Evaluation of Ecosystem Service Changes due to Land Use and Land Cover Dynamics in Cham Chu Nature Reserve

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ABSTRACT

Assessment of ecosystem services is vital for successful natural resource allocation; however, these have been less studied within Vietnam. This study estimated the ecosystem services value (ESV) and its change in Cham Chu nature reserve, Vietnam using a benefit transfer method. Ecosystem service values estimation and trend analyses were carried out based on land use and land cover datasets from 1986, 1998, 2007, and 2017, with their corresponding global value coefficients. The results revealed that the total value of ecosystem services in Cham Chu was approximately 64.4, 63.9, 60.7, and 63.4 million USD in 1986, 1998, 2007, and 2017, respectively. Changes have also occurred in the values of individual ecosystem service functions. From 1986 to 2017, ecosystem service functions showed significant decreases in gas regulation, pollination, biological control, water regulation, water supply, and food production of 62.9%, 51.2%, 44.4%, 24.7%, 23.1%, and 13.0%, respectively. We conclude that the loss of ESV is a result of ecological deterioration in the studied landscape, and we propose further research to examine future solutions and establish action strategies. In summary, the research approach methodology developed can be used by land managers and planners in Vietnam as a guideline to estimate the importance of ecosystem services in Vietnam.

1. INTRODUCTION

Ecosystem services are material, resources, and knowledge flows from natural capital stocks combined with manufactured and human capital services to deliver human welfare (Reid et al., 2005). Ecosystem services are the conditions and uses of ecosystems for human benefit, as well as the ecological processes that humans rely on (Huang et al., 2019). They are also the greatest indicator of environmental effects, and thus monitoring the quantity or quality of ecosystem services is crucial (Zhou et al., 2017). Generally, changes in certain forms of ecosystem services will affect human welfare. Changing the composition of local forests, for example, can change terrestrial and marine habitats, impacting the benefits and costs of local human activities. Alcamo (2003) stated that land use and land cover (LULC) change is a direct factor that affects ecosystem service and therefore affects human welfare. The effect of LULC changes are an important part of the research on global climate change and global environmental change (Dubreuil et al., 2012), and can be characterized from ecosystem services value (Fei et al., 2018). As a result, evaluating improvements in ecosystem services values (ESV) in response to LULC transitions is critical for raising awareness and informing policy and decision-making on resource sharing that provides the best-valued services (Solomon et al., 2019).

The close relationships between LULC change and dynamics of ecosystem service values have been studied largely around the world, such as in mountainous areas in Africa (Gashaw et al., 2018; Kindu et al., 2016), in Asia (Huang et al., 2019; Rimal et al., 2019; Talukdar et al., 2020), for tropical forests in general (Bisui et al., 2021) and in protected areas (Chaudhary and Kastner, 2016), and in biosphere reserves (Abera et al., 2021). These studies show that all the changes in LULC, especially forest cover, will lead to the degradation of ecosystem services, and

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ultimately impact local socio-economic development and living environment.

While forest ecosystem changes have been studied extensively in several ecological contexts in many countries in the world (Mamat et al., 2018a), in Vietnam, only a few studies have been carried out related to ecosystem services, such as modeling and mapping natural hazard regulating ecosystem services (Dang et al., 2018), provisioning services for food production (Son, 2003), non-timber forest products (Wetterwald et al., 2004), and planted forests (Paudyal et al., 2020). Other studies also assessed terrestrial ecosystem services in protected areas such as Bach Ma National Park (Hong and Saizen, 2019), Ba Be National Park (Dai and Ongsomwang, 2019), and Cat Tien National Park (GECD, 2014). However, these studies are often not systematic, or are time-consuming, costly, and usually evaluated for a short period so that they cannot assess the evolution of ecosystem services over time, especially compared with the past. This has led to the following research questions: What is the relationship between LULC and ecosystem services? Is it possible to retrospectively recall the value of ecosystem services in the past using easily accessible and systematically collected information such as remote sensing imagery for areas of high biodiversity value, such as protected areas? This study, therefore, is an attempt to answer these questions.

Cham Chu nature reserve (CCNR) was chosen as a case study to access ESV. The area is located inside Tuyen Quang Province, which has the highest biodiversity value in the northeastern part of Vietnam (Nguyen et al., 2018). The Tonkin Snub-nosed Monkey, one of the world's top 25 most endangered primates, listed as "Critically Endangered" on the IUCN's red list of threatened animals (Hoang and Covert, 2012), is found in the region. FFI (1999) estimates five groups of Tonkin Snub-nosed Monkeys in the Cham Chu region, totaling 75 to 89 primates. Furthermore, recent studies showed high species diversity of mammals (Hai et al., 2019; Tham et al., 2020), reptiles, and amphibians (Pham et al., 2019). This information makes the CCNR become one of the most important sites globally to conserve these species (Hughes, 2001). However, biodiversity conservation is facing some threats due to human activities, especially before 2014, when the CCNR was established. These threats have been intensified by the impact of macro socio-economic development policies, such as the reform policy (known as DOI MOI) in 1986 and WTO accession in 2007, which have contributed to making Vietnam a low-middle income country (2010), reaching 2,389 USD yearly income/per capita in 2017 (GSO, 2017). Vietnam's forestry policy has undergone significant changes, shifting from the economic sector of forest exploitation before 1986, to the policy of protection and limited exploitation of natural forests or "closure of the forest gates" from 1994-1995, and subsequent forest conservation and development policies since 2004 (MARD, 2004). In the period since Doi Moi (1986) to 2012, land use changes in the Northern mountainous region were characterized by the conversion of swidden land into arable land and afforestation land (Shivakoti et al., 2016). Nguyen et al. (2020) showed that forest governance regimes have a significant effect not only on forest LULC but also on the quantity and values of forest ecosystem service derived from forests. Thus, the evolution of forestry policy has affected LULC change and ultimately affects the value of biodiversity and ecosystem services. In addition, DARD (2014) found that illegal logging, woodland clearing for agriculture, forest fires, and hunting are the most severe threats to biodiversity in the CCNR and other mountainous areas in Viet Nam (Wood et al., 2013). The expansion of cropland changes the landscape pattern, as agricultural production is one of the underlying reasons for deforestation and forest degradation, causing a gradual increase in ecological deprivation (Khuc et al., 2018). Orange production on the sloping lands of local communes in the CCNR expanded from 1,473 ha (2008) to 3,595 ha (2017), and up to 3,614 ha (2020), which have contributed to a reduction of forest cover in the area (CCMB, 2020; Son et al., 2020). Therefore, it is necessary to quantify the effects of LULC change on ecosystem services values, which is a crucial tool to develop knowledge on management and to reorientate the attitudes of people towards maintaining biodiversity (Fritzsche et al., 2007). Thus, this study attempts to answer the question, how have LULC in the CCNR changed during development processes over the past 30 years, and how does this affect ecosystem services in the area.

