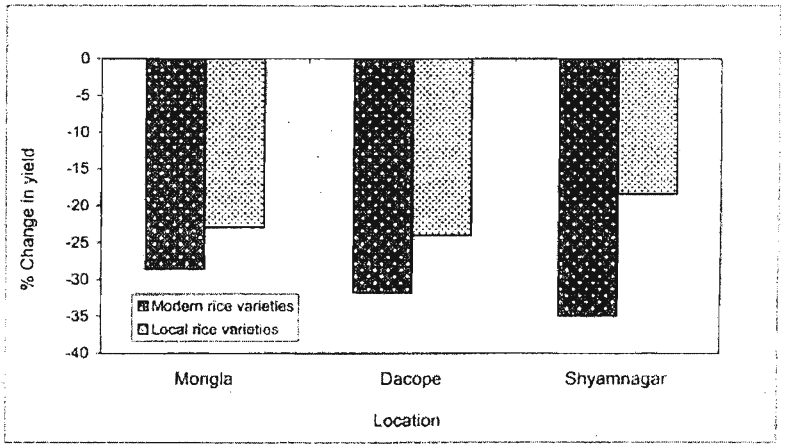

Figure 2: Yield Reduction in Rice Varieties over a Ten Year Period in the Study Areas

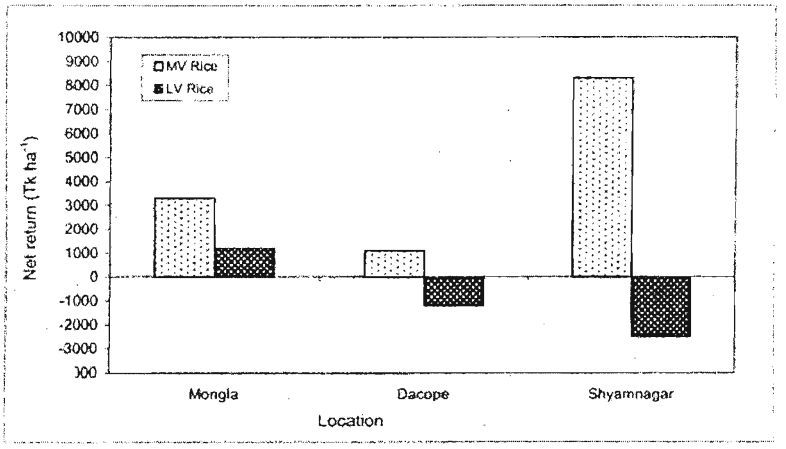

Figure 3: Net Return from Rice Cultivation in the Study Areas

Yield Potential and Profitability of Rice

The average yield of rice in the study areas was much lower than at national as well as at regional averages. Yield reductions between 29-35% with modern varieties, and 18-24% with local varieties were observed (Fig.2). As reported by participants in group discussions, even severe reductions of upto 50% with modern rice varieties have been found in recent years. Reduction in yield potential has also led to lower profit with modern varieties, thus incurring losses with local varieties in some areas

(Fig. 3). Lower productivity of rice has encouraged rice growers to shift to brackish water shrimp cultivation which brings much higher net returns as compared to modern rice cultivation.

Vegetable Cultivation

Vegetable cultivation had been an important farming activity of the study region. But in recent years, the type, acreage and yield of both summer and winter vegetables have been declining considerably. The principal reasons for such a situation has been the transformation and increased submergence of available lands for shrimp cultivation, which has resulted in an increase in soil and water salinity. During the study, 7-8 and 6-10 types of vegetables were found to be common during the summer and winter seasons, respectively.

It was reported that at one time, vegetables were cultivated on a commercial basis by many farmers. But due to the increase in salinity as a result of shrimp cultivation, commercial vegetable cultivation has shifted to other areas. At present, vegetables are brought in from other areas of this region as well as from other regions to meet the demand. As a result, the price of vegetables was also higher, compared to other areas of the regions.

