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RESEARCH ARTICLE Agricultural Science Digest, Volume Issue : ()

Wetland Changes and Ecosystem Services Valuation of Kapla Beel in Assam

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10.18805/ag.D-5934

ABSTRACT

Background: Wetlands are productive ecosystem with immense potentiality of providing various goods and services. But they are fast depleting due to various natural and anthropogenic causes. Kapla beel is a freshwater wetland located in Barpeta district in the lower Brahmaputra valley of Assam. Area of the Kapla beel has been decreasing over the years. This study shall make an attempt to analyse the causes of land use and land cover changes of Kapla beel of Assam and assess its ecosystem services value changes during the period 1990 to 2022.

Methods: To assess the changes, two Landsat images for the year 1990 and 2022 of Kapla beel were taken from the United State Geological Survey (USGS) Earth Explorer. Land-use change analysis was assessed by comparing the areas occupied by each land use in each period using the ArcGIS software. The dynamicity index is used to calculate the rate of change in land cover. In order to assess the changes in the wetland ecosystem service value due to wetland changes, Benefit Transfer Method is used which involves transferring monetary values of ecosystem services from previous studies.

Result: The valuation of ecosystem services underlines the fact that wetlands are highly productive and economically viable ecosystems. Accounting of ecosystem services provides information about the need for optimal decision -making towards judicious use of wetland resources for their sustenance.

Key words: Benefit transfer method, Ecosystem services, Land use and land cover, Wetland.

INTRODUCTION

Wetlands are multifaceted ecosystem having an interface between land and water contributing to ecological, climatic, hydrological, water quality functions and substantially contributing to the livelihood and life support system of people (Arya and Syriac, 2018; Venkatesan *et al*., 2022). It is the most productive ecosystem providing various goods and services such as land for cultivation, water used for growing crops, washing, bathing, consumption, fishing, rearing of animals, collection of fuel-wood, reeds and building materials (Schuyt and Brander,2004). Wetland resources are fast depleting as they are converted and drained off for other uses as most of benefits obtained from wetlands are non-marketable and hence not valued. Economic valuation acts as an important tool for assessing and comparing various benefits obtained from wetlands (Barbier *et al*.,1997).

The dominant factors that lead to change in wetland ecosystem emanates from change in land use and land cover. Wetlands are deteriorating due to encroachment for human settlement, excessive use of wetland soil to carry out agricultural activities, infrastructure development, cutting of trees for timber, fuel wood, overgrazing of animals and over-harvesting of resources such as fish, wild animals, reeds, grazing pastures, thatching grass (Millenium Ecosystem Assessment, 2003). Increasing concentration of nutrients causes eutrophication resulting in shrinking of wetlands, dwindling supply of oxygen and decline storage of carbon-dioxide, loss of aquatic biota disrupting the overall ecological balance of the area (Zhang *et al*., 2007; Swinton *et al*., 2007; Davidson, 2014; CBD, 2015; Zekarias *et al*., 2021). Impairment of wetlands is also caused by natural factors such as erosion, increasing variability in rainfall, sedimentation. This study shall make an attempt to analyse the causes of Land Use and Land Cover (LULC) changes of Kapla beel/wetland of Assam and assess its ecosystem service value changes during the period 1990 to 2022. Inferences drawn from such analysis will help in understanding the importance of wetlands and need for conserving the same without affecting livelihood of wetland dwellers.

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How to cite this article: Mech, A. and Buragohain, P.P. (2024). Wetland Changes and Ecosystem Services Valuation of Kapla Beel in Assam. Agricultural Science Digest. doi: 10.18805/ag.D-5934.

Submitted: 01-01-2024 **Accepted:** 03-04-2024 **Online:** 08-05-2024

MATERIALS AND METHODS

To assess the LULC, two Landsat images for the year 1990 and 2022 were taken from the United State Geological Survey (USGS) Earth Explorer (https://earthexplorer.usgs.gov; accessed on 31st August, 2023). In order to obtain

cloud-free images, datasets were collected in post-monsoon seasons. The remote sensing data is processed to get a good understanding for land use and land cover analysis. The pre-processing of remote sensing data includes atmospheric and geometric correction in order to correct measurement of area, accurate localisation and integration of multi-source data. LULC within Kapla beel are classified into open water, aquatic plants, vegetation, agricultural land and built-up area. Open water includes clear water surface with no vegetation cover of the wetland. Aquatic plants include water with vegetated cover which includes free-floating, floating leaves and emergent aquatic plants. Vegetation includes sparsely vegetated areas, densely vegetated areas and grassland. Agricultural land includes cropland and agricultural fallow land. Built-up area includes settlements, road networks, concrete surfaces and commercial buildings (Lahon *et al*., 2023).

