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

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

PREFACE

In order to correct the phenomena of market and policy failures on the one hand and halt the process of degradation and depletion of natural resources and their functions on the other, economic valuation of ecological functions and benefits have been sought as necessary so that the public policy can be holistic and sustainable. The attempt for valuation has been made at different levels varying from population to ecosystem function to biosphere in the descending order of success. Wetlands have been one such ecosystem, which are called as ‘kidney’ of the landscape. The role of this ecosystem through its diverse and multiple functions becomes crucial if it is in the vicinity of a metropolitan congested city like Delhi. Floodplains and seasonable pools along the river Yamuna in the corridor of Delhi from Wazirabad to Okhla are a typical wetland ecosystem which perform valuable ecological functions e.g. water recharge, nutrient retention, habitat to wildlives and biological productivity. These biologically productive areas are most threatened and are being converted for habitation, slums and industries. This is being done because of the fact that ecological functions of the floodplain remain unacknowledged, unaccounted and unpriced. Therefore valuation of the ecological functions in order to make the decision of conversion efficient and sustainable becomes very important. And this is the central theme of this research study where the scientists have estimated major ecological functions and then the economist of the investigating team has evaluated these functions economically. For valuation, various methodologies of environmental economics have been applied. Market price method has been used for direct and tangible benefits where for water recharge (benefiting agriculture) production function and alternate cost approach (for water supply to Delhi) have been adopted. Other benefits like fodder, nutrient etc. have been computed following indirect opportunity cost approach. For biodiversity and recreational aspects of the floodplains, contingent valuation method (CVM) has been used.

Values for different components have been added which is quite substantial. This value, when compared with other land uses is lower but they will grow exponentially because of greater demand for ecological services in future owing to urbanization of Delhi and ever increasing relative importance of wilderness. This study thus draws attention towards economic value of the floodplain. The planners of this city must take note of it.

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Chapter 1: Introduction

Wetland ecosystems are among the most productive ecosystems in the world, which not only support unique flora and fauna but also provide ecological services beneficial to the human society. Wetlands have become the most threatened ecosystems and are rapidly diminishing due to anthropogenic activities. During last 100 years US has lost around 47% of its wetland whereas UK and New Zealand had lost around 60% and 90% of their wetland respectively (WCMC, 1992; Dugan, 1990). For most of nations of South Asia the loss of wetland has been estimated to the tune of 80% (UNEP, 1992).

Pressure for conversion of wetlands for developmental purposes is very high especially in case of urban riparian wetlands. These wetland ecosystems provide many tangible and intangible benefits on a sustainable basis not only to the urban society but also to the associated dependent ecosystems. Wetland areas on the fringes of river channels in a city are looked upon as a precious property resource with different potential land uses such as agriculture, site for human settlements, industries, civic construction and waste dumping sites etc. This is, particularly true, in the case of wetland ecosystems of Yamuna river corridor in Delhi. Due to rapidly increasing population coupled with increasing number of industries there is an immense pressure for conversion of these wetland ecosystems for various developmental options.

Yamuna river corridor region is approximately 6.5 % of the total area of Delhi. Of the total stretch of the river corridor present in Delhi, the twenty-five kilometers stretch extending from Wazirabad to Okhla is perhaps the most threatened riverine ecosystem in the world because of the immense anthropogenic pressures on this riparian habitat. This river corridor region has been continuously confronted by the encroachments and conversions of land for various commercial purposes putting threat to very existence of its associated wetlands.

A number of development options for this land resource have been suggested by various development agencies. One of the developmental proposals for utilization of this land resource of the river corridor in Delhi region is the channelization of the river

Yamuna in Delhi stretch. Channelization entails construction of artificial channel for the river that is bounded by dykes or bunds on both sides of the channel. This will stop meandering and over-topping of the river that will lead to reclaiming of vast stretches of land which is otherwise periodically inundated when the river floods. The reclaimed land will be subsequently used for the development of civic infrastructure.

Land is a scarce resource in Delhi, thus strong socio-economic justifications are given to carry out such development programmes. These justifications neglect the hidden "economic value" of the ecological functions and benefits that are provided by the wetlands to the urban society and local inhabitants on a sustainable basis. Moreover, due to characteristic position of these wetlands in the landscape they have a critical role in the urban ecosystem of Delhi particularly with respect to ground water recharge.

To assess the relative economic merits of major development options vis-à-vis wetland conservation, the ecological functions and benefits from wetland ecosystems in Yamuna river corridor need to be made explicit and their economic values assigned. Based on the economic value, strategies for sustainable utilization of these wetlands can be evolved with adequate justification for investible funds.

To achieve this the present interdisciplinary multi-institutional research programme on **"Valuation of Ecological Functions and Benefits: A Case Study of Wetlands Ecosystem Along the Yamuna River Corridors of Delhi Region"** was undertaken with the following objectives:

(i) Assessment of the functions and benefits derived from the river front wetlands and identification of the threats to these functions;

(ii) Economic valuation of these functions and benefits of the wetlands and the cost benefit analysis of benefits derived from the maintenance of wetlands and alternative development options;

(iii) Simulation of the development option for wetlands of Yamuna in the Delhi region.

In order to fulfill these objectives the research investigating team comprising of ecologists and economists have attempted to identify and signify the ecological functions and their contributions to the welfare of the society which otherwise are unacknowledged, unidentified, unattended and unaccounted. The specific focus of the study has been to analyse the ecological economic dimension of these wetlands in the urban ecosystem of Delhi, which can be useful for scientists, policy makers and planners.

Chapter 2: Wetland Ecosystems in Yamuna River Corridors of Delhi Region: Their Status and Assessment of Ecological Functions

The precise identification and delineation of wetland ecosystems through time and space is a prerequisite for their economic valuation. Delimitation of wetland types is a must to accurately quantify the benefits arising due their ecological functions.

2.1 The Study Area

Field surveys were carried out for making preliminary assessment of the study area. Based on the survey the study area (Wazirabed to Okhla Barrage) was divided into the following three sectors for identification, delineation and mapping of different types of wetlands.

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

Subsequently, intensive surveys of each of these sectors were carried out and wetland ecosystems were identified by using well-established criteria given below:

1) Vegetation type

a) Identification of areas having hydrophytic vegetation

b) Distribution of hydrophytic plants and their remnants through time and space

2) Soil properties

a) Redox potential

b) Soil type

3) Hydrological status

a) Depth of water table

Diversity of wetland ecosystems present in the Yamuna river corridor was assessed using three sets of criteria, they were:

1) Vegetation characteristics

a) predominant plant species

b) circumscription of areas having similar composition of vegetation

2) Soil characteristics

a) extent of soil moisture in surface layers

b) composition

3) Hydrogeomorphic characteristics

a) predominant source of water

b) residence time of water

c) land forms and topographic position in the landscape

2.2 Types of Wetland Ecosystem

Based on the observations recorded on above-mentioned parameters in the study area, three types of wetland ecosystem were identified. These wetlands are: (a) floodplains; (ii) seasonal pools; and (iii) marshy areas.

These wetlands were spread over an area of 3250 ha. Exact location and size of the study area and different wetland ecosystems were mapped using Geographic Positioning System (GPS) during the field surveys. These geographic coordinates were then used to show the distribution of different wetland types on the toposheet of the study area. Distribution of different types of wetlands in different sectors of study area of Yamuna river corridor is shown in a schematic map (Fig 2.1). The total study area and area covered by different wetlands is given in Table 2.1 and Figure 2.2.

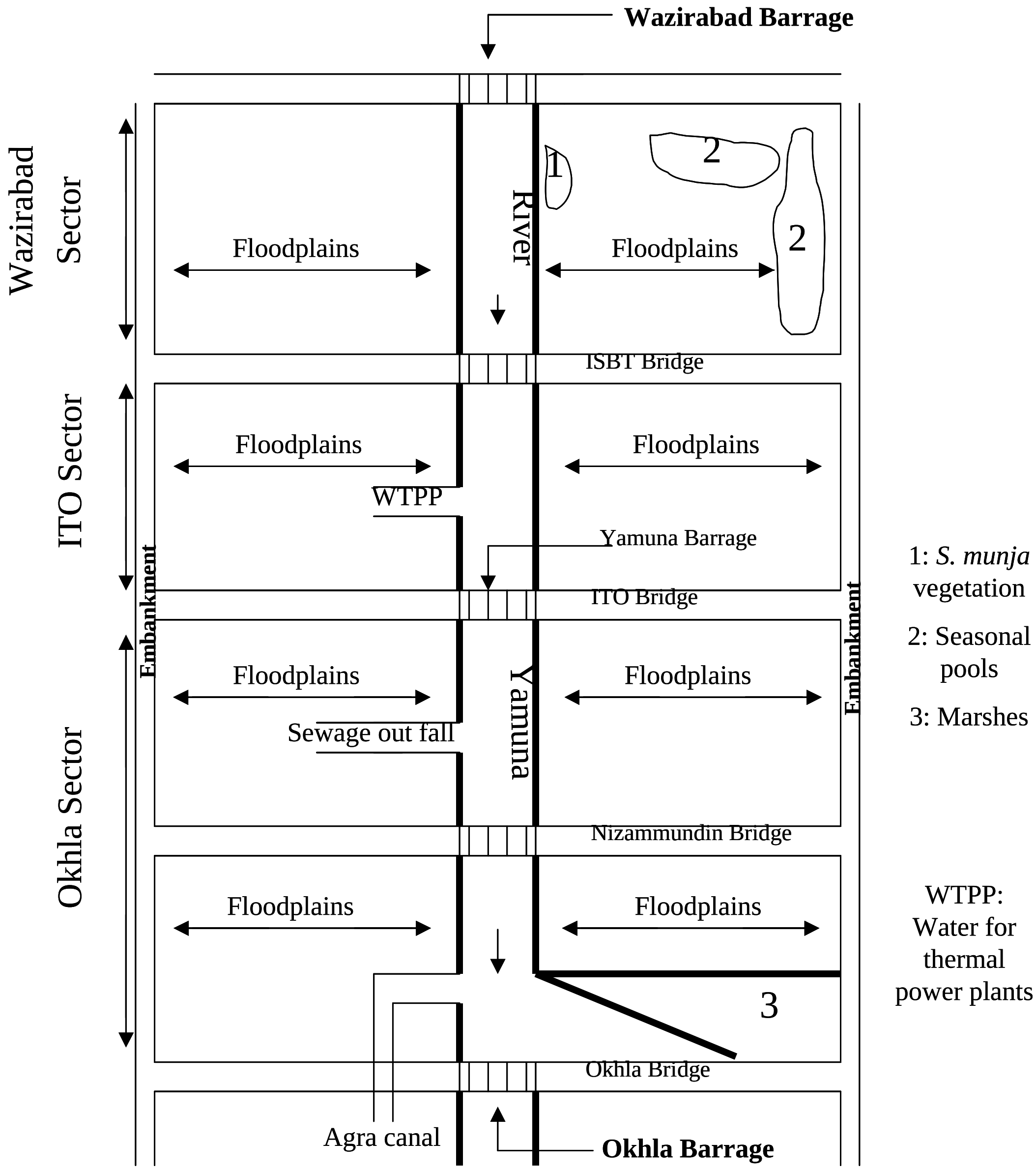


Fig 2.1: Schematic map of the study area showing different sectors and distribution of different wetland types (floodplains, seasonal pools, marshes)

Table 2.1: Area covered by different types of wetlands present in the study area of Yamuna river corridor ranging from Wazirabad to Okhla Barrage

S. No.	Type of wetland ecosystem	Area covered (Ha)
1	Floodplain	3,100
2	Marshy area	110
3	Seasonal pools	40
	Total study area	**3250**

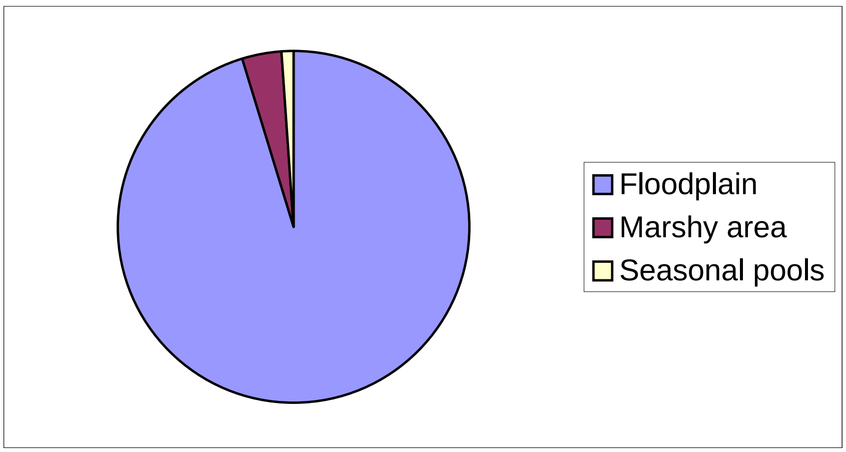


Fig 2.2: Pie chart showing percent area under different wetland types

Floodplains are the most widespread of the wetland ecosystems present in the Yamuna river corridor in the Delhi stretch comprising approximately 95.38% of the total area. Though marshy areas and seasonal pools have small geographic area, they are of critical importance in providing nurseries for the fish fries and nesting sites for the migrating waterfowl respectively.

It may be noted that the extent of the various wetland ecosystems changes seasonally. For example, during the summer season seasonal pools and marshy areas dried up and are used for agriculture and other purposes. Their extent also varies in between a particular season depending upon the change in land use pattern brought about by anthropogenic pressures.

2.2.1 Floodplains

Floodplains are a stretch of flat land present in between the manmade embankments and the levee of the river channel of the study area (Fig 2.3). These areas are regularly inundated with floodwater during the monsoons. Natural vegetation of the floodplains is presently restricted to small pockets near Wazirabad barrage (Fig.2.1). These pockets harbour pure stands of *S.munja*- a characteristic plant species of floodplains.

Floodplains of Delhi region are being used for a variety of purposes, which include, dry season agriculture and temporary makeshift human settlements etc. The local people predominantly use major portion of this floodplains for practicing dry season agriculture.

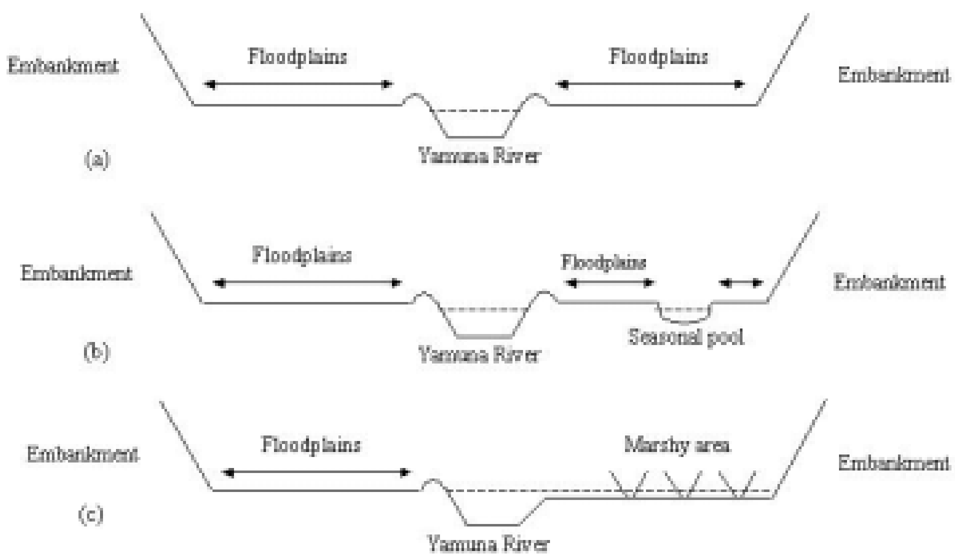


Fig 2.3: Diagramatic presentation of cross section of different kinds of wetlands present in the study area
(a) floodplains;
(b) seasonal pools; and
© marshy areas.

2.2.2 Seasonal pools

Seasonal pools are formed due to filling up of water in the low-lying areas of the river corridor region after the monsoons (Fig 2.3) they are present predominantly on the western banks of the river Yamuna in both Wazirabad and ITO sectors of seasonal pools During the late winter and summer seasons when these pools are dried up human settlements are present in their place.

Seasonal pools are a multiple use resource, for example: (i) for catching different variety of commercially important fishes for about 4-5 months each year; and (ii) serve as water hole for the cattle of local inhabitants. Water present in the seasonal pools also recharge the ground water of the neighboring areas in a gradual and sustained manner.

2.2.3 Marshy areas

Marshy areas are predominantly present in the Okhla sector from Chilla regulator to Okhla barrage (Fig 2.3). *Typha angustata* is the dominant plant species present in the marshy areas. Fragmentation and destruction of these areas have taken place due to the construction of Noida toll bridge and other civic structures. Marshy areas present in the Yamuna river corridor provide nesting and feeding grounds for many migrating waterfowl species. Thus these sites are of prime importance with respect to their potential to act as waterfowl habitat.

2.3 Ecological Functions and Benefits Provided by the Wetlands

Wetlands consist of characteristic assemblages of species that interact with each other and the environment. These interactions within and between the biotic and abiotic components of wetland ecosystems lead to a flow of ecological functions that provide ecosystem services to the human society. Some of the ecological functions provide direct economic benefits whereas others provide indirect support and protection to an economic activity. Wetland ecosystems of the Yamuna river corridor were assessed for five functions based upon the preliminary observations collected during field surveys. The functions that were considered for quantitative estimation of values are:

I. Hydrological functions;

II. Biological productivity;

III. Sediment trapping and stabilization;

IV. Habitat for flora and fauna; and

V. Nutrient storage

The various ecological functions and values of the wetlands are interlinked with each other forming feedback loops. This complex web of interactions (Fig 2.4) between various ecological functions indicates that alteration in the performance of a single ecological function will have a cascading effect on the ecosystem functioning.

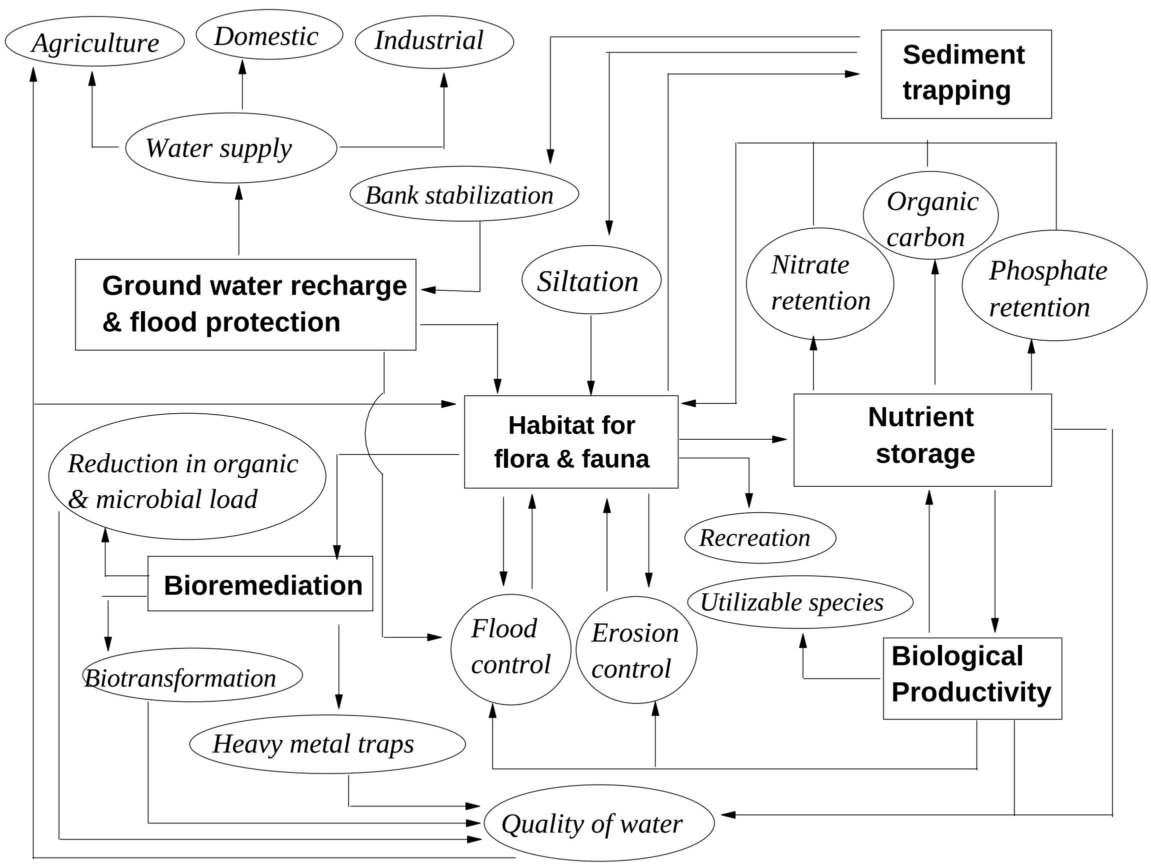


Fig 2.4: Interlinkages between ecological functions and values of wetlands

The rate of performance of these functions varies between different types of wetlands. This depends upon the biotic communities and the hydrological position of the wetland ecosystems in the watershed**.** The ecological functions performed by the wetlands provide a stream of benefits to the human society. Some of the major benefits are:

I. Low-input sustainable agriculture;

II. Fisheries;

III. Water supply for domestic, industrial and agricultural purposes;

IV. Fodder;

V. Utilizable plant species;

VI. Fuel wood;

VII. Recreation; and

VIII. Tourism

Existence of the wetland ecosystems in the Yamuna river corridor is threatened due to the immense anthropogenic pressures of an expanding metropolis. Major threats to the efficient functioning of the wetland ecosystems present in the study area identified are:

I. Civic construction;

II. Alteration in landscape;

III. Pollution;

IV. Change in nature of vegetation;

V. Over-exploitation of species; and

VI. Agriculture

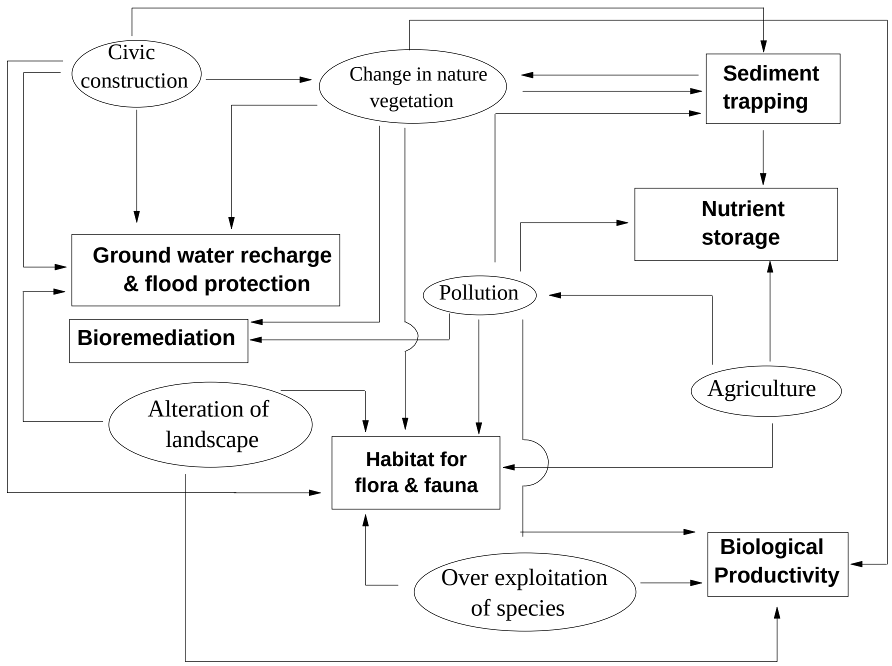


Fig 2.5: Multiple effects of different threats on the ecological functions of the wetlands.

It may be noted that these threats have multiple effects (Fig 2.5) on the performance of the various ecological functions performed by the wetlands present in the study area.

Therefore, they will lead to multiple disruptions that will jeopardize the flow of ecosystem services from the wetlands to the human society.

2.4 Sampling Strategy and Methodologies

It was attempted that all the data on ecological diversity of the wetlands as well as on the extent of ecological services provided by these ecosystems should be primary in nature. Due to the limited time and scope of the project the secondary data was used only when long-term studies were required to generate the primary data on ecological functions. The ecological functions were assessed both by field surveys and laboratory analysis depending on the function in consideration.

2.4.1 Hydrological Functions

Hydrological functions performed by the wetland ecosystems of the study area are of prime importance for the dependent urban society. Ground water recharge is an important hydrological function that is performed by the wetlands. Ground water recharge to an aquifer through the wetlands cannot be measured directly, but can only be inferred by indirect methods.

Water balance method (Brassington, 1993) was employed to estimate the ground water recharge from the wetland ecosystems to the shallow aquifers present in the study area. This method has been widely used by hydrologists for estimation of ground water recharge in applied water resources planning. It is the ability to evaluate the impacts on ground water recharge and runoff due to changing inputs and outputs from a system that makes water balance method a very useful tool.

The water balance method is based upon discrete mass balance principle and a simplified hydrologic system where soil moisture is the only water store. In this method it is assumed that all the water entering a system is equal to the water leaving the system plus or minus any change in soil moisture storage.

The water balance of a system is be represented by the following equation:

Inputs = Outputs + Change in soil moisture

- Inputs and outputs are the inflows and outflows of the water into and from the study area respectively
- Soil moisture storage includes soil retention and ground water recharge

Water balance of the study area

Yamuna is a regulated river in the Delhi stretch, having three barrages: (i) Wazirabad barrage, (ii) Yamuna barrage, and (iii) Okhla barrage. These barrages control the flow of the river for major part of the year except during the floods. The extent of the active floodplains is also limited due to the presence of bunds on both sides of the river. Due to artificial regulation and restriction of the river and the floodplains of the river, water balance of the study area was calculated subject to certain assumptions:

- Aquifers are disposed evenly in the floodplains and behave as a single unit.

- Infiltration and percolation rates are similar in the whole area.
- Rate of withdrawal of water is same in all the areas.

Floodplains account for around 95% of the wetland ecosystems present in the Delhi stretch of the Yamuna river corridor region, thus for simplicity, water balance was computed for the floodplain areas only. Aquifers present in the floodplains are in intimate contact with the river, which passes through the region, the flow of ground water determines whether the river is effluent or influent in nature. Due to this the volume of water present in the river Yamuna is of importance for understanding the hydrology of the floodplain. To understand the hydrology of the floodplains, major inputs and outputs of surface water to study area were identified and quantified (Fig 2.6).

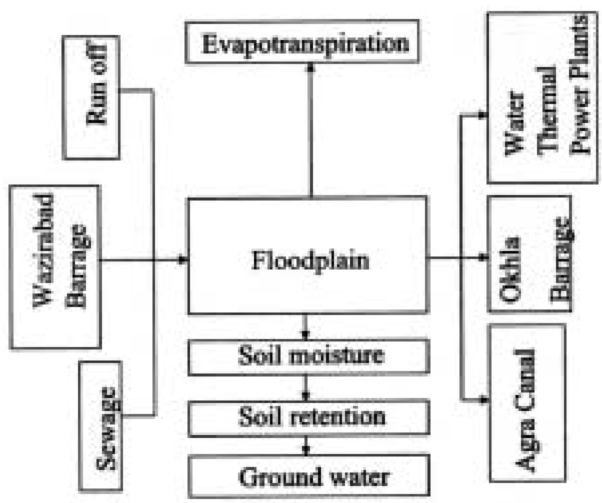


Fig 2.6: Schematic representation of water balance of the study area

The major sources of surface water entering the study area (inputs) are:

I. Water released from the Wazirabad Barrage;

II. Run off generated from Delhi area; and

III. Sewage out falling into the river

The major sources of outflows of surface water from the study area are:

I. Water released from Okhla barrage and Agra canal;

II. Water taken for Indraprastha and Rajghat thermal power plants; and

III. Evapotranspirational losses of Delhi area

Inputs entering into the study area

(i) Water released from the Wazirabad Barrage

Water released from the Wazirabad barrage is the major input of surface water into the study area. Data on the barrage releases of water was obtained from the Flood and Irrigation Department of the Government of NCT of Delhi (Table 2.2).

Table 2.2: Water released from Wazirabad Barrage

Month	**Barrage release from Wazirabad (cumec)**
October 1999	15.05
November	5.77
December	4.24
January 2000	4.06
February	20.73
March	4.41
April	3.19
May	5.89
June	195.23
July	784.45
August	493.93
September	55.47
October	6.3

(ii) Sewage out falling into the river

Urbanization of Delhi has led to increase in the amount of the sewage generated by the city. The sewage generated by Delhi is carried by 17 major drains which outfall into the Yamuna in the Delhi stretch from Wazirabad to Okhla. Information regarding the volume of sewage generated from the Delhi region was procured from the Central Pollution

Control Board (CPCB). Delhi produces on an average about of sewage per day.

(iii) Runoff generated from Delhi

Run off generated from the Delhi area was taken as an input to the study area, because major portion of the run off from the Delhi region reaches the Yamuna River. Estimation of runoff is a complex process involving several variables, which include topography, gradient, soil infiltration characteristics etc. The average value of the run off coefficients of the different blocks of Delhi is 0.32 based upon this value runoff generated from the Delhi area was calculated (Table 2.3).

Table 2.3: Run off generated from Delhi Region during the study period

Month	Rainfall (mm)	Runoff (mm)
October 1999	26.3	8.41
November	0	0
December	0	0
January 2000	32.8	10.49
February	60.3	19.29
March	21.6	6.91
April	1.0	0.32
May	15.6	4.99
June	129.4	41.40
July	295.8	94.65
August	151.4	48.44
September	27.2	8.70

Outputs from the study area

(i) Water released from Okhla barrage and Agra canal

The volume of water released from Okhla barrage and Agra canal forms the major output of surface water from the study area. Data on the release of water was procured from Flood and Irrigation Department of Uttar Pradesh (Table 2.4).

