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EXAMINING THE ECOSYSTEM SERVICE VALUES DUE TO LULC CHANGES: A CASE STUDY ON COX'S BAZAR, BANGLADESH

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Abstract

Ecosystem services can reveal information on how an ecosystem works with all of its components. However, natural ecosystems are under enormous strain globally as a result of rising demand. This study attempts to analyze Ecosystem Service Valuation (ESV) for the Cox's Bazar district, one of the most important tourist destinations that has had considerable Land Use and Land Cover (LULC) changes over the last few decades. Due to considerable tourist demand, this ecologically critical natural resource base, particularly forests, wetlands, and sea beaches, suffers and changes on a regular basis, affecting the ecological balance. LULC-induced changes in ecosystem components and the function's value would eventually alter ecosystem service values. Urbanization is expected to accelerate, particularly in emerging countries, having an impact on both the regional and local levels. Assessing the effects of different land-use scenarios on subsequent changes in ecosystem service has significant implications for sustainable development. This study included six different LULC classes and their effects on ESVs. LANDSAT satellite-derived imagery from year 2000 to year 2021 were utilized and computed at ten-year intervals. The results reveal which LULC classes are more likely to change and how ESV changes throughout this time span. This research would help with sustainable land management and tourism strategy by minimizing encroachment on forests, coastal areas, and wetlands.

Keywords: Ecosystem services, Ecosystem Service Valuation (ESV), LULC, Tourism, Sustainable development

Introduction

Ecosystem services refer to the wide range of benefits obtained freely from various natural environment components (Zhou. et al.,2014). Ecosystem services can provide information about the functioning of an ecosystem with all of its components. The benefits that are provided by the ecosystem to the people, which are known as ecosystem services, are primarily categorized into three different parts,such as provisioning, regulating/supporting, and cultural services (Costanza et al.,1997). These different services of ecological systems

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are vital for human well-being. Anthropogenic activities on ecosystems have been more rapid and extensive over the past 50 years and finally impact on the ecosystem service values (ESV) (M.E.A.,2005). Evaluation of ESV is a topic of great interest in research on the analysis and quantification of the significance of ecosystems to human well-being to form better decisions regarding the sustainable utilization and management of the ecosystem. Rapid land use conversion disrupted ecosystem structural integrity, resulting in changes in ecosystem functions, services, and the values associated with these services (Yirsaw et al.,2017). Land uses that contain higher functions value would influence the ESV more. Methods on ESV valuation with land-use change assessment are growing fast since; considering the value of Ecosystem Services(ES) into land-use policy favors conservation activities(Cumming et al,2014). When communities make investments to protect, support and restore ecosystem services, communities become both more stable and more resilient.

As Bangladesh is an agricultural-based country, it is important to evaluate its environmental quality. ESV can play a significant role in assessing environmental conditions and will guide the future development process (Huq et al.,2019). Agricultural land and forest land transforming into buildup area in a great level by the rapid development in Cox's Bazar area. A considerable number of Refugees forcefully migrated in August 2017 from Myanmar also impacted on the resourceful area of Cox's Bazar (Chakraborty.,2020).

Although there is some research on LULC and its impact on the value of ecosystem services globally, national and regional studies are scarce (Hoque et al.,2020). In general, the value of ecosystem services is not included in land-use planning for urban development policy and environmental protection in local community socioeconomic development.This leads to severe problems in typical ecological fragile zones, including human destruction and other factors, and the lack of practical solutions to the livelihood development of rural communities (Costanza et al.,1997). The findings of this study might serve as a reference for effective decision-making and policy formation for the sustainable use of Cox's Bazar's natural resources. The value of ESV will assist local decision-makers in developing long-term development strategies (Burkhard & Maes.,2017) Prediction of ESV data would aid in the prediction of future planning measures aimed at preserving Cox's Bazar's distinctive natural features and ecological landscape assets.

Materials and Methods

The approach used to analyze changes in coastal ecosystems in the research region is based on spatial and non-spatial data analysis. The study mainly used secondary data for the assessment.

Study area

The study addressed Cox's Bazar district and all 8 Upazilas within it as the study area. The total area of Cox's Bazar district is about 2492 sq. kilometers. It included the longest sea beach of Cox's Bazar, the Island of Teknaf (Saint Martin), many hills, and other natural resources. Approximately 78.5% area of Cox's Bazar is rural, and most community lives in remote areas (World Bank, 11/2016). Like other coastal areas of Bangladesh, Cox's Bazar faces various natural disasters frequently, and climate change affects significant development progress.

Data acquisition and processing

The study used Landsat TM and OLI scenes with a 30 m X 30 m spatial resolution from the US Geological Survey database (USGS) website. Dry-season images with less than 5% cloud coverage were gathered for three years (13th Feb. 2000, 24th Feb. 2010, and 25th Feb. 2021) and used to reduce atmospheric disturbance in the datasets. ArcGIS 10.4 used to pre-process the obtained Landsat 5 TM (Year 2000,2010) & Landsat 8 OLI images (Year 2021). Pre-processing methods included atmospheric correction, image enhancement, radiometric correction, stacking raster

