RESEARCH ARTICLE

Implications of Land Use Dynamics on Ecosystem Service Value: A Case Study from Goalpara District of Assam, Northeast India

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Abstract

Systematic studies on implications of land use change on ecosystem service value (ESV) at landscape level are scarce in Northeast India hence, a case study was undertaken in the vicinity of Ghagra Pahar Forest (GPF) predominated by tropical deciduous forest in Goalpara district of Assam. Study aims to assess the ecosystem services (ES) provided by the forest ecosystem. Altogether 23 ES were identified and grouped based on peoples' knowledge and perceptions. Study area has been categorized in to six land use types. Temporal change analysis revealed that the area coverage under plantation, agriculture and settlement expanded, on the contrary, forest cover, water bodies and grassland decreased remarkably within a time gap of 20 years. The total ESV for the study area was disproportionately distributed among the different functions of ecosystem. Agricultural land contributed the maximum ESV. The total ESV declined at a rate of 0.64 percent per year with a net decrease of 12.7 percent. Sensitivity analysis shows that the values were less than unity indicating that total ecosystem service values would fluctuate only by 0.03-0.42 percent. Results of this study would be useful to the land use planners and policy makers to prioritise conservation efforts for sustainable resource management.

Keywords: Ecosystem services, Land use/cover, LUDD, Management, Sensitivity analysis, Valuation.

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Introduction

Ecosystem services (ES) are emphasised as the benefits that people derive from various ecosystems. The concept of ES gained its momentum when the United Nations published its Millennium Ecosystem Assessment report (MEA, 2005). Another noteworthy global initiative was witnessed between 2007 and 2010 under the banner of The Economics of Ecosystems and Biodiversity (TEEB) by the United Nations Environment Programme (UNEP). A myriad of groups and organisations have emphasized at various scales (worldwide to landscape) and levels (international to regional) for better perception towards utility, valuation, modelling and sustainable management of ecosystem services. The benefits provided by the natural ecosystem to the people accentuated as ecosystem services are primarily categorised into provisioning, regulating, supporting, and cultural services (MEA, 2005). In the present scenario, many of these services of ecological systems are critical to the functioning of Earth's life supporting system (Costanza *et al.*, 1997b). Ecosystem functions are the conditions and processes that can fulfil human needs and living standard in terms of goods and services of the ecosystem (Daily, 1997; TEEB Foundations, 2010; Zhou and Shi, 2011). Valuation of ecosystem services is still limited to a specific services (de Groot *et al.*, 2012) and specially concentrated to tangible benefits such as fire-wood, timber, NTFPs etc. (Ninan and Kontoleon, 2016). Benefits derived from intangible services such as water regulation, water purification, climate regulation, photosynthesis, nutrient cycling etc. have still not gained momentum in valuation mainly because they are not traded or difficult to valuate (Ninan and Kontoleon, 2016). Despite difficulties and fraught with uncertainties (Costanza *et al.*, 1997a,b) included both tangible and intangible services in their work and grouped ecosystem service functions into 17 major categories and provided a global database of ecosystem services values (ESV) for the major biomes of the world. This work inspired later researchers to work on ecosystem services valuation including land use dynamics and to assess the ecological and economic impacts of change in the services (Kreuter *et al.*, 2001; Tianhong *et al.*, 2010; Zhou and Shi, 2011; Bian and Lu, 2013; Gong *et al.*, 2017; Akber *et al.*, 2018; Arowolo *et al.*, 2018).

Land use change is one of the most important drivers of ecosystem change at every level from global to regional and has extensive impact on environmental equilibrium (Bian and Lu, 2013). Land use change also has an influence on climate change, and biodiversity (Wang and Sun, 2016). Alternation of land use mainly due to human interference has significantly affected the natural environment and has modified the earth exterior drastically (Gong *et al.*, 2017). Rapid conversion of land uses has altered the structural integrity of the ecosystems, leading to the change in ecosystem functions and services and the values associated with these services. Although, a handful of literatures are available on land use change and its impact on ecosystem services value across the globe, there is a dearth of studies at national and regional levels. Such studies particularly in the tropical forest ecosystems are meagre for India in general and north-eastern India in particular. Also, systematic studies on implications of land use change on ecosystem service values at landscape level are scarce in Northeast India. Hence,

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a case study was undertaken in Ghagra Pahar Forest (GPF) and its vicinity in Goalpara district, Assam, predominated by tropical deciduous forest and with remarkable land use variations to assess the ecosystem services delivered by the GPF. Study aims to analyse the implications of land use change on ecosystem services values. The ecosystem service concept at the local or regional scale can act as a decision support tool for a land use planner and to attain sustainable land use management (Wang *et al.*, 2015) and to find out the conservation necessities of natural resources and sustainable land use management.