The ultimate goal of this study was to estimate the ESV and its change in the CCNR after more than 30 years since 1986 using a benefit transfer method that applies estimated value from one location to a similar site in another area (Plummer, 2009). From 1986 to 2017, multi-temporal land use data sets were used to determine the ESV transition.

2. METHODOLOGY

2.1 Study area

The study area is the CCNR. It lies between 22°04'N-22°21'N and 104°53'E-105°14'E. It is located in the administrative boundaries of five communes: Trung Ha, Ha Lang, and Hoa Phu in Chiem Hoa District; Yen Thuan and Phu Luu in Ham Yen District, Tuyen Quang Province. The reserve area is 15,262.3 ha, with 6,168.4 ha in Ham Yen District and 9,093.9 ha in Chiem Hoa District. A mountainous topography characterizes the landscape of the CCNR, with the elevation varying from 30 m to 1,577 m.a.s.l. (Figure 1). The area is a large limestone mountain with many peaks such as Cao Duong peak (989 m), Pu Loan peak (1,154 m), Khau Vuong peak (1,218 m), and the highest peak Cham Chu (1,587 m) (Nguyen et al., 2018). Cham Chu region has a tropical monsoonal climate with two seasons: summer and winter. The summer is hot and has high humidity from May to October; the winter is cold and dry from November to April. The annual temperature is 23°C. The average annual rainfall of the area fluctuates in the range of 1,500 mm to 1,800 mm. While the rainfall in summer accounts for 85-94% of total annual rainfall, the value in winter only comprises 6-25% of the total yearly rainfall (Ranzi et al., 2012).

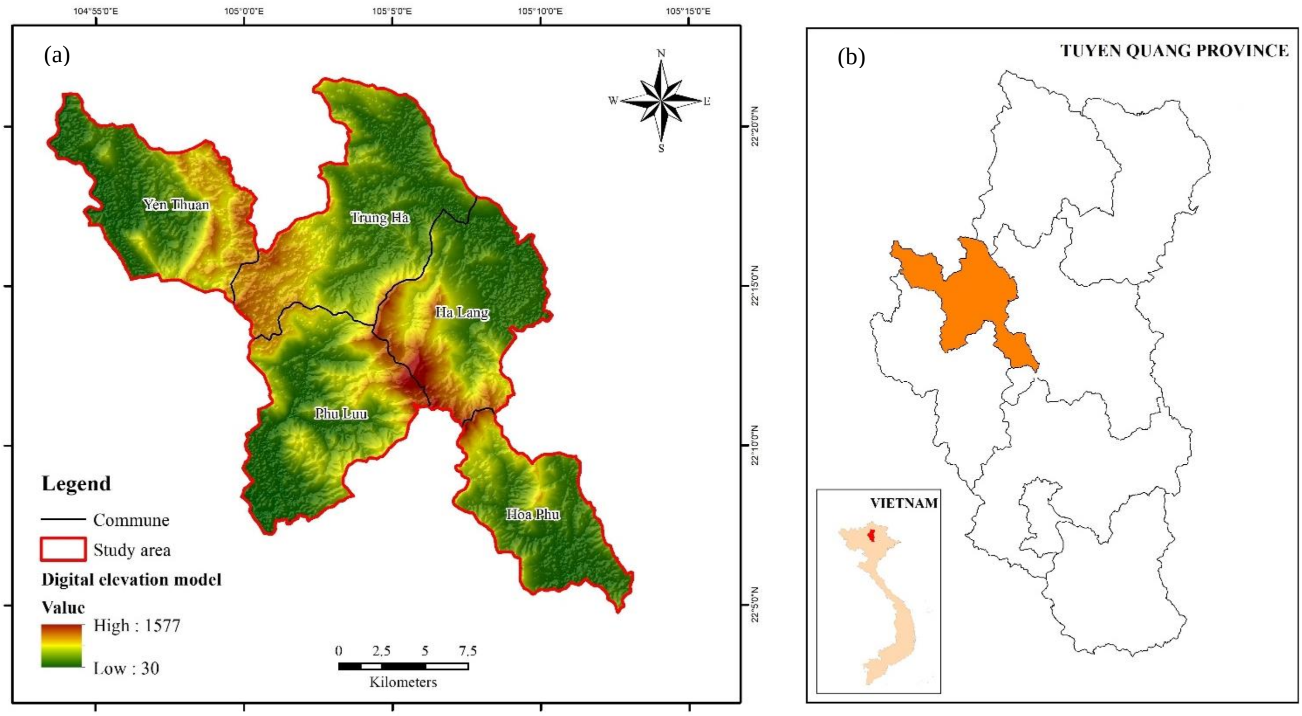

Figure 1. Location of the study area: (a) DEM of the CCNR and (b) the CCNR in Tuyen Quang Province, Vietnam

2.2 Research methodology

The research methodology workflow consisted of two components: (1) LULC classification and (2) ecosystem service evaluation (Figure 2). Details of each component are separately described in the following sections.

2.2.1 LULC classification

Data sources for LULC classification in this study are Landsat images taken over the area of Cham Chu. These images were collected from the United States Geological Survey (USGS) and were used as multi-temporal resolution remote sensing imagery over the study area. A set of four Landsat images from 1986, 1998, 2007, and 2017 was used for LULC classification and interpretation. They have similar acquisition seasons to ensure the image quality and avoid the effects of atmospheric conditions (haze, cloud cover) for compatible detection of LULC types (Table 1).

In this study, geometric corrections of the data were conducted using the image to map rectification based on topographic maps with a scale of 1:50,000 using the Erdas Imagine 2014 software. All data were re-projected to the Universal Transverse Mercator Projection System (UTM) Zone 48N with the World Geodetic System (WGS-1984) datum. After that, we classified LULC into five types, which are forest land, bush, bareland, cropland, and water body. The description of the LULC category is shown in Table 2. The Landsat images were classified using a maximum likelihood classification, which is a method for calculating a known class of distributions as the maximum for a given statistic (Sun et al., 2013). Besides, visual interpretation of image features, e.g., shape, size, color, and texture for each class of LULC, was also performed to correct the misclassified LULC types (Mamat et al., 2018a; Ongsomwang et al., 2019; Thakkar et al., 2017).