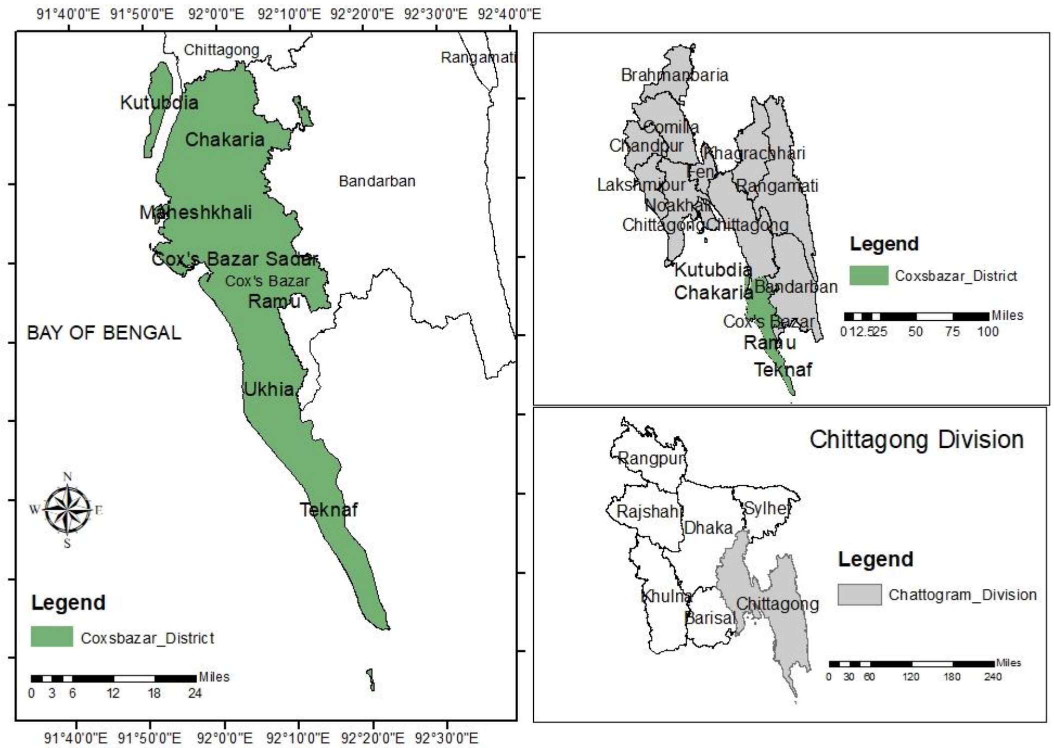

Figure 1. Location map of the study area. (Source: Prepared by Author)

bands, mosaic raster datasets, clipping tools, etc. ESRI provided auxiliary data for the study, such as Bangladesh administrative boundaries, study area shapefiles etc.To match the datum of the satellite image, the topographic maps were first geo-referenced in WGS84 datum. The LULC classes were classified using the maximum likelihood classification algorithm and a pixel-based supervised image classification method. The study area is divided into forest, agriculture, waterbody, wetland, open space, and buildup land use classes for the mentioned three study periods. To compare changes between the study periods, the LULC variations between the analyzed periods were quantified according to the calculation results. Each LULC type's transition probability matrices were also produced to show the net change and net change to persistence ratio. Accuracy assessments for classified photos were performed using a minimum of 25 random points generated per class using the stratified random sampling approach.

Determination of the ecosystem services coefficients

Based on the literature, this study classified the ESs into eleven service types to determine the ES coefficients of the studied landscape based on the major services it has been providing. Such as gas regulation, water regulation, climate regulation, habitat regulation, food production, water supply, raw materials, soil formation and protection, genetic sources, pollination, recreation, and culture(Costanza et al.,1997). This equivalent weight factor is applicable in many places of the world. (Rouwer et al.,2013). The economic worth of agricultural land's average grain yield per

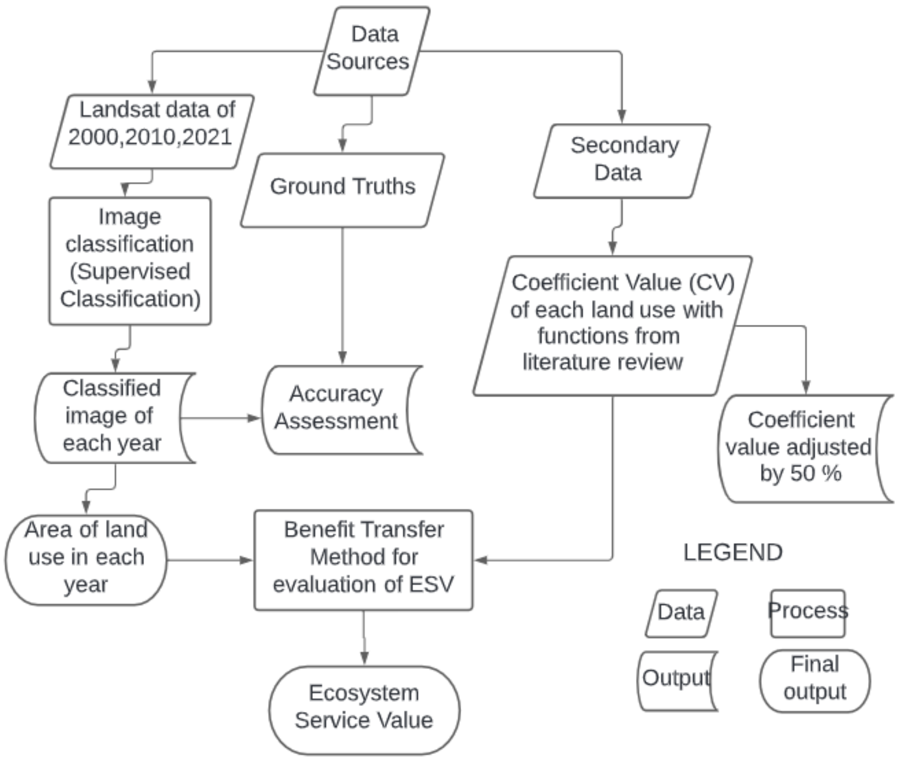

Figure 2. Methodological flow chart of the study. (Source: Prepared by Author)