Table 2.4: Barrage releases from Okhla Barrage and Agra Canal

Month	Barrage release from Okhla (cumec)	Barrage release from Agra Canal (cumec)
October 1999	13.19	74.67
November	3.76	77.16
December	2.82	48.53
January 2000	2.82	48.53
February	24.00	53.73
March	2.82	37.33
April	4.69	38.58
May	2.82	37.33
June	80.40	38.58
July	585.66	112.00
August	298.59	112.00
September	43.20	112.00

(ii) Water taken for Indraprastha (IP) and Rajghat thermal power plants

Water utilized by IP and Rajghat thermal power plants is supplied from the Yamuna Barrage at ITO. This barrage is under the control of Haryana Irrigation Department. Data on the release of water to these thermal power plants was obtained from Haryana Irrigation Department. Haryana Irrigation Department provides a constant supply of **8.43 cumec** of water to both the thermal power plants through out the year.

(iii) Evapotranspiration

Evapotranspiration combines the losses of water that occur by the process of evaporation from various free water surfaces and transpirational losses effected by vegetation. For the calculation of evapotranspirational losses from the Delhi area Thornwaite method (Thornwaite, C.W., 1948), was used. In this method average monthly air temperature is used as the primary variable for estimation of potential evapotranspiration (PET) from an area. PET values were subjected to latitudinal correction taking into account the geographic position of Delhi. PET values provide the upper limit of evapotranspiration, which occurs from an area. Actual evapotranspiration (AET) values are of more relevance for various hydrologic calculations. AET was taken 40% of the PET values (Mutreja, 1986), which is given in Table 2.5.

Table 2.5: Potential and Actual evapotranspiration rates in Delhi

Month	**Mean temperature (°C)**	**PET (cm/month)**	**AET (Cm/month)**
October 1999	26.72	16.1	6.44
November	21.85	14.35	5.74
December	15.77	11.9	4.76
January 2000	13.55	10.91	4.36
February	16.75	12.32	4.92
March	23	14.78	5.91
April	30	17.21	6.88
May	32.05	17.88	7.15
June	31.9	17.83	7.13
July	29.6	17.08	6.83
August	30.9	17.51	7
September	29.2	16.75	6.78

Soil moisture

Water that enters the soil distributes itself into soil moisture retention and the water that goes for recharging of the aquifers. Dynamics of the water in the soil is influenced by the physical characteristics of the soil. Particle size distribution, an important physical characteristic, influences many physical and hydraulic properties of the soil. Particle size distribution of the soils present in the study area was found by the wet sieving method. Soil samples were collected extensively from the study area from each of the three sectors for analysis. The particle size distribution found in the soils of the study area was characteristic of the sandy loam type of soil (Table 2.6).

Table 2.6:Representative soil composition found in the study area

Particle size fraction	Percentage
1mm –500mm	3%
250µm	2%
125µm	36.5%
63µm	27.5%
31µm	11%
<31µm	20%

Utilizing the information on soil type of the study area other parameters related to hydraulic properties of the soil were calculated. Soil moisture retention and plant available soil moisture were calculated using field capacity of sandy loam soil. Plant available soil moisture was calculated by taking the difference between field capacity and permanent wilting point of plant. Field capacity and permanent wilting point of sandy loam soils were 18% and 8% of dry weight of the soil respectively. Ground water recharged to the aquifer was calculated by taking the difference between water entering the soil and the field capacity of the area.

The Water Balance

For analysis, the units of different inputs and outputs were converted into a uniform unit of cubic meters per month. All the inputs viz. Wazirabad Barrage, sewage outfall and runoff were added up to get a consolidated value for the inputs of the study area for a particular month. Similarly, all the outputs were added to get a consolidated monthly value. Inputs and outputs of the study area follow a similar trend around the year with low water flow in the river for most part of the year followed by a characteristic peak (Fig 2.7) when the volume of water in the river and the floodplain increases during the monsoons

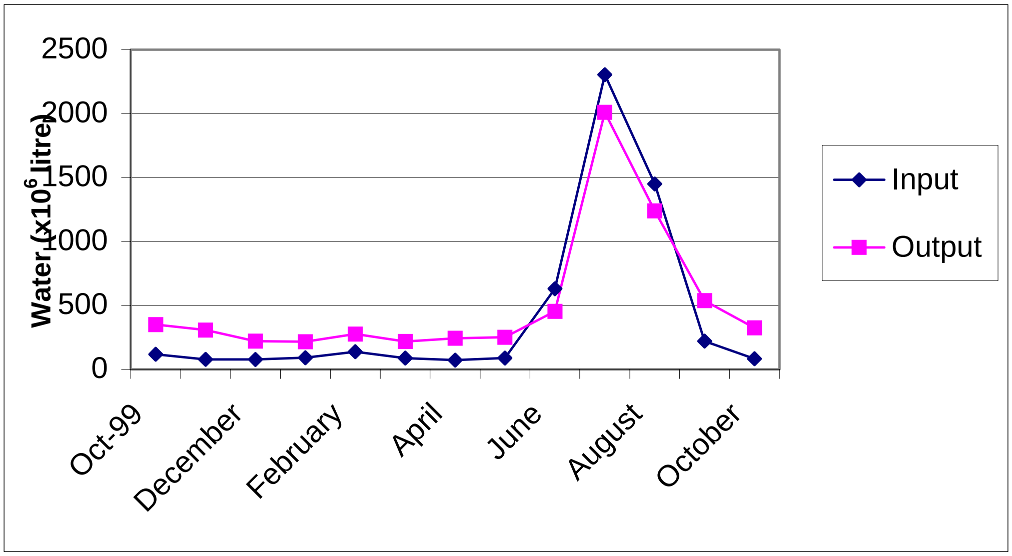


Fig 2.7: Water inputs and outputs profile of the study area

As can be seen in the figure there is a sudden rise in the flow of water into the study area in the month of June, maximum flow of $2.3*10^9$mcm occurs in the month of July. After attaining maximum there is a decline in the river flow so as to reach normal flow in around October. In the three months of the monsoon period approximately 80.71% of the total water that enters into the study area in a year, flows through the river and the floodplains resulting in floods in the study area. Major input for the increase in the water flow of Yamuna is the volume of water that is released from the Wazirabad barrage.

Soil moisture store of the study area shows a negative balance for nine months in a year (Table 6) implying that outputs from the study area are more than the inputs, which can result in reduction of the ground water levels of the area. During the monsoon season, soil moisture is positive (Fig 2.8) indicating a possible increase in the ground water reserve of the area. During this period large amount of water (Table 6) is available in the study area, which is more than sufficient to saturate the floodplain aquifers in the study area.

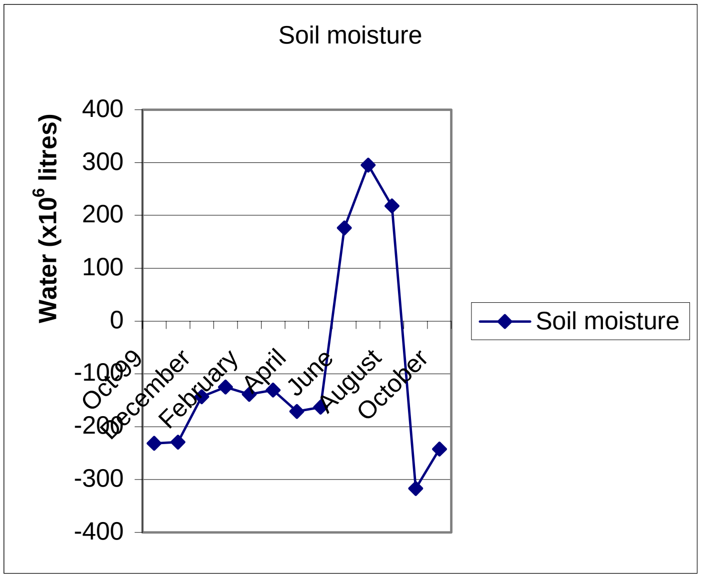


Fig 2.8: Variations in the soil moisture in the study area from October 1999-October 2000.

Table 2.7: Water balance for the period October 1999 to October 2000

Month	Inputs	Outputs	Soil moisture
October 1999	117787038	349210640	-231423602
November	77968800	307221211	-229252411
December	76466273	219695603	-143229330
January 2000	91230929	215958443	-124727514
February	137530401	275995439	-138465038
March	86931896	217576003	-130644107
April	71754062	243090612	-171336550
May	88034634	251189203	-163154569
June	630409547	453917440	176492107
July	$2.3*10^9$	2010000000	295000000
August	$1.4*10^9$	1239000000	218000000
September	219853161	536917440	-317064279
October	81973920	324154511	-242180591

Volume of water that can enter into the subsurface water system of the study area depends upon the maximum lean season water table elevation in the floodplains and the porosity of the soils. Maximum lean season depth of the water table was 3m in the floodplain and neighbouring areas and porosity of the sandy loam soil was calculated and found to be 0.42. Volume of water recharged into the subsurface hydraulic system during the monsoons each year is 4.095 $*10^7$ Kl. Of the total 4.095 $*10^7$ Kl, plant available soil moisture is about $9.75*10^6$ Kl and $2.34*10^7$ Kl reaches the ground water reserve of the study area. Recharge of the ground water reserve after the monsoon leads to an increase in the ground water level from 3m to 2.28m between pre-monsoon and post monsoon seasons. Major recharge to the floodplain aquifers is due to the inundation of the floodplains during the floods in the monsoon season. After the floods recede, the soils of the study area are saturated with water due to which they provide the much needed soil moisture for the growth of cucurbits and other seasonal vegetables.

During the monsoons, excess water is available in the soil moisture store even after recharging of the floodplain aquifers. This implies that there are certain other sinks where the water is present other than in the floodplain aquifers. These possible sinks are:

Floodplain aquifers have hydrologic connections with the aquifers of the neighbouring city areas due to which there is lateral flow of ground water from the floodplain aquifers to the connected aquifers in the city. This is evident from the change in ground water levels in the city areas in the post monsoon seasons. To delimit the area of influence of the recharged water and to quantify the amount of water recharged into the connected aquifers of the city by the floodplains, detailed hydrological investigations are required.

In the water balance model a simplified hydrologic system is considered, where soil moisture is the only water store. Therefore, the volume of water that is present above the surface of the floodplains during the floods and the water present in seasonal pools after the floods recede is also shown as soil moisture in the water balance equation.

The volume of water that is present in the seasonal pools after the floods recede has been quantified. The area, number and distribution of the seasonal pools has also been found out. The approximate amount of water present in the seasonal pools is 0.5 mcm. There are about 22 such seasonal pools spread across the Wazirabad and the ITO sectors.

Water balance of the area has provided key insights of the general pattern of hydrological regimes of the area. Salient findings of the water balance for the area:

- Sandy aquifers present in the active floodplain area are saturated after the monsoons.
- Annually about $4.09 * 10^7$ Kl of water enters into the subsurface hydraulic system of the study area of which $2.34 * 10^7$ Kl recharges the aquifer leading to an increment of .72m in the water table.
- Aquifers present in the city areas are recharged due to lateral migration of ground water from the floodplain aquifers to the connected aquifers in the city.
- Ground water recharged from the floodplains provide an invaluable fresh water reserve which can be used for providing drinking water for the people of Delhi and for practicing dry season agriculture.

Wetland ecosystems in the river corridor region play a critical role in the hydrology of Delhi as is evident from the results of the water balance model. Based upon the insights provided by the study, detailed hydrological investigations are required in the study area. These investigations will help in initiating suitable measures for ground water conservation and augmentation in Delhi.

Simulation Study to Analyze the Effect of Channelization on Hydrological Functions of the Wetlands

Floodplain is a precious land resource that can be used for many different development activities. The development agencies have proposed to channelize the river and reclaim vast stretches of land. To assess the effect of channelization, on the ground water reserve and ground water recharge potential of the study area simulation study area was carried out (Table 2.8). In the study two scenarios were compared: Scenario 1 is the present day situation, Scenario 2 partial channelization of the river is undertaken.

Table 2.8: Effect of partial channelization of the river on the ground water recharge and water table

	Scenario 1	Scenario 2
Area of inundation (ha)	3250	2750
Ground water recharge (Kl/annum)	$2.34*10^7$	$1.98*10^7$
Change in water table (m)	.72	.60

Scenario 1: Study area inundated completely

Scenario 2: Partial inundation of the area due to proposed channelization of the river.

The volume of ground water recharge that occurs from the floodplains to the shallow aquifers is directly proportional to the area of inundation. For the simulation, all the factors which effect the amount of ground water recharged to the aquifers were kept constant and only the inundation area was decreased. Reduction in the area of inundation was carried out on the basis of the proposed channelization of the river that is going to be carried out.

For the present simulation study, area of inundation was reduced by 500ha. Reduction in the inundation area of the floodplains resulted in loss of about $3.6*10^6$ Kl of ground water per annum, which will lead to reduction in the ground water table by about .12m in the study area. This loss of the ground water recharge potential of the floodplain on a long term will effect the water table profile of the city area.

Channelization of the river will also lead to the loss of many other important ecological functions. In the absence of any flood pulse occurring during the monsoons the reclaimed area will not be enriched by the nutrients that are brought by the fresh sediments during the floods. This loss of nutrients will lead to high input agriculture if agriculture is practiced in the reclaimed area. Channelization of the river will also affect the sediment fluxes that occur in between the floodplains and the river thus imbalancing the sediment budget of the river.

2.4.2 Nutrient retention

Wetlands present along the river corridor region, act as nutrient sinks for inorganic nutrients brought by the sediments into the system. Fresh sediments brought by the river during the floods are deposited on the floodplains and other wetland areas. These sediments are enriched in nutrients like nitrogen and phosphorus. Deposition of the sediments in the wetlands fertilizes these areas with fresh supply of nutrients.

For the assessment of nutrient status of the floodplain on a spatio-temporal scale, soil samples were collected from the study area. Three major plant nutrients nitrogen, phosphate and potassium were estimated in the soils of the study area. Samples were collected during the pre-monsoon and post-monsoon seasons to highlight the nutrient enrichment that occurs due to inundation of the study area during the monsoons. For assessment of the spatial variability in the nutrient status of the soils, soil samples were collected in horizontal transects from the river. These transects covered the entire horizontal stretch of the active floodplains of the river corridor region. Samples were collected from each of the three demarcated sectors.

Soil samples were also collected from the non-floodplain areas, to get an estimate on the relative amount of nutrient enrichment that might be present in the wetland areas as compared to the upland areas. Samples from the non-floodplain areas were collected from Bhalswa and its neighbouring areas. This area was chosen for collection of the soil samples because the soil present in this area is geologically similar to the floodplain soils.

Concentration of phosphorus, nitrogen and potassium in the soils was expressed in kg/ha for ease of economic analysis (Table 2.9; Table 2.10; and Table2.11). The nitrogen, phosphorus and potassium content in kg/ha represent the amount of nutrients present in 15cm deep soil layer. This soil depth has maximum proliferation of plant roots and is the zone from where majority of nutrients are taken up by plants for their growth and development.

Phosphorus present in the soil is predominantly in the form insoluble complexes due to which it is not readily available to the plants. Therefore, total phosphorus in the soil does not give a true representation as to how much of phosphorus is actually available to the plants for their growth. Phosphorus estimation in the soils of the study area was carried out so as to provide information on plant available phosphorus in the soils.

Sodium bicarbonate was used as soil extractant to extract plant available phosphorus in solution (Tropical soil Biology and Fertility, 1996). The method followed for the estimation of phosphorus is standard spectrophotometric procedure (Allen, 1974).

PHOSPHORUS 'P'

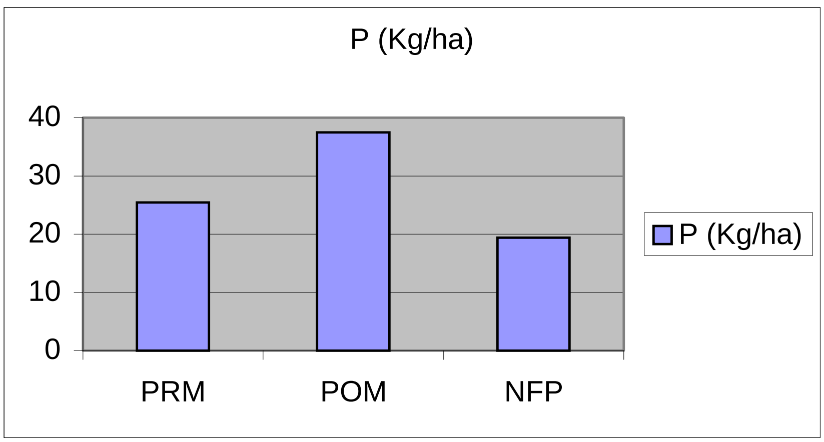


Fig 2.9: Concentration of plant available phosphorus in the soils of floodplain and non-floodplain areas. Floodplain area: PRM: Pre-monsoon season, POM: Post monsoon season. NFP: Non-floodplain area.

Table 2.9: Plant available phosphorus in the soils of the floodplain and non-floodplain areas

S. No.	Site	Season	Range (Kg/ha)	Mean (Kg/ha)*
1.	Floodplain area	Pre monsoon	20.9-29.97	25.43
		Post monsoon	29.97-44.95	37.46
2.	Non- Floodplain area		14.85-23.9	19.37

Note: * Mean is based on 45 samples collected from the site

In the soil, nitrogen can be present in different forms: nitrate, nitrite or ammonia depending upon the redox state of the soil. For the present study nitrate nitrogen was estimated in the soils of the study area. Nitrate nitrogen was estimated because the study area is inundated only for a small period in a year, thus the predominant form nitrogen present in the soils would be nitrate. Nitrate nitrogen was also estimated in the soils of the non-floodplain areas. For the estimation of nitrate in the soils method described in Tropical Soil Biology Fertility (1993) was followed.

NITRATE 'N'

Table 2.10: Nitrate 'N' in the soils of the floodplain and non-floodplain areas

S. No.	Site	Season	Range (Kg/ha)	Mean (Kg/ha)*
1.	Floodplain area	Pre monsoon	3.37-5.62	4.5
		Post monsoon	4.5-7.87	6.18
2.	Non- Floodplain area		1.12-3.37	2.24

Note: * Mean is based on 45 samples collected from the site

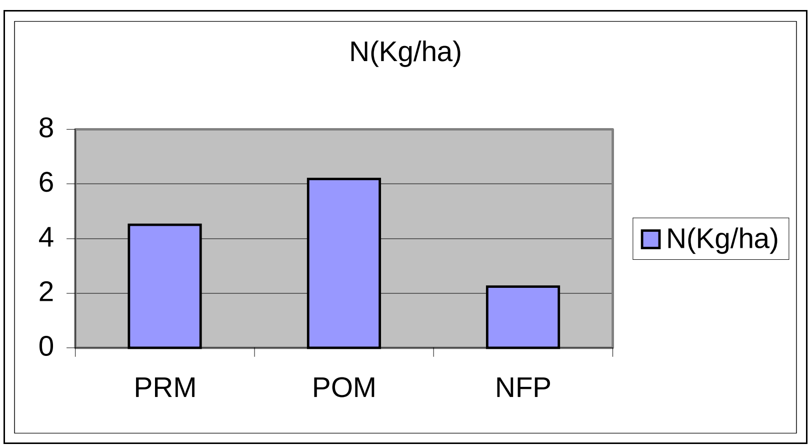


Fig 2.10: Concentration of Nitrate 'N' in the soils of floodplain and non-floodplain areas. Floodplain area: PRM: Pre-monsoon season, POM: Post monsoon season. NFP: Non-floodplain area.

Potassium is another major plant nutrient that is required for the growth and development of the plant. Total Potassium in the soil samples was estimated by digesting the soil samples with sulphuric acid. The soil digest was analyzed for potassium using Atomic Absorbtion Spectrophotometer.

Potassium 'K'

Table 2.11: Potassium 'K' in the soils of the floodplain and non-floodplain areas

S. No.	Site	Season	Range (Kg/ha)	Mean (Kg/ha)*
1.	Floodplain area	Pre monsoon	272.2-281.2	276.7
		Post monsoon	281.2-308.2	294.7
2.	Non- Floodplain area		258.7-281.2	269.95

Note: * Mean is based on 45 samples collected from the site

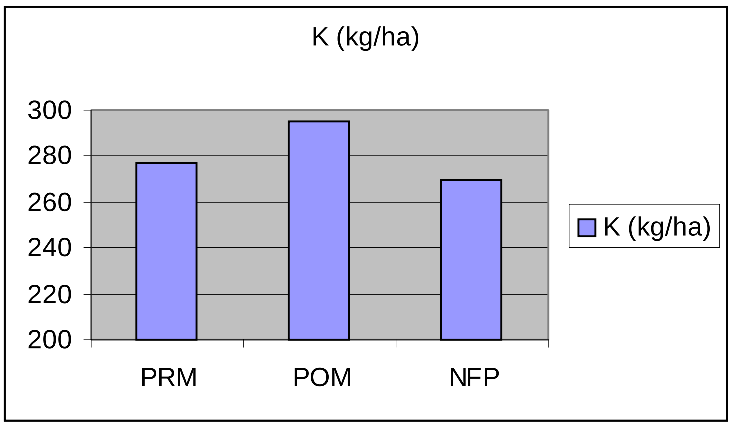


Fig 2.11: Concentration of Potassium 'K' in the soils of floodplain and non-floodplain areas. Floodplain area: PRM: Pre-monsoon season, POM: Post monsoon season. NFP: Non-floodplain area

Floodplain soils are enriched in phosphorus, nitrate and potassium (Table 8, 9 and 10) after the floods recede. The difference in the nutrient status of the soils in the pre and post monsoon seasons suggest the important role the floodplain play so as to act as collecting and storage ground for nutrients which are brought by the river water during the floods. Enrichment of phosphorus, nitrogen and potassium is of prime importance because these nutrients can be readily utilized by the plants for their growth and development.

2.4.3 Biological productivity

The biological productivity of wetlands is high as compared to other upland ecosystems. For ease of analysis and interpretation the biological productivity of the wetland areas has been categorized into primary productivity and secondary productivity. Candidate species of biota were chosen for the estimation of these productivities. These species are defined as utilizable species that are used by the local people for various purposes. Utilizable species of plants *S.munja, Typha* were taken as indicators of primary productivity of the system. Utilizable species of the fish were taken as the indicators of secondary productivity.

Primary Productivity

Primary productivity of the floodplains is among the highest of all wetland types, due to nutrient enriched soil and abundant soil moisture. Candidate species used for the assessment of primary productivity were characteristic for a specific wetland area. Primary productivity of the floodplains can be categorized into cultivated and non-cultivated plant resources. In the Floodplains *S.munja* was the dominant plant species wherever natural vegetation was present. Marshy areas present near Okhla were characterized with the presence of *Typha*. The yield and the uses of the harvested plant parts were assessed by means of structured questionnaire* survey of the local people inhabiting the study area.

Based on extensive field surveys, it was found that the local people of the area utilize these wetland plant species for their livelihood. Major uses of non-cultivated plant resources are:

- Crop protection
- Crop advancement
- Production of Mats and stools
- House construction

Leaves of *S.munja* and *Typha* are used for protection and advancement of the cucurbit crops. The local people inhabiting the study area use plants and their harvestable products not only for commercial purposes but also for their subsistence.

Pure stands of *S.munja* were present in approximately 2.18 ha area near Wazirabad. Local people harvest *S.munja* for its culms. The yield of

S.munja from the area is approximately 7303 bundles of grass culms. Grass culms of *S.munja* are sold to local traders, who then make mats and stool from them and sell the products in the market. A single bundle of grass culms is sold @ Rs. 25/-. Grass culms are harvested for a period 4-5 months in a year from October to March (Table 2.12).

Table 2.12: Area covered by *Saccharum munja* and its yield

Total area covered by *S.munja* vegetation	2.18ha
Yield of the whole area	7303 bundles
Harvest period	4-5 months

Typha – is the dominant plant species present in the marshy areas. Area of marshes covered by *Typha* vegetation is approximately 110ha. Leaves of *Typha* are harvested and used for making of mats. One bundle comprising of 100 *Typha* leaves is sold @ Rs. 15/- in the local market. Total yield of *Typha* bundles from the marshy area is 28,000 bundles of *Typha* leaves (Table 2.13).

Table 2.13: Total area and yield of *Typha*

Total area covered by *Typha*	110ha
Yield of the whole area	28000 bundles
Harvest period	5-7 months

Marshy areas are used as grazing lands during the dry season when there is severe scarcity of fodder in the city area (Table 2.14).

Table 2.14: Yield of different fodder species growing on the floodplain

S. No.	**Variety**	**Yield (Q/Ha)**
1	Jai	185.4
2	Jwar	185.4
3	Barseem	185.4
4	Grass	309

Major portion of the floodplain area is used for practicing seasonal agriculture of crops like wheat, cabbage, cauliflower, Radish, beet root etc. in the winters and cucurbits, tomatoes, water melons etc. are grown in summers. Soils of the wetland areas can sustain and support growth of large variety of seasonal vegetables due to their enriched nutrient status and increased soil moisture.

Table 2.15: Yield of cucurbits growing on the floodplains

Area under cultivation (Ha)	64.77
Total production (Q)	6399.28
Season	November – June

Cucurbits like watermelon, sweet melon, and cucumber are grown exclusively on the floodplains in the Delhi. Cucurbit cultivation is practiced in about 64 ha area of the floodplains from November to June. Cucurbits require characteristic soil properties for their growth, which are present only in the floodplain areas. Data on the yield of the cucurbits grown on the floodplains (Table 2.15) was obtained from Delhi Peasant Multipurpose Cooperative Society.

Secondary productivity

Fish yield was taken as an index of secondary productivity of wetland ecosystems of Yamuna river corridor. Wetlands act as nurseries for the fish fries and thus have a critical effect on the yield of fish in the river. Data on the fish yield on an annual basis (Table 2.16) was obtained from the Fisheries Department Government of National Capital Territory of Delhi.

Table-2.16: Fish catch from Wazirabad to Kalindi Kunj stretch of the Yamuna during last 5 years (in Quintals).

S. No.	**Year**	**Quantity (Q)**
1.	1996-97	1215.3
2.	1997-98	1257.3
3.	1998-99	1337.7
4.	1999-00	1257.6
5.	2000-01	1200.0

2.4.4 Sediment trapping and stabilization

River corridor vegetation helps in trapping and stabilization of sediments brought by the river. This helps in stabilization of the banks against the erosion potential of the flowing water thus reducing the sediment load of the river. For quantifying the exact role of wetland vegetation in sediment trapping and stabilization a detailed sediment budget of the river in the Delhi stretch would have to be prepared. In the absence of any data from recognized scientific institute or department preparation of a sediment budget of the river is an enormous task and beyond the scope of the present project due to limitation of time. To provide an approximate idea to the amount of sediment stabilized by the natural vegetation of the floodplains a preliminary assessment was carried out.

To estimate the amount of sediment stabilized by *S.munja* randomly selected plants of similar age were selected. The amount of sediment stabilized by *S.munja* was found by calculating the volume of soil which was stabilized by the root system of the plant. Two types of clumps of *S.munja* were found in the field, which differed in the type of root network and their soil retention capacities. For finding the volume of soil stabilized by *S.munja* roots of the clump were dug out of the ground carefully to prevent damage to the root system of the clump. After removal of excessive soil attached to the roots, the volume of soil was calculated which was entrapped in the roots. The amount of stabilized sediments by different type of clumps of grasses were assessed (Table 2.17).

Table 2.17: Volume of sediment stabilized by 2.18ha of *S.munja* vegetation

Volume of sediments stabilised in cylindrical monolith of *S.munja*	15331.25 cm^3
Volume of sediments stabilised in cuboidal monolith of *S.munja*	31050 cm^3
Volume of sediment stabilised in 2.18 ha of *S.munja*	3849.88 million cm^3

Detailed scientific investigation related to stabilization of sediments and reduction in erosion was carried out elsewhere (Beeson et al. 1995). This study has shown that natural vegetation of wetlands reduces erosion by about 30%. Though detailed scientific investigation on this aspect could not be carried out in the present study this does not undermine the importance of this very important ecological function carried out by the natural vegetation of the wetlands.

2.4.5 Habitat for flora and fauna

Yamuna river corridor is a highly disturbed area due to the variety of anthropogenic factors. The amount of native biota is thus reduced to small pockets along the corridor region. A checklist of the representative flora of present day wetlands was made after undertaking field surveys. The small pockets of undisturbed vegetation were characterized by *S. munja* in the floodplains and *Typha* in the marshy areas. A complete listing of the plants is given in Annexure 3. Based on the field surveys 115 plant species belonging 27 different families were identified and categorized. Faunistic surveys were restricted to the assessment of diversity in the avifauna of the area during winter season. Some of the waterfowls observed in the Okhla barrage area are endangered birds and are covered under the Convention on Migratory Bird Species. A thorough listing providing a complete picture of the bird species is given in Annexure 4. Avifauna of the study area is represented by 97 species of birds, of which 56% are migratory and are covered under the international conventions.

Biological diversity

Wetlands throughout the world are known for their function as the habitat for the wild species of flora and fauna. The wetlands of Yamuna River in Delhi are no different. Of course, the major differentiating feature of the Yamuna wetlands from other riverine wetlands of the world, lies in the types of wetlands found in the rather small corridors of the river and their extant in relation to the biodiversity they support.

The habitats for the floral and faunal species are defined on the basis of the nutrients available in a given zone and the habits of the species. For example, the ducks prefer waterlogged conditions with depth of water being more than a foot deep. On the other hand the jacanas prefer the waterlogged conditions with large amounts of floating vegetation. So intricate is the relationship of the habitat to the species present therein, that removal or destruction of a habitat may lead to a complete extinction of a species from the given area. Taking the above example, if we have the waterlogged conditions but do not have the floating vegetation then the ducks may prevail but the jacanas may perish.

Most of the birds remain in the Yamuna corridors for about 4 months on an average. During this period, the flow of water in the river is also on the higher side of the average. Which makes the wetlands of the river to function at their prime as wildlife habitats and therefore, one finds as many as seven different types of habitats for wildlife.

The seven types of habitats found in the Yamuna wetlands are:

1. Aquatic
2. Banks
3. Marshes
4. Reeds
5. Grasslands
6. Woodlands
7. Human settlements

The classification is based on the characteristic features of vegetation in each type of habitat. Only the habitat, human settlements, has no direct correlation with the vegetation type. Yet it is included, since many species of birds have adapted to this new type of "habitat" on the Yamuna corridors.