Materials and Methodology

Study area

The study was conducted within a geographical area of 1256 hectares in the vicinity of Ghagra Pahar Forest (Fig. 1). The GPF is a hilly forest patch dominated by Sal trees (*Shorea robusta*) in the foot hills whereas the upper region of the hill is endowed with mixed vegetation. A large number of streams flow down the hill through the forest. The study area also comprises of human habitations grouped into several villages surrounding the GPF. The GPF falls under Rangjuli forest circle and is situated 64 km east from Goalpara, the district headquarters. The district's annual mean temperature ranged between 7-33°C and relative humidity ranged between 67% and 90%. Monsoon begins from early June and experiences heavy showers till the month of October. About 80% of the rainfall is received from the south-west monsoon. The maximum temperature is reached during July to August and dips down to the minimum in the month of January (CGWB, 2013).

The present study undertook GPF area as a case study to assess the existing ecosystem services and functions in order to estimate the ecosystem services value. The study site was a typical rural landscape with a variety of land covers under different land uses. During the field survey and interaction with the local villages it was found that the study site had ethno botanical glory and rich natural wealth in terms of forest, water-bodies and grassland. The villagers especially the elder people mentioned that the natural resources were declining tremendously. A vast change was perceived by them regarding the degradation of the natural resources and noticeable change in land cover area over the period of 20 years. Introduction of economically important trees in place of natural forest, use of pesticides in the agricultural fields as well as home gardens, application of advanced fishing nets was among the major drivers of ecosystem degradation as mentioned by the elder villagers. To strengthen the ground observed hypothesis, the study area was also assessed by satellite imageries from 1998 to 2018 to analyse the changes in land use. The study area was classified into six classes for detailed study (Table 1).

The radius of 2 km from the centre core region (26°0′ 56.32″ N and 90°57′ 47.57″ E) of GPF was demarcated as the study area for detailed study. Reconnaissance field survey was carried out to understand the land use of the study area. A detailed investigations and interviews with the local villagers, ground truth data and GPS points of different land use were collected. Thereafter, cloud free satellite imageries of 30 m resolution of Landsat OLI for the period 1998 and 2018 were downloaded using Earth explorer to estimate the land use change over a period of 20 years. Radiometric enhancement was done where 15 m panchromatic band was used for improving spatial resolution of the images followed by layer stacking. Images were extracted and classified using both supervised and unsupervised classification. Study area was