hectare per year is similar to a weight factor (the potential of an ecosystem to supply an ES) (De Groot et al.,2012; Gashaw et al.,2018 & Deka et al.,2020). The unit of ecosystem service coefficients is in US$ ha−1 yr−1, which was later converted to TK ha−1 yr−1 (1 US$ to 84.79 Tk according january,2022) [Table :1] to use the value locally in this study. These values vary with changes in land-use patterns. The summation of all values for different services is finally used to determine the coefficient value of each land class (Deka et al.,2020). The ES coefficients for each LULC category of the studied landscape were computed, and the values are presented in Table 1.

Equivalent biomes are selected in the study to acquire the relative coefficient values (Table 2). Those assumed biomes are taken as the representative of each specific land use classes.

Assessment of ESV

The Benefit Transfer Method (BTM) is a secondary valuation approach that modifies previously recognized estimates from a novel (primary) valuation research in one geographical region to other areas with similar socio-ecological characteristics. Costanza et al. attempt a per-hectare monetary valuation of several LULC types that contain 16 biomes and give 17 different ESs in pioneering work in the BTM(Costanza et al.,2014). The following

Table 1. Ecosystem service coefficients (TK ha−1 yr−1)

Ecosystem Functions	Forest	Agriculture	Wetland	Open Space	Buildup Area	Water body	Total
Gas regulation(GR)	339.16	0	0	657.9704	0	0	997.1304
Water regulation(WR)	254.37	0	151689.3	767.3495	1356.64	637112	791179.7
Soil formation(SF)	1187.06	45108.28	0	1862.8363	0	0	48158.18
Habitat regulation(HR)	52485.01	0	1055805	0	0	0	1108290
Raw material (RM)	12888.08	18569.01	35272.64	438.3643	0	0	67168.09
Climate regulation(CR)	60285.69	34848.69	16958	1424.472	76734.95	0	190251.8
Water supply(WS)	12124.97	33916	81313.61	0	0	153300	280654.9
Pollination(PO)	763.11	1865.38	0	0	0	0	2628.49
Food production(FP)	22893.3	196967.2	80720.08	219.6061	0	8987.74	309787.9
Cultural(CU)	84.79	0	53926.44	0	0	0	54011.23
Genetic resources(GER)	37985.92	88351.18	20603.97	0	0	0	146941.1
Total	201291.46	419625.7	1496289	5370.5986	78091.59	799400	3000069

(Source: Prepared by Author)

Table 2. Equivalent biomes that taken for the ES coefficient value

Land use type	Equivalent biomes	Coefficient value($/hectare/year)
Forest	Forest	2374
Agriculture	Cropland	4949
Open space	Sandy coasts	63.34
Buildup	Urban	921
Water body	Lakes/Rivers	3990
Wetland	Wetland	17647

(Source: Costenza et.al,2014)

equations are used in this study to evaluate the Ecosystem service values (ESV).

$ESVa = Aa * VCa$.................................... (1)

In eq. 1 ESV is the ESV of land use type 'a'; Aa is the area of land use type 'a' as ha, and VCa is the value coefficient of land use type 'a' as TK $ha^{-1}yr^{-1}$.

$ESVb = \sum_{a=1}^{n} Aa * VCab$........................... (2)

In eq. 2 ESVb is the ESV of ecosystem service function 'b'; VCab is the value coefficient of land use type 'a' as TK $ha^{-1}yr^{-1}$ with ecosystem service function type 'b'.

$ESVc = \sum_{n=1}^{n} Aa * VCa$............................... (3), where ESVc is the total ESV in TK.

After that, the Coefficient of Sensitivity (CS) was calculated based on the standard economic concept of elasticity. It is the percentage change in the output for a given percentage change in an input. It determines the percentage change in ESV for a given percentage change in value coefficient (VC), where z and cal represent the adjusted and initial values, respectively, and l is the land use category. If the CS value is less than unity, the ESV is inelastic, and the ESVs are robust concerning the study area. In contrast, if CS value is greater than one, the ESV is more critical for the study area as the ESV is directly proportional to the coefficient. The following equation was used for sensitivity analysis.

$$Cs = \frac{\frac{(ESVzl - ESV\ cal)}{ESV\ cal}}{(V\ zl - Vcal)/Vcal} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Results

Land use and land cover during year 2000 to year 2021

In terms of urban infrastructure expansion, the lack of attention paid to other LULC categories has resulted in a variety of environmental consequences. For example, it has been discovered that converting LULC into agricultural land and urban areas is detrimental to a variety of Ecosystem services. This conversion degrades ES, which is the sum of ecosystem goods (such as food) and services that represent the benefits that human populations derive, directly or indirectly, from ecosystem functions (Boyd and Wainger., 2002). Agriculture land use class area was approximately 78 thousand hectares in the year 2000, but has since been reduced to 61 thousand hectares in year 2021. Meanwhile, in the year 2000, the buildup area was approximately five thousand acres, which increased to nineteen thousand hectares by the year 2021.Significant changes in open space area have also been addressed between the years 2000 and 2021. Unexpected land use changes have a long-term impact on ecosystems and the environment. These consequences make quantification of Ecosystem Service Values critical for raising awareness, incorporating ESs into socioeconomic and marketing systems, developing decision making for the distribution of scarce resources among competing demands, formulating policy, and for stimulating conservation of ecosystems that provide the most valuable services in support of human well-being (De Groot et al.,2012).The situation of land use classes in Cox's Bazar district are represnting here in the following feagure(Figures 3 and 4).