One common method for estimating changes to ecosystem is to monitor changes in ecosystem services over specific periods. By comparing the changes of ecosystems in different periods, amount of damage can be estimated (Qian *et al*., 2018). The dynamicity index is used to calculate rate of change in land cover which is calculated as follows:

$$K = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100$$

Where,

K = Dynamicity index.

U_a and U_b = LULC area at the beginning and end of the studied periods respectively.

T = Number of years studied.

The value of K represents change rate per year of a certain land-use/land-cover type.

LULC spatial-temporal changes can also be assessed using the following formula:

$$CP\text{- }LULC_k = \frac{LULC\ end - LULC\ start}{LULC\ start} \times 100$$

Where,

$CP - LULC_k$ = Change in the area of the land use type k.

$LULC_{end}$ and $LULC_{start}$ = Area of the land use type k in the present and past years respectively.

In order to assess the wetland ecosystem service value changes, Benefit Transfer Method is used. Benefit transfer is used when it is too expensive or there is too little time available to conduct an original valuation study including the valuation of all ecosystem services provided by wetland. Ecosystem services are benefits provided by wetland ecosystems which value is assessed considering provisioning services, regulating, supporting and cultural services. The provisioning services of wetland are calculated by the following equation (1):

$$PS = \Sigma_{i=1}^{11} PS_i \times A \quad ...(1)$$

Where,

PS = Total provisioning services provided by Kapla beel.

i = Various provisioning services (i=1 to 11 services).

A = Area of Kapla beel but for assessing value of macrophytes, irrigation the macrophyte cover area and irrigated area is considered respectively.

For assessing value obtained from crop cultivation, leased in area of Kapla beel where boro paddy is generally grown is considered. Benefit derived from growing boro paddy is assessed through estimating the net monetary benefit obtained from boro crop per hectare which is estimated with the help of the following equation (2):

$$NF = V - C \quad ...(2)$$

Where,

NF = Net monetary annual benefits from growing boro rice.

V = Annual monetary value obtained from sale of boro rice.

C = Annual costs incurred in growing boro paddy which include seed cost, machine cost, labour cost, cost on manure, pesticides, irrigation and threshing.

The regulating services of wetland are calculated by the following equation (3):

$$RS = \Sigma_{i=1}^{15} RS_i \times A \quad ...(3)$$

Where,

RS = Total regulating services provided by Kapla beel.

i = Various regulating services (i=1 to 15 services).

A = Area of Kapla beel.

The supporting services of wetland are calculated by the following equation (4):

$$SS = \Sigma_{i=1}^{2} SS_i \times A \quad ...(4)$$

Where,

SS = Total supporting service provided by Kapla beel.

i = Two supporting services.

A = Area of Kapla beel.

The cultural services of wetland are calculated by the following equation (5):

$$CS = \Sigma_{i=1}^{7} CS_i \times A \quad ...(5)$$

Where,

CS = Total cultural services provided by Kapla beel.

i = Various cultural services (i=1 to 7 services).

A = Area of Kapla beel.

The Total Ecosystem Services Value (TESV) is calculated by the using the following equation (6) which is the summation of value obtained from provisioning, regulating, supporting and cultural services from the wetland namely Kapla beel.

$$TESV = \Sigma_{i=1}^{4} PS + RS + SS + CS \quad ...(6)$$

Net present value (NPV) of the resources is estimated on the basis that these resources yield an annual flow of non-monetary or “in-kind” values. If this annual value flow is expected to continue indefinitely or for as long as the resource is utilised sustainably then the relationship

between net present value and discount rate can be expressed as NPV= total ecosystem service value /discount rate. Discount rate of 12 per cent which is equivalent of interest rate of loan of Bandhan bank is considered as people residing in vicinity of the wetland rely upon this bank due to easy availability of loan.