Livestock and Poultry Rearing

In the study areas, the number as well as the productivity of livestock and poultry have been declining severely. The declining rate was predominant in the Shyamnagar and Dacope areas. In some areas, reduction of over 90% was reported. The major reasons for such a declining trend were the scarcity of fodder and feed, scarcity of grazing lands, scarcity of drinking water and wider incidence of intestinal diseases due to the drinking of saline water, particularly in the case of cattle and ducks. Respondents reported that at one time, these regions had a great number of buffalo, which had been substantially decreasing in the recent past, due to the scarcity of fodder. All these problems seemed to be created by increased soil and water salinity, as a result of shrimp cultivation in the region. Another problem resulting in the decrease of the duck population was the limited availability of snails, which was the major feed of ducks. The diminishing livestock and poultry population has also lowered the availability of meat, milk and eggs in all the study areas. Due to severe reduction in the cattle population as well as crop residue and homestead plantations, dependency on the forest biomass has been increasing in recent years.

Fishing

Brackish water shrimp cultivation and open water fishing were identified as the two major fisheries activities in the study region. However, pond fisheries activity was also found.

Brackish Water Shrimp Cultivation

Brackish water shrimp cultivation has emerged as an important enterprise in the coastal region of Bangladesh, during the last two decades . The high price of shrimp as an export item, its higher net return as compared to rice, and the cheap availability of shrimp fry in the Sundarbans estuary, have encouraged rich and influential people from outside the region, to start shrimp cultivation. It has also encouraged, and in many instances, forced the local farming communities to convert more and more paddy lands into shrimp farms. Production practices of brackish water shrimp cultivation begins in January and ends in July-September.

The major management practices in shrimp cultivation were fertilizer and insecticide application as well as the change of water on a fortnightly or monthly basis. The use of fertilizer and insecticide, have been increasing in recent years. Insecticide was mainly used in shrimp farms to kill off-type fish in order to reduce competition for food between shrimp and other miscellaneous fish. In recent years, there have been widespread shrimp epidemics across the region, which were strongly believed to be viral diseases, although it was revealed that the problem was due partly to virus and partly to environmental stresses. To combat the epidemics (so-called viral diseases) illiterate shrimp farmers started using insecticide to protect their valuable crop from the so-called virus. In this way, the use of insecticide in shrimp cultivation became a dominant feature in the region. The alarming situation was that when water was changed regularly in the shrimp farms contaminated water was released into the rivers. This contaminated water obviously posed serious threats to the aquatic environment in the rivers and canals in and around the Sundarbans.

Open Water Fishing

Open water fishing includes fishing and shrimp fry collection. Open water fishing has been the traditional occupation of thousands of fishermen in the region. However, besides regular fishermen the numbers of seasonal fishermen have increased manifold. The current figure for fishermen dependant on the Sundarbans estuary was estimated as 200,000,[4] and it should be more than 300,000 by the end of 2000-01.

Shrimp Fry Collection

Historically, open water fishing was an important occupation of the local inhabitants. In recent years however, brackish water shrimp cultivation, which requires a huge supply of shrimp fry, has encouraged the local people, particularly resource-poor groups, to be increasingly involved in shrimp fry collection. Shrimp fry collection has resulted in the employment of thousands of resource-poor groups, particularly women and children in the regions. A total of 44,766 shrimp fry collectors were

Table 1: Shrimp Fry Collection Statistics in the Study Areas

Year	Mongla			Dacope			Shyamnagar		
	Fry Collectors	Bagda fry	Golda fry	Fry Collectors	Bagda fry	Golda fry	Fry Collectors	Bagda fry	Golda fry
1992	4873								
1993									
1994				6000	1077000	211000			
1995				6000	1089000	227000			
1996									
1997	7710	2902500	1149000	7100	1877625	905600			
1998	4500	294500	587500	7200	839275	1067500			
1999	6493	8900430	410400	7200	640100	2070000			
2000				7500	68600000	29500000	30773	98076584	

Source: DoF office records, Mongla, Dacope, and Shyamnagar

identified in the three study areas (Table 1). The highest number of shrimp fry collectors was found in Shyamnagar (30,773), followed by Dacope (7,500) and Mongla (6,493). The number of fry collectors has been increasing and updated figures would be higher than the available figures.

The most adverse impact of shrimp fry collection with fine mesh nets was the destruction of numerous other fish species. Felling a single tree needs 4-5 persons providing an income of Tk. 300.00 per person, whereas shrimp fry collection gives the same earning on a single occasion. Recently, the Government imposed a ban on shrimp fry collection. This would create unemployment, resulting in increasing pressure on other resources of the Sundarbans. There were opinions expressed that the ban should be relaxed for 2-3 seasons, and that gradual re-imposition would be effective. Besides, there should be an alternate income-source and/or employment opportunity for these fry collectors. However, the Forest Department has not yet enforced such a ban, which is why collection is still continuing.