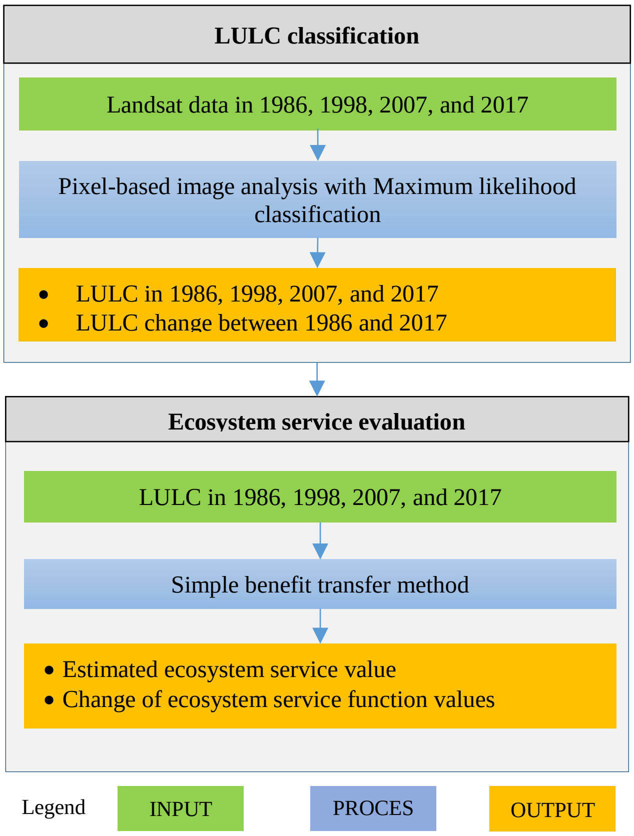

Figure 2. Workflow of research methodology

Table 1. The characteristic of Landsat images obtained for this study

No	Satellite	Path/Row	Date	Spatial resolution	No. of bands
1	Landsat 5-TM	127/045	01 July 1986	30 m	7
2	Landsat 5-TM	127/045	18 July 1998	30 m	7
3	Landsat 5-TM	127/045	24 May 2007	30 m	7
4	Landsat 8-OLI	127/045	04 June 2017	30 m	7

Table 2. LULC categories in the CCNR and their equivalent biome for ecosystem service evaluation

LULC type	Definition	Equivalent biome	Ecosystem Service Coefficient (USD/ha/year)
Forest land	Areas covered by trees both natural and planted, dense forest, and opened forest	Tropical forest	2,003
Bush	Bush mixed with the small woody tree, vines, and grass	Grass/rangelands	244
Bareland	Exposed soils, bare rocks, floodplain, quarries, and sparse vegetation	Desert	0
Cropland	Cropland, orchards, nurseries, horticultural land, fallow land, intensively, moderately, and sparsely cultivated land	Cropland	92
Water body	Rivers, lakes, and artificial water areas	Lakes/rivers	8,498

Note: Ecosystem Service Coefficients were computed from Van der Ploeg and de Groot (2010)

The corrected LULC maps were validated using overall accuracy and Kappa hat coefficient based on the reference maps in 1986, 1998, and 2007 from the Vietnam Ministry of Natural Resources and Environment and a field survey in 2017. Herein, 397 sample points with a confidence level of 95% and a precision of 5% for the LULC class and stratified random sampling were used in this study to assess the accuracy (Congalton and Green, 2008; Israel, 1992). Finally, the post-classification comparison technique (Jensen, 2005) was applied to detect LULC change between 1986 and 2017.

2.2.2 Ecosystem service evaluation

The derived LULC data in 1986, 1998, 2007, and 2017 were used to calculate the ESV based on the simple benefit transfer method, which refers to the process of transferring economic value figures from one place to a relative location (Kindu et al., 2016; Plummer, 2009). The ESV for a given LULC type is determined by multiplying the area of each LULC type by its value coefficients, and the cumulative ESV for each reference year is a total of the LULC types' values (Equation 1).

$$\mathrm{ESV} = \sum(\mathrm{A_k} \times \mathrm{VC_k}) \qquad (1)$$

Where; ESV is the total estimated ESV, A_k is the area (ha), and VC_k is the value coefficient (USD/ha/year) for LULC type k (Table 3).

In addition to estimating the total value of ecosystem services for LULC types, the values of services delivered by different ecosystem functions within the study area were also assessed using the following equation:

$$\mathrm{ESV_f} = \sum(\mathrm{A_k} \times \mathrm{VC_{fk}}) \qquad (2)$$

Where; ESV_f is the calculated ESV of function f, A_k is the area (ha), and VC_{fk} is the value coefficient of function f (USD/ha/year) for LULC type k (Talukdar et al., 2020) (Table 3).

Then, through comparing the values of one dataset to the equivalent value of the second dataset, the ESV change was determined as follows:

$$\text{ESV change} = \left(\frac{\text{ESV final year - ESV initial year}}{\text{ESV initial year}}\right) \times 100 \qquad (3)$$

Where; ESV is the total estimated ESV, positive values of ESV indicate an increase, whereas negative values indicate a decrease in the amount of USD, and the ESV change is presented in percent (Kindu et al., 2016; Ongsomwang et al., 2019).

Table 3. Annual value coefficient for each ecosystem service function according to LULC type (Van der Ploeg and de Groot, 2010)

Ecosystem services	ESV (USD/ha/year) of each land cover type			
	Forest land	Bush	Cropland	Water body
Provisioning services				
Water supply	3			2,117
Food production	32	67	54	41
Raw material	315			
Genetic resources	41	0		
Regulating services				
Water regulation	6	3		5,445
Waste treatment	87	87		665
Erosion control	245	29		
Climate regulation	223	0		
Biological control		23	24	
Gas regulation		7		
Disturbance regulation	5			
Supporting services				
Nutrient cycling	922			
Pollination		25	14	
Soil formation	10	1		
Cultural services				
Recreation	112	2		230
Cultural	2			
Total	2,003	244	92	8,498

Finally, sensitivity analyses were performed to calculate the percentage change in ESV for a given percentage shift in the value coefficient. The sensitivity analysis was performed using the standard economic concept of elasticity, i.e., the percentage change in the output for a given percentage change in the input (Kreuter et al., 2001; Perloff, 2016), as shown in Equation (4). Consequently, the ecosystem modified value coefficients for the forest land, bush, cropland, and water body were individually adjusted by 50%, and the corresponding coefficient of sensitivity (CS) was calculated. If CS is higher than one, the estimated ecosystem value is elastic to the coefficient; but, if CS is less than one, the estimated ecosystem value is inelastic, and the outcome is reliable. The higher the proportional shift in the value of ecosystem services compared to the valuation coefficient, the more meaningful the use of a reliable ecosystem value coefficient (Mamat et al., 2018b; Solomon et al., 2019).

$$CS = \frac{(ESV_j - ESV_i)/ESV_i}{(VC_{jk} - VC_{ik})/VC_{ik}} \quad (4)$$

Where; ESV_i and ESV_j are primary and adjusted total estimated ESVs, respectively and VC_{ik} and VC_{jk} are primary and adjusted value coefficients for LULC type k.