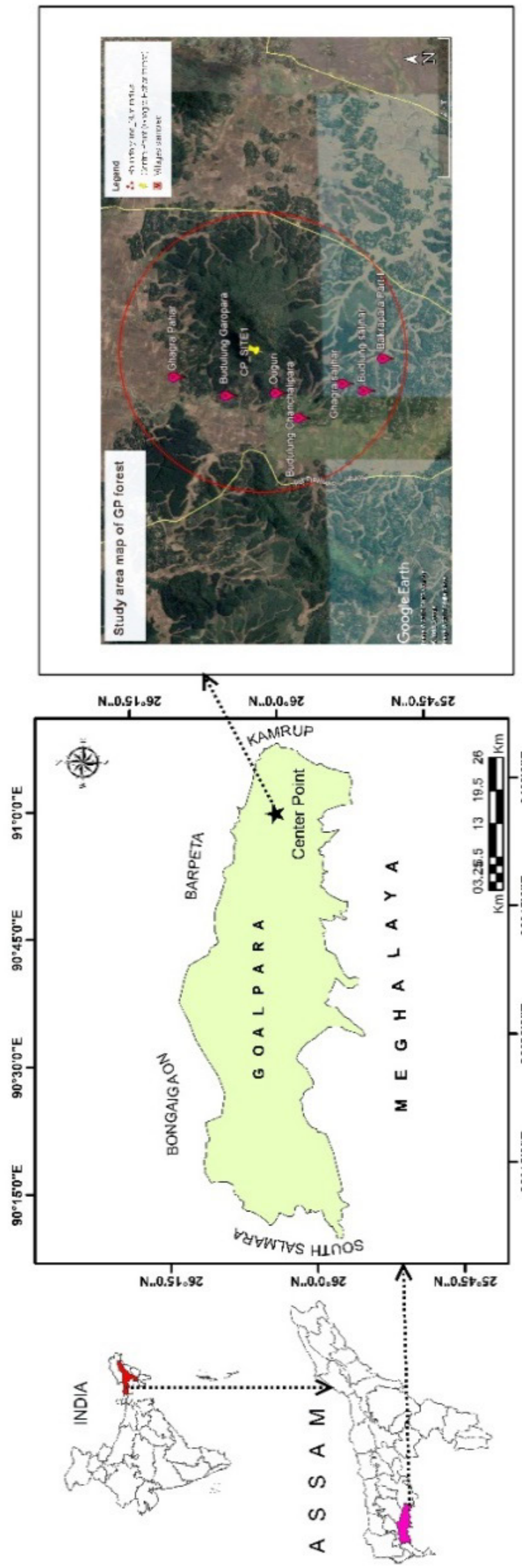

Fig. 1: Map of study area.

Table 1: Ecosystem service value of unit area of different land use types in (2018 Rs./ha/yr) and quantification of land use change between 1998 and 2018 (in hectare) in the vicinity of GhagraPahar forest.

Landuse types	*Equivalent biome*	*Ecosystem service coefficient value (ESV_C) (2018 Rs. $ha^{-1}yr^{-1}$)*	*Area (hectare)*				
			1998	*2018*	*Change (Value)*	*Change (%)*	*LUDD ($\%yr^{-1}$)*
Forest	Forest	162433.83	578.25	392.26	-185.99	-32.16	-1.61
Plantation	Plantation	NA	60.15	179.98	+119.83	+199.22	+9.96
Agriculture	Cropland	338620.48	340.23	351.8	+11.57	+3.40	+0.17
Water bodies	Rivers/lakes	645082.62	45.00	33.05	-11.95	-26.67	-1.33
Grassland	Grass/Rangeland	273003.78	91.96	68.18	-23.78	-25.86	-1.29
Settlement and others	Urban	63016.66	140.41	230.93	+90.52	+64.47	+3.22

(+) indicates increase; (-) indicates decrease

classified into six major land use types (Fig. 2). The software ERDAS (ver. 9.1) was used for pre-treatment of the images and classification and ArcGIS (10.3.1 version) to prepare land use maps. Accuracy assessments were also done using a field investigation technique for validation of the classified map.

Based on peoples' knowledge and perception towards ecosystem, a participatory based approach was adopted to make an assessment. A total of 7 villages werein 70 households and 15 members out of which 9 were female were considered for the assessment (group discussion/personal interview). Categorization of services was based on Costanza *et al.* (1997b) and the report of Ecosystems and Human Well-being: Synthesis of MEA (2005).

Land use dynamic degree (LUDD)

LUDD is among important parameter to quantitatively describe the changing rate of land use change over a period of time. It is also prominently used in comparing land use change and predicting the future trend of land use change (Zhou and Shi, 2011). Hence, the present study emphasizes on LUDD in the study area using following equations:

$$K = \frac{A_i - A_f}{A_i} \times 100\%$$

$$C = \frac{K}{T}$$

Where: K is the percentage of change in area of a land use and A_i and A_f indicates the initial and final area of the land use taken into account. C is the land use dynamic degree of a given land use within the study period and T is the time period in years.

Evaluation of ecosystem services value (ESV)

Ecosystem services value is considered as the total economic value of the services of a given ecosystem at a regional level within the specified area of a particular land use category. In the present study, ESV of five major land use types were evaluated using Costanza *et al.* (2014) average global values of annual ecosystem services (Table 2). The ESV for each land use type per unit area was assigned based on the equivalent coefficient value of the ecosystem services proposed by Costanza *et al.* (2014). The model used to calculate ESV for each land use type is as follows:

$$ESV_l = \sum_f A_l \times VC_{lf} \qquad \text{...(X)}$$

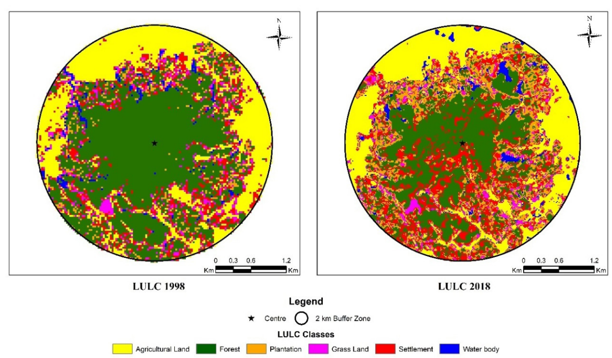

Fig. 2: LULC maps of the study area for two different years (1998 and 2018).