Pond Fishing

Most of the households in the study region had ponds in their homesteads. Most of the ponds were utilized according to traditional methods. Farm households rear common carps and other sweet water fish in these ponds. However, the rearing of estuarine species was also common. The growth and productivity of sweet water fish has decreased in recent years due to the increase in pond water salinity as a result of shrimp cultivation.

Homestead Tree Species

The study revealed that both the number and productivity of homestead tree species, particularly sweet water fruit species, were declining in recent years. The principal reason was the increase in soil and water salinity. Coconut, betel nut, mango, jackfruit, lemon, mahogini, and guava were the main species which have been declining in both number and productivity. Common visible symptoms were growth retardation including the yellowing of leaves, barren trees, premature fruit dropping, followed by top dying and ultimately the death of the whole plant. Decline in the number and productivity of homestead plantations have created a crisis in areas that require feed, fodder, biomass fuel, and timber. At the same time, the decline in fruit tree species has created problems with regard to human nutrition.

Forest Activity

Resource Collection from the Sundarbans

Sundarbans has been playing a vital role in the livelihood of the people of the region for generations because people have been fully or partially dependent on the natural

Table 2: Collection of Selected Floral Resources from the Sundarbans under Legal Permits

Year	Amount				
	Timber (million cft)	Fuelwood (million cft)	Golpata (million t)	Grasses (000't)	Hantal (t)
1984-85	2.8	0.06	0.06	9.31	8910
1985-86	3.15	0.06	0.06	11.06	5412
1986-87	1.21	0.07	0.07	11.74	6087
1987-88	2.49	0.08	0.08	13.44	7848
1988-89	2.42	0.07	0.07	13.53	8339
1989-90			0.07	11.57	7203
1990-91	0.68	10.11	0.07	7.29	6747
1991-92	1.64	6.93	0.07	4.74	9032
1992-93	3.01	6.12	0.07	5.9	6053
1993-94	1.88	7.24	0.07	6.62	6725
1994-95	2.29	5.72	0.06	6.77	1712
1995-96	0.48	1.41	1.69	4.02	4338
1996-97	0.17	0.95	1.57	5.87	712
1997-98	0.19	1.33	1.4	5.26	
1998-99	0.13	1.68	1.0	2.12	
1999-2000	0.18	3.44	2.7	6.78	
2000-01	0.26	8.2	0.92	3.95	

Source: Canonizado and Hossain (1998); FAO/UNDP (1998), Karim (1995); FD records

Table 3: Collection of Fish Resources from the Sundarbans under Legal Permits

Year	Amount			
	Fish (000't)	Bagda shrimp fry (million)	Large shrimp	Small shrimp
1986-87	4.62	0.82		
1987-88	4.51	14.1	391	191
1988-89	3.86	30.43	367	104
1989-90	3.67	70.34	270	132
1990-91	4.95	72.69	241	126
1991-92	4.83	110.36	371	533
1992-93	5.59	127.97	307	791
1993-94	5.14	231.15	274	855
1994-95	5.39	263.41	281	593
1995-96	5.99	253.07	277	655
1996-97	4.29	142.22		
1997-98	4.28	127.98		
1998-99	3.5	81.41		
1999-2000	3.45	101.36		
2000-01	3.14	96.08		

Source: Canonizado and Hossain (1998); FAO/UNDP (1998), Karim (1995); FD records

Table 4: Collection of Selected Minor Resources from the Sundarbans under Legal Permits

Year	Annual collection				
	Honey (t)	Wax (t)	Mud crab (t)	Shell (000't)	Crab
1984-85	257	64.24	-	2.69	-
1985-86	226	56.4	-	2.67	-
1986-87	230	57.49	15	3.2	15
1987-88	223	55.76	15	3.62	15
1988-89	100	25.13	14	3.66	14
1989-90	147	36.56	26	-	26
1990-91	210	52.76	86	-	86
1991-92	160	43.46	274	3.17	274
1992-93	183	45.86	491	3.35	491
1993-94	107	26.63	527	4.36	527
1994-95	91	22	711	3.95	711
1995-96	161	39	851	4.28	851
1996-97	193	-	895	1.02	895
1997-98	131	33	824	0.82	824
1998-99	149	37	440	3.3	440
1999-2000	208	52	488		488
2000-01	130				