Of the total 123 species of birds described by various people in the Yamuna corridors, 97 were observed during the study period. These species belonged to 32 families. The species were identified and their numbers counted for each habitat. There is a seasonal change in the numbers of a species visiting a given habitat depending on the time of the year and the availability of resources. Most of the species found in the wetlands of Yamuna are winter visitors. These are the species which migrate long distances from Asia and Europe during winter months in order to avoid the extremely low temperatures of the north. Many species are passage migrants (species which halt at a place during migration to recover from flight strain and regain nutrition) and move on after a short halt at the Yamuna wetlands, but most of them remain in the area till their return. Of the 97 species visiting the wetlands, 47 species (about 46%) of birds are resident and breed in and around the areas of the wetlands.

The feeding and breeding habits of the birds recorded in the wetlands of Yamuna corridors are different. Some feed in the woods, some on the grasslands, some in the marshes while many species are dependent on the river itself. The barrages on the river act as lake forming devices. If the gates of the barrages were open throughout the year the amount of water staying back will be much less and therefore the diversity of the habitats will also go down. Close to the gates the level of water is maximum and a large lake like water body is formed. The release of water from the barrages is differential through the year and therefore the size and depth of the lake is also variable over a given period of time. On the basis of the depth of water available the birds distribute themselves along the river corridor. Not only the birds are dependent on the wetlands for food and breeding ground but also many of the birds that are not directly dependent on the wetlands have a tendency to pick up plant material from the wetlands for building their nests elsewhere in the city. A very good example of this is the Painted stork. Many painted storks build their nests in the Delhi zoo, where they get ample crown cover as sites for building nests. But in the zoo the supply of raw material for building the nests is not sufficient for all the members of the species found in the area. It has been observed that individuals pick up plant material from the marshes and reeds of the river and use them for their nests. Similar observations have also been made for species like the crow, pigeons, mynas etc.

On the basis of the species recorded for different sites it was found that many species were found in more than one habitat. The reason for such a phenomenon is that the species are dependent on one habitat for food and on another for may be nesting or supply of nesting material. It is also possible that a species is so well adapted that a change in a given habitat makes it shift to another habitat in for food. Only 39 species restrict themselves to one kind of habitat, leaving a large fraction, about 62%, distributed in more than one type of habitat. The percent distribution of species found in each habitat is represented in the Figure 2.12.

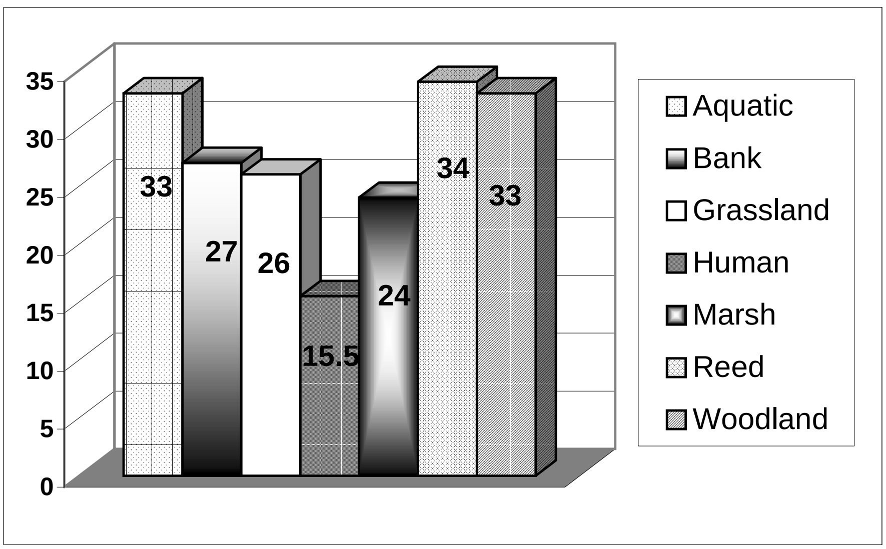


Fig 2.12: Extent of distribution of bird species in different habitats of the study area

From the above depiction it is evident that the bird species found in the Yamuna wetlands in the Delhi region do not restrict themselves to one type of habitat but are distributed well throughout the corridor. The Yamuna river corridor was divided into four sectors, namely – 1. Wazirabad-ISBT, 2. ISBT-ITO, 3. ITO-Nizammudin and 4. Nizammudin-Okhla. Each of these sectors has a distinct type of vegetation that leads to development of wetlands, which are different from the one another within and between sectors. The Figure 2.13 provides a representative picture of the number of species found in each sector:

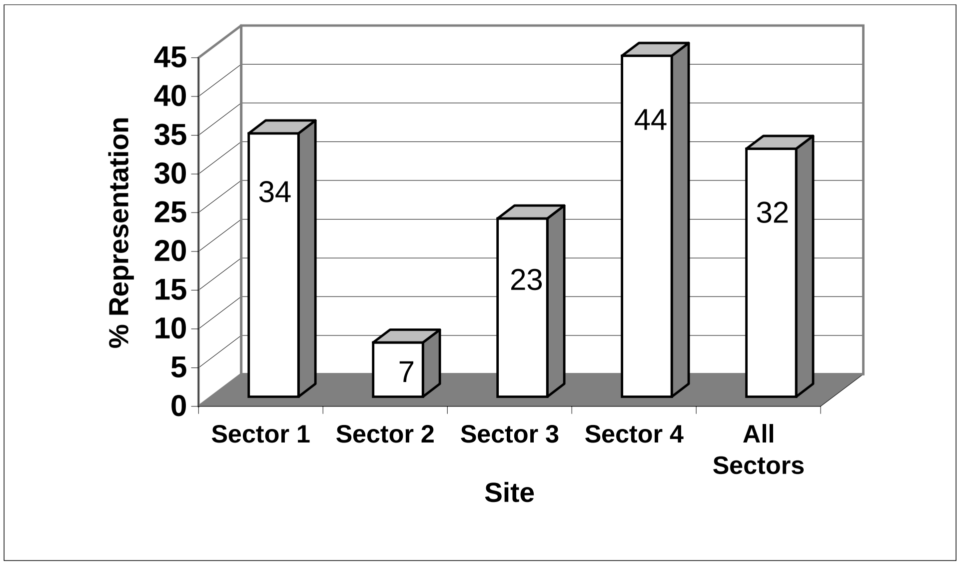


Fig 2.13: Species distribution (%) in different sectors of the study area from the total number of species found in Yamuna wetlands.

The numbers in the graph signify the percent species represented in that sector. It should be noted here that the percentage is the total species found in a given sector. Some species are found in only one sector while most species are found in more than one sector. The "All Sectors" represents the percent species found in all the four sectors. What does this imply? The least number of species are found in Sector 2. This is primarily because in this area the channel of the river is modified into a gorge and there is little horizontal spread of the wetlands. This leads to a poor habitat diversity and hence less number of species. Maximum number of representation is found in Sector 4. This is the extreme downstream portion of the Yamuna river corridor. At the end of this sector is a barrage, which regulates the flow of water from Delhi to Uttar Pradesh. Marshes, seasonal pools, reeds, and islands are found in this broad section of the river channel of variable depths, leading to a high diversity in the habitat types. It should be noted that there is only 32% representation of the species in all the four sectors. This itself shows that there are not many species which adapt to the variable types of habitats found in the area of study.

The avifauna of the river does not present a very visible function but the functions these groups of animals perform are significant and should be included in any economic valuation study on wetlands. Of the many functions these birds perform, a major function which has not been studied so far in economic valuation studies of wetlands (also, could not be conducted during the present study due to time restraints) is that of cleaning the river system by birds as they feed on the organic matter being carried by the river. The implications of this function are manifold. Firstly, if the river is not cleaned regularly, there will be an increase in the organic load of the river leading to eutrophication. The amount of time and energy consumed in cleaning a unit amount of eutrophicated water to make it amiable for consumption purposes can be easily carried out. In addition to this, because of eutrophication, there will be a loss of wildlife habitat. As a result the number of species visiting the wetlands will reduce and hence the attendance of the tourists/ornithologist/birding enthusiasts etc. Although there is little restriction on the recreational facilities on the wetlands of the Yamuna river corridors, but with the implementation of a policy to put monetary restrictions for such facilities, the total value lost because of lack of birds, can be calculated.

Another major function the wetlands of Yamuna perform is that of harbouring and strengthening of resident populations of bird species in the country. The wetlands of Yamuna are one of the many stopover sites for species of migratory birds coming from north. Some of these birds go upto the southern states of the country. In an extreme case, if these wetlands are removed there is a very high probability that the migratory species might change its route or might even stop wintering in India. This will lead to a heavy loss in earnings of the national parks and sanctuaries south of Delhi, which are a major tourist attraction because of migratory bird species alone. The economics of such a dynamic system cannot be studied in one year and a detailed study is required to understand the issue.

The wetlands throughout the world have been criticized for being the breeding grounds of mosquitoes and other water borne diseases and Yamuna in Delhi is no exception. But an important fact that is overlooked is that wetlands in their native form do not cultivate pests and diseases. It is only after human intervention and resultant deterioration of the wetlands because of organic and inorganic wastes that these unique ecosystems become breeding grounds for pests etc. In spite of this fact there are natural pest control systems. Primary of them are the avifauna of the region. Some of the birds, like swallows, drongos, martins, swifts, etc. feed on insects while on wings. Generally these birds are small in size and have high metabolic rates. This forces them to spend more time feeding than resting. All the above-mentioned examples are birds that have a good appetite for insects. The data on their insect intakes for each kind of habitat is not known. A detailed study their feeding rates and number and types of insects exterminated, would give an insight into the economic aspects of pest removal by conventional methods of pesticide spraying etc.

Besides the above functions the bird species perform a very unique function of recreation. Many people just visit a wetland area to have a look at the variety of species found in the area and their behavior. It is difficult to measure the amount pleasure an individual derives out of it, but certain physical parameters have been analysed, such as, the amount of expenditure incurred on traveling from ones residence to the wetland. Standard economic tools have been used to estimate the value of the recreational function of wetlands as bird watching areas.

Another important function of wetlands as habitats for wildlife is in providing hunting grounds for fishermen of the nearby locality. The diversity of habitats not only leads to a diversity of birds but also the fish species. Fishes serve a multipurpose role in the wetland areas. Firstly, they help in providing the fishermen a livelihood. The fishermen sell the catch in the local markets and the value of the catch for the Yamuna wetlands has been calculated.

Secondly, the fishes also play a key role in maintenance of the health of the river. This group of animals keeps a check on the growth phyto- and zooplankton growth in the waters by feeding on them. This rate of cleaning can be compared with the rate of cleaning required by a municipal sewage treatment plant, had the waters of the river reached a given level of pollution. Besides, in the waters of the Yamuna, a fish called *Gambusia sp*, is well known throughout the world, for its specific taste of mosquito larvae. The economics needs to be worked out for this species also, in relation to the amount of expenditure incurred in treating a unit area of wetland of insect pests and the amount of expenditure incurred on the medication of people falling sick due to malaria in the areas in close proximity of the wetlands.

The resilience value of a given species let it be a mammal or a fish, for an ecosystem, can only be calculated after a deep study of the processes and functions each species performs in a given area. The importance of resilience of an ecosystem lies in the fact that the ecosystem, as a dynamic organization, provides mankind with plethora of functions. These functions result in certain usable products and services, which have been exploited by mankind since time immemorial.

Chapter 3: An Ecological-Economic Analysis of Floodplain's Values and Benefits

Wetland characteristics are those properties that describe a wetland area in the simplest and most objective possible term. They are a combination of genetic features. A general list would include the biological, chemical and physical features that describe a wetland such as species present, substrate properties, hydrology, size and shape; for example, Adamus and Stockwell (1983) give 75 wetland characteristics. Wetland structure may be defined as the biotic and abiotic webs of which characteristics are elements, such as vegetation type and soil type. By contrast, wetland processes refer to the dynamics of transformation of matter of energy. The interactions among wetland hydrology and geomorphology, saturated soil and vegetation determine the general characteristics and the significance of the processes that occur in any given wetland. These processes also enable the development and maintenance of the wetland structure, which in turn is key to the continuing provision of goods and services. Ecosystem functions are the result of interactions among characteristics, structure and processes. They include such actions as floodwater control, nutrient retention and food web support (Maltby et al., 1996)

Economic values depend on human preference; what people perceive as the impact wetland have on their well-being. In general, economic value, i.e. the benefits, of an increased (or a preserved) amount of a good or services is defined as what individuals are willing to forego of some other resources in order to obtain the increase (or maintain the status quo). Economic value are thus relative in the sense that they are expressed in term of something else that is given up (the opportunity cost), and they are associated with the type of incremental changes to the status quo that public policy decisions are often about in practice. Economic values will always be contingent upon the wetland performing functions that are somehow perceived as valuable by society. Functions in themselves are therefore not necessarily of economic value; such value derives from the existence of a demand for wetland goods and wetland services due to these functions. For example, fertility and nutrient characteristics would be crucial in providing forestry and agriculture benefits, but these characteristics do not in themselves represent benefits (in the anthropocentric sense). While the total amount of resources that individuals would be willing to forego for an increased (or preserved) amount of a wetland service reveals the total economic value (TEV) of this increase (or preservation). Use value arises from humans' direct or indirect utilisation of wetlands through wetland goods and wetland services, respectively. A value category usually associated with use value is that of option value, in which an individual derives benefit from ensuring that a resource will be available for use in the future. Another type of value often mentioned in the valuation literature is quasi option value, which is associated with the potential benefits of awaiting improved information before giving up the option to preserve a resource for future use (Arrow and Fisher, 1974). Quasi-option value cannot be added into the TEV calculation without some double counting; it is best regarded as another dimension of ecosystem value. Nonuse value is associated with benefits derived simply from the knowledge that a resource, such as individual specie or an entire wetland, is maintained. Nonuse value is thus independent of use, although it is independent upon the essential structure of the wetland and functions it performs, such as biodiversity maintenance. Various component of nonuse value have been suggested in the literature, including the most debated component, existence value, which can be derived simply from the satisfaction of knowing that some feature of the environment continue to exist, whether or not this might also benefit others. This value notion, interpreted in a number of ways, seems to straddle the instrumental/intrinsic value divide. Some environmentalists support a pure intrinsic value of nature concept, which is totally divorced from anthropocentric values. Acceptance of this leads to rights and interests-based arguments on behalf of non-human nature. The existence of such philosophical views is one reason why the concept of TEV should not be confused with the total value of a wetland. Moreover, the social value of an ecosystem may not be equivalent to the aggregate private TEV of that same system's components; the system is likely to be more than just the aggregation of its individual parts. The adoption of a functional perspective is the correct way to identify wetland goods and services, but if each of them is identified separately, and then attributed to underlying functions, there is likelihood that benefits will be double counted. Benefits might therefore have to be allocated explicitly between functions. For instance Barbier (1994) noted that if the nutrient retention function is integral to the maintenance of biodiversity, then if both functions are valued separately and aggregated, this would double count the nutrient retention which is already ‘captured’ in the biodiversity value. Some functions might also be incompatible, such as water extraction and groundwater recharge, so that combining these values would overestimate the feasible benefits to be derived from the wetland. Studies that attempt to value the wetland as a whole based on an aggregation of separate values tend to include a certain number of functions although these studies do not usually claim to encompass all possible benefits associated with the wetland.

3.1. Stakeholders in wetland function and values

Integrated ecological-economic analysis involves an identification of how particular function might be of use, rather than simply the degree to which the function is being performed. The extent of demand for the products or services provided, or the effective ‘market’, also needs to be assessed if the full extent of economic value is to be assessed.

3.2. Monetary valuation techniques and cost-benefit analysis

A range of valuation techniques exists for assessing the economic value of goods and services provided by wetlands. Many wetland functions result in goods and services that are not traded in markets and therefore remain un-priced. It is then necessary to value these goods or services using non-market valuation techniques. Quantifying and evaluating wetland conservation benefits in a way that makes them comparable with the returns derived from alternatives uses can facilitate improved social decisions making in wetland protection versus development conflict situations. Cost-benefit analysis (CBA) based on the economic efficiency criterion offers one method to aid decision-makers in this context. In order to be comprehensive, a CBA of a proposed policy affecting a wetland should take into account the policy’s impact on the wetland’s provision of goods and services. However, it should be clear from the preceding section that such predictions typically require detailed knowledge of how the policy would affect wetland functioning, i.e. the basis for the provision of goods and services. This knowledge is often imperfect and qualitative in nature. In particular, to predict in detail a policy's impact on such wetland functioning as, for example, nutrient and sediment retention, gas exchange, and pollution absorption, for any given segment of landscape, is in many cases likely to push present ecological knowledge beyond its bound. Even wetland structure is incompletely known, changes may affect the insect fauna, or soil fungi, and many of these species may never even have been described taxonomically (Westman, 1985). Adaptations of CBA to address issue of ecological complexity, notably relating to irreversibility and foregone preservations benefits, are useful in performing CBA to extreme scenarios regarding wetlands context (Krutilla and Fisher, 1975; Porter, 1982; Hanley and Criag, 1991; Hanley and Spash, 1993).

Two important conclusions follow from these observations, and they will be further discussed in subsequent sections. Firstly, in order to make CBA of wetland policies more reliable, the economic valuation of wetland goods and services has to be as comprehensive as possible. This calls for integrated modelling of the links between wetland ecology (characteristics, structure, processes and functioning) and wetland economics (the demand for goods and services supplied by wetlands). Secondly, even if improvement in CBAs as a basis for decision-making are desirable, it is clear that the outcome of a CBA is not on its own sufficient. The CBA criterion relies on a particular ethical basis, and it may need to be complemented as policy-makers introduce, or respond to, concerns other than economic efficiency. Moreover the lack of detailed, quantitative knowledge of wetland functioning (in practice) precludes a full economic valuation of wetlands.

3.3. Integrated ecological-economic modelling of wetlands

Integrated modelling comes in two forms. One strives towards a single model, while the other employs a system of heuristically connected sub-models. Coupling wetland ecology and wetland economics within one integrated model inevitably involves compromises and simplifications. In general, in system analysis based on models for wetlands a trade-off is needed between generality, precision and realism (Costanza et al., 1993). Interdisciplinary work may involve economists or ecologist transferring elements or even theories and model from one discipline to another and transforming them for their specific purposes. For example, a simple dynamic model summarising and simplifying some of the statistical and causal relationship of a spatial hydrological model and a statistical wetland vegetation model can be linked to the outcomes to a simplified economic model. A number of approaches to integrated modelling exist, based on generalised input-output models, optimisation model, land use models linked to geographical information system (GIS), and mixed models. Important elements for integration are connected scenarios, models and indicators, and the arrangement of consistency among units, spatial demarcations, and spatial aggregation of information in various sub-models. Considerable effort is devoted to increasing the precision at the natural science description level in order to facilitate the linking to the socio-economic level. The prediction of processes and process change in a wetland – both short and long term – is of utmost importance in the assessment of wetland functions. Many important functions are directly related to hydrology. Moreover water is the transport medium for nutrients and other elements, including contaminants. Based on information and models of hydrological processes, nutrient fluxes, sedimentation, erosion, and even flooding can be quantified. The modelling chain can be continued with chemical modelling and the quantification of nutrient balances. Given these data, the likely presence of plant and animal species in the ecosystem may be predicted, as well as the consequent impacts on biodiversity of hydrological changes.

Different methods and models are available to improve the science of wetland systems. Some are focused on a single dimension, while system modelling requires a multidisciplinary effort. The models are analytical, numerical or statistical and describe steady state or dynamic change. Moreover aerial photography and satellite imaging can be incorporated by way of GIS-system to add spatial relations. The development of method for the practical assessment of wetland functioning has followed the increase in the intensity of wetland scientific research in North America, where a multitude of biophysical methods has been produced to meet a range of operational requirements (Lonard and Clairain, 1995). Within the North American context the main purpose of wetland assessment has been to better inform decision makers of the publicly valuable wetland functions that may be lost or impaired by development projects (Adams and Stockwell, 1993; Larson and Mazzarese, 1994). Both regulatory and policy instruments have driven the need for practical wetland assessment method in North America, but they have generally exclusively biophysical in approach and until recently have lacked the validation of closely coupled scientific process studies. Recent work in both the United States and Europe has focused on the possibilities of predicting wetland ecosystem functioning by their hydrogeomorphic characterisation. Efforts have also been made to establish functional classifications of wetlands (Simpson et al., 1998). Brinson (1993) has outlined a hydrogeomorphic classification for wetlands, which underpins a methodology involving comparison of the 'assessed' wetland with suitable reference sites (Brinson et al., 1999).

A European research initiative (Functional Analysis of European Wetland Ecosystem, FAEWE) recognises the intrinsic value of the hydrogeomorphic approach, and is based on the characterisation of distinctive ecosystem/landscape entities called hydrogeomorphic units (HGMU) (Maltby et al., 1996). Work at field calibration sites has shown that a wetland may be comprised of a single HGMU or may be composed of a mosaic of various units. Empirical scientific research at Europe-wide calibration sites, including process studies and simulation modelling, have been used to assess the validity and robustness of the hydrogeomorphic concept. Clear relationship already has been found to exist between individual HGMUs and specific wetland functions including nutrient removal and retention (Baker and Maltby, 1995), floodwater control (Hooijer, 1996), ecosystem maintenance (Climent et al., 1996) and food web support (Castella and Speight, 1996). Links to economic valuation of fractions have also been set out (Crowards and Turner, 1996; Maltby, 1998). A study has been done in Netherlands that employs a system of integrated hydrological, ecological and economic models. This study adopts a spatial disaggregation into 73 polders and uses a multi-criteria evaluation procedure to aggregate environmental, economic and spatial equity indicators of a wetland.

Chapter 4: Valuing The Floodplain Wetland: Methodology, Evidences And Imperatives

Economic valuation can be defined as the attempt to assign quantitative values to the goods and services provided by environmental resources. The economic value of any good or service is generally measured in term of what we are willing to pay for the commodity, less what it costs to supply it. Where an environmental resource simply exists and provides us with products and services at no cost, it is our willingness to pay alone which describes the value of the resource in providing such commodities, irrespective of the fact whether we make any payment for it.

Many environmental resources are complex and multifunctional, and it is not obvious how the myriad goods and services provided by these resources affect human welfare. In some cases, it may be worthwhile to deplete or degrade environmental resources; in others, it may be necessary to 'hold on' to these resources. Economic valuation provides us with a tool to assist with the difficult decision involved. Loss of environmental resources is an economic problem because values are lost, some perhaps irreversibly, when these resources are degraded or lost. Each choice or option for the environmental resource – to leave it in its natural state, allows it to degrade or convert into another use–has implications in term of values gained and lost. The decision as to what use to pursue for a given environmental resource, and ultimately whether current rates of resource loss are evaluated. This requires that all the values that are gained and lost under each resource use option be carefully considered.

Valuation is only one element in the effort to improve the management of environmental resources such as wetlands. At the same time, decision-makers must take account of many competing interests in deciding how best to use wetlands. Economic valuation may help inform such management decisions, but only if decision-makers are aware of the overall objectives and limitations of valuation. The main objective of valuation in assisting wetland management decision is generally to indicate the overall economic efficiency of the various competing uses of wetland resources.

That is, the underlying assumption is that wetland resources should be allocated to those uses that yield an overall net gain to society, as measured through valuation in term of the economic benefit of each use less its costs. A wetland use showing a substantial net benefit would be deemed highly desirable in efficiency terms, even though the principal beneficiaries may not necessarily be the ones who bear the burden of the costs arising from the use. If this is the case, then this particular wetland use may be efficient but it may also have significant negative distributional consequences. It is therefore often important that many proposed wetland investment or management policies are assessed not only in terms of their efficiency but also their distributional implications.

Economic valuation is also not a panacea for decision-makers, as they have to make difficult choices concerning the management of wetland resources. Too often, decision-makers have already decided on what wetland management strategy pursues, whether conversion or conservation, and simply want economic valuation to confirm this choice ex post facto. In such circumstances, valuation has done little to inform the decision-making process and essentially serves no purpose. At the other extreme, sometimes decision-makers ask the impossible from economic valuation. A major difficulty facing valuation of a complex environmental system such as wetlands is insufficient information on important ecological and hydrological processes that underpin the various values generated by the wetlands. If this information is lacking – which is often the case for many non-market environmental values that may be deemed important to value – then it is incumbent upon the analysts conducting the valuation to provide realistic assessment of their ability to value key environmental benefits. Equally, decision-makers must realise that under such circumstances valuation can not be expected to provide realistic estimates of non-market environmental values – not, at least, without further investment of time, resources and effort in further scientific and economic research. Finally, economic valuation is concerned ultimately with the allocation of wetland resources to improve human welfare. Consequently, the various environmental benefits of wetlands are measured in term of their contribution to providing goods and services of value to humanity. However, some members of society may argue that certain wetland system and the living resources they contain may have an additional 'preeminent' value in themselves beyond what they can provide in terms of satisfying human preferences or needs. From this perspective, wetland resource is a matter of moral obligation rather than efficient or even fair allocation. There may be other motivations for managing wetlands in particular ways, such as political considerations. Thus economic values represent just one input into decision-making, alongside important other considerations. The goal of this text is to assist planners and decision-makers with increasing the input from economic valuation in decision-making.

4.1 Valuation Framework for Wetlands

The issue of valuation is inseparable from the choices and decisions we have to make about ecological systems. Some argue that valuation of ecosystems is either impossible or unwise, that we can't place a value on such "intangibles" as human life, environmental aesthetics or long term ecological benefits.

While ecosystem valuation is certainly difficult, one choice we do not have is whether or not to do it. The valuations are simply the relative weights we give to the various aspects of the decision problem. When we value the wetland uses and decision-makers take these values into account when making policies that affect wetlands, then a framework for distinguishing and grouping these values is required. The concept of total economic value (TEV) provides such a framework and there is an increasing consensus that is the most appropriate one to use. Simply put, total economic valuation distinguishes between use values and non-use values, the latter referring to those current or future (potential) values and are unrelated to use (Pearce and Warford, 1993). Typically, use values involve some human 'interaction' with the resource whereas non-use values do not. Use values are grouped according to whether they are direct or indirect. Former refers to those uses which are most familiar to us: harvesting of fish, collection of fuel wood and use of the wetlands could involve both commercial and non-commercial activities, with some of the latter activities often being important for the subsistence needs of local populations in developing countries. Commercial uses may be important for both domestic and international markets. In general, the value of marketed products (and services) of wetland is easier to measure than the value of non-commercial and subsistence direct uses. As noted above, this is one reason why policy makers often fail to consider these non-marketed subsistence and informal uses of wetlands in many development decisions. A special category of value is option value, which arises because an individual may be uncertain about his or her future demand for a resource and/or its availability in the wetland in the future. In most cases, the preferred approach for incorporating option values into the analysis is through determining the difference between ex ante and ex post valuation. If an individual is uncertain about the future value of a wetland, but believes it may be high or that current exploitation and conversion may be irreversible, then there may be quasi-option value derived from delaying the development activities. Quasi-option value is simply the expected value of the information derived from delaying exploitation conversion of the wetland today. In contrast, however, there are individuals who do not currently make use of wetlands but nevertheless wish to see them preserved ‘in their own right’. Such as ‘intrinsic’ value is often referred to as existence value. It is a form of non-use value that is extremely difficult to measure, as existence value involve subjective valuations by individuals unrelated to their own or others’ use, whether current or future. An important subset of non-use or preservation values is bequest value, which results from individuals placing a high value on the conservation of tropical wetlands for future generations to use. Bequest values may be particularly high among the local populations currently using a wetland, in that they would like to see the wetland and their way of life that has evolved in conjugation with it passed on to their heirs and future generations in general.

In a competitive market, rent reflects the periodic value of all services from the property and the asset price reflects the present value of the stream of services less maintenance costs, given the long life of most property, asset price (P^a) and net rent (NR) measured in constant prices.

4.2 Some Valuation Methods Relevant For Wetland Floodplain Ecosystem

The non-existence of markets for many biological resources and the public good nature of biodiversity make the valuation far from trivial. These things imply that the social value of biological resources can't be derived from simple aggregation of their value to individuals in society, the sum of their private values.

Generally economists follow one of two alternative strategies to obtain behavioural observations directly from markets for environmental resources. The first referred to as stated preference methods avoid conventional markets and searches simulated markets. By this is meant that a survey instrument is designed in which a market-like situation is created. Respondents are asked some hypothetical questions and the data so collected are used to value environmental amenities and other goods or services. It is called 'direct' or stated preference, because the analysis is based on direct taste and preferences.

The second strategy is to infer values from data on behavioural changes in actual markets related in some way to the missing markets for environmental resources. Travel cost, hedonic valuation and production function approaches are examples. For instance, although there may be no market value for a wilderness area its value can be derived by analysing the demand for trips to the area, by those who face different costs per trip.

4.2.1. Contingent Valuation Method

The contingent valuation method (CVM) is a technique which allows the estimation of the value of environmental good or service directly by asking people, usually by means of a survey questionnaire, their willingness to pay (WTP) or their willingness to accept (WTA) compensation for a change in the availability of such an environmental good or service.

The major advantage of this approach compared with the proxy methods is that CVM can elicit both use and non-use values, and it is the only method for the evaluation of non-use values. Another benefit of this approach is that it can handle complexities according to the time and financial resources available for the research and survey.

In this method an individual is asked to show his value decisions about possible environmental changes in different ways.

1. Environmental Improvement**:** Here, the value of the environmental improvement is measured by:
    - the individual's maximum WTP to obtain the environmental improvement; (estimated by the compensating surplus – CSU) or by
    - the individual's minimum WTA as compensation to forgo the environmental improvement (estimated by the equivalent surplus – ESU).
2. Environmental Damage**:** The value of the environmental damage in such a situation can be measured either by:
    - the individual's maximum WTP to avoid the environmental damage (estimated by the equivalent surplus) or by
    - the individual's minimum WTA compensation to consent the environmental damage (estimated by compensating surplus).

There is a problem in CVM studies for estimation of environmental values that whether to ask individuals their maximum WTP or WTA for a given environmental damage.

The CSU measure assumes the individual has no consolidated rights in the environmental improvement, assuming therefore as a benchmark the utility level without environmental improvement U_0. The ESU measure assumes instead that the individual deserves some rights on the environmental improvement and puts the individual at the higher utility level U_1 attained with the environmental improvement.

Carson (1991) argued that when individuals are asked to state their minimum WTA, they tend to state their expectation of the maximum they could hope to extract as compensation, rather than their true minimum WTA.