Table 2: Global average unit values of annual ecosystem services converted in 2018 (Rs. $ha^{-1}yr^{-1}$) from ESV database by Costanza *et al.* (2014, 1997b); de Groot *et al*. (2012).

Ecosystem functions	*Forest*	*Agriculture*	*Water bodies*	*Grassland*	*Settlement and others*
Gas regulation (GR)	273.69	0.00	0.00	615.80	0.00
Climate regulation (CR)	48648.04	28121.44	0.00	2736.88	61921.91
Water regulation (WR)	205.27	0.00	514122.91	205.27	1094.75
Water supply (WS)	9784.35	27368.80	123706.98	4105.32	0.00
Soil formation (SF)	957.91	36400.50	0.00	136.84	0.00
Pollination (PO)	615.80	1505.28	0.00	2394.77	0.00
Habitat regulation (HR)	42353.22	0.00	0.00	83064.31	0.00
Food production (FP)	18473.94	158944.31	7252.73	81559.02	0.00
Raw material (RM)	10400.14	14984.42	0.00	3694.79	0.00
Genetic resources (GeR)	30653.06	71295.72	0.00	83064.31	0.00
Cultural (CU)	68.42	0.00	0.00	11426.47	0.00
Total	162433.83	338620.48	645082.62	273003.78	63016.66

$$ESV_f = \sum_l A_l \times VC_{lf} \quad ...(Y)$$

$$ESV = \sum_l \sum_f A_l \times VC_{lf} \quad ...(Z)$$

Where: A_l represents the area for the land use type in hectare and VC_{lf} represents the value coefficient, VC_{lf} is the ecosystem service function value index for land use type (l) and ecosystem service function (f) in US\$ha^{-1}yr^{-1}. In order to determine the effect of land use change on each of the ecosystem functions within the time frame of 20 years, was calculated using the ecosystem services coefficients value assigned by Costanza *et al.* (2014) in his global ESV database. As in the previous studies, there was no best fit biome that could represent the plantation land use, the calculation of ES value for plantation land use is not considered in the present study.

Sensitivity analysis

Based on the standard economic concept of elasticity, the coefficient of sensitivity (C_S) was calculated. It is the percentage change in the output for a given percentage change in an input (https://opentextbc.ca/principlesofeconomics/chapter/5-1). In the present study, it determines the percentage change in ESV for a given percentage change in V_C. In order to find out the robustness of the estimates and feasibility of the proxy values used for land use categories, C_S was calculated using the following model.

$$C_S = \left| \frac{(ESV_{zl} - ESV_{al})/ESV_a}{(V_{czl} - V_{cal})/V_{cal}} \right| \quad ...(S)$$

Where: z and a represents the adjusted and initial values respectively and l is the land use category. C_S determines the level of dependency of ESV on the ESV coefficient (V_C) and assures that the coefficients used are relevant for the study area. If C_S value was less than unity, the ESV is inelastic and the ESVs are robust with respect to the study area whereas if C_S value was greater than one, the ESV was more critical for the study area as the ESV is directly proportional with the coefficient (Bian and Lu, 2013). It is then essential to use more accurate ESV coefficient (V_C) for better estimate of the ecosystem service value (Kreuter *et al.*, 2001; Li *et al.*, 2008; Zhang *et al.*, 2015). Greater the value of C_S the more critical the accuracy of the ESV coefficient (V_C) on evaluation (Mamat *et al.*, 2018).

Results

Land use change and ecosystem services assessment

Land use/cover was classified into forest, plantation, agriculture, water bodies, grassland and settlement and other categories. The area coverage and changes in area of different land use categories are given in Table 4. The area coverage under plantation, agriculture and settlement expanded during the period from 1998 to 2018. On the contrary, area under forest cover, water bodies and grassland decreased remarkably within a time gap of 20 years. Among all the land use categories, plantation had shown a tremendous change in the land cover showing about three-fold (199.22%). Consequently, giving the highest rate of land use dynamic degree (LUDD) of 9.96%. On the other hand, a least increase was noticed in the agricultural land use (3.40%) giving the least LUDD (0.17%) in the increasing land use pattern. A decrease in land use area was seen highest in forest land use with 32.16% of the land area prevailing in 1998 and the least was seen in grassland category (25.86%). At the same time, forest area recorded the maximum LUDD (1.61%) followed by water bodies (1.33%) and the minimum in grassland (1.29%). Based on the peoples' perception and knowledge from the household surveys and personal interviews,twenty-three ecosystem services were identified (7 villages). On the basis of ecosystem goods and services (Costanza *et al.*, 1997b) the identified services were categorised into eleven functions*. Further, these functions were classified into broader categories**- provisioning (12 services), followed by regulating (6 services), supporting (3 services) and cultural/aesthetic (2 services) (Table 3).