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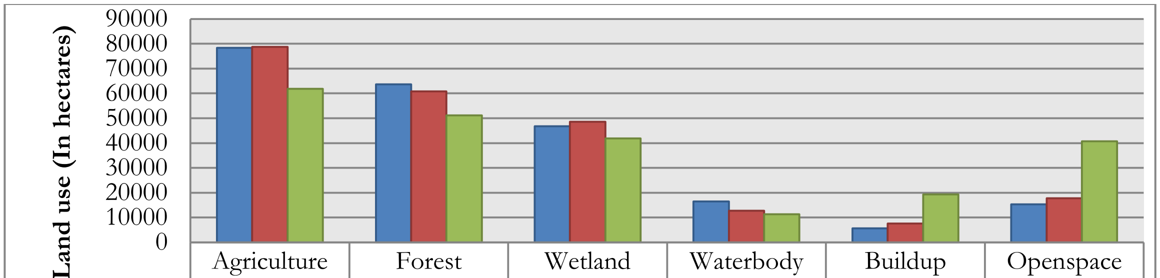

	Agriculture	Forest	Wetland	Waterbody	Buildup	Openspace
Year 2000	78366.6	63714.15	46817.19	16450.74	5636.88	15295.14
Year 2010	78815.52	60857.73	48562.65	12723.21	7603.74	17717.85
Year 2021	61887.7575	51208.8075	41821.245	11314.215	19344.9825	40701.3075

Figure 3. Land uses in Cos's Bazar district. (Source: Prepared by Author)

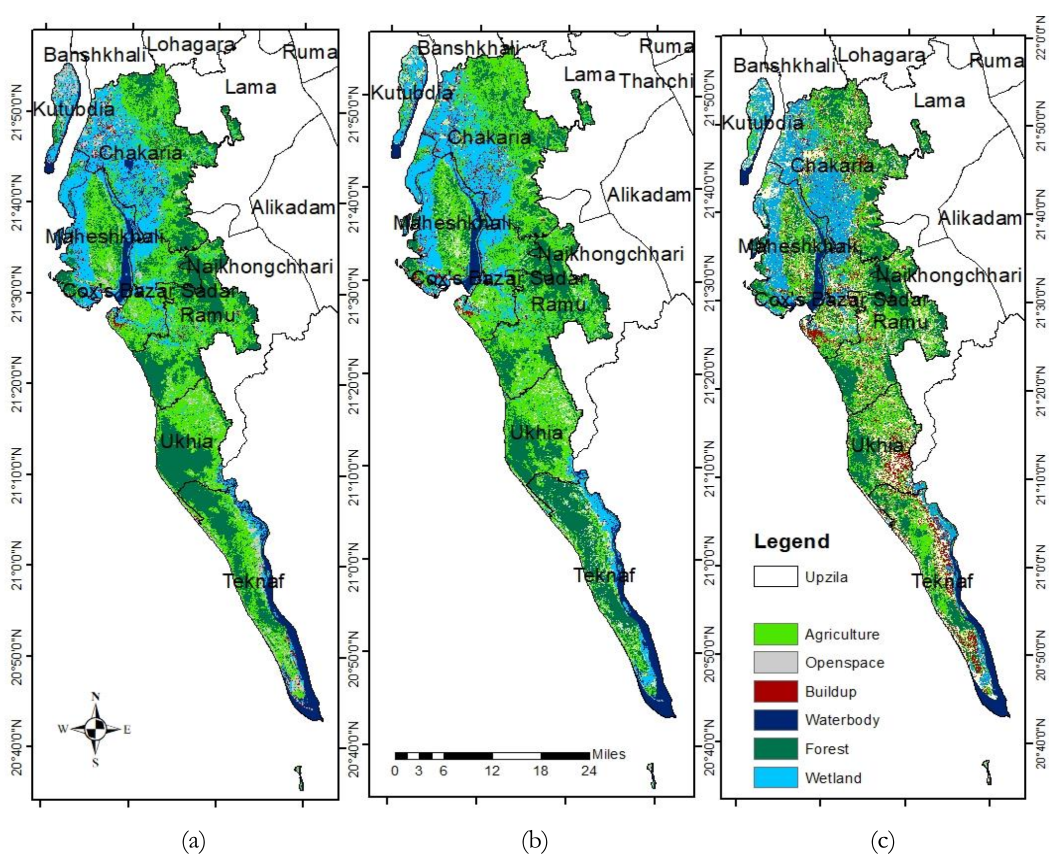

Figure 4. Land use classification maps for different years. (a) 2000; (b) 2010; (c) 2021. (Source: Prepared by Author)

Land use and land cover changes during year 2000 to year 2021

Table 3. Land use conversion (Year 2000-2021)