Besides the issue of WTP/WTA format, several issues regarding the accuracy and reliability of valuations based on CVM are debated. The main concerns regard the biases inherent in the technique, mostly the distortions in eliciting the consumer's preferences. Various formats have been utilised for eliciting the value decisions of the respondents. The major formats are 1) open – ended questions; 2) bidding game; 3) dichotomous choice (referendum) questions, and 4) the payment card.

Simple CVM exercises can be based on the " open ended" elicitation formats, where the individual is simply asked to state his/her maximum WTP or minimum WTA for a given environmental change. However, this approach becomes biased when the respondent state a WTP/WTA lower or higher than the true one in order to influence the decision making process for the sake of his own profit.

To avoid the drawbacks of open – ended format, an iterative technique called the " bidding game" is used. In this technique the respondent is asked whether he accepts to pay a given amount of money. If he refuses, the proposed amount is reduced (increased) by a given percentage (say 10 %). The procedure is repeated until the respondent answers "yes". The penultimate amount is taken as his maximum WTP (minimum WTA) for obtaining (to give up) the environmental improvement of the individual accepts the proposed amount it is increased (decreased) of say 10 %. The procedure continues until the individual answers "no". Here also the last amount proposed is taken as his maximum WTP (minimum WTA) for obtaining (to give up) the environmental improvement.

To solve the problems faced in bidding game, the "dichotomous choice" (referendum) format is often recommended. Here, a possible range of values for the maximum WTP (minimum WTA) of individual is pre-set by the analyst. The sample of interviewed individuals is divided in sub-samples. A value within the pre-set range is assigned to each sub-sample. Each individual within a sub-sample is then asked whether he is willing to pay (to accept) the assigned value to obtain (to consent) the environmental improvement (damage). He does not know the range of values within which the proposed amount is bounded.

CVM Methodology: -

To elicit WTP/WTA in CVM:

1. a scenario is described where the impacts of the change in the provision of an environmental good/service are explained;
2. the respondents are invited to consider and to understand the proposed context within which the choice concerning the environmental good/service will occur;
3. the respondents are invited to supply their statements concerning their WTP/WTA, from which the value attached to a change in the provision of the good/service in question is inferred.

The Steps of CVM methodology: -

There are five steps for evaluation of environmental change through CVM.

1) defining the objective
2) questionnaire design
3) survey of sampled visitors
4) data base creation & data analysis
5) WTP estimation

- What to value**:** Here, the purpose of survey and object of valuation has to be clearly defined i.e. which environmental good/ service we want to value.
- Type of the value and measure unit**.** Is the analyst eliciting marginal value or average value to the individual of the good/service?
- Time span of valuation: The analyst must decide whether to collect monthly, annual multi-period WTP/WTA or lump sum WTP/WTA.
- Who should be interviewed: The relevant economic agents have to be identified, i.e. who is affected by the change in the provision of the environmental good/service (individual, households, or production units).

The second step concerns the design of the questionnaire. The questionnaire should be very well constructed for the successful valuation exercise.

- Introduction: Generally the interviewer presents him/herself and explains some reasons for the survey to the interviewer to make him involved.
- Socio-economic information: To analyse the answers and to interpret them in the socio-economic context of the respondent, data about the interviewer, his household and his social environment are normally collected.
- Scenario design: The scenario generally provides a clear and careful description of the environmental good/service that is the object of the valuation, its changes under given conditions, the impacts of the change on the user/consumer, i.e. how the respondents will (could) be affected by the change (present) and who will pay for these policies. The WTP/WTA question must be phrased so as to present a clear, readily understood and plausible scenario.
- Elicitation format: Different formats exist for obtaining the value judgments. The main among them are I) open-ended II) bidding game III) dichotomous choice & IV) payment card.
- Payment vehicle: This aspect is very crucial in CVM questionnaire. Possible payment vehicles are entrance fees (e.g. National Parks), taxes (e.g. Pollution tax) one shot contribution to funds (e.g. Existence values such as protection of endangered species), changes (eg. water use for agricultural, individual or domestic purposes.)

The steps concerning the estimation of maximum WTP/minimum WTA depends upon the elicitation format chosen and the resources available to the analyst.

4.2.2. Production Function Method

Many biological resources and natural systems are used directly in production as inputs or used indirectly in the sense that ecological functions and resources support or protect economic activity. Therefore, we use the production function instead of CVM or any other method to correctly evaluate the functions of those resources. The method is related to the household production function, which is used for surrogate market valuation based on the derived demand by households for environmental quality.

The method:

It consists of a two- step procedure. First, the physical effects of changes in a biological resource or ecological function of an economic activity are determined. Second, the impact of these environmental changes is valued in terms of the corresponding activity.

Symbolically,

If Q is the marketed output of an economic activity, then Q can be considered to be a function of a range of inputs:

$Q = F(X_i \ldots X_k, S)$ (1)

For illustration,

A common ecological function of mangroves is the support of offshore fisheries by serving both as a spawning ground and as a nursery for fry. The area of mangroves in a coastal region, S, may therefore have a direct influence on the catch of mangrove dependent species, Q, which is independent from the standard inputs of a commercial fishery, $X_i \ldots X_k$. Inclusion of mangrove area as a determinant to fish catch can capture some elements of the economic contribution of this important ecological support function.

Non-marketed but significant economic values can be estimated through the production function approach applied to the various indirect use values of biological resources and systems. However, the relationship between any environmental regulatory function and the economic activity it protects or supports should be well understood.

Maler (1991) distinguishes between applications of the production function approach. When production, Q, is measurable and either there is a market price for this output or one can be imputed, then determining the marginal value of the resource is relatively straightforward. If Q cannot be measured directly, then either a marketed substitute has to be found, or possible complementarity's or substitutability between S and one or more of the other (marketed) inputs, $X_i \ldots X_k$, has to be specified explicitly. In the case of single use systems i.e., resource systems in which the predominant economic value is a single regulatory function, or a group of ecological functions providing support or protection for an economic activity in concert, the production function approach may be most useful.

Ellis and Fisher (1987) use this technique to model the environmental function of Gulf Coast estuarine and wetland systems in support of the commercial blue crab fishery. Taking the sum of consumer's and producer's surpluses as the measure of economic value, they hypothesise that an increase in wetland area increases the abundance of crabs and thus lowers the cost of catch. The value of the wetlands' support for the fishery – which in this case is equivalent to the value of increments to wetland area – can then be imputed from the resulting changes in consumer's and producer's surpluses.

Freeman (1991) has added one point to the production function model of Ellis and Fisher that the values imputed to the wetlands are influenced by the market conditions and regulatory policies that determine the conditions of access and rate of utilisation of the fishery.

Freeman also calculates the social value of the marginal product of wetland area, given by:

$$VMP_S = bPQ/S, \qquad (2)$$

P is the price of crabs. As optimal regulation should lead to a higher price than open access, an inelastic demand means that VMP_S is higher under optimal regulation.

Problems:

There are some problems in specifying ecological-economic relationships for the application of the production function approach to estimating indirect use values in multiple use value systems. The main problems are the ‘double counting’ and ‘trade offs’ between various direct and indirect use values, which arise when these values are aggregated.

Barbier et al (1991) could not establish the contribution of groundwater recharge from the floodplain to economic activities in neighbouring regions. Though, they were able to use a hydrological model of the wetlands to estimate the productivity of agriculture, fuel wood and fishing activities within the floodplain area, and to compare the results with the returns per cubic meter of water diverted to an upstream irrigation project. Moreover, the floodplain benefits were adjusted for the ‘unsuitability’ of much pump-irrigated wheat production within the flooding area. The results show that, even without considering the economic benefits of the groundwater recharge function, diverting water for upstream development does not make much economic sense if it is detrimental to the natural flooding system downstream.

4.3. Revealed preference methods: Travel cost and Random utility models.

4.3.1. Travel Cost Method

This method is one of the oldest approaches to environmental valuation, first used by Wood and Trice in 1958, and popularised by Clawson and Knetsch (1966). The method involves using travel costs as a proxy for the price of visiting outdoor recreational sites. A statistical relationship between observed visits and the cost of visiting is derived and used to derive a surrogate demand curve from which consumer’s surplus per visit per day can be measured (by integrating under this curve). The method is widely used for valuing the non-market benefits of outdoor recreation (national parks and public forests).

The TCM assumes weak complementarity between environmental asset and consumption expenditure. This implies that when consumption expenditure is zero, the marginal utility of the public good is also zero. So if traveling to a forest becomes so expensive that no one goes any more, the marginal social cots of a decrease in the quality of that forest is also zero. The TCM, therefore, can’t estimate non-use values. An implicit assumption is that if the activity of interest is fishing, then the utility function is such that demand for fishing trips can be estimated independently of demand, say, for cinema trips (alternative leisure activity) or for heating oil (alternative marketed non-leisure goods). Finally, like all other valuation methods, the TCM assumes the existence of utility function where the environment appears in a similar manner to other goods).

4.3.2. Random Utility Model

The model attempts to place values on the recreational resources (Bocksteal et al. 1987; Coyne and Adamoviez 1992), which shares a theoretical foundation with some stated preference approaches, in particular, the dichotomous choice variant of CVM. Here utility is assumed to be composed of an observable, deterministic component and a random error term. The travel cost data and characteristics data for alternative sites are collected. The probability that a given individual will visit site 'a' rather than site 'b' can then be calculated, depending upon the costs of visiting each site and their characteristics, in relation with the characteristics of all sites in the individuals' choice set. In return, estimates of the welfare effects of changing a characteristic can be arrived at. Bocksteal et al estimate a random utility model for choice of saltwater beach sites in the Boston area, and show that sites with higher pollution levels, higher noise levels, and more crowding are less likely to be chosen. An estimate of a 'count' model is also made that predicts how many trips will be made in total to all beaches in the area. Then the money value of benefits associated with reducing oil, chemical oxygen and faecal coliform pollution levels at all sites in the study area is calculated by combining these models. Ethicists and philosophers argue that the valuation of biodiversity in monetary terms is nonsensical, since it implies a trade-off between the survival of a species and some quality of a commercially traded good.

Rejection of valuation overlooks the fact that it can be a more effective means to the end of conservation than an appeal to moral principles. At present, species are being lost at the rate of around 1-11% per decade (Reid 1992).

4.4. Valuing the Environment in Product Markets

When goods are not marketed, their values can often be inferred from the prices of close market substitutes.

The benefit (b) of an environmental change to producers is the change in

$$b = \left(\sum_{i=1}^{k} piqi - \sum_{j=1}^{1} cjqj \right) x - \left(\sum_{i=1}^{k} piqi - \sum_{j=1}^{1} cjqj \right) y \quad \text{...}(2.1)$$

the

net value of output:

where p, c and q denote prices, costs and quantities; there are i=1……k outputs and j=1 inputs; and the subscripts x and y denote the environment with and without change respectively.

To estimate Equation 2.1 three complications should be noted:

- All changes in net output direct and indirect, associated with the environmental change should be valued. For example, deforestation may open up agricultural land, but also cause soil erosion and increase sedimentation in waterways.
- To value output changes, we generally need to forecast both the impacts of the proposed action on the environment and the relationship between this environmental change and output. For example, in order to value the effects of a power station we need to forecast its impact on air quality and the impacts of marginal changes in air quality on vegetation, structures and human health.
- Producers may respond to environmental changes by altering their output or their method of production, for example by changing their crop or their mix of inputs.
- Productive effects of some environmental changes

Table 4.1: Environmental changes

Environmental changes	**Output**	**Input**
Improvement in soil quality	Increases	Fall
Reduced pollution of fisheries	Increases	Constant
Conservation of forests	Increases	Increases
Improved water quality	Constant	Fall
Soil erosion	Falls	Increases
Increased Pollution of Fisheries	Falls	Constant
Loss of forests	Falls	Falls
Degraded water quality for industry	Constant	Increases

4.5. Hedonic Price Analysis

Hedonic analysis is widely used to estimate the implicit prices of the attributes of goods. A common application is estimation of the value of environmental attributes in the housing market, which can be applied to wetlands as well after making some adjustments.

Implicit hedonic prices are often reasonable proxies for the amounts that people are willing to pay for environmental goods.

A simplified relationship between house prices (p^h) and environmental and other variables:

$$P^h = P\,(S, A, E)$$

(2.3)

where S, A and E are sets of structural access, and environmental attributes of houses. The partial derivatives, dP^h/ds & so on, show the implicit price for each attribute.

4.6. Energy Analysis

The energy analysis valuation technique looks at the total biological productivity of wetland versus adjacent open water ecosystems as a measure of their total contributory value.

The theoretical basis for energy analysis as an economic value estimation tool is discussed in Costanza and Farber (1985) & Turner et al (1988). The method looks at the total amount of energy captured by natural ecosystems as an estimate of their potential to do useful work for the economy.

4.7. Gross Primary Production (GPP)

This is a simplified technique, which uses the GPP of the whole ecosystem as an index of the solar energy captured by the system, and converts this energy value into dollars using a single dollar–energy conversion factor. GPP is used to power all the plants and animals in the system. GPP for an eco-system can be thought of as analogous to GNP for an economy. GPP and GNP measure the value of inputs (or outputs) of ecological and economic system, respectively.

Procedure

1) Determine by field measurements and laboratory experiments the GPP of the natural area in question, under with and without project conditions.

2) Convert this estimate (usually measured in grams of carbon fixed per time unit or the heat equivalent energy content of the carbon) to fossil fuel equivalents (FFE) by considering the fuel efficiency of each source.

Convert the FFE value into dollars using an economy–wide ratio of economic value per unit of energy, usually the ratio of GNP to total economy energy use. This step is certainly the most controversial with critics arguing that energy consumption and economic value are to necessarily relate.

4.8. Wetland ecosystems are undervalued in decision-making process

Wetland resources are particularly susceptible to misallocation decisions because of the nature of the values associated with them. Wetlands are multifunctional resources par excellence. Not only do they supply us with a number of important resource outputs (e.g., fish, fuel wood and wildlife), but they also perform an unusually large number of ecological functions, which support economic activity. Many of these latter services are not marketed; that is, they are not bought and sold because the support they provide to economic activity is direct and therefore largely goes unrecognised. In the case of tropical wetlands, many of the subsistence uses of wetland resources are also not marketed and thus often ignored in development decision. Some of the ecological services, biological resources and amenity values provided by wetlands have the qualities of what economist call a public good, so that it would be virtually impossible to market the services, even if this were desired. For example, if a wetland supports valuable biodiversity, all individuals potentially benefit from this service, and no one individual can be excluded from the service. Such situations make it extremely difficult to collect payment for the service, since whether you pay or not, you may still reap the benefit. In such circumstances, wetland services are liable to be undervalued. Some of the difficulty arising from the public good quantities of wetland values would be unimportant if all wetland benefits could be enjoyed simultaneously, without any conflict among the various uses. Aggregating all possible use values together in such an unfettered multiple-use situation would be more likely to lead to recognition of the importance of conserving a wetland in its natural or semi-natural state. However, amongst many wetland uses there are inherent conflicts or tradeoffs, even when the wetland is maintained in a more-or-less natural state (Turner, 1991). For instance, it may not be possible to manage a wetland for recreation or commercial fishing while at the same time using it for wastewater treatment. Even if the latter use is more valuable, its non-market and public good properties mean that its value is unlikely to be reflected in market decisions automatically. If public policy is to allow individuals responding to market signals to determine the allocation of wetland uses – the so-called ‘free market’ solution – then it is unlikely that the wetland will be used for wastewater treatment. Thus, the resulting ‘undervaluing’ of a key ecological service may once again lead to inappropriate wetland uses.

A wetland and its resources may also be undervalued and thus misallocated because of the property rights regime governing wetland access and use. For example, the wetlands in question may be subject to open access, where no rules apply and use of its resources may be open to all and unregulated. Alternatively, informal and traditional arguments may govern their use as communal or common property resources. Finally state or private property rights may be characterised by quite distinct conditions of resource exploitation. For instance, open-access resources are often over harvested, so observed use values may be very low. As a result, if attempts to value environmental resources are based on simple observations of current use rates, without taking into consideration the institutional context, they may undervalue the resource. This may be especially important if the institutional arrangement is changing informally, as when indigenous common property system are reasserted after a period of dormancy, or a change has been mandated as an element in a project or programme affecting a wetland area, as when land is suddenly privatised or nationalised. Undervaluing of wetlands can be a serious problem when outright conversion of the wetland area is at stake. Development and conversion of the wetland tends to produce marketable outputs, while maintaining the wetland in a natural or managed state usually leads to the preservation of non-market goods and services. Such a dichotomy often results in the development option – e.g., conversion to agriculture, fishponds and commercial or residential property – being widely regarded as the most valuable wetland use. As such activities also generate additional government revenue, it is not surprising that decision-makers also support the conversion of wetlands to 'commercial' uses. Even where revenues may not be the primary objective of wetland exploitation and conversion, agriculture, aquaculture, property development and other conversion activities are generally considered important for economic development and regional growth. They are seen as having significant 'linkages' to other sectors, especially processing and construction, and can provide much-sought-after jobs in regions with few other industrial alternatives. These are compelling arguments for planners and decision-makers in many countries for supporting wetland conversion at the expense of other wetland values. In contrast, non-marketed ecological functions and amenity values generated by natural or managed wetlands may create little in the way of spin-off benefits, and instead may even substitute for employment-generating activities (e.g., water treatment, flood control and storm protection) or require additional investments of scarce public resources (e.g., tourist facilities and roads for recreational uses). Some wetlands may also generate negative external effects in the form of support for disease vectors such as malaria-carrying mosquitoes, which may be recognised while other indirect support functions are ignored. In sum, the undervaluing of wetland resources and functions is a major resource reason why wetland systems are misallocated–often to conversion or exploitation activities yielding immediate commercial gains and revenues. Economic valuation may provide decision-makers with vital information on the costs and benefits of alternative wetland use options that would otherwise not be taken into account in development decisions.

4.9. Survey of Empirical Studies on Economic Valuation of Floodplain (wetland) Ecosystem

The valuation of the ecological functions of wetland ecosystems has been carried out in many countries. All the studies have applied the tools and techniques of economics science, though, there are differences in the type of the wetland studied. In one of the interesting studies, Costanza (1993) tried to compare the benefits from wetland preservation versus those from wetland conversion to agriculture. The study applied the Travel Cost Method (TCM) and analysed the study area taking a 50-year time period at 4% real discount rate. The study concluded that the difference per hectare between preservation benefits and conversion benefits is highly positive.

Michael Kosz (1994) has done a cost- benefit analysis on funding a national park, shipping, production of electricity, visitor's benefits, ground water protection and the concept of hydraulic engineering for stabilizing the riverbed. The rate of discount was set at 2 % and the time span chosen was 72 years. The discounted benefits for power station were 44.62 billion (bn) ATS. The value of a visit to the national park was calculated as 80 ATS per visitor. Jaime Echeverria, Michael Hanrahan and Raul Solorzano (1995) have used CVM to attach numeric values to non- marketed environmental amenities provided by the Monteverde Cloud Forest Preserve, Costa Rica. The estimated mean individual Hicksian equivalent surplus across the 42 Costa Rican respondents is $137.41 and across the non- Costa Rican respondents is $118.76. This difference showed that Costa Ricans are willing to pay 3.4 times more than non- Costa Ricans to preserve the environmental good.

There have been many similar studies world wide for determining the economic importance of wetland ecosystems. In India, not many studies are available on this aspect but some attempts have been made for valuation of wetlands in the recent years. Chopra et al (1997) has conducted a significant study on economic valuation of Keoladeo National Park, which is a Ramsar site of national importance. Chopra et al has mainly emphasised on the importance for tourist and hence applied the travel cost method (TCM). She has calculated consumer's surplus from local cost estimates, which amounts to Rs.427.04 per visit by an Indian and Rs.432 per visit by a foreigner. Estimating the total number of tourists between 1992-93 and 95-96, she calculates the total value as Rs.42.5 million.

Following table provides a brief summary of some of the studies on valuation of wetland ecosystem, which have widely been discussed and debated in the literature:

Table 4.2a: (International Case Studies)

S. No	Author & Year	Name of the study	Methodology &Results
1.	Eaton & Search May 1997	Economic Importance of the wild resources in the Hadejia – Nguru Wetlands	• Participatory Rural Appraisal/ Market Value *Valuation of* *Value* *Unit* Firewood 11 US$/Year Agriculture 500 US$/Year Doum Palm Fronds 110 US$/Year Potash 0.75 US$/Year
2.	Gilbert & Janssen 1996,1997	Valuation and evaluation of the management alternatives for the Pagbilo Mangrove Forests	• Cost Benefit Analysis/Multi criteria Analysis *Valuation of* *Value* *Unit* Forestry 151 US$/ha Fisheries 60 US$/ha Acquaculture -7124* US$/ha * Negative value is interpreted as an opportunity cost for a beneficial alternative forgone
3.	Ruitenbeek, Jack	Modeling economy – ecology linkages in	• Cost Benefit Analysis/Multi Criteria Analysis

S. No	Author & Year	Name of the study	Methodology &Results
		mangroves - Economic evidence for promoting conservation in Bintuni Bay, Indonesia	*Valuation of* *Value* *Unit* Traditional Non-Commercial Uses 33 US$/ha/yr. Commercial Fisheries 116.7 US$/ha/yr. Selective Mangrove Cutting 66.7 US$/ha/yr.
4.	Kooten,G. Cornelis Van	Bio-economic evaluation of Government agricultural programs on Wetland Conversion.	Valuation of wetlands/wetland products in different use scenarios. *Valuation of* *Value* *Unit* Grazing 13.20 US$/acre Cost of Conversion to agriculture 92-324 US$/acre
5.	Pate & Loomis	Effect of distance on Willingness to Pay values: a case study of wetlands & salmon in California	• Estimation of WTP by CVM Sjv* Ca* Or* Wa* Nv* Wetland Improvement 175 2357 81 203 102 Contamination Control 190 2490 62 175 105 • Different states of USA Million US$ Aggregate WTP
6.	Walsh, Loomis & Gilman	Valuing option, Bequest & Existence demands for wilderness	• Measurement of non-use values through a CVM estimate Non-use Value Estimate Unit Recreation Use Value 14 $/visitor day/annum Preservation Value 13.92 $/households/ per annum Option Value 4.04 $/households/ Per annum Existence 4.87 $/households/ Per annum Bequest 5.01 $/households/ Per annum

S. No	Author & Year	Name of the study	Methodology &Results
7.	Gren, Folke, Turner & Bateman	Primary & Secondary values of wetland ecosystems	• Provides a description of the biophysical, technological and behavioral methods of valuation • Discusses three empirical case studies Case study / Approach / Results Broadland Wetlands: Estimation of WTP for Conservation per of broads households via a per annum protection strategy; Mean WTP=140 Martebo Mire, Sweden: Estimate of monetary replacement Cost for all Functions of the wetlands (Energy estimates); 2.5-7m SEK Gotland Wetlands, Sweden: Valuation of improved water quality due to nitrogen purification; SEK 5/kg – N Reduction
8.	Costanga, Maxwell & Farber	Valuation and management of wetland ecosystems	• Estimation on marginal productivity of wetlands Benefit / value / unit Commercial fishing: 25.36 US$/year; (317*) US$/year Recreational (Annual WTP using TCM): 3.9millions US$/year Storm Protection: 1604 US$/acre/year Fur trapping: 12.4 US$/acre; (151*) US$/acre (* =PV@8%) • Energy analysis based value estimation • Average value of Gross Primary productivity of wetlands is $631/acre/year
9.	Stavins, Robert N.	Alternative Renewable Resource Strategies: A simulation for optimal use	• Base hypothesis: investment in drainage and flood protection have been a significant cause in depletion in wetlands • Dynamic Optimization Model • Simulation with respect to several variables as improved drainage, agriculture prices • In the absence of public investments, there would have been protection to 1.15 million acres from conversion of wetlands to agriculture.
10.	Lynne, Conroy & Prochaska	Economic Valuation of marsh areas for marine production processes	• Quantification of contribution of marsh estuarine areas of the production of marketable marine life (blue crab fishery) over Golf coast of

S. No	Author & Year	Name of the study	Methodology &Results
			Florida Results: • Total present value of a marsh acre in human food consumption = $3.00 for marginal acre
11.	Stephen Farber	Value of coastal wetlands for protection of property against Hurricane wind damage	• Damage function estimation Results: • Total incremental annual damage from loss of one mile of wetland = $63,676 based on 1980 costs and population
12.	Kramer & Shabman	Effect of Agricultural and Tax Policy reforms on the Economic Returns to Wetland Drainage in the Mississippi Delta Region	• Econometric Modeling, Cost Benefit Analysis Results: • On the basis of modeling, it was proved that the wetland reform had reduced the returns on conversion of wetlands to alternate uses
13.	Kosz, Micheal	Valuing Riverside wetlands: the case of " Donau – Auen " National Park	• Cost Benefit Analysis/ Estimation of WTP through Contingent Valuation Method Estimation of Value Unit Existence 167.39 ATS/year Value Bequest value 122.61 ATS/year Option value 39.25 ATS/year
14.	Batie & Mabbs	Opportunity Costs of Preserving Coastal Wetlands: A case study of a Recreational Housing Development	• Cost Benefit Analysis of putting wetlands to alternate uses through estimation of the marginal returns from wetlands
15.	Stavins & Jaffe	Unintended Impacts of Public investments on Private Decisions: Depletion of forested wetlands	• Hypothesis: Public infrastructure investment induce major changes in private land use by affecting relative economic returns • Method: Econometric Analysis & Simulation Results: • Public Investments in flood and drainage projects had accelerated the conversion of wetlands to agriculture lands • Public investment since 1934 account for 31% of the forested land depletion
16.	Barbier, Edward B.	Valuing Environmental Functions: Tropical	• Econometric modeling of the problem of conversion of tropical wetlands

S. No	Author & Year	Name of the study	Methodology &Results
		Wetlands	• Formulation of the cost benefit framework for wetland based uses Results: • The rate of conversion of wetland is influenced by two factors: social discount rate and the social opportunity cost of retaining the wetlands
17.	Bergtorm & Stoll	Value Estimator Models for Wetland Based Recreational use Modes	• Theoretical formulation of a value model based on empirical relationships between the value measure and its determinants • Proposed for use in the estimation of benefits from different management policies regarding wetland based recreation
18.	Janssen & Padilla	Preservation or Conversion: Valuation and Evaluation of a Mangrove Forest in the Philippines	• Cost Benefit Analysis/ multi Criterion Analysis • Valuation of resources under various management alternatives • Evaluation of alternatives based on value of resources under alternatives Results: See Annexure 1
19.	Navrud & Managatana	Environmental Valuation in developing countries: the recreational value of wild life viewing	• Contingent Valuation Method/Travel Cost Method Results: US$(per annum) TCM CVM WTP for Flamingoes 5-5.5 m 2.7 m
20.	Soderqvist, Tore	Empirical Cost Equations for wetland Creation: The case of wetlands as nitrogen sinks in Scania, South Sweden	• Estimation of cost equation for wetlands specifically for two river basin projects was done Results: • Cost of creation of 1.16 ha of wetland is SEK 7300 • Creation of wetland for Nitrogen sink amounts to SEK10 per kg of Nitrogen reduced
21.	Doerig et al	Evaluation of the Economic Costs and Benefits of Methods of reducing Nutrient Loads to the Gulf of Mexico	• Cost Benefit Analysis • A 20% nitrogen loss-reduction goal was set to be met • On an evaluation of the alternatives it was found that a 5 million acre wetland restoration project along with a 20% fertilizer reduction goal was the most effective and practicable approach
22.	Randall, Ivis & Eastman	Bidding Games for Valuation of Aesthetic Environmental	• Bidding Games Approach • Estimation of benefits of abatement of aesthetic environmental damage

S. No	Author & Year	Name of the study	Methodology &Results
		Improvement	associated with a power plant and a mine Results: • Three levels of emissions were defined (A=max. emission, C=No emission) • Three options: bidding through sales tax and electricity games were used • WTP for situation B/annum =$50 • WTP for situation C/annum =$85
23.	Kahn & Kemp	Economic Losses associated with the Degradation of an Ecosystem: The case of Submerged Aquatic Vegetation in Chesapeake Bay	• Damage function approach/ Demand Supply Analysis • Estimation of a marginal damage function
24.	Hammack J & Brown G.M.(1947)	Waterfowls and Wetlands: Towards Bio-economic analysis	• CVM, Production Function Results • Value of additional (marginal) waterfowl: 2.40 – 4.65 per bird, depending on pond cost (1968-69 costs) depending on pond costs
25.	Smith V.K., Jin Long Liu & Palmquist B Raymond	Marine Pollution & sport fishing quality: Using Poisson model to assess household production function	• Valuation of the impact of pollution on sport fishing quality • Household Production Function Approach Results: • Non-point and point sources of pollution have an impact on the sport fish catch
26.	Kaoru, Smith & Liu	Using Random Utility Models to Estimate the Recreational Value of Estuarine Resources	• Household Production Function Approach • Estimation of consumer surplus (individual Willingness to Pay) for catch improvement due to reduction in nitrogen loading Benefit Estimates Alternative / 35 Site Model / 23 Site Model / 11 Site Model Loss of site a) 35 Site: -$4.3- -$80 b) 23 Site: -$3.25- -90.24 c) 11 Site: -$0.33- / -$123.94 5% increase in fish catch at all sites: $8.92- $42.31 / $7.50- $37.24 / $3.77- $19.07 36% decrease in nitrogen loading at all sites: $1.66- $9.05 / $0.76- $11.00 / $0.12- $9.04
27.	Roberts & Leitch	Economic Valuation of some wetland outputs of Mud Lake, Minnesota – South Dakota	• CVM, Market Based Methods Results: Beneficial Output / Value / Unit Flood Control / 2200000 / US$/year

S. No	Author & Year	Name of the study	Methodology &Results
		Dakota	Water Supply 94000 US$/year Fish/Recreation & 2396000 US$/year Aesthetics Use and Non-use values Detrimental Outputs Water Quality 180000 US$/year Net Benefit 2216000 US$/year
28.	Pearse, Peter H.	A new Approach to evaluation of Non-Priced Recreational Resources	• Indirect estimation of consumer surplus through estimation of demand curve Results: • Total consumer surplus for Resident Big Game Hunters in the East Kootney in 1964=$2,900,242
29.	Whitehead, Blomquist, Hoban & Clifford	Assessing the validity and reliability of Contingent Values : A comparison of On site users, Offsite users, and non users	• Concepts of validity and reliability of WTP estimate introduced Results: • Statistically, WTP estimates provide by on site users are more valid and reliable than off site users
30.	Walsh, Miller & Gilliam	Congestion and Willingness to Pay for Expansion of Skiing Capacity	• Contingent Valuation • Willingness to Pay specified as a function of congestion, income, substitution, user days and socio-economic variables Results: • Avg. WTP for a lift ticket=$18.61/person/trip
31.	Spaninks, Frank & Beukering (1997)	Economic Valuation of Mangrove Ecosystems	• Review of 6 case studies (Refer Annexure II) • Methodology for valuation of mangroves of Pagbilao Bay

In the last decades carrying forward from the international experience some of the quality studies on valuation of wetland ecosystem have emerged. Following list provide a brief summary. This is a representative list can no way claims to be comprehensive and complete.