Ecosystem services compositions function value

Utilizing the land use data (Table 1), and the ESV_C (Table 1-2) and applying them in the models (X), (Y) and (Z), the ecosystem services value (ESV) for different time period for each land use categories of every ecosystem function and the ESV for the entire study area were calculated. The ESV of all the identified individual ecosystem functions of the study area were calculated using the model (Y) and presented in Table 4 for both the years (1998 and 2018). It was noticed that the total ESV for the entire study area was disproportionately distributed among the different functions of ecosystem. In the forest land use category, ecosystem functions such as climate regulation, habitat regulation, genetic resources and food production had recorded greater ESV_f and their overall contribution towards total ESV was above 86.27%. In the agricultural land use category, food production, genetic resource and soil formation, were in the higher range (10.75-46.94%) in terms of contribution ratio towards total ESV. Cultural service function was the least to contribute in the total ESV with 0.04%. Pollination function accounted for least contribution of 0.44% of the total ESV. In case of water bodies, water resource, water supply and food production were the only functions whose ESV_f were taken into account in estimation of the total ESV for this category of land use. Water resource contributed the highest (79.70%) followed by water supply (19.18%) and food production (1.12%) to the total ESV for water bodies as land use category. In the grassland land use, genetic resource and habitat regulation were the two ecosystem functions that contributed with an equal service value of Rs. 7,638,593.76 (in 1998) and Rs. 5,663,324.52 (in 2018) rendering a contribution ratio of 30.43% of the total ESV in each case. Soil formation (0.05%) and water regulation (0.07%) contributed the minimum ESV_f toward the total ESV for the grassland land use. Climate regulation and water regulation were the only two function that contributed the entire ESV for the settlement category of land use with contribution ratio of 98.26 % and 1.73%, respectively. In the time series analysis, a similar kind of shape and trend was noticed in the contribution ratio curves for the two assessment periods among different ecosystem services functions (Fig. 3).

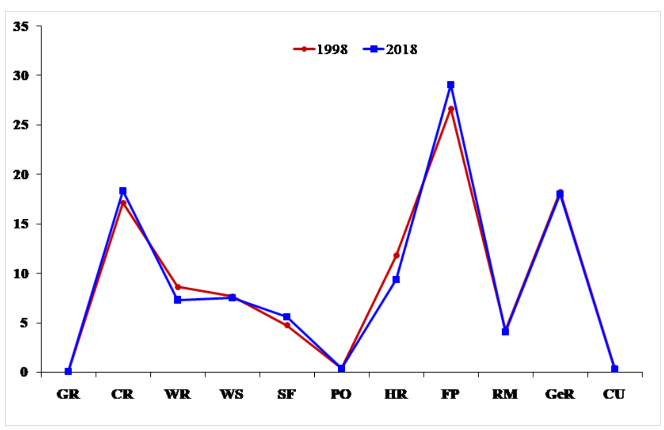

Fig. 3: Contribution ratio curve for individual ecosystem service function value from (1998-2018).

Table 3: Ecosystem services identified from the study site and their categorization following Millennium of Ecosystem Assessment (2005) and Costanza*et al*. (1997).

*Ecosystem services category** (MAE, 2005)*	*Global ecosystem functions**	*Regional ecosystem services*
Provisioning	Water supply, food production, raw material, genetic resources	Fresh water, drinking water for cattle and wild elephants, irrigational supply, timber, bamboo, thatch, canes, NTFPs, fodder, fuel wood, medicinal plants, aromatic and pharmaceuticals plants.
Regulating	Gas regulation, climate regulation and water regulation and pollination	Air quality regulation, climate regulation, carbon sequestration, water regulation, water purification and pollination
Supporting	Soil formation, Habitat regulation	Soil formation, provision of habitat for wild elephants and other wildlife and birds and provision of aquatic bodies for fishes.
Cultural/Aesthetic services)	Culture	Spiritual belief/inspiration of folklore

Table 4: Estimated ecosystem services value of individual ecosystem function for each land use category in the year 1998 and 2018.