Land Use conversion	Year 2000-2010		Year 2010 -2021	
	Percentage	Area(In Hectares)	Percentage	Area (In Hectares)
Agriculture-Buildup	5.58	12626.46	11.09	25104.99
Agriculture-Forest	6.91	15636.00	0.28	627.01
Agriculture-Open space	3.30	7467.26	9.45	21377.42
Agriculture-Water body	0.01	22.63	0.01	30.84
Agriculture-Wetland	1.84	4163.56	2.27	5134.93
Buildup-Wetland	0.01	22.63	0.17	388.15
Forest-Agriculture	8.15	18441.88	10.70	24221.07
Forest-Buildup	0.18	407.31	3.72	8417.87
Forest-Open space	0.50	1131.40	4.72	10678.69
Forest-Water body	0.01	22.63	0.01	12.80
Forest-Wetland	0.38	859.87	0.77	1734.17
Open space-Agriculture	1.61	3643.12	3.03	6855.31
Opens pace-Buildup	0.28	633.59	4.52	10217.35
Opens pace-Wetland	1.39	3145.30	0.78	1772.89
Water body-Agriculture	0.10	226.28	0.15	347.49
Water body-Open space	0.03	67.88	0.18	411.80
Wetland-Agriculture	2.66	6019.07	2.50	5656.66
Wetland-Buildup	1.51	3416.84	2.68	6063.84
Wetland-Forest	0.71	1606.59	0.38	851.83
Wetland-Open space	0.51	1154.03	1.63	3685.18
No change	64.32	145543.75	40.96	92690.40

(Source: Prepared by Author)

LULC transition indicated the conversion of land uses from one specific class to another class within time period (Table: 3). In the following table, horizontally, there represented the changing time period and in vertically there represented land use classes conversion. About 64.32 % of land use class remains constant from year 2000 to 2010. About 5.58 %, 6.91 %, 3.30%, and 1.84% of agricultural land converted to build up, forest, open space and wetland land use classes respectively. From Year 2000 to 2010, the open space, built-up, and agriculture areas showed growing tendencies among the various LULC categories (Figure 3).

Agricultural land uses had the highest land use conversion from 2010 to 2021 (23.1%), and it was dominated by the conversion into buildup and open spaces (11.09 % & 9.45 %). Forest had the second highest land use conversion (19.92 %), where was converted into agriculture dominantly. Nearly 22% of buildup area has been developed from other land use types since 2010. About 4.52 % of open space and 3.72 % of forest cover converted to build up area from year 2010 to 2021 which affect the results of ESV significantly.

Ecosystem Service Values (ESV) in different years

Using the adjusted ES coefficients for the relevant biome (Table 1) and the area of each LULC type, the ESVs for each LULC category and the overall value for different year were calculated (Table 4). The findings demonstrate that during the trial, each LULC type had varied ESVs and different gain/loss trends. For example, as shown in Table 4, total ESV decreased slowly from Year 2000 to 2010 and decreased dramatically from Year 2010 to 2021.

Different function values associated with ESV decrease with time, as seen by the ESV of different years. Water control, habitat regulation, water supply, and food production are the function values that impact the ESV value to decline. However, the region's ongoing extraction and exploitation of the forest, wetland, and farmland for diverse reasons have reduced the area covered by those land-use types, lowering its ES provisioning. More than any other terrestrial biome, wetlands are the most significant LULC class for supplying various ESs. ESV might serve various purposes, including environmental conservation and climate mitigation. The ES coefficient of wetlands is more than 1.7 times that of a water body and 11.5 times that of agricultural land. The landuse category that has most significant impacts on ESV are wetlands, agriculture, and forests. Total ESVs in the studied landscape decreased from 129434.88 million TK/Yr in Year 2000 to 109628.12 million TK/Yr in Year 2021, a loss of 19806.76 million TK/Yr (Table: 4). According to the study, the Cox's Bazar region has deteriorated due to a rise of development land with increased urbanization and migration rate. Similarly, unless adequate LULC management is performed to prevent and reverse the issue, this pattern of change (losses) in the total ESVs of the region will continue in the future.

Table 4. ESV change in million TK/Yr (From year 2000 to year 2010 & year 2021)

Ecosystem Functions	Year 2000	Year 2010	Year 2021	Chages in Year (2010 to 2000)	Changes in Year (2021 to 2000)
Gas regulation(GR)	31.68	32.30	44.15	0.62	12.47
Water regulation(WR)	17618.23	15511.94	13622.76	-2106.29	-3995.46
Soil formation(SF)	3639.11	3660.48	2928.26	21.37	-710.85
Habitat regulation(HR)	52773.86	54466.81	46842.78	1692.95	-5931.09
Raw material (RM)	3934.42	3968.57	3302.17	34.15	-632.25
Climate regulation(CR)	7820.29	7847.70	7495.48	27.42	-324.80
Water supply (WS)	9759.19	9310.28	7855.00	-448.91	-1904.19
Pollination (PO)	194.80	193.46	154.52	-1.34	-40.28
Food production (FP)	20824.58	20955.53	16848.64	130.95	-3975.94
Cultural (CU)	2530.09	2623.97	2259.61	93.88	-270.47
Genetic resources (GER)	10308.64	10275.76	8274.75	-32.88	-2033.89
Total	129434.88	128846.80	109628.12	-588.08	-19806.76

(Source: Prepared by Author)

Ecosystem service value changing with the variations of LULC classes

The changes in ecosystem service value from year 2000 to 2021 were calculated using the ESV equation (equation 2). Agriculture, forest, and wetland are valuable land use types, according to the figure below. Agriculture land use produces 32.88 billion Tk/Yr, or approximately 24.5% of total value in the year 2000; 33.073 billion Tk/Yr, or approximately 24.54% of total value in year 2010; and 25.96 billion Tk/Yr, or approximately 21% of total value in year 2021. Agriculture ecosystem value decreased by about 3.5% in the study area over the previous decade. The primary cause of these unforeseen situations is the unplanned destruction of agriculture and construction of infrastructure.Wetland, on the other hand, has an ecosystem value of 70.05 billion TK/Yr in year 2000, 72.66 billion in year 2010, and 62.57 billion in year 2021. Wetland degradation has resulted in a loss of nearly 8.5 billion TK/year over the last two decades.