Source: Canonizado and Hossain (1998); FAO/UNDP (1998), Karimi (1995); FD records

resources of the Sundarbans. Resource collection from the forest include timber, fuelwood, goalpata, keora fruits, honey, bee-wax, and from rivers/canals include fish, shrimp fry, mud crab, shell etc. Data on the collection of major and minor resources from the Sundarbans (as shown in Tables 2, 3 and 4) indicate the increased pressure on the resources of the Sundarbans ecosystem in recent years.

Causes for Resource Depletion of the Sundarbans

Several causes for resource depletion have been identified. The major causes behind resource depletion were population pressure, poverty, shrimp cultivation, over fishing, fishing with insecticide, over-exploitation, illegal logging/hunting, political influence and weak management by the Forest Department. In the case of fuel wood collection, it was reported that villagers and loggers collect mature as well as tender trees for fuelwood with no regard to their age and other economic values.

Overall Dependency on the Sundarbans

For generations, people living in close vicinity of the Sundarbans have been dependant on its resources. This dependency has gradually been increasing and in recent years, has increased manifold. Dependence on the Sundarbans was mainly in the areas of fishing and fuel material collection. Respondents view was that dependency on the Sundarbans has increased by upto 50-100%. Almost all the participants mentioned that dependency on the forest has been increasing dramatically during the last 10 years. According to the respondents, dependency on the forest was only 10-20% about 20 years ago, but at present, dependency has increased to 50-100%

Ecology, Biodiversity and Socioeconomic Issues and the Impact on the Ecosystem

Ecological Issues and Impacts

a) *Modification of Upland Agro-Ecosystems into Lowland Ecosystems*: Unplanned expansion of brackish water shrimp cultivation, along with its associated activities have already led to severe ecological deterioration in the Sundarbans as well as in the whole coastal region. Shrimp cultivation has caused seasonal transformation, and in some cases year round transformation of upland agro-ecosystems into lowland ecosystems. Such transformation has resulted in the reduction of rice and vegetable growing areas, grazing lands, other natural vegetation areas and homestead areas.

b) Reduction in Rice Crop Areas: Expansion of shrimp cultivation which apparently has a very high net return compared to rice (Fig. 2) has encouraged rice growers of the region to convert more and more paddy lands into shrimp farms.

c) Reduction in Vegetable and Other Crop Areas: Structural modification as well as the transformation of the agro-ecosystem, has also eliminated other minor cereal and non-cereal crops from the study areas. Particularly, areas used for vegetable cultivation have been considerably reduced. Increased submergence and scarcity of land, has pushed vegetable plots to upper elevation areas and homesteads further interior.

d) Reduction in Grazing Land and Other Open Areas: Structural modification has caused submergence as well as reductions in grazing lands. Besides, due to the steep dykes of the shrimp-cum rice fields, cattle graze on the aisle (borders) of these fields as they did before.

c) Modification of the Forest Ecosystems: It was revealed that the Sundarbans forest has been encroached for establishing shrimp farms. The Chokoria Sundarbans has virtually been completely destroyed as a result of human activities, such as the over exploitation of forest resources, shrimp farming, salt production etc. Over crowding and riverbank erosion inside the forest by shrimp fry collectors as well as fishermen have also been identified.

Impact on the Ecosystems

a) Increase in Soil and Water Salinity: Salinity was the single most significant problem in the study areas, chiefly caused by brackish water shrimp cultivation. In terms of both growth and yield, rice and vegetable crops were adversely affected by soil and water salinity. Increased pond and groundwater salinity have been causing problems with regard to irrigation and drinking water. Increased salinity was also reported to be responsible for topdying of Sundri and other forest tree species.

b) Deterioration in Soil Fertility and Productivity: Use of chemical fertilizer as well as the use of overdoses of N and P fertilizer in rice cultivation were identified as the major causes for deterioration in soil fertility and productivity. Moreover, the deterioration of the quality of soil, lesser availability of soil flora and fauna, and incidence of human diseases were also identified as some notable outcomes of fertilizer use. Soil physico-chemical properties of different land categories indicated lower levels of available P and higher levels of Ca. Organic matter contents were lower as well.