3. RESULTS AND DISCUSSION

3.1 Land use and land cover classification

The results of the LULC classification in the CCNR between 1986 and 2017 are shown in Table 4 and Figures 3 and 4. Overall, forest land persists as the dominant cover type over 30 years. Forest land showed an initial decrease and then an increase, with a reduction from 76.41% of the total land in 1986 to 72.0% in 2007, and then an increase to 76.42% in 2017. The most significant land cover change occurred in bush and bareland. The bush experienced an initial increase then decrease, with an increase from 9.93% of the total land in 1986 to 11.31% in 2007, and then decrease to 3.68% in 2017. Bareland rapidly increased from 8.54% in 1986 to 10.30% in 2007 and then expanded to 15.23% in 2017. Likewise, cropland showed an increase from 4.71% in 1986 to 6.11% in 2007, then decreased to 4.39% in 2017. Water body initially experienced a slight increase from 0.40% in 1986 to 0.47% in 1998, then reduced to 0.28% in 2007 and 2017. The considerable increase in cropland and bareland, together with the decrease in forest land in 2007, is a result of the rapid development of illegal exploitation of forest products, clearance of forest for agriculture, and inadequate regulations for the protection of natural ecosystem in this period. However, after ten years, from 2007 to 2017, the forest land increased from 72.00% to 76.42%, and the cropland decreased from 6.11% to 4.39%. These findings imply the practical effort of nationwide reforestation programs of Vietnam's government (Clement and Amezaga, 2009; Huong et al., 2014).

Furthermore, the accuracy of LULC classification in 1986, 1998, 2007, and 2017 were 90%, 93%, 91%, and 89%, and the Kappa coefficients were 0.891, 0.918, 0.875, and 0.886, respectively. According to Fitzpatrick-Lins (1981), a Kappa hat coefficient of more than 80% represents strong agreement or accuracy between two maps. Turan and Günlü (2010) also stated that the overall accuracy is acceptable if it is greater than 80%. Both findings indicate that the LULC classification result in this study meets the accuracy requirement for land use classification.

Table 4. LULC pattern in the CCNR in 1986, 1998, 2007, and 2017

LULC types	1986		1998		2007		2017	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Forest land	30,906	76.41	30,541	75.51	29,122	72.00	30,908	76.42
Bush	4,017	9.93	3,791	9.37	4,573	11.31	1,489	3.68
Bareland	3,456	8.54	4,070	10.06	4,165	10.30	6,161	15.23
Cropland	1,907	4.71	1,854	4.58	2,471	6.11	1,775	4.39
Water body	160	0.40	190	0.47	115	0.28	113	0.28
Total	40,446	100.00	40,446	100.00	40,446	100.00	40,446	100.00

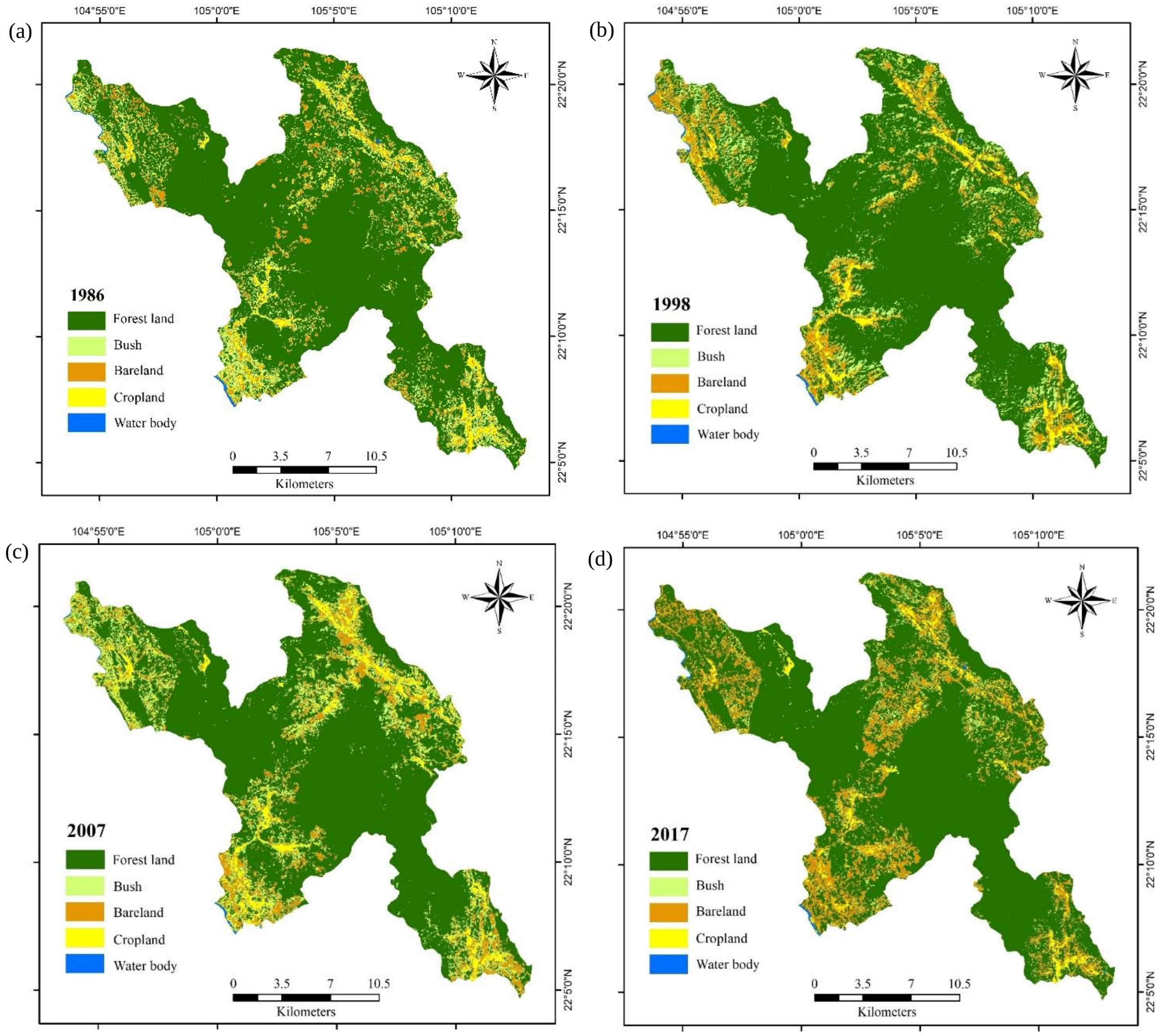

Figure 3. Spatial distribution map of LULC in the CCNR in (a) 1986, (b) 1998, (c) 2007, and (d) 2017