Ecosystem services	*Eco-system func-tions*	*Forest*		*Agriculture*		*Water bodies*		*Grassland*		*Settlement & others*	
		1998	*2018*	*1998*	*2018*	*1998*	*2018*	*1998*	*2018*	*1998*	*2018*
Provisio-ning	WS	5657798.07	3838007.56	9311686.82	9628343.84	5566813.92	4088515.56	377525.23	279900.72	0.00	0.00
	FP	10682555.81	7246587.70	54077621.23	55916606.85	326372.94	239702.79	7500167.85	5560694.26	0.00	0.00
	RM	6013883.27	4079560.49	5098148.54	5271518.25	0.00	0.00	339772.70	251910.65	0.00	0.00
	GER	17725129.63	12023967.75	24256944.18	25081835.70	0.00	0.00	7638593.76	5663324.52	0.00	0.00
	Total	40079366.78	27188123.50	92744400.77	95898304.65	5893186.86	4328218.35	15856059.54	11755830.14	0.00	0.00
Regula-tory	GR	158260.09	107356.85	0.00	0.00	0.00	0.00	56628.78	41985.11	0.00	0.00
	CR	28130730.29	19082680.95	9567758.21	9893123.30	0.00	0.00	251683.48	186600.48	8694455.38	14299626.68
	WR	118695.06	80517.64	0.00	0.00	23135530.86	16991762.11	18876.26	13995.04	153714.13	252811.08
	PO	356085.19	241552.92	512142.78	529558.91	0.00	0.00	220223.05	163275.42	0.00	0.00
	Total	28763770.63	19512108.37	10079900.99	10422682.21	23135530.86	16991762.11	547411.58	405856.04	8848169.51	14552437.76
Suppor-ting	SF	553910.30	375748.99	12384543.48	12805697.31	0.00	0.00	12584.17	9330.02	0.00	0.00
	HR	24490748.31	16613473.29	0.00	0.00	0.00	0.00	7638593.76	5663324.52	0.00	0.00
	Total	25044658.61	16989222.28	12384543.48	12805697.31	0.00	0.00	7651177.94	5672654.54	0.00	0.00
Cultural	CU	39565.02	26839.21	0.00	0.00	0.00	0.00	1050778.55	779057.00	0.00	0.00
	Total	39565.02	26839.21	0.00	0.00	0.00	0.00	1050778.55	779057.00	0.00	0.00
ESV		93927361.04	63716293.37	115208845.23	119126684.16	29028717.72	21319980.46	25105427.61	18613397.72	8848169.51	14552437.76

Total ecosystem services value

The total ESV from the study area for 1998 and 2018 was Rs. 272,118,521.10 and Rs. 237,328,793.50, respectively with a net decrease of Rs. 34,789,727.60. It indicated that during a period of 20 years' time gap the ESV declined at a rate of 0.64% per year and the overall net decrease in ESV was 12.7% for the study area. Among the land use categories, the settlement land use ESV recorded highest increase of Rs. 5,704,268.25, with the highest changing rate of 3.22%. Agricultural land is the only other land use that showed an increase of ESV with 0.17% of changing rate. The other land uses of the study such as forest, water bodies and grassland had shown considerable decrease of ESV over the period of 20 years. Forest recorded the maximum decline of ESV followed by water bodies and the least with grassland (Table 5). The ESV was recorded maximum in the provisioning category (56.80%) followed by regulating (26.23%), supporting (16.57%) and minimum in cultural category (0.04%) and remained consistent over time. The ESV_f value for each ecosystem functions under different land uses classified according to MAE, 2005 categories were calculated and presented in Table 4.

Contribution

Among all the land use categories, agricultural land contributed the maximum to the total ESV recorded a contribution ratio of 42.34% for the year 1998 and 50.19% for the year 2018. Forests contributed with ESV of 35.42% (1998) and 26.85% (2018) to the total ESV of the study area. Grassland, settlements and water bodies had lesser ESV and thereby contributed at lower rate to the total ESV of the study area (Table 5). Although the ESV showed wider contrast among each category and variation in their contribution ratios toward the total ESV, but a similar trend was noticed in the contribution ratio for each land use category towards total ESV for both the years of assessment.