c) Impact on Homestead Plantations: Salinity has caused adverse effects on both diversity and the growth of homestead plantations.

d) Increase in Disease and Pest Problems: The introduction of modern rice cultivation has resulted in more diseases and pest infestations to both crops and shrimps.

e) Impact on Biomass Fuel: Traditionally, besides fuelwood from the Sundarbans villagers used rice straw, cow dung, twigs and leaves of homestead plantations as fuel material. However, at present the entire area is facing a serious fuelwood crisis. Because of the decline in local rice varieties, straw production has declined as modern varieties of rice do not yield as much straw as the local ones. Due to the decline in livestock, dung production was almost nil. Decline in homestead plantations has resulted in lesser production of twigs and leaves in the home gardens. Twenty years ago, dependency on the Sundarbans was around 25%, however, at present the dependency has mounted to almost 75-100% (Table 5).

f) Impact on Human Health: Increased salinity in pond and groundwater has caused drinking water problems for rural households. It has also caused intestinal problems and other diseases. Due to this, householders harvest rainwater in earthen pots/ jars for drinking purposes, and it is a common practice across the region. Moreover, collection of drinking water from long distances is also a common feature for housewifes. Moreover, salinity has created problems in that pond water cannot now be used for other purposes like bathing, washing, cleaning, religious needs, and other household activities. Continuous shrimp fry collection in the saline waters of riverbanks has reportedly also caused skin diseases and wounds in the hands and bodies of fry collectors.

Table 5: Fuel Usage Patterns at Three Areas as Reported by the Respondent Farm Households

Fuel type	% Respondents					
	Mongla		Dacope		Shyamnagar	
	20 yrs before	Now	20 yrs before	Now	20 yrs before	Now
Cow dung	100.00	25.00	100.00	20.00	100.00	20.00
Agricultural residue	100.00	90.00	100.00	100.00	100.00	100.00
Homestead plantation	85.00	70.00	90.00	35.00	80.00	40.00
Sundarban	30.00	75.00	35.00	70.00	25.00	75.00

g) Impact of Other Activities on the Sundarbans Ecosystems: Fertilizer and insecticide use have caused pollution of soil and water resources leading to an adverse impact on rivers and other water bodies across the Sundarbans.

Biodiversity Issues and Impacts

Loss of Biodiversity in Areas Adjacent to the Sundarbans

a) Reduction in Crop Varieties: Cultivation with new varieties of rice, and brackish water shrimp cultivation have already accelerated the extinction process of local rice varieties of the region. In this way, it is anticipated that within the next 5-10 years, no local rice variety would be available in the region. The major effects of such an extinction process are the loss of rice genetic resources, reduction of thatching materials, fodder, and biomass fuel. Scarcity of biomass fuel has already increased the pressure on the Sundarbans.

b) Reduction in Homestead Plantations: Both fruit and forest species in the homegardens have been adversely affected due to higher levels of salinity.

Table 6: Trends in Livestock Population over Time in the Study Areas

Location	Livestock	Population (No.)				%
	Category	1990	1995	2000	2001	Change
Dacope	Cattle	-	44576	-	34716	-22.12
	Buffalo	-	1244	-	1067	-14.23
	Goat	-	13956	-	11915	-14.62
	Sheep	-	3211	-	3079	4.11
	Duck	-	50117	-	34096	-31.97
	Poultry	-	206162	-	122354	-40.65
Shyamnagar	Cattle	74735	-	-	45355	-39.31
	Buffalo	7533	-	-	1750	-76.77
	Goat	40213	-	-	13200	-67.17
	Sheep	20505	-	-	6500	-68.30
	Duck	33490	-	-	10400	-68.95
	Poultry	92881	-	-	95975	+3.33