Table 4.2b: (Indian Case Studies)

S. No.	Name, Year	Organisation	Title of study	Methodology & Results
1.	Hadker N. et al, (1995)	Indira Gandhi Institute of Development Research, Mumbai	Willingness to Pay for Borivli National park: evidence from a CVM	• Contingent Valuation Method Results • True Willingness to Pay (after adjustment for biases) = Rs. 7.5 /household/month • Net Present Value of WTP = Rs. 17 million/annum.
2.	Chopra K. (1997)	Institute of Economic Growth, Delhi	Economic Valuation of Biodiversity	• Travel Cost Method/Multi Criteria Analysis Results Consumer Surplus per Visit Model Indians foreigners Quadratic 4168.99 4167.91 Semi Log 23940.53 23935.32
3.	Chopra Kanchan & Kadekodi Gopal, (1997)	Institute of Economic Growth, Delhi	Natural Resource Accounting in the Yamuna Basin: Accounting for Forest Resources	• Contingent Valuation Method / Multi Criteria analysis Results Market Valuation Methods values Timber Market Price Rs5587/m^3. NTPFs Market Price Rs7509/sq.km. Preservation & Recreation Travel Cost Method Rs.505.44/ person/visit Non-Market Valuation Recreation & Protection of Forests CVM Rs. 19.87/hh/year Rs. 55.12-73.6/person 176.0-3509.05/ha 1011.41-25154.48/CUM Non-Use Values MCA Relative Values
4.	James. A.J. & Murty M.N., (1998)	Institute of Economic Growth, Delhi	Measuring Non-User Benefits from Clearing Ganges	• Contingent Valuation Method Results Mean WTP For all Users (Rs./Household/annum) Levels of River Water Quality Basis for household Best 1995 1985 1995 WTP Calculation Quality Quality Quality Quality With with with without GAP GAP GAP GAP Sample Mean 500 200 100 Estimated Mean 533.02 217.79 91.64 (Model With Quality) Estimated Mean 557.94 192.81 101.48 97.51 (Model Without Quality) For other results see Annexure
5.	Rath Anita (1997)	Delhi School of Economics	Preservation Value of a Wetland Ecosystem: A Case Study of Chilika	• Contingent Valuation Method Results Estimate of use values Value Unit Recreation 152.7millions Rs./annum Non-use Values Bequest 219.2 millions

S. No.	Name, Year	Organisation	Title of study	Methodology & Results
				Rs./annum Existence 432.9millions Rs./annum
6.	Ghatak R. N. & Singh, Katar (1994)	Institute of Rural Management, Anand	The Contingent Valuation Method of Pricing Canal Water: An Exploratory Study in Kheda District of Gujarat	• Contingent Valuation Method Results • WTP for irrigation water = 119-205 % of the existing irrigation water rates
7.	Mishra S. (1996)	Institute of Economic Growth, Delhi	Measuring Benefits from Industrial Water Pollution Abatement: Use of Contingent Valuation method in Nandesri Industrial area of Gujarat in India	• Contingent Valuation Method Results • WTP for water quality = Rs. 5.49/hh/annum Rs. 106.87 million/annum for entire population (six villages)
8.	Santra & Ghosh	School of Environmental Sciences, University of Kalyani, West Bengal	Wetland Resources: Non-Conventional Resource Evaluation	• Market Price Method Values of Commercial cultivation of Aquatic Pants Species Net Profit (First Year) Net Profit (Second Year) Typha Elephantia 3300 3700 Cyperus Corymbosus 42000 52000 Aeschynomene Aspera 16000 16000 Trapa natans 8000 10000 Azolla pinnata 15000 15000 Euryle ferox 25000 30000
10.	Murty & Menkhaus (1994)	Institute of Economic Growth, Delhi	Economic Aspects of Wildlife Protection in Developing Countries: A case study of Keoladeo National Park, Bharatpur, India	• Contingent Valuation Method Results Average WTP per person for recreational benefits: • For Domestic Tourists = Rs. 11.5/annum • For International Tourists = Rs. 82.9/annum

S. No.	Name, Year	Organisation	Title of study	Methodology & Results
11.	Kadekodi G. & Gulati S.C. (1999)	Centre for Multidisciplinary Development Research, Dharwad &Institute of Economic Growth, Delhi	Root Causes of Biodiversity Loss in Chilka Lake: Reflections on Socio-economic Magnitudes	• Econometric Modelling Linking Socio-Economic Variables to Ecological Changes
12.	James et al. (1998)	Centre for Water Resources Development and Management, Kozhikode, Kerala	A Comprehensive study on the Wise Use of Vembanad-Kol Wetaland System and its Drainage basins	
13.	M.Verma2001	Indian Institute of Forest Management, Bhopal.	Economic valuation of Bhoj Wetland	• Contingent Valuation Method Results Estimated Willingness to Pay for the Bhopal city: Total voluntary WTP = Rs. 4,84,68,956/annum Total WTP as tax = Rs. 59,32,922/annum • Hedonic Price Method Here, the Multi criteria Analysis has been used Results Proximity to the Lake has resulted in 50% difference in property prices.

Chapter 5: Floodplains Conversion: Pressure, Externalities and Market Failure

The benefit of a healthy floodplain wetland ecosystem emerges from the integrated approach of ecology and economics. Ecological processes give rise to several tangible and/or intangible outputs which society perceives as crucial for their consumption, production and overall welfare. The interactions of ecological functions/ interactions and perceived societal values/ benefits in Yamuna Floodplains area have been shown in the following figure.

The upper part of the figure shows ecological concepts including the characteristics that depict the floodplain area in the simplest terms. Floodplain wetland structure has been defined as the biotic and abiotic meshes of vegetation type and soil type. Wetland processes are referred to as the dynamics of transformation of matter or energy. Ecosystem functions like floodwater control, nutrient retention and food mesh support are the outcomes of interactions among characteristics, structure and processes**.**

The second part of the figure represents the ecology-economics interface, where we go from wetland functioning to the uses of wetlands. For instance, groundwater recharge and nutrient characteristics play an important role in providing agricultural benefits, but they are not the functions in themselves.

The lower part of the figure explains the concepts of different values and valuation of goods and services provided by the wetlands with the help of methods like contingent valuation method, production function approach and hedonic pricing. The concept of total economic value has been expressed as a combination of different use and non-use values. The use value has further been divided into direct and indirect use values. The non-use value category has been split into existence, bequest and philanthropic values. The concept of total economic value TEV should not be confused with the 'total value' of a wetland. The valuation of wetland goods and services needs great caution and clarity of concepts otherwise the problem of overestimation may crop up. Benefits should be allocated explicitly between functions.

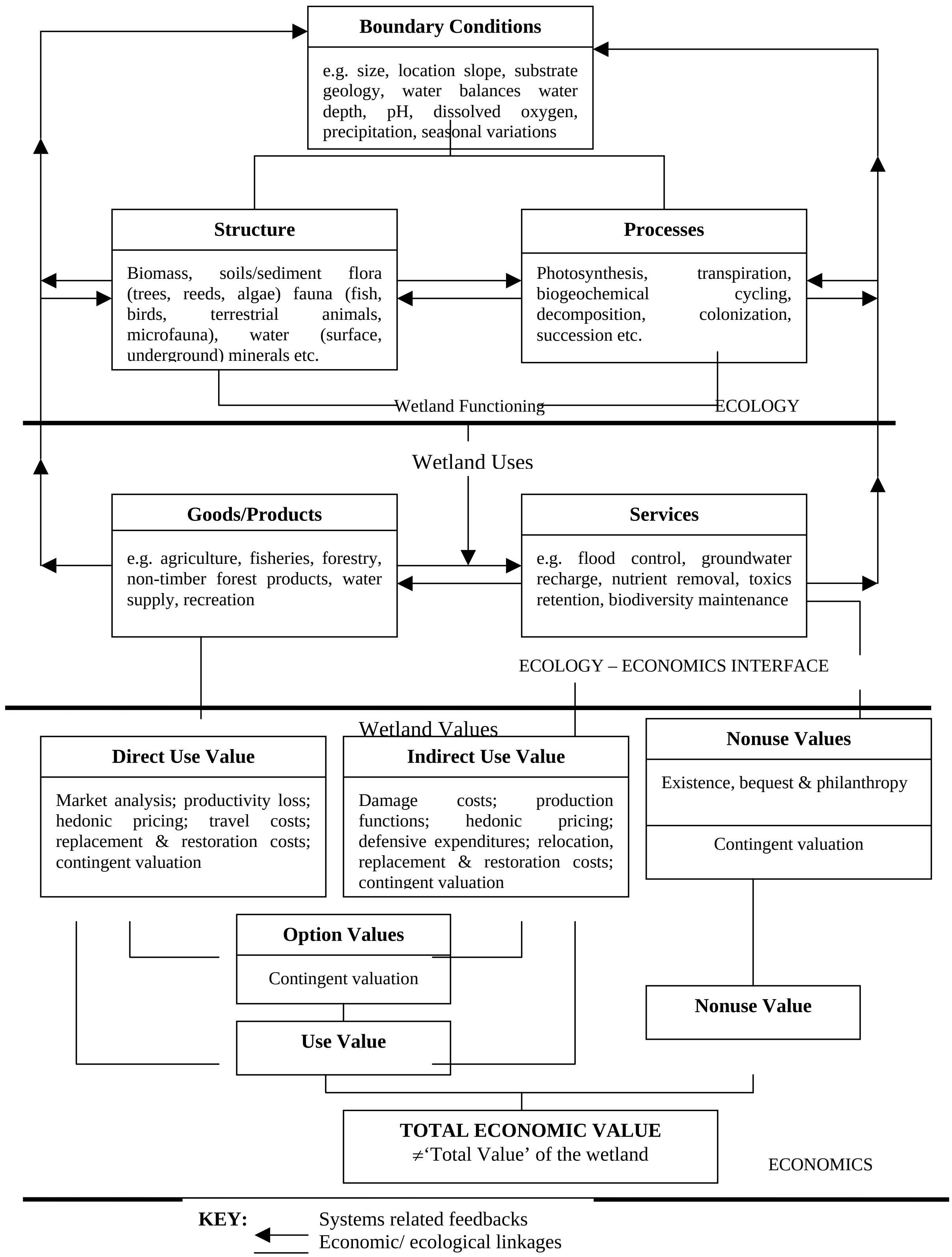


Figure 5.1: Floodplain Functions, Uses and Values

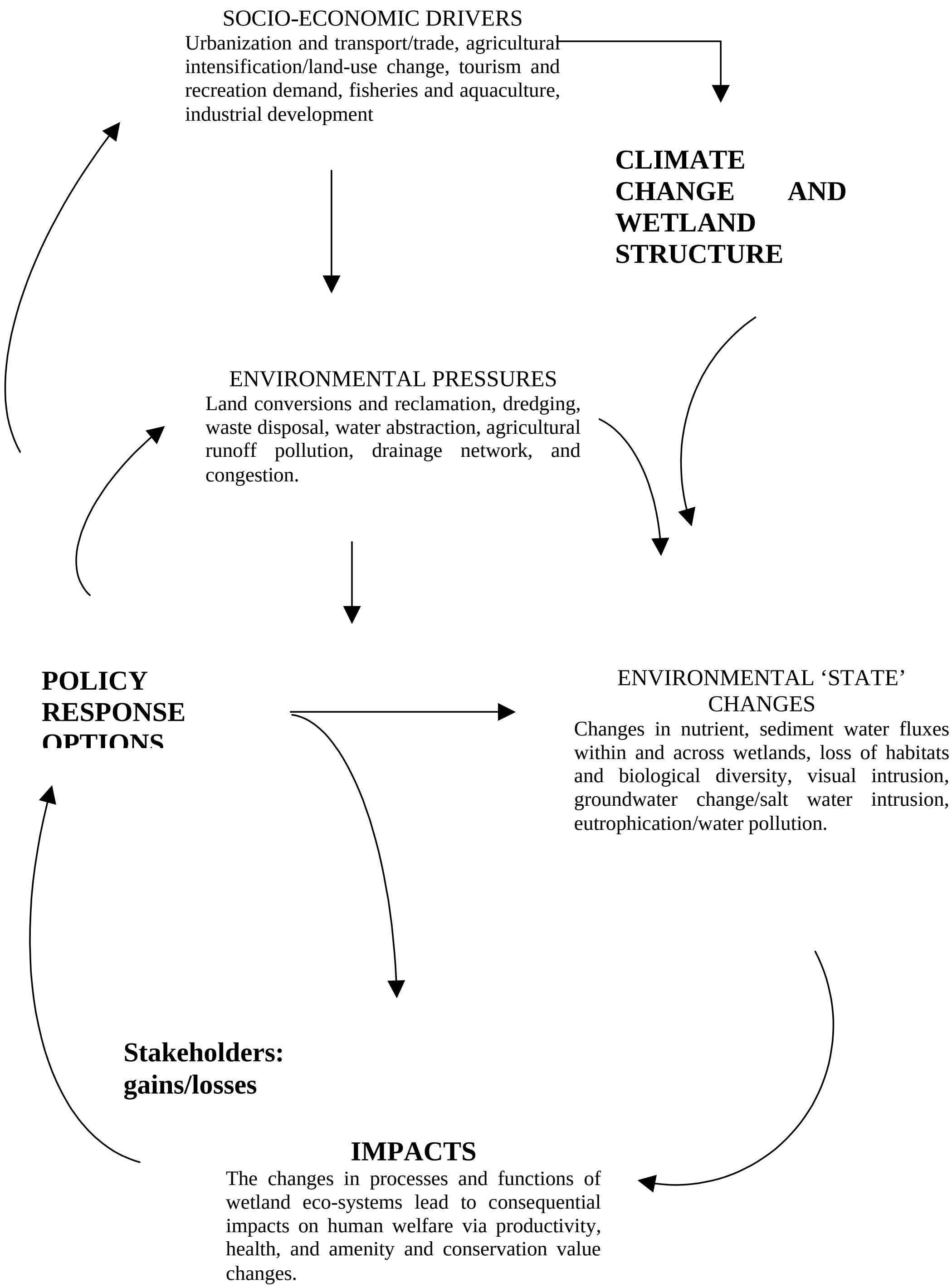
5.1 Pressure on Yamuna wetland Ecosystem

In the last 100 years, the floodplain wetland area has reduced or has severely been degraded primarily due to habitation (slum and towns) and agriculture. Following figure shows the mechanism how the pressure deforms the resilience of the pristine floodplain ecosystem and then impairs its ecological function-ultimately adversely affecting the potential benefits accruing to the society.

Figure is known as the Driving Pressures-State-Impact-Response (DP-S-I-R) approach. It is flexible enough to be conceptually valid across a range of spatial scales. It also serves to highlight the dynamic characteristics of ecosystem and socio-economic system changes, involving multiple feedbacks with a possible co-evolutionary process. The urban ecosystem of Delhi environment pressure builds up via socio-economic driving force-demographic, economic, institutional and technological-which cause changes in environmental systems 'states'. These changes include increased nutrient fluxes, wetland habitat loss due to conversion, fragmentation and quality degradation and pollution of soil and water. The processing and functioning capabilities of wetlands is affected and this results in impacts on human welfare via productivity, health, amenity and other value changes. The impacts impose social welfare gains and losses across spectrum of different stakeholders.

In standard literature of environmental economics the rate of destruction and degradation of wetland ecosystem has been attributed to the phenomena of information failure, market failure and intervention failure. The first failure i.e. information failure where economic agents are not able to appreciate the contribution of wetland ecosystems through their explicit actions, causes the other tow failures. The cumulative impact of these failures translate into severe threats to the wetlands and their ecological health through excessive anthropocentric pressure in form of pollution, hunting, drainage for agriculture and disturbances from unsustainable recreation etc.

Figure5.2: Pressure-State-Impact Framework Applied on Yamuna Floodplain



(Adapted from Turner et al 2000)

5.2 Conversion Model of floodplain of Yamuna River

Floodplains areas in Delhi Corridors of Yamuna River are shrinking just because of the fact that their alternate uses prove to be more lucrative. A wetland ecosystem can have other alternate uses for the society which seemingly might have more attractive returns but once we incorporate the values of its ecological/social benefits the conversion of the wetland areas for other purposes might not be attractive in the true sense. A formal framework for the wetland conversion can show why the wetlands areas are shrinking .It has been found that for one hectare piece of the wetland the marginal benefit of conversion exceeds the marginal cost of its conversion. Following section shows this analysis for the floodplain wetland of Yamuna River where construction activities for housing and township development is supposed to give better return than preserving this area exclusively for its ecological functions which in turn provide various user and non user benefits values.

Let us presume that the land owner (may be private or public like DDA) seeks to maximise its net revenue/return over the relevant time horizon, say N. For a typical land owner in the floodplain area of Yamuna in Delhi Corridor the representative expression for wetland conversion for housing purpose will be as follows:

$$\underset{y_t}{Max} \sum_{t=0}^{N-1} \beta_t [(R_t q(U_t) - AC_t)(\overline{U} - U_t + y_t)$$

$$-c(y_t, U_t) + r_t U_t] + \beta^N F(U_N) \quad (1)$$

Subject to

$$U_{t+1} - U_t = - y_t \; [U_t - U_{t+1} = y_t]$$

$$U_0 = \overline{U} \qquad (2)$$

$$-\overline{y} \leq y_t \leq \overline{y}$$

Where

β = discount factor

R_t = expected annual revenue per hectare in the floodplain area when the land is given for construction purpose.

q = quality of land suited to construction

AC_t= operational and maintenance cost (expected) on the land

y_t = annual area of floodplains

U_t = total area of floodplain potentially available for construction

c = cost of conversion of a hectare of land of floodplain for house construction

r = rate of return on the pristine floodplain (per hectare)

F = the value of floodplains wetland at the end of the time, N

In the set of constraints, the first constraint shows the change in marginal land over one year. Second constraint shows the availability of total land in the floodplain for construction. Finally, the third constraint shows the maximum floodplain area that can be converted annually for construction activities.

The entire problem can be formulated in a dynamic programming problem as It is assumed that all the functions can be differentiated and the solution is an interior one. First order condition for optimality is

$$V_t(U_t\,y_t)\max_{y_t}[(R_t\,q(U_t)-AC_t)(\overline{U}-U_t+y_t)$$

$$-c(U_t,y_t)+r_tU_t]+\beta V_{t+1}(U_{t+1}) \qquad (3)$$

$$R_t\,q(U_t)-AC_t-\frac{\partial c}{\partial y_t}=r_t+\beta\lambda_{t+1} \qquad (4)$$

Equation (4) shows that for marginal hectare of floodplains land, the benefits of conversion of land for construction is equal to the present value of losses occurred over future time period due to conversion. Alternatively it can be said that marginal cost of conversion is getting equalised with it marginal benefits. In our scheme of the thing, marginal cost of conversion comprises marginal user cost of retaining the land i.e. ($\beta\lambda_{t+1}$) and the marginal cost of conversion and the marginal current loss in revenue from these areas of floodplains.

from equation (4)

$$R_t\,q(U_t)-AC_t-\frac{\partial c}{\partial y_t}=r_t+\beta\lambda_{t+1}$$

Generally, the benefits of retaining the floodplain land is either ignored or unaccounted due to their nature, which is social and external. Left Hand Side (LHS) of Eq. (4) exceeds the R.H.S. This implies that in the general perception the marginal benefit of conversion of floodplain land is greater than the cost of conversion. Here the value of ecological functions of floodplain is unaccounted. They are albeit acknowledged by the expert scientists; the policy makers ignore them. It leads to erroneous action on the part of decision makers and more and more area of floodplains is converted for activities like construction and township development. This is precisely the reason that one of the most productive (biologically) ecosystems i.e. the floodplain wetland of Yamuna River in Delhi corridor is serious threatened. This clearly justifies the mandate for valuation of ecological functions, which are social and external in nature. The next chapter exclusively attempts to do this.

Chapter 6: Estimation and Economic Evaluation of Ecological Functions of Yamuna Floodplains

As explained earlier, floodplain area recharges the ground water. In the post-monsoon season the mean depth or water table goes up to 2.28 meter from 3.00 meter in the pre-monsoon season. This translates into around 23.4 mcm of water tapped in the aquifer. Refer to table 6.1. The availability of water can help agriculture or it can be used to extract the water for household consumption in Delhi. Both of these benefits are not exclusive of each other. However, we derive the estimates of both the values.

This recharged water helps agricultural activities in the floodplain where farmers incur lower cost on irrigation (lower cost of pumping of the water) and hence their following section focuses on the valuation of recharged water through agricultural production function.

Table 6.1: Ground Water Recharge

Area of the demarcated study zone:	3.25$*10^7$ **m**
Water recharged into the available aquifer space:	40.95 **mcm/annum**
Plant available moisture in the study area:	9.75 **mcm/annum**
Water reaching into the ground water reserve:	23.4 **mcm/annum**
Depth of water table during pre-monsoon period:	3m
Increase in the mean height of the ground water table:	**.72m**
Depth of water table during post-monsoon period:	2.28m

6.1 Theoretical Framework of Groundwater Recharge Valuation of Yamuna Floodplain Wetlands

The contribution of a typical floodplain wetland ecosystem to the agricultural activities through its water recharge function is estimated through various methods. In some cases agricultural production function approach has recently been used (Ellis & Fisher 1987, Acharya, G., 2000, Acharya & Barbier, 2000). Here we are using agricultural production function approach to value the recharge function of this floodplain. Subsequently we apply alternate cost approach to value the same water if it can be used for household supply for Delhi Region.

Assuming that farmers produce I=1…n crops, irrigated by groundwater. Let y_i be the aggregate output of the ith crop produced by the farmers. The production of y_t requires a water input W_i, abstracted through shallow tubewells, and j=1 of other variable inputs (e.g. fertilisers, seed, labour), which are denoted as $x_i,\ldots,x_j$ or in vector form as X_j. Because of the relationship between recharge and the level of water in the aquifer it is assumed that the amount of water available to the farmer for extraction is dependent on the groundwater level, R. The aggregate production function for crop i can be expressed as:

$y_i = y_i\ (x_{i1}\ldots x_{ij}, W_i(R))$ for all i (1)

and the associated costs of producing y_i are:

$C_i = C_x X_j + cw\ (R)\ W_i$ for all i (2)

where C_j is the minimum costs associated with producing y_i during a single growing season, c_w is the cost of pumping water and C_x is a vector of $c_{xi}\ldots c_{xj}$ strictly positive, input prices associated with the variable inputs $x_{i1}\ldots x_{ij}$. We also assume that c_w is an increasing function of the groundwater level, R, to allow for the possibility of increased pumping costs from greater depths, i.e. $c'w > 0$, $c''\ w > 0$. We first assume that there exists an inverse demand curve for the aggregate crop output, yi:

$P_i = P_i(yi)$ for all i (3)

where P_i is the market price for y_i, and all other marketed inputs prices are assumed constant.

Denoting S_i as the social welfare arising from producing y_i, S_i is measured as the area under the demand curve (3) less the cost of the inputs used in production:

$$S_i = S_i(x_{i1}...x_{ij} ,W_i(R))$$

$$= \int_0^y 1 P_i(u)du - C_x X_j - c_w(R)W_i \ \text{for all } i, j \quad (4)$$

To maximise (4) we find the optimal values of input x_{ij} and water input W_i through setting the following first order conditions to zero:

$$\frac{\partial S_i}{\partial x_{ij}} = P_i(y_i)\frac{\partial y_i}{\partial x_{ij}} - c_{xj} = 0 \ \text{for all } i,j \quad (5)$$

Eqs.(5) and (6) are the standard optimality conditions indicating that the socially efficient level of input use occurs where the value of the marginal product of each input equals its price. If each farmer is a price-taker, then this welfare optimum is also the competitive equilibrium. We assume that this is the case.

The first order conditions in (5) and (6) canbe used to define optimal input demand functions for all other inputs as $x_{ij}* = x_{ij}* (c_{xj}, c_w(R), R)$ and for water as $W_i^* = W_i^* (c_{xj}, c_w(R) R)$. In turn, the optimal production and welfare functions are defined as $y_i^* = y_i^* (x_i^*,..., x_j^*, W_j^*(R)$ and $S_i^* = S_i^* (x_{ij}^* ...,W_j^*(R); c_w(R))$.[1]

From the above relationships, we are interested in solving explicitly for the effects on social welfare of a change in groundwater levels, R, due to a fall in recharge rates. Assuming that all other inputs are held constant at their optimal levels, and that all input and output prices (with the exception of c_w) are unchanged, it follows from the envelope theorem that:

$$\frac{dS_i}{dR} = (P_i(y_i^*)\frac{\partial y_i}{\partial W_i} - C_w)(\frac{\partial W_i}{\partial C_w}\frac{\partial C_w}{\partial R} + \frac{\partial W_i}{\partial R}) - W_i^*(\frac{\partial C_w}{\partial R}) \quad (7)$$

The net welfare change is, therefore, the effect of a change in groundwater levels on the value of the marginal product of water in production, less the per unit cost of a change in water input. The marginal change in pumping costs also affects the total costs of water pumped $(W_i^*(\partial c_w/\partial R).$=0 The effect

[1] Denotes optimally chosen quantities.

of a change in water input due to a change in groundwater levels occurs both directly $(\partial W/\partial R).$=0 and indirectly through the marginal effect of a change in pumping costs on water input $((\partial W_i/\partial c_w)\partial c_w/\partial R)$=0. As long as per unit pumping costs are not prohibitively high, one would expect an increase in groundwater levels (to a point to lead to a welfare benefit, or at least to maintain the initial welfare levels, whereas a decrease in groundwater levels would result in a welfare loss, either due to increased pumping costs and/or change in productivity.

If we now assume that all farmers face the same production and cost relationships (1) and (2) for each crop i and are price takers, then it is possible to derive the aggregate welfare effects of a non-marginal change in groundwater levels. Let there be 1...k farmers producing y_{ik} output of crop i and using w_{ik} water inputs. It follows that by integrating (7) over R_0 (old level) to R_1 (new level) and aggregating across all K farmers yields the welfare the welfare effects of a no marginal change in groundwater levels on the aggregate output of crop i.

$$\Delta S_i = \sum_{k=1}^{k} \frac{\Delta S_{ik}}{dR} = \sum_{k=1}^{k} \int_R 0^R 1 \left[\left(P_i(y_i^*) \frac{\partial y_{ik}}{\partial W_{ik}} - cw_k \right) \right.$$

$$\left. x \left(\frac{\partial W_{ik}}{\partial cW_k} \frac{\partial c\, w_k}{\partial R} + \frac{\partial W_{ik}}{\partial R} \right) - W_{ik}^* \left(\frac{\partial c\, w_k}{\partial R} \right) \right] \quad (8)$$

Here $\frac{\partial y_{ik}}{\partial w_{ik}}=$ 0 = Marginal productivity of water in ith crop for kth farmer.

C_{wk} = Cost of water pumping for kth farmer

$\frac{\partial w_{ik}}{\partial C_{wk}}$=0 = Rate of change of water input w.r.t. C_w for kth farmer for ith crop.

$\frac{\partial w_{ik}}{\partial R}$ =0 = Rate of change of water input w.r.t. water recharge level for relevant i and k (and may be treated as 0)

W^*_{ik} = Optimal water input

$\frac{\partial C_{wk}}{\partial R}$ =0 = Rate of change of cost of water pumping w.r.t. R.

Implementing the above welfare measure in (8) requires knowledge of the production function for each crop, as well as how the equilibrium output and inputs change with R. Alternatively, we could measure the aggregate welfare effects directly from changes in social welfare, S_i, in Eq.(4) above. This would imply:

$$\Delta S_i = (S_R 1) - (S_R 0) = \int_0^y 1 P_i(y_i^*)dy$$
$$- C_x X_j^* - c_w(R_1)W_j^*(R_1)\int_0^y 1 P_i(y_i^*)dy$$
$$- C_x X_j^* + c_w(R)W_j^*(R_0) \text{ for all } i, j \quad (9)$$

where y_0 is the initial output level and y_1 is the final output level. To use (9) as a welfare measure we would also need to estimate production functions for each crop and calculate optimal levels of inputs and outputs. We returns to these welfare measures in Section 6 where, using the information from estimated production functions, we use both measures to calculate welfare change for our sample of wheat and vegetable farmers.

6.1.1 Estimating Production Functions for Wheat & Vegetables in the Floodplains

In the production functions estimated below, we assume that output (y) depends on land (L), labour (B), Seeds (S), fertiliser (F) and water inputs (W). The farmers in the Yamuna floodplains area mainly grow wheat and vegetables (turnip, Radish, Cabbage, Tomato and Onion). Accordingly the crops have been divided into six groups because of the different nature of water requirement, fertiliser application, and other factors. Wheat is grown in the October-April and vegetables are grown throughout the year. Estimation of production relationships for different crops that is wheat and vegetables has been done.

Linear and log-linear functional forms have been considered for wheat and vegetable production. The linear form assumes constant marginal products and excludes any interaction between the inputs. Although the lack of interaction terms is restrictive, we observe in the literature that linear relationships are likely, particularly for wheat production and with low levels of inputs. The log-linear form assumes constant input elasticities and variable marginal products. Note that the coefficients estimated by using this form represent output elasticities of individual variables and the sum of these elasticities indicates the nature of returns to scale. Table 1 lists the variables used in the analysis. The production function has been taken as generalised Cobb-Douglas production function which are written as:

$$Y_i = \alpha\, L_i^{\beta_1} B_i^{\beta_2} F_{1i}^{\beta 3} F_{2i}^{\beta 4} W_i^{\beta_5}$$

$$i = 1......6 \text{ crops} \quad (10)$$

The estimated linear and log-linear production functions for wheat are:

$$Y = \alpha + \beta_1 L + \beta_2 B + \beta_3 F_1 + \beta_4 F_2 + \beta_5 W + \varepsilon_1 \quad (11)$$

and ε_1 is the random disturbance associated with the production function.