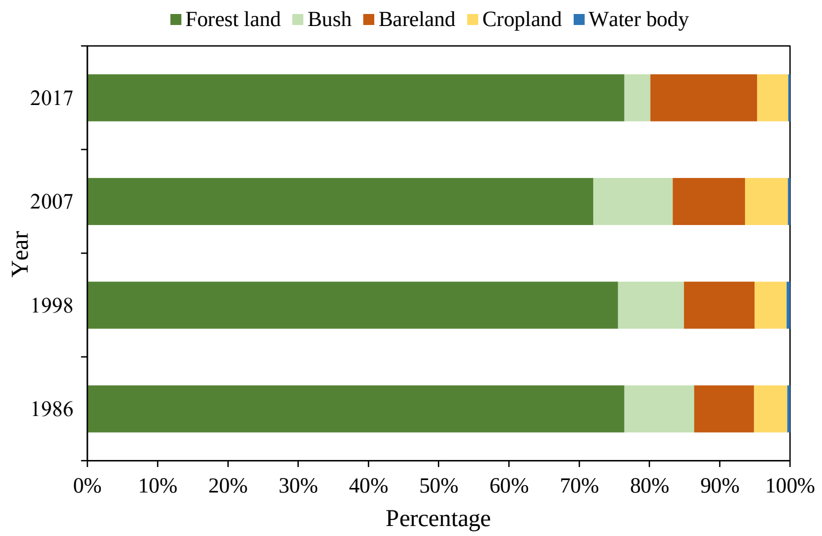

Figure 4. Multi-temporal LULC changes in the CCNR in 1986, 1998, 2007, and 2017

3.2 Land use and land cover change

Table 5 and Figure 5 revealed a complex transformation that occurred among each LULC type in the Cham Chu region from 1986 to 2017. Of about 30,907 ha of forest land in 1986, 26,282.61 ha were unchanged, while about 977.40 ha, 3,217.59 ha, 422.01 ha, and 6.93 ha were lost to bush, bareland, cropland, and water body, respectively. The total loss of forest land between 1986 and 2017 was about 4,624 ha. On the contrary, about 4,625 of forest land in 2017 was gained from the bush (about 2,220 ha), bareland (about 1,816 ha), cropland (about 574 ha), and water body (about 15 ha). Accordingly, the forest land increased over the study period by 1.17 ha, with an annual increased rate of 0.04 ha.

Table 5. LULC change matrix between 1986 and 2017

LULC type		LULC 1986 (ha)						
		Forest land	Bush	Bareland	Cropland	Water body	Class total	Gain
LULC 2017 (ha)	Forest land	**26,282.61**	2,220.03	1,816.02	574.02	15.03	30,907.71	4,625.10
	Bush	977.40	**259.56**	213.03	39.06	0.27	1,489.32	1,229.76
	Bareland	3,217.59	1,322.19	**1,081.89**	528.57	10.53	6,160.77	5,078.88
	Cropland	422.01	211.68	341.28	**752.85**	47.07	1,774.89	1,022.04
	Water body	6.93	3.96	3.96	10.17	**87.48**	112.50	25.02
	Class total	30,906.54	4,017.42	3,456.18	1,904.67	160.38		
	Loss	4,623.93	3,757.86	2,374.29	1,151.82	72.90		
Area change (ha)		1.17	-2,528.10	2,704.59	-129.78	-47.88		
Annual change rate (ha/year)		0.04	-81.55	87.24	-4.19	-1.54		