Because of their lower equivalent value per unit area, agriculture and forest values are lower than wetland ecosystem values. Over the last 30 years, the total economic value of forests has decreased by about 2.5 billion. Because of their increasing total area, the total economic value of open space land increased by 136.43 million. Overall, land use/land cover changes in the Cox's Bazar region resulted in a net loss of 19.81 billion Tk/Yr in ecosystem service value between year 2000 and 2021.

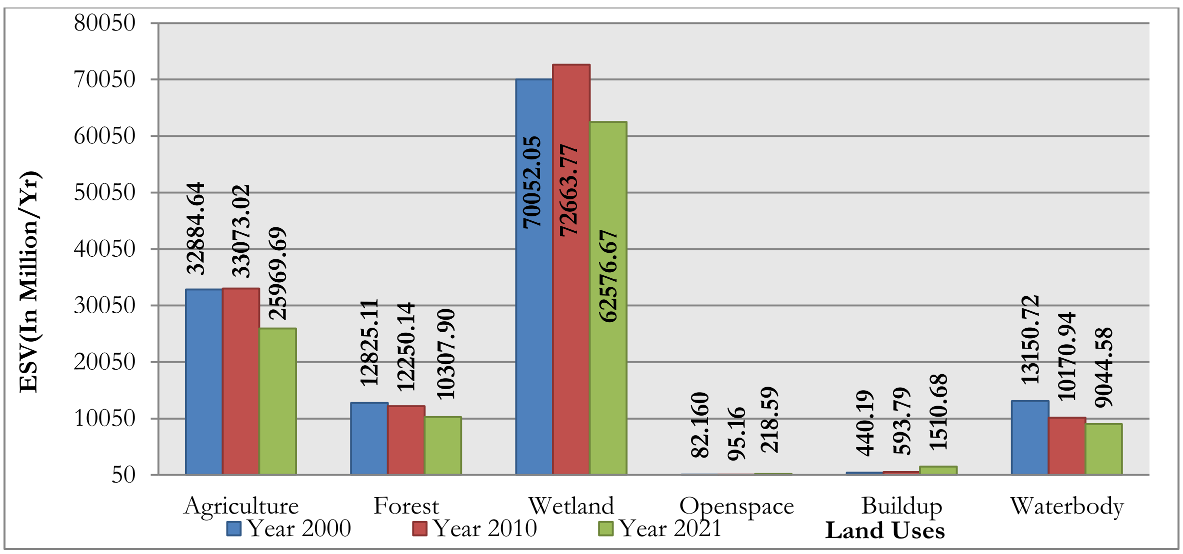

Figure 5. ESV in different years according to LULC(Year 2000-2021). (Source: Prepared by Author)

Ecosystem service value changing with the variations of ecosystem functions

In this study, there estimated the ES Value of 11 individual ecosystem functions based on Equation (3), the area of different LULC types in Figure 3, and the value coefficient of individual ecosystem functions provided in Table 1 (Costanza et al.,2014).Furthermore, the influence of LULC alterations on the modification of individual ecosystem function from year 2000 to year 2021 was evaluated. Table 4 displays the values of 11 separate ecological services. The value of each ecosystem function aids in understanding how each ecosystem function contributes to overall ESV. Figure 6 shows that six services provide the most to total ESV in the research region, followed by water regulation, habitat regulation, climate regulation, water supply, food production, and genetic resource services. In the years 2000, 2010, 2021 the most significant service (Habitat regulation, HR) provided around 40.88 percent, 42.27 percent and 42.72 percent of total ESV. In the case of habitat regulation services, that contributed the most (54466.81 Million/yr) in 2010. Climate regulation (CR) and water supply (WR) contribute less to total ESV as compared to other services, accounting for 6.83 percent and 7.16 percent, respectively.

Food production (FP), Water regulation (WR), and genetic resources (GR) are the other three significant contributors, accounting for 16.26 percent, 12.04 percent and 7.98 percent of total ESV in 2010.HR ecosystem activities create larger ESV and contribute a big share of total ESV due to the vast quantity of agriculture and forest land uses and the higher value of the coefficient. Although the proportion of contribution to total ESV of the key three ecosystem functions (HR,FP,WR) stayed constant from year 2000 to year 2010, the quantity of the major ecosystem functions (HR,FP,WR) declined to 70.52 percent (77314.18 million TK) in year 2021.