Source: DLS Office records, Mogla, Dacope and Shyamnagar

c) Reduction in Livestock and Poultry Resources: Increased salinity has adversely affected the livestock and poultry population in the region (Table 6). Increased salinity has drastically hampered the production of grasses, homestead plantations, other sweet water vegetation and snails, thus creating a severe feed and fodder crisis. Moreover, salinity has caused drinking water problems for livestock, particularly for ducks and poultry, and has also resulted in intestinal diseases in cattle and ducks. During the field study, sick cattle and goat were seen desperately searching for food and even feeding on rotten fruit floating across the rivers from the Sundarbans on to the banks of the rivers. Reduction in livestock and poultry resources has adversely affected the supply of protein sources. Other negative outcomes were the reduced availability of draught power, livestock and poultry products as well as price hikes of these products.

d) Reduction in Numbers of Birds and Animals: It was revealed that in recent years bird populations have decreased drastically in regions adjacent to the forest. Among the principal reasons were the lack of sweet water and the increased use of insecticide in rice and shrimp cultivation. It was suggested that birds usually feed on the grains of cereal and other crops. In recent years, they have had to feed on toxic grains caused by the application of insecticide, which might be the prime reason behind the decrease in their population.

Loss of Biodiversity in the Sundarbans Forest

a) Floral Diversity: Depletion of tree resources was found in the study areas. The principal causes behind the depletion of trees were over logging and illegal logging of valuable trees for timber, the indiscriminate cutting of trees for fuelwood, cutting of tender trees to give support to boats carrying other resources, etc. The number of matured Sundri and Gewa trees (these species cover 89% of the tree resource of the Sundarbans) per unit area were less than the previous estimates.

Sundri top-dying had been a subject of study for several years, it was later revealed that salinity was the prime reason for the top-dying of this unique mangrove species. It was also evident that Sundri (*Heritiera fomes*) was able to grow in saline areas but that the full development of the species was only found in areas where freshwater flushing occured. Bhuiyan[3] found moderate to severe top-dying in areas where soil salinity was relatively high. In areas of lower salinity, there was evidently no top-dying.

b) Fish Diversity: The fish population has been declining in the study areas as well as in the whole coastal region. The main reason was over collection of fish and shrimp fry. Fishing inside the SRF with poisons and insecticide was also argued to be a major reason behind the severe adverse effects to fish and other aquatic beings.

It was revealed that in all the areas, there were fewer fish species and other aquatic animals.

c) Wildlife Diversity: It was reported that the population of wild animals has gradually been reducing in the region. Tiger and deer hunting, particularly with the aid of poisoned baits and sedatives were some of the main reasons. Other causes were the reduction in forest cover and increase in human activities. Humans were reportedly intervening the food chain of tigers and other predatory animals including birds. The bird population too has been decreasing in the region and the major causes are the reduction in forest cover, absence of tall trees, increase in human activities, depletion of food sources, and feeding on contaminated grain and fish.

Other Factors Affecting the Ecology of the Sundarbans

In addition to the predominant agricultural activities, other important anthropogenic factors causing damage to the Sundarbans ecosystems were also identified. These factors were polder construction, Farakka barrage, industrial discharge and oil pollution.

a) Polder Construction: Construction of coastal embankments was started in the late 1960s. More than 125 polders had been constructed in the southwest region along the upper catchment areas of the Sundarbans rivers during the late 1960s. These polders were constructed mainly to control saline intrusion into agricultural fields. Increased security of the enclosed areas of these polders stimulated the expansion of shrimp cultivation. Tidal lands with embankments for protection from saline water intrusion for rice cultivation were being used increasingly for shrimp cultivation. Thus embankments raised to protect agricultural crops from salinity have been turned into agents for increased salinity.

b) Farakka Barrage: The unilateral withdrawal of the Ganges flow through the Farakka Barrage built during the 1960s, appeared to be a major cause of damage to the ecosystem in the Sundarbans forest.[8] The Farakka barrage caused a reduction in the sweet water flow through the Ganges systems and ultimately to the Passur-Shibsha systems resulting in a higher salinity build-up in river water. This was considered to be a major cause behind the top-dying of Sundri trees since the relationship between top-dying and higher salinity has been established.[6,3]

c) Industrial Discharge: Industrial setups in the upstream areas of the Sundarbans are also responsible for damage of the ecosystems. There are about 165 industries in the Khulna district. The wastewater discharged by these industries and factories are also responsible for water pollution that is being carried to the Sundarbans through the Passur-Shibsha river systems.[5,14]

d) Oil Pollution: Oil pollution also affects the environment of the Sundarbans.[14,6] Crude oils derived from mechanized boats, fishing trawlers, and passenger launches cause damage to saplings and their breathing roots,[10,9] as well as to other fauna of the Sundarbans. The aromatic hydrocarbons present in crude oil were found to be harmful for the marine environment including fish resources, as these have a tendency to be biologically accumulated in fish tissues and can pass into organisms of higher trophic levels in the food chain.[7]