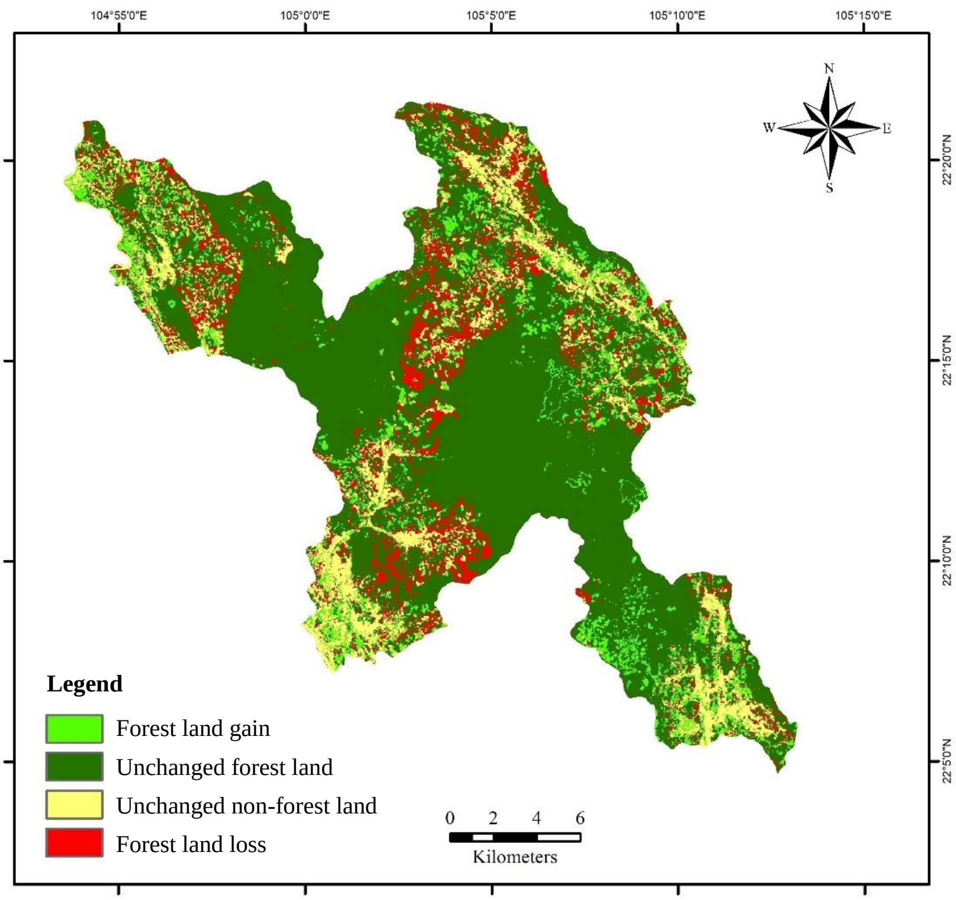

Figure 5. Forest land change map between 1986 and 2017 in the CCNR

About 260 ha of bush remained unchanged during the study period, while about 3,758 ha of bush in 1986 was converted into other LULC types in 2017, and about 1,230 ha of bush in 2017 was gained from different LULC types. The total area of bush decreased in the study period by 2,528.1 ha with an annual decrease of 81.55 ha/year. Meanwhile, about 1,082 ha of bareland was unchanged between 1986 and 2017, whereas about 2,374 ha was converted into other LULC types, and about 5,079 ha was gained from different LULC types. The annual increase of bareland was 87.24 ha/year. For cropland, about 752.85 ha remained unchanged, about 1,152 ha was converted into other LULC types, about 1,022 ha was gained from different LULC types, and the annual rate of decrease was 4.19 ha. About 87.48 ha was unchanged for the water body in the same period, about 723 ha was converted into other LULC types, and about 25 ha was gained from different LULC types. The total water body area decreased by 47.88 ha, with an annual rate of decrease of 1.54 ha.

3.3 Status of ecosystem service value

Table 6 shows the estimated ESV for each land cover type from 1986 to 2017. The total ESVs of the whole study area were about 64.4, 63.9, 60.7, and 63.4 million USD in 1986, 1998, 2007, and 2017, respectively. In 1986, forest land, bush, cropland, and water body accounted respectively for about 96.1%, 1.5%, 0.3%, and 2.1% of the total ESVs. In 1998, forest land contributed the most significant part (i.e., 95.8%), while bush, cropland, and water body accounted, respectively, for about 1.4%, 0.3%, and 2.5% of the total ESVs. Also, forest land, bush, cropland, and water body accounted for approximately 96.2%, 1.8%, 0.4%, and 1.6%, respectively, of the total ESVs in 2007. In 2017, forest land, bush, cropland, and water body accounted, respectively, for about 97.7%, 0.6%, 0.3%, and 1.5% of the total ESVs.

Table 7 and Figure 6 show changes in ecosystem services values between different periods. The total ESV during the first study period (1986-1998) decreased by about 0.5 million USD, which is about 0.8% of the value that existed in 1986. The total ESV was further reduced by approximately 3.2 million USD (5.1%) during the second period (1998-2007). Still, total ESV was increased by approximately 2.7 million USD (4.5%) during the third period (2007-2017). Nevertheless, the total ESV was reduced by roughly 1.0 million USD (1.6%) for the whole study period (1986-2017). During the whole study period, the change in ESVs for each land use type also showed a significant reduction of the values from bush, and water body, representing about 0.6 million USD (62.9%), and 0.4 million USD (29.4%) of the value that existed in 1986, respectively.

Table 6. Estimation of ESVs for each land use type of the different years in USD million per year of the study area

LULC types	1986		1998		2007		2017	
	ESV	%	ESV	%	ESV	%	ESV	%
Forest land	61.9	96.1	61.2	95.8	58.3	96.2	61.9	97.7
Bush	1.0	1.5	0.9	1.4	1.1	1.8	0.4	0.6
Bareland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cropland	0.2	0.3	0.2	0.3	0.2	0.4	0.2	0.3
Water body	1.4	2.1	1.6	2.5	1.0	1.6	1.0	1.5
Total	64.4	100.0	63.9	100.0	60.7	100.0	63.4	100.0

Table 7. Changes in ESVs between different periods.

LULC types	1986-1998		1998-2007		2007-2017		1986-2017	
	Million USD	%	Million USD	%	Million USD	%	Million USD	%
Forest land	-0.7	-1.2	-2.8	-4.6	3.6	6.1	0.0	0.0
Bush	-0.1	-5.6	0.2	20.6	-0.8	-67.4	-0.6	-62.9
Bareland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cropland	0.0	-2.8	0.1	33.3	-0.1	-28.2	0.0	-6.9
Water body	0.3	18.8	-0.6	-39.5	0.0	-1.7	-0.4	-29.4
Total	-0.5	-0.8	-3.2	-5.1	2.7	4.5	-1.0	-1.6

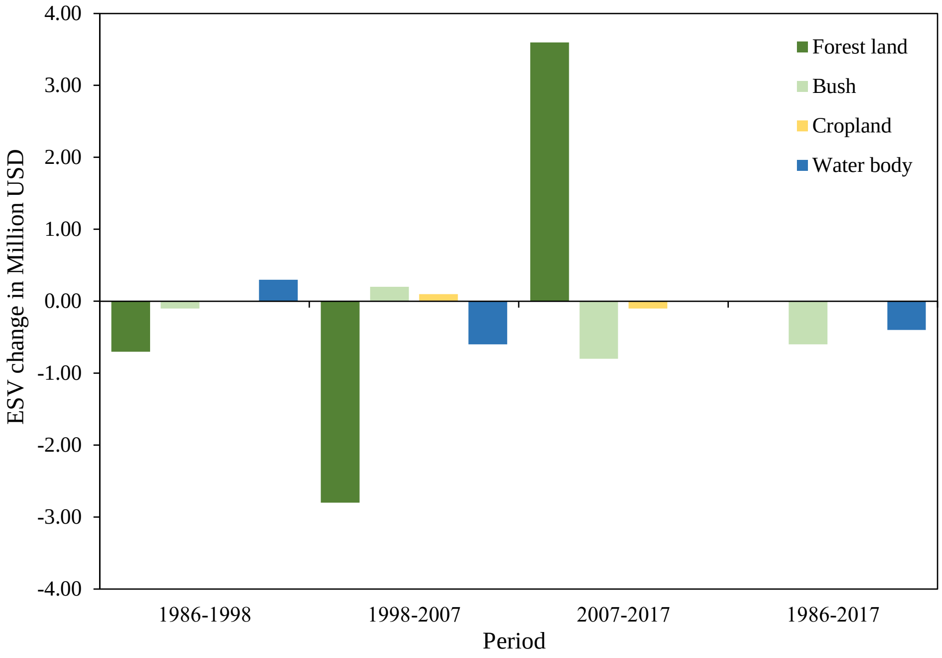

Figure 6. ESV change chart of the CCNR for 1986-1998, 1998-2007, 2007-2017, and 1986-2017

3.4 Estimated service value of individual ecosystem function and its change

The ecosystem function was determined using the value coefficients in Table 3 and areas of the land use categories (Table 4) to assess the impact of land use transition on each of the ecosystem functions and their contribution rate to the overall ESV within the CCNR over 30-year.