Sensitivity analysis of ecosystem service value (ESV)

Sensitivity analysis was done to find out the reliability and robustness of the ESV estimates. The value coefficients of each land use used were adjusted by 50 %. Using the adjusted V_C the ESV was also readjusted to find the coefficient of sensitivity (C_S) by applying the model (S). C_S was calculated for both the periods of assessment and presented in Table 6. It was observed that the C_S of ecosystem service value were all less than unity. The lowest sensitivity coefficient was found in settlement and others category (0.03 in 1998 and 0.04 in 2018). The maximum was recorded in agricultural land use (0.42 in 1998 and 0.32 in 2018). The C_S ranged between 0.03 (for settlement and others) and 0.42 (for agricultural land) indicates that total ecosystem service values would fluctuate only between 0.03-0.42 percent responding to the $\pm$50% adjustment of the ecosystem value coefficient (V_C). Hence, the total ESV calculated in this study was relatively inelastic in nature corresponding to change in $V_{C.}$ It indicated that modified value of coefficient were applicable to the study emphasizing that the ecosystem value coefficient (V_C) used in the study were reliable to present robust ESV for the study area.

Table 5: Ecosystem service value (ESV) for each land use category in the year 1998 and 2018, change percentage, change rate and contribution rate.

	1998		*2018*		*Change (1998-2018) (2018 Rs. $ha^{-1}yr^{-1}$)*		
Land use type	*ESV*	*Contribution ratio (%)*	*ESV*	*Contribution ratio (%)*	*Value*	*Percentage (%)*	*Change rate (%/yr)*
Forest	93927361.04	34.52	63716293.37	26.85	-30211067.7	-32.16	-1.61
Agriculture	115208845.23	42.34	119126684.16	50.19	3917838.93	3.40	0.17
Waterbodies	29028718.72	10.67	21319980.46	8.98	-7708737.26	-26.56	-1.33
Grassland	25105427.61	9.23	18613397.72	7.84	-6492029.89	-25.86	-1.29
Settlement and others	8848169.51	3.25	14552438.76	6.13	5704268.25	64.47	3.22
Total ESV	272118521.10	100	237328793.50	100	-34789727.60	-12.78	-0.64

Table 6: Ecosystem services value estimated after (±50 %) adjustment of ecosystem value coefficient (V_C), change value from 1998 to 2018 and its percentage change along with the coefficients of sensitivity (C_S) of the ESV.

Value coefficient	*Adjusted ESV*		*Change*		*1998*	*2018*
	1998	*2018*	*Value*	*%*	*C_S*	*C_S*
Forest V_C +50%	140891041.56	95574440.06	-45316601.50	-32.16	0.35	0.17
Forest V_C -50%	46963680.52	31858146.69	-15105533.83			
Agriculture V_C +50%	172813267.84	178690026.24	5876758.40	3.40	0.42	0.32
Agriculture V_C -50%	57604422.61	59563342.08	1958919.47			
Waterbodies V_C +50	43543076.58	31979970.69	-11563105.89	-26.56	0.11	0.06
Waterbodies V_C -50%	14514358.86	10659990.23	-3854368.63			
Grassland V_C +50%	37658141.41	27920096.58	-9738044.83	-25.86	0.09	0.05
Grassland V_C-50%	12552713.80	9306698.86	-3246014.94			
Settlement and othersV_C +50%	13272254.27	21828656.63	8556402.37	64.47	0.03	0.04
Settlement and othersV_C-50%	4424084.76	7276218.88	2852134.12			

Discussion

Ghagra Pahar Forest is locally known for its rich natural resources and past ethno botanical glory. But in the present scenario, the GPF as well as other natural resources surrounding it are in the path of degradation because of several natural and anthropogenic causes. Degradation was seen in terms of land use change, decline in forest products, extinction of biological species, increase pollution and many more. As no data was available on ecosystem services valuation in monetary term in the region hence present study was undertaken. Spatial as well as perception based analysis results demonstrate that area under forest land use decreased which could be associated to encroachment and change in land use pattern. It was also recorded that people have shifted to monoculture plantation of some economically important plant by clearing the natural forest. Therefore an increase in three-fold area under plantation land use was recorded during the study period. Similarly, Sumarga and Hein (2014) have reported in their case study of Central Kalimantan, Indonesia that the actual cause of forest degradation was the rapid expansion of oil palm plantation as well as encroachment (Hartanto and Rachmawati, 2017). Besides, grassland and water bodies also decreased remarkably as a result, grazing lands were decreased for cattle and fish population also declined substantially (Deka *et al*., 2018). The study area has also experienced high percentage of land use conversion to settlement and others. Several other findings have also revealed that there were expansions of agricultural land (Santhiya *et al*., 2010; Gashaw *et al*., 2018) and built-up area (Santhiya *et al*., 2010; Rawat *et al*., 2013; Rawat and Kumar, 2015; Gashaw *et al*., 2018) as well as thinning of forest (Rawat *et al.,* 2013) and grassland (Mtui *et al*., 2017) in their respective study area under different time frame. Rapid population growth and isolation of families resulting into an increase in household numbers might be the cause of expansion of settlement area. Remarkable change was not noticed in agricultural land use type as the LUDD recorded low.