The production function for different vegetables have been estimated separately (11) and (12).

Table 6.2: Table of variables

Variable	Definition
Y	Output (Kg)
L	Land (ha)
B	Labour (man-hour)
F_1	Chemical Fertiliser (DAP + urea in kg)
F_2	Dung (kg.)
W	Water (l)
LY	LN (Y)
LL	LN (Land)
LB	LN (Labour)
LF_1	LN (Fertiliser)
LF_2	Dung
LW	LN (Water)

6.1.2 Valuing the Recharge Function

Hydrological evidence for the relationship between flood extent and recharge to village wells show that there is some fluctuation with flood extent and mean water depth of the shallow aquifer. The effect of planned channelization/embankment will have an impact on producer welfare within the wetlands through changes in flood extent therefore groundwater recharge.

Our team of hydrologists have found an increment in the mean depth of water table in the floodplain area from 3m to 2.28m, on average after flooding every year. The expected change in welfare associated with this reduction in recharge is sought to be calculated. This exogenous change affects the farmers decision making process during the farming season, i.e. after decisions on other inputs have already been taken since the effect of the reduced recharge will not be felt until after the dry season agriculture has started.

The welfare change measure for non-marginal changes in R (level of naturally recharged groundwater) is given by (8). This welfare change measure is used together with the results of the production function estimates to calculate welfare changes for individual farmers. We also assume that farmers in the Yamuna floodplain area are price takers and hence face a `horizontal' demand function, i.e. $P_i(y_i) = P_i$.

From Eq. (8) we see that the effect of R on welfare is felt through a change in water input due to increased costs $((\partial W \, \partial c_w))$=0 and/or a change in water availability $(\partial W_i/\partial R)$=0. This second effect will occur only if a change in recharge were to cause a decline in groundwater levels below 6m. This is unlikely to happen within a single season and we do not therefore consider this aspect in calculating welfare change. Instead we consider the effect of changing pumping costs on water input and use the production function estimated earlier for the purpose of estimating welfare changes. However, in order to do so, we need to calculate $(\partial W_i/\partial c_w)$=0, the marginal change in water demand due to a marginal change in the cost of pumping. Holding all other inputs constant and noting that only water input will vary, we use the log linear production functions together with the optimality conditions in Eqs.(5) and (6) to solve for W_i as:

$$W_i^* = \left(\frac{C_w}{P_i \alpha \beta_5 L^{\beta 1} B^{\beta_2} F_1^{\beta_3} F_2^{\beta_4}} \right)^{1/(\beta_5 - 1)} \quad (14)$$

where L,B, S and F_1 and F_2 are all the other inputs in the specified production function (for crop i) with estimated parameters β_L, β_B, β_s and β_F.[2] We solve for $(\partial W_i / \partial c_w)$=0 as:

$$\frac{\partial W_i}{\partial c_w} = \frac{1}{\beta_5 - 1} \left(\frac{C_w}{P_i \alpha \beta_5 L^{\beta_1} B^{\beta_2} F_1^{\beta 3} F_2^{\beta 4}} \right)^{(2-\beta_5)/(\beta_5}$$

$$x \left(\frac{1}{P_i \alpha \beta_5 L^{\beta_1} B^{\beta_2} F_1^{\beta_3} F_2^{\beta_4}} \right) \quad (15)$$

This is calculated for each farmer, using the estimated values for the relevant parameters and constant terms and the market price of the crop.

We now calculate welfare change due to a drop in groundwater levels to 3m, for individual farmers, using the welfare measures in Eq. (8) or Eq.(9). However we have used the expression (9) to derive the value of change in the welfare. For this, first of all production for all the crops have been estimated. Generalised Cobb-Douglas model has been adopted for estimation purpose. The log-linear estimate has been preferred to the linear one because of its better results.

[2]For the vegetable production function, the variable S (seeds/seedlings) is not included and is therefore not included in the estimation of W_i either.

Table 6.3: Results for the Wheat production function
Dependent Variable: Wheat output

Explanatory Variables	Log Linear	
	Coefficient	**t-statistics**
Ln (DUD)	0.68	8.40
Ln (W)	-1.10	-4.89
Ln (MH)	-3.96	-4.96
Constant	40.77	5.78
R^2	0.837	-
Adjusted R^2	0.805	-
Durbin-Watson	2.089	-
Stat.	25.79	-
F-Statistic	19	-
Observations		

Notes: DUD- organic and inorganic (DAP, Urea and Dung), W-Water, MH-man hour

Table 6.4: Results for the Cabbage production function
Dependent Variable: Cabbage output

Explanatory Variables	Log Linear	
	Coefficient	**t-statistics**
Ln (DUD)	-0.66	-2.31
Ln (W)	0.10	0.36
Ln (MH)	0.78	1.43
Constant	8.82	1.67
R^2	0.285	-
Adjusted R^2	0.172	-
Durbin-Watson	1.329	-
Stat.	2.521	-
F-Statistic	23	-
Observations		

Notes: DUD- organic and inorganic (DAP, Urea and Dung), W-Water, MH-man hour

Table 6.5: Results for the Onion production function
Dependent Variable: Onion output

Explanatory Variables	Log Linear	
	Coefficient	t-statistics
Ln (DU)	0.39	1.59
Ln (D)	0.56	2.39
Ln (W)	0.36	2.38
Ln (MH)	0.12	0.47
Constant	2.01	0.76
R^2	0.707	-
Adjusted R^2	0.617	-
Durbin-Watson	1.428	-
Stat.	7.848	-
F-Statistic	18	-
Observations		

Notes: DUD- organic and inorganic (DAP, Urea and Dung), W-Water, MH-man hour

Table 6.6: Results for the Radish production function
Dependent Variable: Radish output

Explanatory Variables	Log Linear	
	Coefficient	t-statistics
Ln (DUD)	0.696	6.100
Ln (W)	0.252	0.893
Ln (MH)	0.627	1.608
Constant	-1.894	-0.521
R^2	0.628	-
Adjusted R^2	0.582	-
Durbin-Watson	1.693	-
Stat.	13.559	-
F-Statistic	28	-
Observations		

Notes: DUD- organic and inorganic (DAP, Urea and Dung), W-Water, MH-man hour

Table 6.7: Results for the Tomato production function
Dependent Variable: Tomato output

Explanatory Variables	Log Linear	
	Coefficient	t-statistics
Ln (DUD)	0.734	5.636
Ln (W)	0.421	1.607
Constant	4.455	3.357
R^2	0.638	-
Adjusted R^2	0.598	-
Durbin-Watson	1.500	-
Stat.	15.904	-
F-Statistic	21	-
Observations		

Notes: DUD- organic and inorganic (DAP, Urea and Dung), W-Water, MH-man hour

Table 6.8: Results for the Turnip production function

Dependent Variable: Turnip output

Explanatory Variables	Log Linear	
	Coefficient	t-statistics
Ln (DUD)	0.627	5.665
Ln (W)	0.133	0.418
Ln (MH)	0.484	1.416
Constant	0.052	0.015
R^2	0.673	-
Adjusted R^2	0.611	-
Durbin-Watson	1.432	-
Stat.	10.981	-
F-Statistic	20	-
Observations		

Notes: DUD- organic and inorganic (DAP, Urea and Dung), W-Water, MH-man hour

Table 6.9: Welfare Change

S. No.	Crop	Welfare Change for All Farmers (Rs. / Ha)	Welfare Change per farmer (Rs. / Ha)	Land under cultivation for each crop (Ha)	Total Welfare Change (Rs.)
1.	Wheat	133092.8	7828.98	88.90	695996.94
2.	Cabbage	73001.16	3318.23	186.44	618651.73
3.	Onion	-45025.1	-2401.40	161.00	-386625.40
4.	Radish	-20105.3	-718.04	256.32	-184049.29
5.	Tomato	-29012.4	-1450.62	194.40	-282000.52
6.	Turnip	7497.202	394.58	187.46	73969.76
	Total				**535943.22**

From the table it is clear that welfare change which is in fact the revenue earned on account of recharged water or cost saved due to the recharging facilities provided by the floodplain wetland are coming as – ve in case of tomato, radish and onion, this means that for these crops water are not optimally used. For other crops the values of the welfare changed are +ve. Overall the level of welfare change is + ve of the order of more than Rs.5 lakh for the cultivated area of approximately 772 ha in the floodplains. It should be noted here that this value is of the recharge function alone.

6.2 Estimating the recharging through Alternate Cost of Water Supply

The recharged water not only provides the quantity but this water is nearly potable on several criteria applied (Table 6.10).

Table 6.10: Yamuna in Delhi Corridor

	Water at Palla	Water at Nizammudin	Water in the aquifer of Yamuna floodplains
Total coliforms (No./100 ml)	5766.16	154764.5	13.2
Faecal coliforms (No./100 ml)	1904.69	148454.5	0.0

Note: Water quality at Palla represents the raw water quality for Delhi's water supply. The water quality at Nizamuddin reflects the impact of wastewater discharge from Delhi and the water quality within the Delhi stretch. One of the most critical parameters which is taken into account while deciding the potability of drinking water is the Faecal coliform count because these organisms have the potential to cause various gastro intestinal diseases.

Alternatively, the same quantity of water can be exploited to supply the water in Delhi. Thus otherwise significant cost of raw water from Western Yamuna Canal and Upper Ganga Canal, the transportation cost can easily be avoided, on the basis of total coliforms and faecal coliforms, the recharged water is nearly potable. So the treatment cost has also been accounted along with other costs, which this Floodplain saves. Table 6.11

and 6.12 summaries the detail. This approach is called as alternate cost approach widely used in environmental economics related practical issues.

Table 6.11: Cost of Water Supply from different sources in Delhi

Source	Raw water Cost (Rs./Kilo Litre)	Transportation Cost (Rs./Kilo Litre)	Treatment cost (Rs./Kilo Litre)	Total cost (Rs./Kilo Litre)
Western Yamuna canal	0.0487	0.0331	2.5	2.5818
Upper Ganga Canal	0.0714	0.0331	2.5	2.6045

(Source: Delhi Jal Board, 2000)

Table 6.12: Alternate cost of water supply in Delhi

	Total Cost (Rs./Kilo Litre)*	Water recharge into the ground water reserve (KL/Annum)	Value of water supply exclusive of distribution cost (Rs./Annum)
Scenario 1			
1) Western Yamuna Canal	2.5818	2.34*10^7	**6.0414*10^7**
2) Upper Ganga Canal	2.6045	2.34*10^7	**6.0945*10^7**
Scenario 2			
1) Western Yamuna Canal	2.5818	1.98*10^7	**5.112*10^7**
2) Upper Ganga Canal	2.6045	1.98*10^7	**5.157*10^7**

Notes:
Scenario 1: Study area inundated completely.
Scenario 2: Partial inundation of the area due to proposed channelization of the river.
(*Source: Delhi Jal Board, 2000)

6.3 Estimation of livestock benefits of the floodplains

A large number of livestock especially goats, buffaloes and cows exclusively depend and get their fodder from the floodplains areas for seven months in the year when the flooding water recedes. These benefits have been estimated through the cost of procurement of the same amounts of fodder otherwise provided by this floodplain. Total quantity of fodder needed has been estimated and then its market value has been calculated. This method is popularly known as indirect substitute cost method. The fodder value of benefits has been estimated through the opportunity cost of time needed in collection of same amount of fodder.

As expected the labour abundant region has lower wage rate and hence estimation of this fodder benefit is lower than the market value of fodder. Table 7.13a and 7.13b describe the details.

Table 6.13a: Estimate of Fodder contribution of the floodplain through the Indirect Substitution Method

S. No.	**Variety of Livestock**	**Number***	**Daily Intake of Fodder [1] (Kg.)**	**Quantity (Q.) of Fodder Required[2]**		**Amount (Rs.) [3] (at the market price of the fodder)**	
				Daily	**Annual**	**Daily**	**Annual (7months)** (In Rs.lakh)
1	Buffaloes	9250	25	2312.50	4856.25	138750	291.37500
2	Cows	1545	12.5	193.13	4055.73	11587.8	24.33438
3	Goats	2555	8.3	212.07	4453.47	12724.2	26.72082
	Total	13350	45.8	2717.7	13365.45	163062	**342.43020**

Notes:
1 Daily Intake (1 Buffalo = 2 Cows = 3 Goats)
2 Quantity (Q.) - No. of livestock multiplied by per capita daily intake of fodder (Grass)
3 Amount (Rs.) – Quantity multiplied by price of grass (Rs60./Q) for an annum (7 months) has been taken because the area is available for grass only for 7 months.
(Source: * Delhi Peasant Multipurpose Cooperative Society, Delhi, 2001)

Table 6.13b: Opportunity Cost of the People in the Area in Collection of the same Fodder

Average time required to collect fodder from floodplain/ similar places	15 Kg./Hour
Opportunity cost of time of the labour at floodplain	Rs.50/Day
Total fodder supplied by the floodplain to the exclusively dependent livestock (Q. /annum) (7 months)	13365.45
Opportunity cost saved in the floodplain (hours)	89103[a]
Opportunity cost saved in the floodplain (Days)	11137.875[b]
Opportunity cost saved in the floodplain (Rs.)	**556893.75[c]**

Notes:
[a] Total fodder supplied by the floodplain to the exclusively dependent livestock is divided by the average time taken to collect fodder (15 Kg./Hour)
[b] Opportunity cost saved in the floodplain (Days) is calculated by dividing 89103 by labour hours per day
(8 hours/day)
[c] Opportunity cost saved in the floodplain (Rs.) is calculated by multiplying (11137.875) with wage rate (Rs.50/day)

Table 6.14a: Nitrogen (N) retained by the Floodplain area

S. No.		**Minimum availability of Nitrogen (N) (Kg./Ha.)**	**Maximum availability of Nitrogen (N) (Kg./Ha.)**	**Mean availability of Nitrogen (N) (Kg./Ha.)**	**Total Area receiving the post-monsoon sediments (Ha.)**	**Total Nitrogen (N) inflowing (Kg.)**
1.	Pre-monsoon Season	3.37	5.62	4.5	772.94	873.42
2.	Post-monsoon Season	4.50	7.87	6.19		1739.115
3.	Difference of Post & Pre monsoon	1.13	2.25	1.69		1306.27

Table 6.14b: Phosphorus (P) retained by the Floodplain area

S. No.		Minimum availability of Phosphorus (P) (Kg./Ha.)	Maximum availability of Phosphorus (P) (Kg./Ha.)	Mean availability of Phosphorus (P) (Kg./Ha.)	Total Area receiving the post-monsoon sediments (Ha.)	Total Phosphorus (P) inflowing (Kg.)
1.	Pre-monsoon Season	20.9	29.97	25.44		7010.56
2.	Post-monsoon Season	29.97	44.95	37.46	772.94	11578.64
3.	Difference of Post & Pre monsoon	9.07	14.98	12.02		9290.74

Table 6.14c: Potassium (K) retained by the Floodplain area

S. No.		Minimum availability of Phosphorus (P) (Kg./Ha.)	Maximum availability of Phosphorus (P) (Kg./Ha.)	Mean availability of Phosphorus (P) (Kg./Ha.)	Total Area receiving the post-monsoon sediments (Ha.)	Total Phosphorus (P) inflowing (Kg.)
1.	Pre-monsoon Season	272.2	281.2	276.7		6956.46
2.	Post-monsoon Season	281.2	308.2	294.7	772.94	20869.38
3.	Difference of Post & Pre monsoon	9.0	27.0	18.0		13912.92

6.4 Nutrient Benefits

As mentioned earlier flooding brings nutrient rich sediments every year and this benefits the agriculture. We have estimated the major three nutrients in terms of N, P and K coming into the agricultural fields in the floodplain areas. The cost in order to replace the same amount of N, P and K with the help of chemical fertilizers have been estimated. This approach, known as replacement cost method, measures the comprehensive value and provides the estimates of benefits accruing from floodplain on account of nutrient retention process.

Table 6.15: Calculation of Nutrient Benefits

Season	Nutrients	Quantity Brought (Kg.) [2]	[1]Price (Rs./Kg.)	Total Brought (Rs.)
	Nitrogen			
Difference of post and pre monsoon	N (Min.)	873.42	10	8734.20
	N (Max.)	1739.115	10	17391.15
	N (Mean)	1306.27	10	13062.7
Difference of post and pre monsoon	Phosphorus			
	P (Min.)	7010.56	15.43	108172.94
	P (Max.)	11578.64	15.43	178658.43
	P (Mean)	9290.74	15.43	143356.12
Difference of post and pre monsoon	Potassium			
	K (Min.)	6956.46	7.09	49321.30
	K (Max.)	20869.38	7.09	147963.90
	K (Mean)	13912.92	7.09	98642.60

(Source: [1] Fertiliser Association of India, Statistics 2000.)
[2] Estimated by the ecologists on the basis of large no. of samples from the floodplain area.
N based on Urea
P based on DAP
K based on MOP

6.5 Fisheries Production

For valuing the fisheries, the market price approach has been applied. Under market price approach to valuation the information on price and the quantities traded are used to arrive at the net benefit estimation from the wetland use. In a perfectly competitive market (and in the absence of distortions), the prices are the best indicators of value. The quantity exchanged at a perfectly competitive price represents an equilibrium for a utility maximizing user of the product. Hence, these two variables can be used to determine the net monetary benefit from the products derived from the wetland.

This methodology can be used to measure only those values of wetland uses or products for which reliable market prices are available. This methodology cannot be used to value the functions or attributes of the wetland for which there are no market price. The distortions in the prices, if any, should be known so as to incorporate them in the calculation. If we deduct the cost of supply of the wetland, the net monetary benefit accruing from that product can be calculated.

However, the measure of the net monetary benefit that accrues to this transaction as calculated above is a measure of consumer's expenditure only. Thus, what is represented in this monetary benefit is the benefit of the producer and not of the consumer. The consumer may have realized a benefit by accruing the product at a cheaper cost than anticipated, but this is not captured in the methodology. Hence, this method can, at best, provide only the lower value of the net social benefit.

The steps followed in the determination of net monetary benefit are as follows:

1. i)Determination of the quantity of product (from the wetland), which is traded.
2. ii)Determination of the market price of the product.
3. iii)Using the two results to determine the total revenue generated in the transaction
4. iv)Determination of the costs involved in the manufacture of a unit of the product
5. v)Using the above results, to determine the total costs involved in the production process

Fishes

Net monetary benefit from fishing can be estimated in two ways

1. By the use of Catch Data from commercial fishing
2. By the use of yield data

The net monetary benefit from commercial fishing (F) by the use of catch data can be defined as:

$$F= \Sigma_i V_i - [f*d*w+X]$$

V_i = Monetary value of the fish catch of ith species (Annual Value)

f = Total number of fishermen engaged in an annum in the fishing activity

d = Total number of days in an annum that the fishermen are engaged

w = daily wage rate

X = Annual costs involved in the fishing activity

The above-mentioned result has been divided as follows:

Let set S describe the species that are caught from the wetland

$S = \{S_i\}$ where i = 1.....n n is the number of species

C_i = Annual Catch of species i

P_i = Total monetary value of annual fish catch

$$= \Sigma_i V_i = \Sigma_i C_i P_i$$

f = Total number of fishermen engaged in fishing activity

d = number of days in an annum for which engaged

w = daily wage rate

f* d* w = Total labour cost involved, annual

X = Other costs involved (storage and equipment), annual

F = Net monetary benefit from the product

$$= \Sigma_i V_i - [f*d*w + x]$$

Alternatively, the monetary value of the yield per hectare of a species (M_i) can be calculated as follows:

$M_i = P_i * Y * N_i$

If A is the total area of the wetland, then the total monetary benefit (F) can be calculated as:

$F = M_i * A$

This is derived as follows:

Let, Y = Total yield of fishes/hectare

and $N_i = C_i / \Sigma_i C_i$ = proportion of species i in the annual catch

$Y^* N_i$ = yield/ha of i*th* species

$M_i = P_i^* Y^* N_i$ = monetary value of yield per hectare of the ith species

Assumptions

- The market for fishes is competitive, there are a large number of buyers and sellers and there are no externalities in the market.
- The prices are not distorted by subsidies.

Table 6.16: Fisheries Production

Year	(Quantity) (000'Kg.)	Amount* (Rs.)
1996-97	1215.30	36459000
1997-98	1257.30	37719000
1998-99	1337.70	40131000
1999-2000	1257.60	37728000
2000-2001	1200	**36000000**

(Source: Warden, Fisheries department, Govt. of NCT of Delhi)
*Amount-Average Price of fish is Rs.30/Kg.

6.6 Miscellaneous benefits

Significant amount of cucurbits grow in the floodplains every year. Besides, various plant species also grow which are used by the local people for various uses. Table 6.17 and 6.18 provide the details.

Table 6.17: Cucurbits Production

S. No.	Area under cultivation (Ha)	64.77
1	Varieties	Watermelon, Kakri, Cucumber, Sweet melon
2	Total production (Q)	6399.28
3	Total production (Rs.)	***1919784**
4	No. of dependent families	150
5	Total population dependent	850
6	Season	November - June

(Source: Delhi Peasant Multipurpose Cooperative Society, Delhi, 2001)
*Total Production (Rs.)= Average price of Cucurbits (Rs.300/Q) multiplied by Quantity

Table 6.18: Utilizable plant species

Types of Species	**Quantity**
Total area covered by S.munja vegetation (ha)	2.18
Number of grass culms in one clump	55
Number of grass culms in one bundle of S.munja	110
Price (Rs per Bundle)	20-25
Number of grass clumps present in 100m^2 plot	67
Time period for which S.munja is harvested (months)	4 (November to March)
Yield of the given area (in bundles)	7303
Value (Rs.)	**146060-182575**

T.aungustata

Total area covered by T.aungustata vegetation (Ha)	140
One bundle of Typha (leaves)	100
Price (Rs per Bundle)	12-15
Yield of the given area (in bundles)	28000
Value (Rs.)	**336000-420000**
Total	**482060-602575**

6.7 Valuing Habitat for Biodiversity and Recreational Benefits through Contingent Valuation Method (CVM)

The Yamuna floodplains in Delhi region play different functions and benefits besides the ecological functions and recreational activities. The nature of these functions is such that the markets do not capture them and for that some other special techniques are needed. To study the recreational activities and wildlife functions of the floodplains the contingent valuation method (CVM) is used. The method evaluates environmental goods and services for which market is absent. The CVM is a technique in which respondents are directly questioned to elicit their WTP (Willingness to Pay) or WTA (Willingness to Accept) for an environmental change. The questions are asked directly with the help of a designed questionnaire. In this study the WTP for wild lives (biodiversity) and recreational benefits has been elicited from the local people surrounding this area.

Sampling Technique Used

The principle of Statistical Regularity has been used, in which a large number of items were chosen at random from the population. Simple random sampling has been used to include each and every item of the population with an equal chance to avoid personal bias.

Sample Characteristics

A sample of 501 was taken for the study. The population represents the people residing near the Yamuna River. The sample reflects diverse age, income, education and household-size groups.

Methodology

The technique of questionnaire-based survey was considered best for the study, as it requires fewer amounts of time and resources. Personal interviews at respondents' residence as well as on the site interviews were carried out in order to get the maximum real responses.

The questionnaire was designed to elicit the true WTP of the respondents in the following manner:

1. Interviewer introduced himself and explained the reasons of survey with the help of scenario design, which included the description of the study area and their functions and benefits. The respondents were shown some photographs of the floodplains to make them more acquaint with the actual features of floodplains. In order to get their true WTP values, the respondents were exposed to the possible threats to the very existence of floodplain ecosystems as a result of construction activities and continual negligence by the concerned authorities.
2. The respondents were asked about their visits to the floodplains for different recreational activities like boating, picnicking, sightseeing etc. that is very crucial for planners and futuristic policy formulators.
3. The socio-economic aspects of the respondents were asked to know what different stakeholders of society think about the preservation of such floodplains.
4. The Payment Card elicitation format was used in which some hypothetical values (yearly) were placed before the respondents and they were free to assign the maximum value for the floodplains.
5. The Payment Vehicle comprised of use permits to participate in recreational activities at floodplains and voluntary donations to preserve the wildlife habitat and recreational activities for future generation.
6. At the end of the interview each respondent was asked to suggest ways and manners to manage the floodplain areas.

Duration of survey and average time spent

The survey work was started in the last week of June 2000 and completed in the third week of September 2000. The average time spent in interviewing a respondent was 20 minutes. Two teams of surveyors were assigned this task to interview people in different locations.

Problems faced during survey

The survey teams faced the following problems:

1. Most of the respondents were unaware of the functions of the wetlands and it took a great deal of time and efforts to make them understand the concepts.
2. Respondents were reluctant to reveal their true income.
3. A few respondents objected the questions on personal details e.g. name, address and phone numbers etc.

Personal problems:

1. Most of the respondents were very cautious due to the security reasons and answered the questions from inside their houses and so the interviewers were forced to write down the entries standing on their feet.
2. Some of the respondents were reluctant to entertain the teams and considered them to be sales executives.

6.8 Recreation and Wildlife Habitats in Yamuna Floodplain

Recreational values of wetland are often the most readily recognised wetland values (Coreil 1993). Recreational uses may include sightseeing, hiking, fishing, hunting, swimming, canoeing, photography, wildlife observation and picnicking (Bardecki 1984). The contingent valuation method (CVM), a survey method, was used to assess people's preferences for non-market, wetland resources (Mitchell and Carson 1989). Net benefits were estimated by asking people directly how much they value non-market goods. CVM, a stated preference method, is an alternative to other indirect valuation methods, which estimate the value of resources by using market data (i.e., revealed preference method) (Scodari 1990).

With the help of a CVM questionnaire a survey was conducted in the households within an 8-Kilometer radius of floodplain area, included questions regarding both habitat and recreational values. Sample size was chosen to obtain a usable response of at least 493 households.

There were three broad components of the survey instrument used, with the following objectives:

1. Familiarization of the respondents with the location of floodplain area and recreational sites,
2. Eliciting willingness-to-pay for water related recreation and fish/wildlife habitat.
3. Eliciting behavioural trends of recreational usage, and
4. Identification of personal characteristics of the respondents.

6.9 Salient features of Respondents Under the CVM Survey

Table 6.19: Gender Classification of the Sample

S. No.	Class	Percentage
1.	Male	76.87
2.	Female	23.12

Table 6.20: Age Profile of the Sample

S. No.	Class (in years)	Percentage
1.	15-29	48.07
2.	30-49	35.50
3.	50-69	14.80
4.	70-89	1.62

Table 6.21: Distribution of Household sizes of the Sample

S. No.	No. of Members in the household	% to the total Sample
1.	1-5	73.83
2.	6-10	26.16

Table 6.22: Literacy Profile of the Sample Population

S. No.	Category	% to total
1.	Illiterate	0.60
2.	Middle	0.60
3.	Secondary	2.84
4.	Sr. Secondary	4.26
5.	Diploma	0.40
6.	Graduation	91.27

Table 6.23: Income Profile of the Sample Population

S. No.	Annual Income Range (in Rs. Thousand)	% to total sample
1.	20-60	24.74
2.	61-100	25.15
3.	101-140	21.29
4.	141-180	28.60

Table 6.24: Professional Profile of the Sample

S. No.	Category	% to total sample
1.	Teachers	14.40
2.	Doctors	2.43
3.	Engineers	3.65
4.	Administration	9.53
5.	Media	2.03
6.	Clerical	7.30
7.	Business	11.97
8.	Student	26.57
9.	Housewife	8.92
10.	Others	13.18

Table 6.25: Principal Activities Associated with Yamuna Floodplains

S. No.	Activity	% to total
1.	SW	3.45
2.	SP	3.25
3.	PW	6.29
4.	W	8.52
5.	P	11.76
6.	B	10.14
7.	SS	0.61
8.	Others	56.59

Abbreviations:
SW sightseeing & walking
SP - sightseeing & picnicking
PW picnicking & walking
W - walking
P - picnicking
B - bicycling
SS - sightseeing

Table 6.26: Frequency Distribution of Willingness to Pay for Use Value of Biodiversity (WTP1)

S. No.	WTP Range (in Rs. / Annum)	Percentage to sample population
1.	0	10.34
2.	1-50	8.52
3.	51-100	23.94
4.	101-150	10.55
5.	151-200	7.91
6.	201-250	6.90
7.	251-300	5.27
8.	300 & above	26.57

Table 6.27: Frequency Distribution of Willingness to Pay for Bequest Value of Biodiversity (WTP2)

S. No.	WTP Range (in Rs. / Annum)	Percentage to sample population
1.	0	12.17
2.	1-50	13.79
3.	51-100	15.82
4.	101-150	12.17
5.	151-200	6.69
6.	201-250	6.49
7.	251-300	3.65
8.	300 & above	29.21

Table 6.28: Frequency Distribution of Willingness to Pay for Existence Value of Biodiversity (WTP3)

S. No.	WTP Range (in Rs. / Annum)	Percentage to sample population
1.	0	21.91
2.	1-50	19.47
3.	51-100	16.84
4.	101-150	7.51
5.	151-200	5.27
6.	201-250	3.65
7.	251-300	2.23
8.	300 & above	23.12

45**%** of respondents had, and 55**%** had not, visited the floodplain area for recreation within past 12 months. The dominant activities in which respondents participated at floodplain area included fishing, sightseeing, pleasure driving and wildlife observation.

Survey participants were asked, “If floodplain area was managed primarily for water-related recreation and fish/wildlife habitat, what would you be willing to pay through an annual use permit to participate in recreational activities at different floodplain like Okhla, stretch of Noida Morh etc.?” In response to this “use value” question, 10.34% respondents stated Rs.0 (nothing), 8.52% stated Rs.1-50 annually, 23.94% saying from Rs.51-100 annually, 10.55% stating Rs.101-150 annually, 7.91% saying Rs.151-200 annually, 6.90% were saying Rs.201-250 annually, 5.27% stated Rs.251-300 annually and 26.57% willing to pay Rs.300 or more.