RESULTS AND DISCUSSION

Kapla beel is a freshwater wetland located in Barpeta district in the lower Brahmaputra valley of Assam covering an area of about 91 hectares. It lies at the intersection of 26°15″-26°30″N latitude and 91°0″- 91°15″E longitude. The beel lies about 120 km from Guwahati; almost 4 km from Sarthebari and 28 km from Barpeta town. The beel is surrounded by villages, grazing lands, agricultural lands and wetlands. Most of the people residing in its vicinity are directly or indirectly dependent upon wetland resources for their living (Deka, 2009). The section below discusses about the LULC changes of Kapla beel area.

Analysis of land-use/Land-cover changes of kapla beel

Land-use/Land-cover analysis within Kapla beel comprises of open water, area under aquatic plants, vegetation, agricultural land and built-up area. The areas of five land use/Landcover classes within Kapla beel for the year 1990 and 2022 are shown in the following Table 1. Out of the total area of the Kapla beel, area under open water within the wetland has been declining by 53.88 percent with increasing weed proliferation. The water spread area has been declining from 47.75 hectare in 1990 to 22.02 hectares in 2022 due to expansion of agricultural activities in the wetland area, construction of fish ponds within the wetland area through making of bunds around the ponds, construction of dykes around the wetland which has restricted the connectivity of wetland with the river, aggravating the problem of eutrophication. Due to blockage of feeder channels area under aquatic plants has been increasing by 49.96 per cent while that of vegetation has been declining by 88.83 per cent. Area under agriculture and built-up area has been increasing as wetlands are encroached for carrying out boro paddy cultivation and for settlement.

In order to understand importance of wetland and need for conserving the depleted wetland, assessment of wetland ecosystem service value changes is studied in the next section.

Assessment of the wetland ecosystem service value changes of kapla beel

Ecosystem services are accounted through benefit transfer method which involved compilation of data from primary and secondary sources (government agencies, published papers in peer-reviewed journals). Provisioning services of ecosystems are accounted through the residual value method which has been utilised to estimate value of an ecosystem services by taking gross value of final marketed goods to which ecosystem services provides input and then cost of all non-ecosystem inputs including labour, produced assets, intermediate inputs are deducted (UNSD, 2021). Regulating, supporting and cultural services are based on case studies from India which are compared with the global ecosystem service valuation database (ESVD) and published literature comprising of various case studies from India considering GDP (PPP) per capita for India and currency exchange rate. The provisioning services includes food, water, timber, fiber, genetic resources, microalgae, fish and macrophytes. The value of food which includes crop and fish are obtained from field analysis. The value of other provisioning services such as water, raw materials, genetic resources, medicinal resources, ornamental, fuelwood, irrigation, microalgae and macrophyte are obtained from secondary sources.

Summer paddy locally know as *boro* rice is generally cultivated in the fringe areas of Kapla beel after the water level recedes. These areas are rich in organic matter with available moisture and requires minimum tillage with low application of manures and fertilizers. The cost incurred and returns obtained from one hectare boro rice production is shown in the following Table 2. Seed requirement for transplanting one hectare of the main field is 40-45 kg costing about Rs 2800. Wet seed beds are used for raising boro rice seedlings and most of the farmers grew boro rice in these swampy areas without ploughing and few ploughed once or twice. They generally do not apply fertilisers as the soil is fertile. They practice manual weed clearance measures to clear weeds which grows haphazardly in the swamp areas disturbing the growth of boro paddy crops. Households who grow boro paddy around the buffer zone of Kapla beel cultivates in marginal lands with an average size of 0.13 hectares (1 bighas) to 0.54 hectares (4 bighas). They do not possess any land

Table 1: Land-use/Landcover changes within Kapla Beel, 1990-2022.

Classes	Area (in hectares) 1990	Area (in hectares) 2022	Spatial-temporal changes	Dynamicity index
Total area of the kapla beel	91	61.42	-32.51	-1.016
Open water	47.75	22.02	-53.88	-1.684
Aquatic plants	27.20	40.79	49.96	1.561
Vegetation	10.56	1.18	-88.83	-2.776
Agricultural land	4.67	25.91	454.82	14.213
Built up area	0.82	1.10	34.146	1.067

ownership rights as these lands are government-owned. About 25.91 hectares of land in the fringe areas of the Kapla beel are used for growing boro paddy.