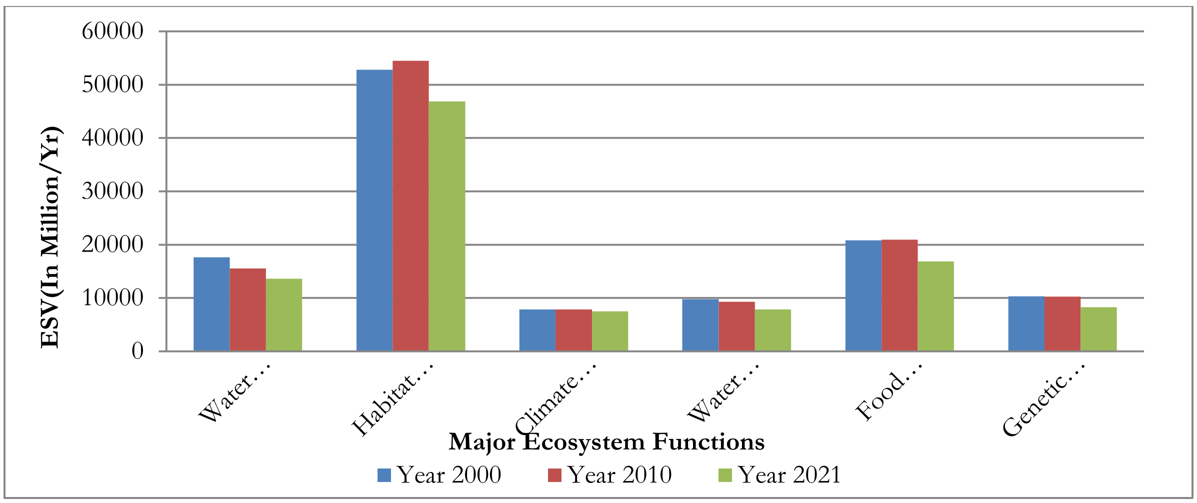

Figure 6. ESV variations in different years according to major ecosystem services. (Source: Prepared by Author)

Discussions

Ecosystem services sensitivity

Equation (4) was used to compute the percentage change in the total ESVs and the associated coefficient of sensitivity (CS) for chosen LULC classes as a result of a 50% change in the ESV coefficient values (Table 5). For the validity of this study, results need to be reliable.For that reason there need a relatively low sensitivity of ESVs to changes in the ES coefficients (CS<1). The computed CS results were all less than one, indicating that the total ESVs examined in this study were inelastic primarily in terms of ESV coefficient fluctuations (Table 5). Because of the vast area cover and high coefficient value for this LULC type, the wetland class had the highest sensitivity coefficient (0.57 to 0.54).

Table 5. Ecosystem Services Sensitivity Analyses

Change in value coefficient	Year 2000		Year 2010		Year 2021	
	%	Cs	%	Cs	%	Cs
Agriculture ±50%	±12.70	0.25	±12.83	0.26	±11.84	0.24
Forest ±50%	±4.95	0.10	±4.75	0.10	±4.70	0.09
Wetland ±50%	±27.06	0.54	±28.19	0.56	±28.54	0.57
Openspace ±50%	±0.03	0.00	±0.03	0.00	±0.09	0.00
Buildup ±50%	±0.17	0.00	±0.23	0.00	±0.69	0.01
Waterbody ±50%	±5.08	0.10	±3.94	0.08	±4.13	0.08

(Source: Prepared by Author)