The estimated values of ecosystem service functions under each service category for different reference years and their changes are shown in Table 8. The values of ecosystem service functions ranged from 0.02 to 28.5 million USD, 0.02 to 28.2 million USD, 0.03 to 26.9 million USD, and 0.01 to 28.5 million USD in 1986, 1998, 2007, and 2017, respectively. The highest value was recorded for nutrient cycling for the whole study period, while the lowest was gas regulation. In this study, the value of the supporting services is the highest, indicating that supporting services are the main driver of the ecosystem services in the Cham Chu region ecosystem.

The changes in ecosystem service functions between periods are showed in Figure 7 and Table 8. From 1986 to 1998, most ecosystem function values decrease, except for water supply (14.5% increase) and water regulation (15.0% increase). From 1998 to 2007, the most significant change was observed for water regulation (33.7% decrease), followed by water supply (33.0% decrease), biological control (24.9% increase), pollination (23.3% increase), and gas regulation (20.6% increase). Between 2007 and 2017, the highest change was observed in gas regulation with a decrease of 67.4%, followed by pollination and biological control, which accounted for 58.3% and 53.3%, respectively.

For the whole study period (1986 to 2017), the change in ecosystem service functions showed significant decreases in gas regulation, pollination, biological control, water regulation, water supply, and food production of 62.9%, 51.2%, 44.4%, 24.7%, 23.1%, and 13.0%, respectively.

3.5 Ecosystem service sensitivity analysis

From 1986 to 2017, the coefficient of sensitivity (CS) was lower than one in all cases, indicating that the total ESVs estimated in the study area were relatively inelastic regarding the modified conservative ecosystem value coefficients (Table 9). In this study, the CS ranged from 0.00 to 0.97, and changes in the total value of the ecosystem services ranged from 0.16% to 48.74%. Adjusting the value coefficient by 50% for forest land affected the estimated 2017 ESV more (±48.74%) than the 1986 value (±48.14%). Adjustment to the modified value coefficient for bush affected the estimated 1986, 1998, 2007, and 2017 ESVs by ±0.78%, ±0.63%, ±0.82%, and ±0.32%, respectively. Adjusting the water body coefficient by 50% affected the estimated 1986, 1998, 2007, and 2017 ESVs by ±1.09%, ±1.25%, 1.65%, and

0.79%, respectively. Adjusting the cropland coefficient barely affected the estimated ESV by ±0.16% for the whole study period. Despite inconsistencies in the adjusted value coefficients used in the study, the sensitivity analysis indicated that the ESV prediction was robust. The value coefficients had a substantial impact on the precision of the predicted improvement in ESV from 1986 to 2017, implying that our findings are reliable and that the ESV index used in the study is a good match.

Table 8. Value of ecosystem service functions under each service category for different reference years and their changes in the CCNR

Ecosystem services	ESV million USD/year				ESV changes (%)			
	1986	1998	2007	2017	1986-1998	1998-2007	2007-2017	1986-2017
Provisioning services								
Water supply	0.4	0.5	0.3	0.3	14.5	-33.0	0.3	-23.1
Food production	1.4	1.3	1.4	1.2	-2.1	2.8	-13.6	-13.0
Raw material	9.7	9.6	9.2	9.7	-1.2	-4.6	6.1	0.0
Genetic resources	1.3	1.3	1.2	1.3	-1.2	-4.6	6.1	0.0
Regulating services								
Water regulation	1.1	1.2	0.8	0.8	15.0	-33.7	-1.2	-24.7
Waste treatment	3.1	3.1	3.0	2.9	-1.0	-3.4	-3.8	-8.0
Erosion control	7.7	7.6	7.3	7.6	-1.2	-4.3	4.8	-0.9
Climate regulation	6.9	6.8	6.5	6.9	-1.2	-4.6	6.1	0.0
Biological control	0.1	0.1	0.2	0.1	-4.7	24.9	-53.3	-44.4
Gas regulation	0.02	0.02	0.03	0.01	-5.60	20.60	-67.40	-62.90
Disturbance regulation	0.2	0.2	0.1	0.2	-1.2	-4.6	6.1	0.0
Supporting services								
Nutrient cycling	28.5	28.2	26.9	28.5	-1.2	-4.6	6.1	0.0
Pollination	0.13	0.12	0.15	0.06	-5.00	23.30	-58.30	-51.20
Soil formation	0.3	0.3	0.3	0.3	-1.2	-4.3	5.0	-0.8
Cultural services								
Recreation	3.5	3.5	3.3	3.5	-1.0	-5.0	5.9	-0.4
Cultural	0.1	0.1	0.1	0.1	-1.2	-4.6	6.1	0.0
Total	64.4	63.9	60.7	63.4	-0.8	-5.1	4.5	-1.6

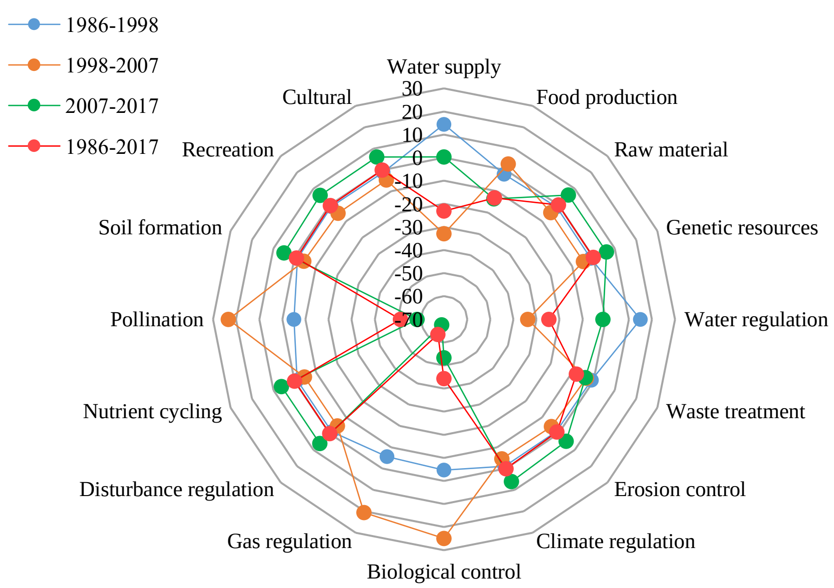

Figure 7. Changes in ecosystem service functions between the reference years in the percentage

Table 9. Changes in estimated total ESVs and CS

Change of ESV coefficient	1986		1998		2007		2017	
	%	CS	%	CS	%	CS	%	CS
Forest land ±50%	±48.14	0.96	±47.89	0.96	±47.94	0.96	±48.74	0.97
Bush ±50%	±0.78	0.02	±0.63	0.01	±0.82	0.02	±0.32	0.01
Cropland ±50%	±0.16	0.00	±0.16	0.00	±0.16	0.00	±0.16	0.00
Water body ±50%	±1.09	0.02	±1.25	0.03	±1.65	0.03	±0.79	0.02

3.6 The impact of LULC change on ecosystem service values

This research examined developments in ESVs over 30 years in the CCNR as a result of land cover dynamics. The total ecosystem service function value decreased in the first and second periods (1986-1998 and 1998-2007) then increased in the third period (2007-2017). The total ecosystem service function value in the entire study period still decreased. Among sixteen ecosystem services functions, gas regulation, pollination, biological control, water regulation, water supply, and food production functions experienced the most significant decline. These findings indicate the impact of LULC change on ecosystem function service in the area.