Total labour cost which includes both hired and family labour is Rs 11,900 for growing boro rice. After harvesting of crops, plants are tied in bundles and are carried to the backyard of farmers' house where threshing is done costing about Rs.4998 per hectare. As boro crop is grown in the winter season so irrigating the crops becomes essential and per hectare average cost of irrigation is Rs 6,720. About one tone of manure is applied to the crops per hectare costing about Rs 1200 and 16 litres of pesticides are applied to the crops costing about Rs 2400. The paid-out costs constitute the working capital and the prevailing bank rate *i.e.*, 10 per cent is used to assess the interest on working capital for duration of the crop and is found to be Rs 1763.40. Rental value of land is taken as rent paid for leasing in the land as the land is leased out by the village panchayat and rent paid for one hectare of land is Rs 11,250. Depreciation of farm implements includes the cost incurred on the minor repairs which is about Rs 1250. Fixed capital includes the assets, equipment and the prevailing bank rate of interest of 10 percent is used to assess the interest on fixed capital and is estimated as Rs. 3161.50. The total cost incurred in boro rice cultivation is estimated to be Rs 52,692.90 per hectare. The grain yield of boro rice is 67.23 quintals per hectare and the income obtained from the main product *i.e.*, grains is Rs 1,21,014. Return from by-products includes straw, husk and rice bran and average income obtained from selling these by-products is Rs 3800. Gross return from main product and by product is Rs 1,24,814 and the net return which is obtained by deducting cost from gross income is Rs. 72,121.10. As 25.91 hectares of land in the fringe areas of Kapla beel is used for growing boro paddy so the total net return is Rs 18,68,658.

The benefit obtained from crop cultivation has increased over the years from 1990 to 2022 with the increase in the area used for cultivation from 4.67 hectares to 25.91 hectares. Kapla beel has been continuing to be lost due to conversion of wetland area into agricultural land during dry season to support livelihood of the wetland dwellers.

The Wetland ecosystem services valuation changes of Kapla beel has been depicted in Table 3.

Fish compose protein, micronutrients and essential fatty acids which is an important component of human diet. *Labeo rohita, Labeo gonius, Catla catla, Chitala chitala, Channa striatas, Channa punctatus, Heteropneustes fossilis, Labes calbasu* and *Wallago attu* are commonly found in the beel. Fish catch per hectare has been declining over the years due to increasing weed proliferation; blockage of feeder channel; construction of embankments around the beel hampering fish movement and growth, overfishing and wetland pollution due to flow of chemicals and pesticides from the nearby agricultural areas.

Table 2: Economic analysis of per hectare boro rice production in the fringe areas of Kapla beel.

Name of items	Cost incurred and returns obtained
Seed (kg/hectare)	2800
Tractor/Power tiller cost	5250
Human labour cost (in Rs) (3.1+3.2+3.3+3.4+3.5+3.6)	11900
Land preparation	1200
Transplanting	1600
Weed clearance	2400
Harvesting and bundling	2800
Carrying	2400
Insecticide application	900
Fertiliser used	-
Manure (kg/ha)	1200
Fuel for irrigation	6720
Cost of pesticides	2400
Cost on Threshing	4998
Interest on operating capital @10% for 6 months	1763.4
Rental value of land	11250
Depreciation of farm implements	1250
Interest on fixed capital @ 10%	3161.50
Total cost	52692.90
Return from the main product (grains)	1,21,014
Return from the by-product (straw, husk and rice bran)	3800
Gross return	1,24,814
Net return	72,121.10

Source: Field survey.

Table 3: Wetland ecosystem services valuation of Kapla beel.