Following are the reasons as given by the respondents for choosing Rs.0:

- I am not familiar with the Floodplain (7.84%),
- Floodplain does not have any value to me (11.76%),
- I do not care about Floodplain (5.88%),
- Floodplain is too far from my home (5.88%),
- Floodplain does not have the recreational facilities I need (0%),
- There are other recreational sites that I prefer to visit (0%),
- Other reasons (56.86%).

Out of 51 respondents who sited other reasons for choosing Rs.0, 58.62% said that govt. should provide these recreational facilities free of cost. Negative values were not provided as choices on the questionnaire, although some respondents might have chosen a negative Rupee amount for use, option, or existence value(s).

The next question on revealing the true WTP for bequest/option value was asked. “What is the maximum amount you would be willing to pay through an annual voluntary donation to ensure that recreational activities and fish/wildlife habitat at floodplains are available in the future to you or your descendants?” In response to this “bequest/option value” question, 12.17% respondents stated Rs.0 (nothing), 13.79% stated Rs.1-50 annually, 15.82% saying from Rs.51-100 annually, 12.17% stating Rs.101-150 annually, 6.69% saying Rs.151-200 annually, 6.49% were saying Rs.201-250 annually, 3.65% stated Rs.251-300 annually and 29.21% willing to pay Rs.300 or more.

The next question on revealing the true WTP for existence value was asked. “What is the maximum amount you would be willing to pay through an annual voluntary donation to ensure that recreational activities and fish/wildlife habitat at floodplains are available for other people, even if you do not intend to visit the floodplain area?” In response to this “existence value” question, 21.91% respondents stated Rs.0 (nothing), 19.47% stated Rs.1-50 annually, 16.84% saying from Rs.51-100 annually, 7.51% stating Rs.101-150 annually, 5.21% saying Rs.151-200 annually, 3.65% were saying Rs.201-250 annually, 2.23% stated Rs.251-300 annually and 23.12% willing to pay Rs.300 or more.

6.10 Estimation of Mean Willingness To Pay (WTP)

WTP1: Use Value

Table 6.29: Descriptive Statistics

	Mean	Std. Deviation	
WTP1	172.3844	110.6969	
AGE	33.1460	13.7109	
EDU	16.4088	1.8289	
HHSIZE	4.8832	1.8976	
INCOME	104.9878	44.1747	
SEX	1.7567	.4296	

Table 6.30: Pearson Correlations among Variables

Variables	WTP1	AGE	EDU	HHSIZE	INCOME	SEX
WTP1	1.000	-.037	.056	-.126	.130	.096
AGE	-.037	1.000	-.007	-.088	.049	.047
EDU	.056	-.007	1.000	-.082	.220	.031
HHSIZE	-.126	-.088	-.082	1.000	-.080	.130
INCOME	.130	.049	.220	-.080	1.000	-.021
SEX	.096	.047	.031	.130	-.021	1.000

6.11 Model: Linear

Model Specification

WTP = a + b (INCOME) +c (AGE) + d (HHSIZE) + e (EDU)+ f(SEX)

Where, a, b, c, d, e, f are constants

SEX is a dummy variable , with value =0 for female & 1 for male

Table 6.31: Model Summary										
					Change Statistics					
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**R Square Change**	**F Change**	**df1**	**df2**	**Sig. F Change**	**Durbin-Watson**
1	.217(a)	.047	.035	108.7245	.047	4.002	5	405	.001	1.675
a Predictors: (Constant), SEX, INCOME, AGE, HHSIZE, EDU										
b Dependent Variable: WTP1										

Table 6.32: ANOVA (b)						
Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	**Regression**	236548.431	5	47309.686	4.002	.001(a)
	Residual	4787514.829	405	11821.024		
	Total	5024063.260	410			
a Predictors: (Constant), SEX, INCOME, AGE, HHSIZE, EDU						
b Dependent Variable: WTP1						

Table 6.33: Frequency Distribution:				
WTP1	**Frequency**	**Percent**		**Cumulative Percent**
25.00	39	9.5		9.5
75.00	118	28.7		38.2
125.00	52	12.7		50.9
175.00	39	9.5		60.3
225.00	34	8.3		68.6
275.00	26	6.3		74.9
300.00	92	22.4		97.3
350.00	1	.2		97.6
450.00	1	.2		97.8
500.00	9	2.2		100.0
Total	411	100.0		

WTP2: Bequest Value

Table 6.34: Descriptive Statistics		
	Mean	**Std. Deviation**
WTP2	167.6813	112.4399
AGE	32.8679	13.2718
EDU	16.3912	1.8642
HHSIZE	4.9404	1.9135
INCOME	105.0130	43.8230
SEX	1.7513	.4328

Table 6.35: Pearson Correlation among Variables

	WTP2	AGE	EDU	HHSIZE	INCOME	SEX
WTP2	1.000	.020	.031	-.103	.053	.052
AGE	.020	1.000	-.014	-.087	.055	.043
EDU	.031	-.014	1.000	-.082	.211	.034
HHSIZE	-.103	-.087	-.082	1.000	-.105	.126
INCOME	.053	.055	.211	-.105	1.000	-.018
SEX	.052	.043	.034	.126	-.018	1.000

Table 6.36: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.129(a)	.017	.004	112.2246	.017	1.296	5	380	.265	1.533

a Predictors: (Constant), SEX, INCOME, AGE, HHSIZE, EDU

b Dependent Variable: WTP2

Table 6.37: ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	**Regression**	81594.969	5	16318.994	1.296	.265(a)
	Residual	4785854.837	380	12594.355		
	Total	4867449.806	385			

a Predictors: (Constant), SEX, INCOME, AGE, HHSIZE, EDU

b Dependent Variable: WTP2

Table 6.38: Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
WTP2	386	25.00	500.00	167.6813	112.4399
AGE	386	15.00	79.00	32.8679	13.2718
EDU	386	2.00	17.00	16.3912	1.8642
HHSIZE	386	1.00	10.00	4.9404	1.9135
INCOME	386	15.00	350.00	105.0130	43.8230
SEX	386	1.00	2.00	1.7513	.4328

Table 6.39: Frequency Distribution of WTP2

		Frequency	Percent		Cumulative Percent
	25.00	64	16.6		16.6
	75.00	78	20.2		36.8
	125.00	60	15.5		52.3
	175.00	33	8.5		60.9
	225.00	32	8.3		69.2
	275.00	18	4.7		73.8
	300.00	92	23.8		97.7
	350.00	1	.3		97.9
	400.00	1	.3		98.2
	500.00	7	1.8		100.0
	Total	386	100.0		

WTP3: Existence Value

Table 6.40: Descriptive Statistics

	Mean	Std. Deviation
WTP3	147.8632	119.5485
AGE	32.6040	13.9722
EDU	16.4302	1.7501
HHSIZE	4.9060	1.9123
INCOME	104.0883	45.7933
SEX	1.7578	.4290

Table 6.41: Pearson Correlations among Variables

	WTP3	AGE	EDU	HHSIZE	INCOME	SEX
WTP3	1.000	-.010	.039	-.112	.082	.007
AGE	-.010	1.000	.015	-.041	.043	.042
EDU	.039	.015	1.000	-.065	.198	.055
HHSIZE	-.112	-.041	-.065	1.000	-.103	.118
INCOME	.082	.043	.198	-.103	1.000	-.028
SEX	.007	.042	.055	.118	-.028	1.000

Table 6.42: Model Summary										
					Change Statistics					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1	.137(a)	.019	.004	119.2811	.019	1.314	5	345	.257	1.564
a Predictors: (Constant), SEX, INCOME, AGE, HHSIZE, EDU										
b Dependent Variable: WTP3										

Table 6.43: ANOVA						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	**Regression**	93492.414	5	18698.483	1.314	.257(a)
	Residual	4908655.021	345	14227.986		
	Total	5002147.436	350			
a Predictors: (Constant), SEX, INCOME, AGE, HHSIZE, EDU						
b Dependent Variable: WTP3						

Table 6.44: Frequency Distribution of WTP3					
		Frequency	Percent		Cumulative Percent
	25.00	92	26.2		26.2
	75.00	82	23.4		49.6

	125.00	37	10.5		60.1
	175.00	26	7.4		67.5
	200.00	1	.3		67.8
	225.00	18	5.1		72.9
	275.00	11	3.1		76.1
	300.00	75	21.4		97.4
	500.00	9	2.6		100.0
	Total	351	100.0		

6.12 Model: Log-Linear

Model Specification:

Ln WTP = a + b (ln INCOME) +c (ln AGE) + d (ln HHSIZE) + e (lnEDU) + f (SEX)

Where, a, b, c, d, e, f are constants

Table 6.45: Descriptive Statistics

	Mean	Std. Deviation
LNWTP1	4.8954	.7822
LNAGE	3.4187	.3966
LNEDU	2.7847	.2029
LNHHSIZE	1.5050	.4291

LNINCOME	4.5249	.5878	
SEX	1.7561	.4300	

Table 6.46: Pearson Correlations among Variables

		LNWTP1	**LNAGE**	**LNEDU**	**LNHHSIZE**	**LNINCOME**	
	LNWTP1	1.000	-.022	.084	-.112	.090	
	LNAGE	-.022	1.000	-.039	-.059	.058	
	LNEDU	.084	-.039	1.000	-.071	.194	
	LNHHSIZE	-.112	-.059	-.071	1.000	-.061	
	LNINCOME	.090	.058	.194	-.061	1.000	

Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**Change Statistics**				
					R Square Change	**F Change**	**df1**	**df2**	**Sig. F Change**
1	.201(a)	.040	.029	.7709	.040	3.402	5	404	.005

Durbin Watson	1.704

Table 6.48: ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	10.109	5	2.022	3.402	.005(a)
	Residual	240.104	404	.594		
	Total	250.213	409			

a Predictors: (Constant), SEX, LNINCOME, LNAGE, LNHHSIZE, LNEDU

b Dependent Variable: LNWTP1

Table 6.49: Descriptive Statistics

	Mean	Std. Deviation	
LNWTP2	4.8120	.8804	
SEX	1.7513	.4328	
LNAGE	3.4165	.3870	
LNEDU	2.7831	.2081	
LNHHSIZE	1.5171	.4244	
LNINCOME	4.5235	.5858	

Table 6.50: Pearson Correlations among Variables		LNWTP2	SEX	LNAGE	LNEDU	LNHHSIZE
	LNWTP2	1.000	.106	.005	.081	-.102
	SEX	.106	1.000	.054	.029	.074
	LNAGE	.005	.054	1.000	-.043	-.067
	LNEDU	.081	.029	-.043	1.000	-.071

	LNHHSIZE	-.102	.074	-.067	-.071	1.000
	LNINCOME	.022	-.016	.048	.183	-.082

	LNINCOME
LNWTP2	.022
SEX	-.016
LNAGE	.048
LNEDU	.183
LNHHSIZE	-.082
LNINCOME	1.000

Table 6.51: Model Summary

					Change Statistics					
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**R Square Change**	**F Change**	**df1**	**df2**	**Sig. F Change**	
1	.168(a)	.028	.016	.8735	.028	2.215	5	380	.052	

a Predictors: (Constant), LNINCOME, SEX, LNAGE, LNHHSIZE, LNEDU

b Dependent Variable: LNWTP2

Durbin-Watson 1.642

Table 6.52: ANOVA

Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	**Regression**	8.451	5	1.690	2.215	.052(a)
	Residual	289.938	380	.763		
	Total	298.390	385			

a Predictors: (Constant), LNINCOME, SEX, LNAGE, LNHHSIZE, LNEDU

b Dependent Variable: LNWTP2

Regression Analysis for WTP3: Log linear Model

Table 6.53: Descriptive Statistics

	Mean	Std. Deviation	N
LNWTP3	4.5948	.9710	350
LNAGE	3.3977	.4040	350
LNEDU	2.7879	.1856	350
LNHHSIZE	1.5077	.4382	350
LNINCOME	4.5029	.6201	350
SEX	1.7571	.4294	350

Table 6.54: Pearson Correlation among Variables

	LNWTP3	LNAGE	LNEDU	LNHHSIZE	LNINCOME	SEX
LNWTP3	1.000	-.040	.048	-.113	.022	.039
LNAGE	-.040	1.000	-.015	-.023	.045	.042
LNEDU	.048	-.015	1.000	-.057	.191	.056
LNHHSIZE	-.113	-.023	-.057	1.000	-.081	.065
LNINCOME	.022	.045	.191	-.081	1.000	-.023
SEX	.039	.042	.056	.065	-.023	1.000

Table 6.55: Model Summary					
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**Durbin-Watson**
1	.136(a)	.018	.004	.9690	1.473
a Predictors: (Constant), SEX, LNINCOME, LNAGE, LNHHSIZE, LNEDU					
b Dependent Variable: LNWTP3					

Table 6.56: ANOVA						
Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	**Regression**	6.057	5	1.211	1.290	.268(a)
	Residual	322.970	344	.939		
	Total	329.026	349			
a Predictors: (Constant), SEX, LNINCOME, LNAGE, LNHHSIZE, LNEDU						
b Dependent Variable: LNWTP3						

6.13 Estimation of Total Willingness to Pay

Total No. of Households living in the vicinity of
the Yamuna Floodplains : 56923

Total No. of Sample Households : 501

Model: Linear

OPTION A: Aggregate WTP = Mean WTP * Total Population

Table 6.57: Simple Aggregate WTP

	Qualified Bids	Mean WTP	Aggregate WTP
WTP1	411	172.3844	9,812,637.20
WTP2	386	167.6813	9,544,922.64
WTP3	351	147.8632	8,416,816.93

OPTION B: Aggregate WTP = Mean WTP * Relative Population Weight * Total Population, where, Relative Population Weight = No. of qualified Bids / Total no. of bids

Table 6.58: Weighted Aggregate WTP

	Qualified Bids	Weight	Mean	Aggregate WTP
	(A)	(B) = (A)/ 501	(C)	(D)= (C) * Population * (B)
WTP1	411	0.820359281	172.3844	8,049,888.00
WTP2	386	0.770459082	167.6813	7,353,972.33
WTP3	351	0.700598802	147.8632	5,896,811.86

Model: Log Linear

Table 6.59: Simple extrapolation

OPTION A: Simple extrapolation to the population

	Qualified Bids	Mean	Aggregate
WTP1	411	133.67	7,608,897.41
WTP2	386	122.97733	7,000,238.56
WTP3	351	98.96834	5,633,574.82

Table 6.60: Weighted Extrapolation

OPTION B: Extrapolation with reference to weights in sample

	Qualified Bids	Weight	Mean	Aggregate WTP
	(A)	(B) = (A)/ 501	(C)	(D)= (C) * Population * (B)
WTP1	411	0.820359281	133.67	6,242,029.61
WTP2	386	0.770459082	122.97733	5,393,397.37
WTP3	351	0.700598802	98.96834	3,946,875.77

Table 6.61: Range of Values Obtained through CVM

	Range (Rs. Lakh Per Annum)	Mean Rs. Lakh Per Annum
Use Value (WTP_1)	62.42 – 98.13	80.275
Bequest Value (WTP_2)	53.93 – 95.45	74.690
Existence Value (WTP_3)	39.47 – 84.17	61.820
Total	155.82 – 277.75	216.785

Thus, the value of recreation and wildlives varies between Rs.155.82 to Rs.277.75 lakh per annum. The mean value comes out as Rs.216.785 lakh per annum. The range reflects different model specification and assumption.

Chapter 7: Values of Ecological Benefits of Floodplains and Other Alternate uses

Valuation of ecosystem services of floodplain wetland in terms of water recharge, nutrient retention, and tangible benefits like fisheries, fodder, thatching grasses, habitat for flora and fauna and recreation has been done so far. Valuation methodologies used for different ecological functions is given in Table 7.1 and the annual economic estimate of selected ecological functions are given in table 7.2.

Table 7.1: Valuation methods of different Ecological functions of Yamuna Floodplain

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

Table 7.2: Annual Economic Estimation of Selected Ecological Functions of the Floodplain

S. No.	Ecological Functions	Value (in Rs. Lakhs)			Remarks
		Min.	Max.	Mean	
1.	Water Recharge Benefits to Agriculture	5.36	5.36	5.36	i) Production function for six major crops have been estimated from the cross section survey of farmers in the floodplains ii) Only water input has been allowed to be used optimally iii) 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	511.20	609.45	560.325	i) Alternate cost of water has been estimated for different sources of supply. ii) The cost of supply includes raw water cost, transportation cost and treatment cost. Distribution cost has been excluded. iii) For calculation purpose, only that water, which reaches the aquifer in the study area, has been considered.
3.	Nutrient Retention (N, P and K)	1.66	3.44	2.55	i) The cost in procuring the equivalent amount of N, P & K through the chemical fertilisers (Urea, DAP and Muriat or Potash) has been treated as the nutrient retention benefits. ii) Maximum and minimum values of nutrients are according to the availability of nutrients along with the amount of sediments in the flooding season.

S. No.	Ecological Functions	Value (in Rs. Lakhs)			Remarks
		Min.	Max.	Mean	
4.	Biological Productivity i) Fishery	377.28	503.04	440.16	i) Two prices (composite) i.e. contract and market gives the lower and higher estimate.
	ii) Fodder	5.57	342.43	174.00	ii) 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	i) 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	ii) Here, the production of Watermelon, Sweet melons etc. have been accounted.
5.	Habitat to Wild lives and Recreations	155.82	277.75	216.785	i) Under Contingent Valuation Method (CVM), through the dichotomous choice questionnaire the value for option, bequest and existence has been cited. Choice of model (linear and log-linear) gives the range of values.
6.	Total	1080.91	1766.69	1423.80	

These functions are neither exhaustive nor complete. For example, the water recharge functions have considered for the local aquifer and not the bigger aquifer around Delhi. Establishing hydraulic links between the recharge from the floodplains to all the aquifers needs longer time series experimentation, which was not possible within the stipulated time of the project. There are more functions one can anticipate a wetland ecosystem to perform. But all of which have not been attempted for estimation due to lack of time as well as financial constraints. However, even the most conservative estimate gives very significant value. The preservation value of the floodplains comes to be 1423.80 lakh for the entire 3250 ha areas of floodplains yielding Rs. 0.438 lakh/ha. This value is of the flow of benefits during one year. Even if the floodplain areas are preserved in its current form this benefit of Rs 0.438 lakh/ha will keep accruing every year. Thus the capitalized value of the benefits accruing forever comes to be Rs.71190 lakh for the total area. In order to obtain the capitalized value of X benefits accruing for infinite period at 'r' rate of discount, X/r has been used at 2% social rate of discount.

Following table provides the capitalized value for 3250 ha of flood plains at different rate of discounts.

Table 7.3: Capitalised Values of Total land due to Ecological functions (discounted at different rates) of the Floodplains (Rs. Lakh)

Rate of Discount (r) (%)	Capitalised Value (X/r) Rs. Lakh	*Capitalised Value Rs. Lakh/Ha
2	71190	21.90
5	28476	8.76
8	17798	5.48
10	14238	4.38
12	11865	3.65

Note: X (= Rs.1423.80 lakh) is the estimated mean value of the ecological functions performed by the floodplains.
* Capitalised Value Rs. Lakh/Ha has been calculated by dividing the capitalised value (X/r) Rs. Lakh by the total area (3250 ha) of floodplain in the study area.

The capitalized value declines as the rate of discount increases. Thus the total value of Rs.71190 lakh comes down to Rs.11865 lakh at 12% rate of discount. Correspondingly the per ha value varies between Rs.21.90 lakh to Rs.3.65 lakh.

Alternate Uses of Land

Since these floodplains are part of 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 station etc. Also, a major part of the floodplains area has been encroached upon by the illegal slum dwellers. The developmental benefits of the floodplain 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 become difficult. One good approximation of developmental benefits could be the price of the land paid by the development agency like DDA (DDA, 1998). This one time price paid by the DDA may be treated as the discounted value (Capitalised Value) of all the development benefits accruing over a period of time extending to infinity.

DDA acquires land in this area by paying a price of Rs.11.20 lakh per acre and if this land is in the riverbed, the price is lesser by 30%. Since all the floodplains are in the riverbed, this price Rs.7.84 lakh/acre can be approximated with the discounted (Capitalised Value) of the floodplain land for developmental activities, which become Rs.3.174 lakh/ha. Alternatively this value may be treated as the cost of preservation (in terms of the forgone developmental benefits) of the floodplains.

Benefit – Cost Analysis of the Floodplain Conservation

Now, we have streams of benefits of conservation of floodplain at different rate of discount. We have taken several rates of discounts for simulation purpose. Planning Commission of India prescribes 12% rate of discount in social projects. But it does not take into account the environmental implications of the project. Lower rates of discount of 10%, 8%, 5% and 2% have also been considered to make the decision criteria more sustainable (Pearce and Markandaya, 1988). However, the cost of conservation i.e. forgone developmental benefits remains the same as it is already discounted.

Thus by applying the B – C Ratio Criteria,

i.e. $$\int_0^\infty B_t e^{-rt}\, dt \Big/ \int_0^\infty C_t e^{-rt}\, dt$$

We get the following table-

Table 7.4: Benefit-cost ratio calculated at different social rates of discount

Social Rate of Discount (r) (%)	Benefits of Preservation (B)	Cost of Preservation (Capitalised Value of Floodplain Land for Developmental Purposes) or Forgone developmental Benefits (C)	B/C Ratio
2	71190	10302	6.91
5	28476	10302	2.76
8	17798	10302	1.73
10	14238	10302	1.38
12	11865	10302	1.15

The B/C ratio varies from 6.91 to 1.15 at 2% and 12% rates of discount respectively. Such a favourable ratio eminently justifies the conservation arguments on the basis of efficiency criteria. We acknowledge the DDA's price as administered one. But to a greater extent it reflects the best possible price for such purpose. Moreover, a few ecosystem functions e.g. bioremediation and recharging of distant aquifer remains unaccounted and unpriced in this study due to time and resource constraints. In any case this exercise provides rationale for preservation of this floodplain. This also suggests that any activity like channelization of river, which impairs the health of floodplain ecosystem, should be avoided.

Chapter 8:Summary and Conclusions

8.1 Summary

Wetland ecosystems present along the Yamuna river corridor are looked upon as a precious property resource that has different potential land uses. Twenty-five kilometer stretch of river Yamuna and associated wetlands from Wazirabad to Okhla are immensely threatened due to increasing anthropogenic pressure of the growing city. To understand the various ecological functions performed by these wetland ecosystems and to value the benefits derived there from, the research project entitled " Valuation of Ecological Functions and Benefits: A Case Study of Wetlands Ecosystems Along the Yamuna River Corridors of Delhi Region" was set forth with the following objectives (i) assessment of the functions and benefits derived from the river front wetlands and identification of the threats to these functions; (ii) economic valuation of these functions and benefits of the wetlands and the cost benefit analysis of benefits derived from the maintenance of wetlands and alternative development options; and (ii) simulation of the development option for wetlands of Yamuna in the Delhi region.

Wetland ecosystems present in the Yamuna river corridor were identified and delineated using well-established criteria, which are: (i) vegetation type; (ii) soil properties; and (iii) hydrological status. Ecological diversity of the wetland ecosystems present in the study area was assessed using: (i) vegetation characteristics; (ii) soil characteristics; and (iii) hydrogeomorphic characteristics. On the basis of these criteria, three wetland types were identified in the study area. These wetland types are: (i) floodplain; (ii) seasonal pools; and (iii) marshy areas.

Extent and location of the wetland types were mapped using Geographic Positioning System; subsequently the geographic coordinates were mapped on the toposheet of the study area. Floodplains are the most extensive wetland ecosystems comprising approximately 95.38% of the study area followed by marshy area (3.38%) and seasonal pools (1.24%). Wetlands in the study area are found to be extremely perturbed ecosystems. It is also supported by the observation that only small pockets in floodplains and marshy area support pure stands of *S.munja* and *Typha* respectively.

Interactions of the biotic and abiotic components of wetland ecosystems lead to a flow of ecological functions. The ecological functions that were considered for quantitative estimation are: (i) hydrological functions, (ii) biological productivity, (iii) sediment trapping and stabilization, (iv) habitat for flora and fauna, (v) nutrient storage

Ground water recharge is an important hydrological function that is performed by the wetlands present in the study area. Water balance method was used to estimate the ground water recharge that occurs from the wetlands to the shallow aquifers. The inputs that were considered for the water balance model are: (i) water released from the Wazirabad Barrage, (ii) run off generated from Delhi area and (iii) sewage out falling into the river. The outputs that were considered are: (i) water released from Okhla Barrage, (ii) water taken for Indraprastha and Rajghat thermal power plants, (iii) water released into the Agra canal and (iv) evapotranspirational losses of Delhi area.

Annually about $4.09*10^7$ Kl enters the subsurface hydraulic system of the study area, of which $2.34*10^7$ Kl recharges the aquifer leading to an increment of 0.72m in the water table. Aquifers present in the city areas are recharged due to lateral migration of ground water from the floodplain aquifers to the connected aquifers in the city.

To analyze the effect of channelization of the river on the ground water reserve and the water table of the study area a simulation study was carried out. Area inundated by the floodwaters in the study area was reduced by 500ha due to the proposed partial channelization of the river. Reduction of the inundation area lead to decrease in the ground water reserve by $3.6*10^6$ Kl and depletion of water table by approximately 0.12m. Channelization of the river will not only affect the hydrological functions of the wetlands but also affect other ecological functions performed by the wetlands.

Wetlands present along the river corridor region, act as nutrient sinks for inorganic nutrients brought by the sediments into the system. Nutrient status of the floodplains was assessed with respect to nitrogen, phosphorus and potassium (N, P and K) on a spatio-temporal scale. Soil samples were collected in the pre- and post-monsoon seasons from the floodplain areas. Soil samples were also collected from geologically similar site in the non-floodplain areas to highlight relative amount of nutrient enrichment that might be present in between the wetland and upland areas. Distinct nutrient enrichment was present in the floodplain soils with respect to nitrogen, phosphorus and potassium between the pre- and post- monsoon season.

Biological productivity of riparian wetlands is high due to the characteristic hydrology of the system. The biological productivity of the study area was categorized into primary and secondary productivity. Primary productivity of the wetlands was assessed using *S. munja* and *Typha* as candidate species. *S.munja* is harvested for grass culms that are used for manufacture of mats and stools. Leaves of *Typha* are harvested and are used for manufacture of mats. Approximate yield of *S.munja* and *Typha* from the study area is 7303 and 28000 bundles respectively. Dry season agriculture, cultivation of seasonal fruits and vegetables is also practiced in the floodplain areas. Cucurbits are grown exclusively in the floodplain areas. During the dry season pockets in the study area having characteristic wetland vegetation are used as grazing lands by the cattle of the local people. Fish catch was used as an index of secondary productivity of the wetland ecosystems. Fish catch for the study period is 1200 tonnes.

River corridor vegetation helps in trapping and stabilization of sediments brought by the river. To estimate the sediment trapping and stabilization that occurs in the floodplains detailed sediment budget is required. Preliminary studies on the sediment stabilized by the *S.munja* were undertaken for the present study.

Wetlands are transition zones between aquatic and terrestrial habitats and thus support a wide variety of biota. Wetland ecosystems in the Delhi stretch of the Yamuna river corridor are highly disturbed habitats with few isolated pockets of characteristic wetland biota. Standard ecological survey techniques were used to prepare a detailed checklist of the flora and avifauna in different seasons. Based on the field surveys 115 plant species belonging 27 different families were identified and categorized. Different plant species of ecological and economic significance from floodplain area have been identified. Avifauna of the study area is represented by 97 species of birds, of which 56% are migratory and are covered under the international conventions.

Ecological functions of a floodplain wetland ecosystem, albeit complex and evolving one, can be identified and estimated. Valuations of these functions are required to correct the anomalies of market failure arising out of the problems of externalities. Due to the lack of information on these functions and their significance, these areas are encroached upon for habitation, industries and other economic activities. Benefits exceed cost because elements of benefits are by and large visible and quantifiable in monetary terms where the cost of conversion, which is intangible and social in nature, remain unaccounted and non-monetised. This leads to reductionist and tunnel- visioned decision where conversion becomes sought after. However this conversion leads to disappearance of this productive ecosystem, which in the long run makes the shrinkage in the base of natural capital. Thus continuous conversion of floodplain in the urban ecosystem inflicts heavy cost to the society in terms of reduced level of social provision and other tangible-intangible benefits accruing to different stakeholders.

Table 8.1: Appropriate Annual Rupees Values of the Floodplain of Yamuna River in Delhi Corridor [a] (from Wazirabad to Okhla)

S. No.	Output	Value (in Lakh)		
		Mean	Per Hectare	Percentage
1.	Water Supply	560.325[1]	0.17240	39.35
2.	Water Recharge Benefits to the Agriculture	5.36	0.001649	0.37
3.	Nutrients (N, P and K)	2.55[2]	0.00329	0.17
4.	Fodder	174.00	0.05353	12.22
5.	Fisheries	440.16	0.13543	30.91
6.	Thatching Grass (*S. Munja* and Typha)	5.42	0.04927	0.38
7.	Other Production (cucurbits etc.)	19.20	0.29643	1.35
8.	Wildlives & Recreation • Use Value (WTP_1) • Bequest Value (WTP_2) • Existence Value (WTP_3)	216.78 [80.27] [74.69] [61.82]	0.06670	15.28 5.66 5.26 4.35
9.	Sub Total (A)	1423.80		100
10.	All Other Outputs	Not Estimated		
11.	Detrimental Outputs	Not Estimated		
12.	Sub Total (B)	----------------		
13.	Gross Total (A+B)	1423.80+/- value of other outputs		

[1] Mean value of water supply is the average alternate cost of water supply under two scenarios
(pl. refer table 6.12)

[2] Summation of mean value of N, P & K (pl. refer Table 6.15)

8.2 Conclusions

Based on the observation and results of the present research project following conclusions emerge:

1. Three types of wetland ecosystems exist in the Yamuna river corridor of Delhi region. These are (i) floodplain, (ii) seasonal pools, and (iii) marshy areas. Floodplains are the most extensive of all the wetland ecosystems.

2. These wetlands provide a stream of benefits to both the urban society and the inhabitants of Yamuna river corridor. These benefits include (i) water supply for domestic, industrial and agricultural purposes, (ii) fodder, (iii) utilizable plant species, (iv) fisheries, (v) low input sustainable agriculture, (vi) recreation, and (vii) tourism.