A significant change in the different land use types occurred between 1986 and 2007 in the Cham Chu region. Cropland and bareland increased, while forest land decreased. The changes in ESV of the land use types varied according to the changes in the area. The overall ecosystem service value declined during this period due to the degradation of forest land. The inefficiency of the State Forest Enterprises system for forest management during this period was the fundamental cause of the loss of forest land (MARD, 2001; Nguyen et al., 2001). USAID (2015) also stated that forest conversion to annual crops and commercial perennial plantations at household scale by local people and official forest conversion to infrastructure and commercial perennial plantations by both state-owned companies and private companies as a direct driving force for deforestation. Communities encroached on fields in order to obtain wood for fuel, building products, more arable land, and livestock feed, resulting in a slight decline in cover (Cochard et al., 2020). Between 2007 and 2017, the total estimated ESVs showed a slight increase resulting from the rise in forest land because the community and the government of Vietnam have implemented several interventions to modify the existing practices and reduce the effects of deforestation. Forest management in Vietnam is also moving towards greater participation of local citizens, especially indigenous communities, in managing forest resources, and reforestation policy also helps to explain the successes in increasing forest cover for the latter period in Vietnam (Tan, 2005).

3.7 Evaluation of ecosystem services and policy implication in Vietnam

Despite the fact that there are few studies in Vietnam on measuring total ESV, Table 10 shows a comparison of ecosystem services for forest ecosystems in protected areas in Vietnam in terms of total ESV per hectare. For comparison, a mangrove forest ecosystem in Thai Thuy Nature Reserve has a total ESV of 1,758 USD/ha (including provisioning, regulating, supporting, and cultural services) (ISPONRE, 2018), while forest ecosystems in Cat Tien Natural Park have a value of 726 USD/ha (including provisioning, regulating, and cultural services) (GECD, 2014). Meanwhile, Ca Mau mangrove forest ecosystem provisioning and regulating services are valued at up to 3,316 USD/ha (Vo et al., 2015). Although there are certain differences in the results of these studies because of different methods, the findings of this study using the value transfer method combined with the remote sensing gives a relative benefit that fits the particular context of Vietnam.

The overall assessment methodology in this study can be applied to the rapid assessment of ecosystem services for specific protected areas and regions, and be considered as the basis of land use planning and biodiversity conservation. While the value of global ecosystem services is estimated to be around 125-145 trillion USD for 2011 (in 2007 USD) (Costanza et al., 2014), the value of the ecosystems services in Vietnam is estimated at about 28.87 billion USD (WWF, 2013), equivalent to 16.8% of GDP in 2013. In fact, ecosystem services have not been appropriately considered in Vietnam in policymaking processes, while globally sustainable development policy is making more use of ecosystem services valuation (Brondizio et al., 2019). Ecosystem services values are increasingly integrated into strategic environmental assessments and development policy for national and global conservation and resource management (Mukherjee et al., 2014).

Table 10. Comparison of total ESV for forest ecosystems in protected areas in Vietnam

Study sites/Area (Year of publication)	Total ESV (USD/ha)	Provisioning service (USD/ha)	Regulating service (USD/ha)	Supporting service (USD/ha)	Cultural service (USD/ha)	Main methods used and reference
CCNR/40,446 ha (2017)	1,569.2	309.1	457.6	713.5	89.0	Value transfer and GIS/RS
Cat Tien Natural Park/71,000 ha (2014)	726	39	668	-	11	Market price, cost-based, benefit transfer (GECD, 2014)
Ca Mau Mangrove Forest/187,533 ha (2015)	3,316	2,344	973	-	-	Market price, remote sensing (Vo et al., 2015)
Thai Thuy Mangrove Forest/13,100 ha (2016)	1,758	1,172	463	20	103	Market price, direct interview, value transfer (ISPONRE, 2018)

While the policy of payments for ecosystem services has strongly developed in North America and Europe, in Vietnam, this policy has only partly been demonstrated through payments for forest environmental services, mainly focusing on regulating services. Luong (2018) argued that the value of regulating services is about VND 1,700 billion for 2017 (74.1 million USD). This policy is also an important resource to support the conservation of forest ecosystems for local people. Although Vietnam has developed an essential legal basis related to the application of ecosystem services in policy, such as the Environment Law (No. 72/2020/QH14), which identifies the role of ecosystem services in development policy, or the Law on Forestry (No. 16/2017/QH14), which includes a policy on payment for forest environmental services, the lack of appropriate approaches and methodologies to quickly assess the value of ecosystem services limits the effects of these policies. Despite the limitations mentioned above, the results of this study also contribute to the implementation of biodiversity conservation policies through the assessment of ecosystem services in Vietnam.

4. CONCLUSION

The simple benefit transfer method was successfully applied to examine ecosystem service change due to land use and land cover change between 1986 and 2017 in Cham Chu nature reserve, Tuyen Quang Province, Vietnam. The study discovered that areas of forest land and water body were stable over time. Simultaneously, bare land, which did not provide any ecosystem service value, has continuously increased. This finding indicates the effects of land use and land cover change on ecosystem service values in the study area. Consequently, the total ecosystem service values decreased from 64.4 million USD in 1986 to 63.4 million USD in 2017. Also, ecosystem service functions under the provisioning, regulating, and supporting services of the Cham Chu nature reserve significantly decreased water supply, water regulation, biological control, gas regulation, and pollination. While the results of this study are quite consistent and comparable with the studies carried out so far in Vietnam, more importantly, this study is more systematic and assessed for a long period of time (1986-2017).

In conclusion, the current research framework can be used as a guideline to local governments for assessing ecosystem services values and functions in nature reserve areas. Additionally, the results of this study can provide essential information to support policymakers and decision-makers in managing and protecting the nature reserve area of the country. Furthermore, when ESVs are calculated using the simple benefit transfer method, the local coefficient value of ecosystem services should be investigated in more detail for each LULC type.

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