Ecosystem service space distribution

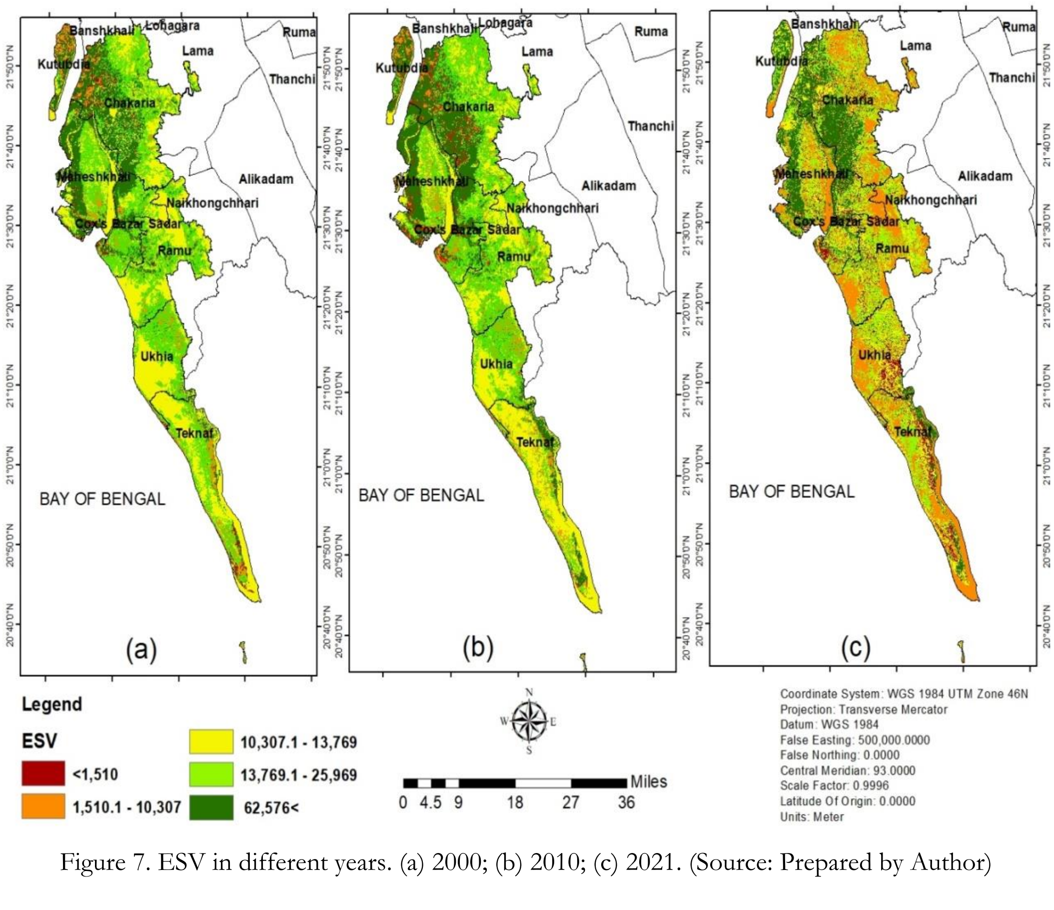

Figure 7. ESV in different years. (a) 2000; (b) 2010; (c) 2021. (Source: Prepared by Author)

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To depict the spatial distribution of ecosystem services in the Cox's Bazar district, ecosystem service maps for the years 2000, 2010, and 2021 were generated, and the ecosystem service value with area was calculated (see Figure 7). The value of ecosystem services in the Cox's Bazar area gradually decreased from the Chakaria mountainous area to the Teknaf plain lands. The most valuable areas are in Maheshkhali and Chakaria Upazila, while Ukhia, Teknaf, and Cox's Bazar Sadar Upazila are the least valuable. Many environmental consequences have resulted from urban expansion activities and unplanned land-use transformations, particularly in densely populated, small developing countries (Boyd and Wainger., 2002; Chakraborty.,2020). The rapid development in Cox's Bazar is transforming agricultural and forest land into significant buildup areas.A huge number of Refugees from Myanmar also impact on the resourceful area Cox’s Bazar (UNDP.,2018).

Implications for planning and sustainable development

This study concentrated on variations in ESVs in Cox's Bazar, over time. Significant economic growth has occurred in Cox's Bazar, Bangladesh's most quickly expanding tourist area. Over the previous three decades, although the ES level has fallen with time. A well-balanced LULC strategy is required to ensure the sustainability of the ecosystem, and it should be more focused on services that are negatively impacted by LULCs, such as habitat control, water regulation, food production, and so on. (Rouwer et al.,2013).The current socioeconomic and urbanization scenarios are adding additional strain on the environment, therefore planning and development in the study area should consider ecosystem sustainability. Proper management, decision-making, and the provision of local ecosystem services that minimize future vulnerabilities are required to ensure the sustainability of ecosystem services. In general, ESs in metropolitan areas are more complex than those in rural areas. These assessment approaches will become increasingly crucial and vital for human well-being in the future.

ESV and sustainable development goal

The 16 Ecosystem Services are inextricably linked to 12 SDGs (Sustainable Development Goals) and 41 objectives. Water supply, carbon storage, food supply, habitat, and biodiversity are all critical services that help to meet nearly 14 SDG targets. Water supply, water management, and climate regulation are examples of ecosystem services that contribute significantly to SDGs 1 and 2 (No Poverty and Zero Hunger), SDG 6 (Clean Water), SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Production and Consumption), and SDG 15 (Environmental Sustainability) (Life on Land). SDG 6 (Clean Water and Sanitation), SDG 13 (Climate Action), SDG 14 (Life Below Water), and SDG 15 are all inextricably linked to ecosystem functioning (Life on Land).SDG 1 (No Poverty), 2 (Zero Hunger), and 13 (Climate Action) benefited from increased food supply . ESs of various types contribute varying amounts to the SDGs (Siwei et al.,2022). In Cox's Bazar, losses in ESs such as habitat control, water regulation, and food production have a negative impact on SDG 15 (Life on Land), SDG 6 (Clean Water), and SDG 2 (Zero Hunger). Goal-oriented actions aimed at improving ecosystems, as well as sustainable ecosystem management and exploitation, will eventually contribute to the achievement of sustainable development goals. All of these demonstrated strong connections between ES services and the SDGs. In order to identify key ESs and SDGs for decision-making, ES services must be included in SDG evaluation. Ecosystem management can provide people with enough food and water. The research region and other areas in Bangladesh will be critical for conserving or even restoring the remaining ESVs, as well as implementing sustainable agricultural, forest, and wetland management approaches.

Conclusion

This study examined LULC change scenarios and anticipated the resulting changes in linked ESVs. The validation of ecological model with actual LULC data from Year 2000 to 2021 yields satisfactory results. According to the

LULC results, forest, agricultural land, and wetlands would be reduced under all three years land use classification scenarios, while buildup area and open space will be enhanced in year 2000 to year 2021.The total ESV of the studied region dropped by about 588.08 million TK/Yr between year 2000 and 2010, owing to a rise of agricultural and wetland usage. Between year 2010 and 2021, there was a significant shift in land usage. ESV values alter drastically as well in this time period. During that time, ESV values dropped by 19806.76 million TK/Yr. Given the trade-offs between ESVs and regional food supply gaps, the ESV scenario may be better for future land management, but policymakers and governmental organizations must think about it further. The ESV data will be useful in providing additional information to be incorporated in global data for the development of techniques and decision-making processes. Most significantly, ESV statistics would allow residents to see the monetary worth of natural resources(Cumming et al,2014).This research can also be used as a database and as an alternative in data-deficient areas with comparable conditions in the future. The ecological approaches for ESV computation and land use management scenarios provided in this study will provide critical guidance for further improving the ecosystem services of the studied landscape.

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