The total ecosystem services value during the period 1998-2018 reduced from Rs. 272,118,521.10 to Rs. 237,328,793.50 at reducing rate of 0.64%. In the entire study, ESV changed unevenly among the land use categories. ESV of forest, grassland and water bodies decreased, and this was the driving factor leading to reduction in the total ecosystem services value from 1998 to 2018. Agriculture land use category has higher ESV mainly because this category is represented by both larger ecosystem service value coefficient (except for water bodies) and larger area (except for forest) as compared to other land use categories. In case of forest land use, it represented the dominant land use category resulting into higher ESV. Although, water bodies represented the least land cover but it recorded higher ESV compared to grassland and settlement land primarily because the ESV_C for water bodies is more. Similarly, ESC_V for grassland is much higher than settlement category, although the area is smaller compared to the latter category hence total ESV is higher. Maximum ESV was recorded in the provisioning category (56.80%) followed by regulating (26.23%), supporting (16.57%) and cultural category (0.04%) that remained consistent over time. In case of regulatory category, total ESV was contributed by all the land use categories. But, the individual ecosystem service function (ESV_f) values were lesser than the function values under provisioning category. In case of supporting category, total ESV was contributed by only two functions hence, it could contribute very less to the total ESV. Similarly, cultural category consisted of one function only thereby contributed the least ESV.

The global data for value coefficient (V_C) was used and converted into Indian currency for present study. The similar method of ecosystem valuation was also used in several literatures (Tianhong *et al*., 2010; Zhou and Shi, 2011; Bian and Lu, 2013; Zhang *et al*., 2015; Akber *et al*., 2018). We used ecosystem coefficient values as proxies for different land use to approximate the value. There exist uncertainties in these values for the regional study because these values are unique for a vast range of biomes. The proxy biomes used for different equivalent land use may not be the correct match for every category (Kreuter *et al*., 2001; Tianhong *et al*., 2010). The highly undervalued and overvalued coefficients can substantially affect the estimates of ESVs over time (Akber *et al*., 2018). Besides several other negative externalities such as pollution, land degradation, etc. was not taken into consideration in the present valuation process. In addition, variation in market price, inflation rate, exchange rate, monetary value has direct relation with the monetary values of ecosystem services (Ainscough *et al*., 2018; Akber *et al*., 2018). Any fluctuation in the above parameters can directly affect the value coefficient and results to a coarse ESV with higher uncertainty. Konarska *et al*. (2002) mentioned that the spatial scale used to identify and classify the land use categories also has an influence on ecosystem service valuation. In present study we used the scale of 30 m resolution to classify the land use categories for estimation of ESV. Similar methods of image classification were used in various published literatures (Tolessa *et al*., 2017; Akber *et al*., 2018; Gashaw *et al*., 2018; Temesgen *et al*., 2018). But the ESV and the changes over time might vary extensively under different scales (Tianhong *et al*., 2010). Besides we did not attempt to try any other method of valuation to check the reliability of the method used here. Hence, the study extensively mentions the need of cross-checking the present method with another robust method to account the uncertainties and errors (Gashaw *et al*., 2018).

Conclusion

Our study is mainly concerned with the detection of ESV changes over time. Despite several drawbacks mentioned above, we can assume our study to be the best possible guesstimate in absence of any benchmark method to estimate the value of prevailing ecosystem services at a regional scale. Furthermore, the sensitivity analysis acted as a beacon to the entire study as it indicated that the total estimated ESV were relatively inelastic with respect to the ecosystem value coefficient (V_C) and provided robustness in the estimates of total ESV for the study area. Since studies of this kind are scarce in the region as well as the country, the study added a new dimension by providing ESV data of regional level based on knowledge and perception of the local villagers and using the global data set to estimate the ecosystem services value of the GPF and its vicinity area. Our study would be helpful to the policy makers to formulate land use policies and implement resource conservation measures for the study area and related areas of other ecosystems or biomes. The ESV data will also be helpful in providing additional information to be included in global data for formulating methods and decision-making processes. It will also be of great importance for further study to use as database and in data deficient areas of similar conditions to use as substitute. Most importantly the estimated ESV figures would enable the local folk to visualize the importance of the natural resources in terms of monetary value. This in turn would fascinate the economically poor villagers to have self-indulgence and motivate to conserve the existing resources through sustainable utilization.

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