3. Floodplains play a crucial role in ground water recharge to the sandy aquifers present in the study area and connected aquifers in Delhi city. These floodplain aquifers provide vast resource of fresh ground water that can be used for supplying drinking water to Delhi and for practicing agriculture. The importance of the water recharge function of the wetlands is amply reflected in the economic value, which is the highest among all the economic estimates of all ecological functions that were assessed.

4. Channelization of river Yamuna in the Delhi stretch will have detrimental effect on the ground water recharge which occurs through the floodplains. (Even the most conservative estimate of the amount of ground water recharge through the floodplains indicates that approximately 25% of the Delhi's population drinking water needs can be satisfied by the ground water recharged annually through the floodplains).

5. Distinct enrichment is present in the wetland soils of the study area with respect to Nitrogen, Phosphorus and Potassium after the floods have receded from the wetland areas. The nutrient enriched soils of the wetlands support the growth of many agricultural crops with low input of fertilizers into the soils.

6. The local people inhabiting the Yamuna river corridor region utilize plant and animal resources that are available to them due to the existence of wetlands

for commercial and subsistence purposes. These biological resources account for approximately 42.94% of the total economic value of the wetlands. Thus, any change in the biological resource base of the Yamuna river corridor region due to urbanization will have detrimental effect on the socio-economic status of the people inhabiting these areas.

7. The communities, which enjoy the benefits from low input agriculture and other activities, are those that are marginal, in economic terms and in terms of their capacity to earn an alternate source of living. There does exist a case for subsidization of some of their living costs, which is done by the wetlands, by reducing a significant portion of total cost of their principal economic activity, i.e. agriculture. Hence, wetlands maintain a sort of equity in the society.
8. Wetland vegetation plays a crucial role in sediment trapping and stabilization. *S.munja* the dominant plant species present in the floodplains has an extensive root network due to which it can stabilize large volume of sediments.
9. Even though, wetlands in the Yamuna river corridor are perturbed ecosystems they support a wide variety of flora and fauna as 155 plant species of 27 families and 97 bird species have been documented from this area. Of the total bird species 56% are migratory in nature. The willingness to pay of the people for the preservation of the habitat for flora and fauna is significant.
10. Wetland ecosystems in the Yamuna river corridor are under continuous threat for conversion to alternate uses due to the pressures of a fast expanding city. Major portion of the wetland area has already been diverted to other uses, which include agriculture, civic structures, thermal power plants and temporary human settlements. The vanishing ecological functions inflict heavy cost on the society in terms of loss of tangible and intangible benefits.
11. Benefit-Cost Analysis favourably suggests the conservation of floodplain area.

Chapter 9:Recommendations

The wetlands of Yamuna river corridor in Delhi stretch have a significant economic value. Most of these values are generally not captured through the present market processes. Proper investigation of several vital functions of these wetlands (as water supply, nutrient enrichment, production of fodder and other products which form economic base of sustenance of a vast population), had not been investigated prior to this study, and therefore no economic base existed for undertaking conservation measures of these wetlands. Some of the recommendations that emerge from this study are:

1. An investment strategy needs to be worked out for the wetlands of Yamuna river corridor so that the present stream of benefits is appropriated sustainably. A significant proportion of the investment should be in physical and ecological interventions so as to maintain and conserve the ecological and hydrological character of the wetlands, which at present is under stress due to rapidly increasing anthropogenic pressures. Investments should be prioritized based on the contribution to the total economic value. As it appears from the present investigation, the hydrological functions comprise of 39.35% of the total economic value. Hence, to maintain the ground water recharge potential of the floodplains, it is imperative to prevent any fresh civic structures to come up in these areas. This is necessary because fresh ground water resources present in the floodplain and connected aquifers in the city are replenished annually due to the floodplains. 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 generation too.
2. Channelization of the river in the Delhi stretch should not be carried out. Channelization will not only lead to reduction of the ground water reserve, it will completely stop the ground water recharge that occurs from the floodplains. In the light of the acute scarcity of fresh water in Delhi, reduction of the ground water reserves will further aggravate the water problem.

Channelization of the river will also adversely affect ecological functions performed by the wetlands in the Delhi stretch.

3. The recharged water into the aquifer from this floodplain area is of very high quality, maintenance and preservation of this wetland will substantially save the treatment cost of water, which we have to meet otherwise.

4. The study reveals that these wetlands have a significant biodiversity value, which is presently unaccounted. Economic instruments should be developed to enable the people to contribute to the cause of conservation of the wetland habitats. In the present study, the feasibility of two modes of public payments was assessed, i.e. voluntary donations and permit system. However, public investment in development of riverfront and eco-tourism at strategic locations is a prerequisite to setting up the mechanism of permits. This would assist in appropriating the aesthetic values of the wetlands. The response of the willingness to pay to the socio-economic variables as income, household size, education, profession, should be used as inputs in targeting the instrument.

5. Since the wetlands provides habitat to large number of bird species in Okhla bird sanctuary and the Willingness To Pay (WTP), for preservation of biodiversity is quite high, wetland preservation needs an added attention.

6. Pockets of characteristic wetland vegetation present near Wazirabad, seasonal pools and marshy areas near Okhla, support animal and plant resources that are utilized by the local people for their livelihood and sustenance. These areas should be protected and conserved from anthropogenic pressures to sustain their ecological services.

7. Wetland vegetation (*S. munja*) found in the floodplains should be planted on the riverbanks to stabilize them against the erosive action of moving water. These activities will help in reduction of government expenditure to set up mechanical bank stabilization devices.

8. Riparian buffer strip of wetland vegetation should be developed between the river channel and the agricultural fields. So as to reduce the non-point source of pollution occurring due to the use of fertilizers and other agrochemicals.

9. To reduce pollution load of the river, new sewage treatment plants should be set up and the performance of the existing sewage treatment plants should be optimized which will help in mitigating adverse impacts of pollution on wetland and riverine biota.

10. No proper resource allocation framework is at present in place, which has led to characterization of these wetlands as open access, leading to their encroachment and conversion to alternate resource uses. The optimality of the present resource appropriation in light of its sustainability needs to be worked out through further ecological assessments, and definite regulatory framework should be in place to correct the anomalies.

11. The present study should be extended to the entire Yamuna river basin, so that the strategies for resource allocation and investments for resource enhancement are undertaken at a basin level.

12. Further ecological investigations need to be carried out on the relationship of the different components of the wetlands and their contribution in creation of an economic value to the stakeholders.

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APPENDICES

Appendix: 1

Checklist of plant species inhabiting wetlands of the study area.

S No	Family	Plant species
1.	Acanthaceae	*Rungia repens*
		Peristrophe bicalyculata
		Justicia diffusa
		Hemigraphis hirta
2.	Amaranthaceae	*Alternanthera sessilis*
		Achyranthes aspera
		Celosia argentea
		Amaranthus hybridus
		A. blitum
		Gomphrena globosa
		G. celosiodes
3.	Caryophyllaceae	*Stellaria media*
4.	Compositae	*Anagallis arvensis*
		Sonchus arvensis
		Launaea aspleniifolia
		Xanthium stromarium
		Ageratum conyzoides
		Youngia janponica
		Vernonia cinerea
		Conyza aegyptiaca
		Pulicaria crispa
		Gnaphalium indicum
		G. luteo-album
		Blumea obliqua
		Eclipta prostrata
		Bidens latifolia
		Cirsium arvense
5.	Convolvulaceae	*Ipomea batatas*

S No	Family	Plant species
		I. pentaphylla
		Evolvulus alsinoides
		Convolvulus arvensis
6.	Crucifereae	*Sisymbrium irio*
		Coronopus didymus
		Raphanus sativus
		Nasturtium officinale
		Farsetia hamiltonii
		Brassica oleracea var *capitata*
		B. olearacea var *botrytis*
		Eruca sativa
7.	Euphorbiaceae	*Euphorbia pulcherrima*
		E. geniculata
		E. hirta
		Acalypha indiaca
		Phyllanthus simplex
		Croton bonplandianum
		Ricinus communis
8.	Labiatae	*Salvia plebeia*
9.	Leguminosae-Papilionoideae	*Trigonella corniculata*
		T. foenum-graecum
		T. incisa
		Medicago denticulata
		M. sativa
		Melilotus alba
		M. indica
		.Trifolium alexandrianum
		Indigofera linifolia
		Sesbania sesban
		S. aegyptica
		Tephrosia purpurea

S No	Family	Plant species
		Desmodium triflorum
		Cicer arietinum
		Vicia faba
		V. sativa
		Lathyrus sativus
		Pisum sativus
		Pongamia pinnata
		Dalbergia sissoo
10.	Leguminosae-Mimosoidae	*Albizzia lebbeck*
		Leucaena lucocephala
		Pithecelobium dulce
		Prosopis cineraria
		Acacia nilotica
11.	Leguminosae-Caesalpinodae	*Bauhinia variegata*
		Parkinsonia aculeata
		Tamarindus indica
		Cassia tora
		C. obtusa
12.	Liliaceae	*Aloe barbadensis*
		Asphodelus tenuifolium
		Allium cepa
13.	Meliaceae	*Azadirachta indica*
		Toona ciliata
		Melia azedarch
14.	Myrtaceae	*Eucalyptus globus*
		Syzygium cumini
15.	Onagraceae	*Jussiaea repens*
16.	Oxalidaceae	*Oxalis corniculata*
		O. mauritina
17.	Papaveraceae	*Argemone mexicana*
18.	Polygonaceae	*Polygonum plebeium*

S No	Family	Plant species
		P. glabrum
		Rumex dentatus
19.	Pontederiaceae	*Eichhornia crassipus*
20.	Ranunculaceae	*Ranunculus scleratus*``
21.	Salicaceae	*Salix tetrasperma*
22.	Scrophularaceae	*Mazus japonicus*
		Lindernia parviflora
		Verbascum chinense
		Veronica agrestis
		V. anagallis-aquatica
23.	Tamaricaceae	*Tamarix troupii*
		T. dioica
24.	Typhaceae	*Typha angustata*
25.	Verbenaceae	*Phyla nodiflora*
26.	Graminae	*Cenchrus setigerum*
		Penisetum typhoides
		Imperata cylindrica
		Phalaris minor
		Eragrostis pilosa
		E. ciliaris
		E. diarrhena
		Chloris virgata
		Paspalum distichum
		Cynodon dactylon
27.	Cyperaceae	*Scripus tuberosus*
		S. articulatus
		S. affinis
		Cyperus alopecuroides
		Carex fedia
		Carex rotundus

S No	Family	Plant species
		Fimbristylis monostachya
		F. ferruginea

Appendix: 2

Checklist of avifauna of wetlands of the study area

S. No	Name of Species		Family	Site	Habit
	Common	**Zoological**			
1.	Ashy wren warbler	*Prinia socialis*	Muscicapidae	1,2,3,4	GR
2.	Asian house martin	*Delichon dasypus*	Hirundinidae	1,2,3,4	BMR
3.	Avocet	*Recurvirostra avosetta*		4	B
4.	Bank myna	*Acridotheres ginginianus*	Sturnidae	1,2,3	B
5.	Bay backed shrike	*Lanius vitatus*	Laniidae	1,2	RW
6.	Baya	*Ploceus phillipinus*	Ploceinae	1,2,3,4	R
7.	Black tailed godwit	*Limosa limosa*	Charadriidae	1,3,4	B
8.	Black headed gull	*Larus ridibundus*	Laridae	1,2,4	A
9.	Black drongo	*Dicrurus adsimilis*	Dicruridae	1,2,3,4	GRW
10.	Black necked stork	*Ephippiorhyncus asiaticus*		4	BMR
11.	Black winged stilt	*Himantopus himantopus*	Recuvirostridae	1,2,3,4	BM
12	Black winged kite	*Elanus caeruleus*	Accipitridae	1,3,4	G
13.	Blossom headed parakeet	*Psittacula cynocephala*	Psittacidae	1,2,3	HW
14.	Bluethroat	*Luscinia svecica*		4	R
15.	Blue rock pigeon	*Columba livia*	Columbidae	1,2,3,4	GH
16.	Brahminy duck	*Tadorna ferriginea*	Anatidae	4	AB
17.	Brahminy myna	*Sturnus pagodarium*	Sturnidae	1,2,3,4	GHW
18.	Bronze winged jacana	*Metopidius indicus*	Jacanidae	3,4	MR
19.	Brown headed gull	*Larus brunnicephalus*	Laridae	1,2,3,4	A
20.	Cattle egret	*Bulbulcus ibis*	Ardeidae	1,2,3,4	BGH MR
21.	Common teal	*Anas crecca*	Anatidae	3,4	A
22.	Common pochard	*Aythya ferina*	Anatidae	4	A
23.	Common shelduck	*Tadorna tadorna*	Anatidae	4	A
	Common	*Sturnus vulgaris*	Sturnidae	1,3,4	W

S. No	Name of Species		Family	Site	Habit
	Common	Zoological			
24.	starling				
25.	Common Hawk-cuckoo	*Cuculus varius*	Cuculidae	1,2,3,4	W
26.	Common crow	*Cvorvus splendens*	Corvidae	1,2,3,4	BGH W
27.	Common myna	*Acridotheres tristis*	Sturnidae	1,2,3,4	BGH W
28.	Coot	*Fulica atra*	Ciconiidae	1,3,4	A
29.	Cormorant	*Phalacrocrax carbo*	Phalacrocoracida e	1,2,3,4	AW
30.	Crested lark	*Galerida cristata*	Alaudidae	1,2,3,4	G
31.	Crow phaesant	*Centropus sinensis*	Cuculidae	1,2,3	W
32.	Dusky leaf warbler	*Phylloscopus fuscatus*		1,4	HW
33.	Egyptian vulture	*Neophron perinopterus*	Accipitridae	1,4	BGH W
34.	Gadwall	*Anas strepera*		4	A
35.	Grey heron	*Ardea cinerea*	Ardeidae	1,4	ABM R
36.	Grey hornbill	*Taucus birostris*	Bucerotidae	1,3,4	W
37.	Grey shrike	*Lanius exeubitor*	Laniidae	1,2,3,4	W
38.	Gull billed tern	*Gelochelidon nilotica*		1,2,3,4	GRW
39.	Hoopoe	*Upupa epops*	Upupidae	1,2,3,4	GW
40.	Hodgson's bushchat	*Saxicola insignis*		4	R
41.	Indian shikra	*Accipiter badius*	Falconiformes	1,2,3,4	BGR
42.	Indian shag	*Phalacrocrax fuscicollis*	Phalacrocoracida e	3,4	A
43.	Indian roller	*Coracias benghalensis*	Coraciidae	1,2,3	GW
44.	Jungle crow	*Corvus macrohynus*	Corvidae	1,4	W
45.	Jungle babbler	*Turdoides striatus*	Muscicpidae	1,2,3,4	BGH W
46.	Large egret	*Ardea alba*	Ardeidae	1,3,4	BMR
47.	Large pied wagtail	*Motacilla maderaspatensis*	Motacillidae	1,2,3,4	BMR
48.	Lesser black backed gull	*Larus fuscus*	Laridae	1,2	A
49.	Lesser flamingo	*Phoenicopterus minor*		4	B
50.	Little grebe	*Tachybaptus*	Podicipitidae	1,2,3,4	AR

S. No	Name of Species		Family	Site	Habit
	Common	Zoological			
		ruficollis			
52.	Little egret	*Ergetta garzetta*	Ardeidae	1,2,3,4	ABG HMR
53.	Little ringed plover	*Charadrius dubius*	Charadriidae	1,3,4	BM
54.	Little cormorant	*Phalocrocrax niger*	Phalacrocoracidae	4	A
55.	Mallard	*Anas platyrhyncha*	Anatidae	3,4	A
56.	Marsh harrier	*Circus aeruginosus aeruginosus*	Falconiformes	4	AMR
57.	Marsh sandpiper	*Tringa stagnatilis*		1,4	BM
58.	Painted stork	*Mycteria leucocephla*	Ciconiidae	1,4	AW
59.	Pariah kite	*Milvus migrans govinda*	Accipitridae	1,2,3,4	ABG HMR W
60.	Pheasant tailed jacana	*Hydrophasianuus chirurgus*		4	BMR
61.	Pied myna	*Sturnus contra*	Sturnidae	1,2,3,4	ABG HMR W
62.	Pied bush chat	*Saxicola caprata*	Muscicpidae	1,2,3,4	GR
63.	Pied Kingfisher	*Ceryle rudis*	Alcedinidae	1,3,4	A
64.	Pintail	*Anas acuta*	Anatidae	3,4	A
65.	Pond heron	*Ardeola grayii*	Ardeidae	1,2,3,4	AMR
66.	Purple moorhen	*Porphyrio porphyrio*	Ciconiidae	2,3,4	MR
67.	Purple sunbird	*Necteriana asiatica*	Nectarinidae	1,2,3,4	HW
68.	Red munia	*Amandava amandava*		1	GR
69.	Red vented bulbul	*Pycnonotus cafer*	Pycnonotidae	1,2,3,4	HW
70.	Red whiskered bulbul	*Pycnonotus jococus*	Pycnonotidae	1,3,4	W
71.	Redwattled lapwing	*Vanellus indicus*	Charadriidae	1,2,3,4	BMR G
72.	River Tern	*Sterna aurantia*	Laridae	1,3,4	A
73.	River/Spur winged lapwing	*Vanellus spinosus duvaucelli*	Charadriidae	1,4	BMR
74.	Rose ringed	*Psittacula krameri*	Psittacidae	1,2,3,4	W

S. No	Name of Species		Family	Site	Habit
	Common	Zoological			
	parakeet				
75.	Scarlet minivet	*Pericrocotus flammeus*	Campephagidae	1	W
76.	Shoveller	*Anas clypeata*	Anatidae	1,3,4	A
77.	Small green bee eater	*Merops orientalis*	Meropidae	1,2,3,4	W
78.	Snipe	*Gallinago gallinago*		1,4	BM
79.	Sparrow	*Passer domesticus*	Ploceidae	1,2,3,4	GH
80.	Spoonbill	*Platalea leucorodia*	Threskiornithidae	4	AM
81.	Spotbill duck	*Anas poecilorhyncha*	Anatidae	1,4	AM
82.	Spotted owlet	*Athene brama*		1	WH
83.	Swallow	*Hirundo rustica*	Hirundinidae	1,2,3,4	AGM R
84.	Tailor bird	*Orthotomus sutorius*		1,2,3,4	HRW
85.	Tawny eagle	*Aquita vindhiana*	Accipitridae	1	GW
86.	Tree pipit	*Anthus trivialis*		1	GW
87.	Tufted duck	*Aythya fuligula*	Anatidae	4	A
88.	Water hen	*Amaurornis phoenicurus*	Rallidae	1,3,4	AMR
89.	Whiskered tern	*Chlidonias hybridus*		1,2,3,4	A
90.	Whistling teal	*Anas crecca*		3,4	A
91.	White necked stork	*Ciconia episcopus*	Ciconiidae	4	MR
92.	White breasted kingfisher	*Halcyon smyrnesis*	Alcedinidae	1,2,3,4	ABG HMR W
93.	Whitethroat	*Sylvia communis*		1,2,3,4	RW
94.	White throated munia	*Lonchura malabarica*		1	GR
95.	Wigeon	*Anas penelope*	Anatidae	4	A
96.	Wood shrike	*Tephrodornis virgatus*	Campephagidae	1,2	W
97.	Yellow wagtail	*Motacilla flava*	Motacillidae	2,3,4	BMR

A: Aquatic; B: Banks; G: Grasslands; H: Human settlements; M: Marsh; R: Reeds;W:Woodlands; 1: Wazirabad-ISBT sector; 2: ISBT-ITO sector; 3: ITO-Nizammudin sector; 4:Nizammudin-Okhla sector

Appendix: 3

Questionnaire for Agricultural Survey in the Yamuna Floodplain

FACT SHEET

1. NAME AND ADDRESS OF THE INTERVIEWEE OF THIS FORM:

2. NAME OF THE LOCALITY:

3. GENERAL DESCRIPTION OF THE AREA:

(a) Area (in hectares):
(b) Location: (include the nearest well-known administrative region)
(c) Jurisdiction: (territorial, e.g, state/region and functional, e.g, Dept. of Agriculture/Dept. of Environment etc.)

(d) Land ownership:

At site:

(a) government (ha) (   )
(b) private property (ha) (   )
(c) leasehold (ha) (   )
(d) freehold (ha) (   )
(e) unauthorized occupancy (ha) (   )

At surrounding area:

(a) government (ha) (   )
(b) private property (ha) (   )
(c) leasehold (ha) (   )
(d) freehold (ha) (   )
(e) unauthorized occupancy (ha) (   )

(e) Management authority: (name and address of local body directly responsible for managing the wetland)

(f) Social and cultural values: (e.g., fisheries production, forestry, religious importance, archaeological site, etc.)

4. CURRENT LAND USE:

I. At Site:

(a) residential (ha) ( )

(b) commercial (ha) ( )

(c) agriculture (ha) ( )

(d) native vegetation (ha) ( )

(e) tourist spot/others (ha) ( )

(f) commercial logging and forestry ( )

(g) wood cutting for domestic use ( )

(h) grazing land for domestic stock ( )

II. At Surrounding Area:

5. LANDUSE PATTERN (FOR DIFFERENT SEASONS)

S.No.	Usage	Season or Period	Area Under Use (ha)
1	Agriculture		
2	Horticulture		
3	Floriculture		
4	Sand mining		
5	Fishing		
6	Tourism		
7	Forestry		
8	Grazing land		

9	Logging for domestic or commercial use		
10	Others (specify)		

6. AGRICULTURE/HORTICULTURE/FLORICULTURE (SPECIFY):

A. Kind of farming:

(a) mechanized farming ( ) (b) conventional/traditional ( )

(c) hours involved/labour

B. Details of the Cropping Pattern

(a) number of crops during dry season ____________________________

(b) name of the crop under cultivation _____________________________

(c) area under cultivation (ha) __________________________________,

(d) yield/productivity (kg/ha) __________________________________

(e) value of exploit ____,

(f) Season ______________________________

C. Details on Irrigation Technology:

I. Source of irrigation

(a) river water ( )

(b) rain fed ( )

(c) well ( )

(d) tube well ( )

II. Mode

(a) manual ( )

(b) bullock ( )

(c) pump set ( )

If manual

(i) no. of labourers required ________________

(ii) hrs/day spent __________________________

(iii) total time spent in a season (in days) __________________

(iv) labour cost for irrigation (in Rs.) _____________________

If bullock,

(i) no. of bullocks used _______________,

(ii) hrs/day used ______________________

(iii) total period (no. of weeks) of bullocks used

(iv) source of fodder: market _________, wetland __________

(v) total cost of fodder (Rs.) ________________

If tube well,

(i) manpower required (no. of labours) ____________

(ii) no. of tube wells ( ),

(iii) depth of tube wells ( )

(iv) change in depth over a period of time of dug well ___________

If pump set,

(i) type:

(a) fuel based: diesel ________, petrol ________, kerosene______,

(b) electricity driven ( )

(ii) efficiency: _________ liter/hr supplied

(iii) consumption of fuel or electricity _____________________

(iv) hrs/day used ____________, total usage in a season______ hrs

(v) cost of fuel or electricity consumed (in Rs)_______________

(vi) volume of water used (in liters) _______________________

(vii) frequency of irrigation ______________________

D. Details on Chemical Fertilizers/pesticides Used.

(a) whether use any chemical in agriculture Y/N

(b) name(s) of the widely used fertilizers/pesticides ________________

(c) amount of application (kg/week or kg/season, specify) ___________

(d) frequency of application in a season (the period of season) _______

7. Factors (past, present or potential) adversely affecting the site's ecological character, including changes in land use and development projects:

(a) at the site:

(b) around the site:

Appendix: 4

CONTINGENT VALUATION QUESTIONNAIRE FOR THE VALUATION OF BIODIVERSITY/WILDLIVES/ RECREATION OF FLOODPLAIN WETLAND ECOSYSTEM OF YAMUNA RIVER IN DELHI CORRIDOR

TO BE FILLED BY THE INTERVIEWER

FILL IN BEFORE INTERVIEW

1. Respondent's Name: ____

   Mr./Mrs./Ms. ____

2. Address: ____

   ____

   ____

   Telephone: ____

3. Date of Interview: ____

4. Start time of the Interview:

____

FILL IN AFTER INTERVIEW

5. End time of the Interview: ____

6. Length of Interview: ____

7. Name of the Interviewer: ____

Please answer the following questions:

1. Have you or other people in your household visited floodplains within the past 12 months?

_____Yes
_____No

® SKIP AHEAD TO QUESTION 2

_

IF YES, which recreational activities have you or other people in your household participated in within the last 12 months? (Please estimate the total number of days of participation for each activity for you and other household members).

RECR RECREATIONAL ACTIVITIES	TOTA TOTAL DAYS OF PARTICIAPTION DURING THE PAST 12 MONTHS

SIGHT SEEING/PLEASURE DRIVING ____________ DAYS

PICNIKING ____________ DAYS

BICYCLING ____________ DAYS

BOATING ____________ DAYS

HIKING, WALKING/JOGGING ____________ DAYS

WILDLIFE OBSERVATION ____________ DAYS

PHOTOGRAPHY (NATURE AND WILDLIFE) ____________ DAYS

DAILY PUBLIC CONVENIENCES ____________ DAYS

OTHER (PLEASE LIST) ____________ DAYS

The next section is about the recreational and wildlife habitat value of floodplains TO YOU. The details presented in this section DO NOT reflect any indication of proposed management plan on behalf of the Delhi/U/P/ Government.

2. The functions of the floodplain along Yamuna in Delhi corridor are flood control, water storage, and preservation of fish and wildlife. If floodplain were managed PRIMARILY FOR WATER RELATED RECREATION AND WILDLIFE HABITAT, what is the MAXIMUM amount you would be WILLING TO PAY in order to have the option of availing these facilities in future through an annual use permit to participate in recreational activities at different floodplain like Okhla, Stretch or Noida More etc (WTP1)

__________________ Rs.0 (NOTHING) ® GO TO QUESTION 3
__________________ Rs. 1-50 ANNUALLY }
__________________ Rs. 51-100 ANNUALLY } SKIP AHEAD TO QUESTION 4
__________________ Rs. 101-150 ANNUALLY } AND DO NOT ANSWER
__________________ Rs. 151-200 ANNUALLY } QUESTION 3
__________________ Rs. 201-250 ANNUALLY }
__________________ Rs. 251-300 ANNUALLY }
__________________ Rs. 300 and above

3. If you chose Rs.0 (NOTHING) in Question 2, which statements best explain your answer. (Check as many that apply)

__________________ I AM NOT FAMILIAR WITH THE FLOOPLAIN
__________________ FLOODPLAIN DOES NOT HAVE ANY VALUE TO ME
__________________ I DO NOT CARE ABOUT FLOODPLAIN
__________________ FLOODPLAIN IS TOO FAR FROM MY HOME

_________________ FLOODPLAIN DOES NOT HAVE THE RECREATIONAL FACILITIES

I NEED

_________________ THERE ARE OTHER RECREATIONAL SITES THAT I PREFER TO

VISIT. (PLEASE LIST ONE OR TWO SITES)____________________

____

________________________ OTHER REASONS (PLEASE LIST)

4. What is the MAXIMUM amount you would be WILLING TO PAY through an annual voluntary donation to ensure that recreational activities and wildlife habitat at floodplains are available in THE FUTURE TO YOU OR YOUR IMMEDIATE DESCENDANTS (WTP2)?

_________________ Rs.0 (NOTHING) ®
_________________ Rs. 1-50 ANNUALLY }
_________________ Rs. 51-100 ANNUALLY }
_________________ Rs. 101-150 ANNUALLY }
_________________ Rs. 151-200 ANNUALLY }
_________________ Rs. 201-250 ANNUALLY }
_________________ Rs. 251-300 ANNUALLY }
_________________ Rs. 300 and above

5. What is the MAXIMUM amount you would be WILLING TO PAY through an annual voluntary donation to ensure that recreational activities and fish/wildlife habitat in the floodplain are AVAILABLE FOR OTHER PEOPLE, even if you do Not intend to visit the floodplain area (WTP3) ?

_________________ Rs.0 (NOTHING) ®

__________________ Rs. 1-50 ANNUALLY }
__________________ Rs. 51-100 ANNUALLY }
__________________ Rs. 101-150 ANNUALLY }
__________________ Rs. 151-200 ANNUALLY }
__________________ Rs. 201-250 ANNUALLY }
__________________ Rs. 251-300 ANNUALLY }
__________________ Rs. 300 and above

In the next section, we would like to find out some characteristics of our survey respondents.

6. Which best describes your home area?

RURAL AGRICULTURAL IN THE CITY
_________ WITH IN 1-5 KM. PERIMETER
__________ WITH IN 6-10 KM "
__________ WITH IN 11-15 KM "

RURAL NON-AGRICULTURAL IN THE CITY
_________ WITH IN 1-5 KM. PERIMETER
__________ WITH IN 6-10 KM "
__________ WITH IN 11-15 KM "

URBAN
_________ WITH IN 1-5 KM. PERIMETER
__________ WITH IN 6-10 KM "
__________ WITH IN 11-15 KM "

7. How far is the one-way distance to the floodplain ever from your home? ________ KM.

8. What is your gender? ________ MALE _______ FEMALE

9. What is your age? _________ YEARS

10. How many people, including yourself, are in your household? (Please circle)

1 2 3 4 5 6 7 8 9 10 OR MORE

11. What is the highest level of education completed by anyone living in your household? (Please check ONE answer)

_____________ Illiterate
_____________ Matriculation (10^{th})
_____________ Intermediate (+2)
_____________ Graduation and above

12. Please indicate the income category that best describes the total gross income from all sources (before taxes and deductions) by you and your family in 1999.

_____________ Less than Rs. 20,000 _________ Rs. 110, 000 to Rs. 129,999
_____________ Rs. 20,000 to Rs. 49,999 _________ Rs. 130,000 to Rs.149,999
_____________ Rs. 50,000 to Rs. 69,999 _________ Rs. 150,000 and above
_____________ Rs. 70,000 to Rs. 89,999
_____________ Rs. 90,000 to Rs.109,999

13. Do you have any suggestions about the management of these floodplain areas?