Sl no.	Services	Unit value (INR/ha/year)	Kapla beel (Area = 91 hectares) 1990	Kapla beel (Area = 61.42 ha) 2022	Differences in ecosystem services value (1990-2022)
I.			**Provisioning services (in ₹)**		
PS1	Crop cultivation		3,36,806 (4.67 hectares)	18,68,658 (25.91 ha)	15,31,852
PS2	Fish		19,65,600 (270kg × ₹ 80 × 91 ha)	9,33,584 (190kg × ₹ 80 × 61.42 ha)	-10,32,016
PS3	Water	15,359	7,33,392 (47.75 ha)	338205(22.02 ha)	-3,95,187
PS4	Raw materials	13,358	12,15,578	820448	-3,95,130
PS5	Genetic resources	476	43,316	29236	-14,080
PS6	Medicinal resources	786	71,526	48276	-23,250
PS7	Ornamental resources	905	82,355	55585	-26,770
PS8	Fuelwood	5,833	61,596 (10.56 ha)	6883 (1.18 ha)	-54,714
PS9	Irrigation	1826	0	19922 (10.91 ha)	19,922
PS10	Microalgae	1,10,467	30,04,702 (27.20ha)	45,05,949 (40.79 ha)	15,01,247
PS11	Macrophyte	11,291	3,07,115 (27.20 ha)	460560 (40.79 ha)	1,53,445
	Total provisioning service value (₹)		78,21,987	90,87,306	12,65,319
II.			**Regulating services (in ₹)**		
RS1	Air quality regulation	270	24,570	16583.4	-7987
RS2	Climate regulation	1,191	1,08,381	73151.22	-35,230
RS3	Moderation of extreme events	1,05,781	96,26,071	6497069	-31,29,002
RS4	Regulation of water flows	28,891	26,29,081	1774485	-8,54,596
RS5	Waste treatment	16,225	14,76,475	996539.5	-4,79,936
RS6	Erosion prevention	20,704	18,84,064	1271640	-6,12,424
RS7	Maintenance of soil fertility	13,604	12,37,964	835557.7	-4,02,406
RS8	Biological control	7,529	6,85,139	462431.20	-2,22,708
RS9	Carbon sequestration	2,34,716	2,13,59,156	14416257	-69,42,899
RS10	Water-borne diseases	1,941	1,76,631	119216.2	-57,415
RS11	Pollination	19	1729	1166.98	-562.02
RS12	Water conservation	2,875	2,61,625	176582.5	-85,043
RS13	Flood control	7,053	6,41,823	433195.3	-2,08,628
RS14	Habitat	1,825	1,66,075	112091.5	-53,984
RS15	Groundwater recharge	2,15,123	1,95,76,193	13212855	-63,63,338
	Total regulating services value (in ₹)		5,98,54,977	4,03,98,821	-1,94,56,156
III			**Supporting services (in ₹)**		
SS1	Lifecycle maintenance	14,978	13,62,998	9,19,948.8	-4,43,049
SS2	Maintenance of genetic diversity	27,216	24,76,656	16,71,607	-8,05,049
	Total supporting services value (in ₹)		38,39,654	25,91,555	-12,48,099

Table 3: Continue....

Table 3: Continue....

IV			**Cultural Services (in ₹)**		
CS1	Aesthetic information	389	35,399	23892.38	-11,507
CS2	Opportunities for recreation and tourism	12,111	11,02,101	743857.6	-3,58,243
CS3	Inspiration for culture, art and design	905	82,355	55585.1	-26,770
CS4	Spiritual experience	8	728	491.36	-236.64
CS5	Information for cognitive development	953	86,723	58533.26	-28,190
CS6	Existence and bequest values	91,312	83,09,392	5608383	-27,01,009
CS7	Education	29,144	26,52,104	1790024	-8,62,080
	Total cultural services value (in ₹)		1,22,68,802	82,80,767	-39,88,035
	Total ecosystem supply value (TESV)		8,37,85,420	6,20,66,798.6	-2,17,18,621.40
	Net present value of wetland ecosystem services		69,82,11,836	51,72,23,321.7	-18,09,88,514.30

Source: Unit value/hectare/year related to crop cultivation and fish is collected from field survey; other services unit value data were obtained from Ramachandra, Sincy and Asulabha, 2021.

Value of provisioning services provided by raw materials, genetic resources, medicinal resources and ornamental resources has been declining with the fall in the area of the Kapla beel due to invasion of exotic aquatic weed like *Eichhornia crassipes* and some other dominant aquatic macrophytes which after death and decay increased the peat formation in the wetland increasing the shallowness of the Kapla beel (Deka *et al*., 2015).