Socioeconomic Issues and Impacts

Social Conflicts

Both structural dimensions as well as production systems have resulted in social conflicts among the rural communities. The structural setup of the shrimp farms have forced rice growers within or alongside these shrimp farms to convert their paddy land into shrimp farms, as there is no scope for rice growing. In case of joint venture farms, social conflicts include deprivation of the right to utilize land according to one's choice, conflicts regarding ownership of joint-ownership lands, deprivation of right shares, suing, harassment, etc. by the rich and influential partners. In case of lease arrangements, the social effects included, deprivation of the amount defined in the lease agreement, deprivation of payment in the last year, unusual delays in shrimp harvests hampering rice transplanting schedules, harassment, suing, and other disturbances.

Food Security

Decrease in rice and vegetables production has led to transformation of food sufficient areas into food deficit areas. Elimination of livestock resources has resulted in resource-poor communities facing severe hardship in sustaining their livelihood under such circumstances.

Increased Dependency on the Sundarbans

Increased social conflicts and social disharmony as well as fragile food security have resulted in eviction from land, surplus labour, unemployment, increase in the cost of living, leading to a vicious poverty cycle. The ultimate outcome has been the increased dependency on the Sundarbans, and hence the increased deterioration of the Sundarbans ecosystems, coupled with more hardships for the resource-poor communities.

Management Strategy

The following recommendations are put forward to combat the whole range of issues, though it is difficult to forward recommendations after only a short period of study.

At Macro Level

- Provision for the creation of a separate division for the conservation and management of the natural resources of the Sundarbans and surrounding areas.
- Develop distinct policy and management implementation strategies for mangrove resources of the Sundarbans.
- Develop policies to regulate and restrict brackish water shrimp cultivation and to reduce encroachment onto agricultural lands.
- Strengthen interdisciplinary efforts involving governmental and non-governmental agencies to conserve forest and other natural resources.
- Create awareness through the national media of the adverse impact of present unsustainable systems of shrimp cultivation, fishing, shrimp fry collection, and exploitation of forest resources.
- Develop salinity tolerant crop and vegetable varieties for the coastal region.
- Empower the Department of Fisheries to monitor, manage and control the fisheries resource in the Sundarbans.
- Create alternate employment and/or income sources for the resource-poor groups in order to reduce dependency on the forest.
- Form a national committee involving educationalists, researchers, environmentalists, foresters, agriculturists, and representatives of different NGOs, to monitor, review and make necessary recommendations to conserve the ecosystem of the Sundarbans.

At Micro Level

- Control the establishment of new shrimp farms.
- Improve the management systems of shrimp farms.

- Restrict after season shrimp fry collection and fishing, and restrict collection and fishing from protected areas.
- Ban the use of fine mesh nets and insecticide for shrimp fry collection and fishing.
- Identify and introduce salinity tolerant crop and vegetable varieties for the coastal region.
- Discourage over use of fertilizer and pesticide.
- Develop Integrated Pest Management (IPM) packages.
- Develop an immediate action plan to control top-dying of Sundri
- Develop and introduce social forestry, agroforestry and riverside forestry programmes.
- Promote replanting and regeneration programmes in the depleted forest areas.
- Enforce laws and regulations with regard to illegal logging and hunting in the Sundarbans.

Future Research Needs

This short period of study (5 months) is not enough to critically examine the whole range of issues pertaining to the Sundarbans and surrounding areas. It is essential to conduct an in-depth study for two years to acquire a better understanding of agricultural and other livelihood activities of the farmers. Monitoring environmental parameters over time on different ecosystems, e.g. soil physico-chemical properties; salinity and toxicity, are essential to draw more definite conclusions regarding ecological issues. Monitoring rice and shrimp production practices as well as fuel use by different categories of people over time is also essential. Continuous monitoring of flora and fauna across the Sundarbans in the deeper areas of the forest is also essential. Monitoring of species of fish over time at different sites, and of marketing channels are also essential in a future study.

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