Microalgae are photosynthetic microorganism sequestering carbon during photosynthesis in the presence of solar energy converting to carbohydrates and oxygen. (Ramachandra *et al*., 2021). With the increase in area under microalgae in Kapla beel the value that can be obtained if such microalgae biomass is converted to some productive use increases. Macrophyte provides food, fodder, medicine, green manure, source of fibres, fuel, leaves used as vegetables, used as fish food. Wetland dwellers of the Kapla beel are engaged in collecting various aquatic plants such as *Marsilea quadrifolia, Eichornia crassipes, Azolla pinnata, Ipomoea aquatica, Aeschynomene indica, Alternanthera sessilis, Colocasia esculenta, Alpinia galanga, Lemna perpusilla, Ipomoea fistulosa, Hymenachne assamica, Leersia hexandra, Eichhornia crassipes, Enhydra fluctuans* which have numerous value such as used as food and medicinal purpose. Water hyacinth is used as raw material in crafting industry (Deka and Dutta, 2020). Value obtained from macrophytes has increased by ₹ 1,53,445 over the period 1990-2022 with the increase in the area under aquatic plants from 27.20 hectares to 40.79 hectares.

Wetlands regulate several important ecosystem processes. Three significant regulating services are water quality improvement, flood abatement and carbon management. Wetlands purify water through storing nutrients and other pollutants in their soils, vegetation and trapping sediments. Wetlands are natural frontline defences against catastrophic weather events, providing a physical barrier to slow speed and reduce heights and force of floodwaters. The roots of wetland plants bind the wetland- water boundary to resist erosion. Wetlands have capacity to reduce flood peak magnitude by acting as natural reservoirs that can receive volumes of flood water and also regulate water flow by slowly releasing flood water to downstream areas (Ramsar, 2009; Tanner and Sukias, 2011; Clarkson *et al*., 2013). The value of regulating services of Kapla beel over the period 1990 to 2022 has declined by ₹ 1,94,56,156.

Supporting services such as lifecycle maintenance and maintenance of genetic diversity are necessary for sustaining vital ecosystem functions and the production of all other ecosystem services. They differ from other services such as provisioning, regulating and cultural services as their impact on people and societies are often indirect or occur over long-time frames whereas change in other services have relatively direct and short-term impacts (TEEB, 2013). The value of supporting services of Kapla

beel over the period 1990 to 2022 has declined by ₹ 12,48,099.

Wetlands also provide some non-material benefits such as cultural, spiritual, aesthetic and educational values. They also provide opportunities for recreation and tourism. The wetland landscapes and wildlife we value typically result from complex interactions between people and nature over centuries. Once these intimate linkages are damaged or destroyed it is rarely possible to restore or recreate them (Ramsar, 2009). Kapla beel has immense potentiality of attracting diverse recreational and ecotourism. Total cultural service value of Kapla beel has been declining by ₹ 39,88,035.

Total ecosystem service value depends on spatial extent and condition of the ecosystem. TESV has decreased from ₹ 8,37,85,420 in 1990 to ₹ 6,20,66,798.60 in 2022. Net present value is computed on basis of annual flow of TESV shows the worth of ecosystem services of wetlands.

CONCLUSION

Valuation of ecosystem services underlines the fact that wetlands are highly productive and economically viable ecosystems and accounting of ecosystem services provides information about the need for optimal decision - making towards judicious use of wetland resources. But wetlands are changing due to anthropogenic and natural causes and the need of the hour is to conserve the wetland. It needs to be protected and enhanced by restricting conversion of wetland for agriculture purpose; reducing use of fertilizers and pesticides; promoting integrated sustainable diverse farming practice combining crop-livestock and fishing system maintaining the ecological character of Kapla beel. Removal of unwanted aquatic weeds periodically will enhance nutrient status of the Kapla beel. Stringent actions should be taken against illegal encroachers. Ecotourism projects should be undertaken without endangering the biological diversity of Kapla beel for flourishing wetland tourism which will enhance employment opportunities.

Funding and conflict of interest

There was no funding available for this study and there is no conflict of interest.

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