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Original Research

Response of Ecosystem Service Value to Changes in Ecosystem Structure

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Abstract

Changes in the ecosystem structure and ecosystem service value of the Fuping basin of the Daqing River from 1985 to 2015, as ascertained through remote sensing and a value assessment model, respectively, showed that forest land had contributed the most to the total ecosystem service value, followed by cultivated land and grassland. The ecosystem structure had changed markedly, the area under different land uses showing both positive and negative changes: the positive changes were in construction land (139.57%), forest land (90.66%), cultivated land (68.79%), and water body (6.55%), and the negative changes were in unused land (-83.48%) and grassland (-54.92%). The ecosystem services were valued, in billions of yuan RMB, at 4.429 in 1985, 4.462 in 1990, 4.465 in 1995, 5.808 in 2000, 5.171 in 2005, 5.322 in 2010, and 5.272 in 2015. Of the various ecosystem services, soil conservation made the largest contribution, followed by biodiversity protection, gas regulation, and climate regulation. The ecosystem service value was positively correlated to the area of forest land and negatively correlated to the area of unused land.

Keywords: ecosystem service value, ecosystem structure, value assessment model, Daqing River Fuping basin

Introduction

Ecosystem services refer to benefits that people derive from an ecosystem. Such benefits include not only food, fresh water, and raw materials provided by the ecosystem for industrial and agricultural products, but they also support the earth's life system and maintain the biogeochemical and hydrological cycles, the equilibrium of atmospheric chemistry, biodiversity, and cleaning the environment [1-3]. Ecosystem services are thus essential for human survival and development. The underlying cause of most ecological problems faced by humankind today is the destruction and degradation of ecosystem services. According to millennium ecosystem assessment, ecosystem services can be divided into four categories, namely those related to provisioning, regulating, habitat, and culture [4]. Techniques to assess the value of ecosystem services have been developed to quantify the contributions of various types of ecosystem services. The seminal paper by Costanza et al. [1], "The value of the world's ecosystem services and natural capital," effectively promoted the assessment of the economic value of ecosystem services, and research on ecosystem services and their value assessment has

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received widespread international attention ever since. Scholars have not only studied and discussed the theory and the method of assessing the value of ecosystem services, but also conducted many field projects and undertook research of practical value and achieved significant results with reference to global or regional ecosystems [5-7], watershed ecosystems [8-9], and individual ecosystems [10-11]. For example, Xie on the basis of Costanza's method, developed a new method, namely "unit value," suited to environmental conditions in China [12]. Chen and his coworkers carried out a dynamic evaluation of ecosystem services in the Three-River headwater region [13]. Under the framework of the millennium ecosystem assessment, Zhang evaluated the potential and actual economic values of ecosystem services and losses in their service value due to marine pollution and eutrophication in Haizhou Bay [14]. Zhao, using the current international system that offers a functional classification of common ecosystem services, evaluated the current value of the forest ecosystem in Sichuan Province based on socio-economic statistics and data from remote sensing and field surveys [15].

Recent years have seen a great deal of research on the concept of ecosystem services, their classification, and the assessment of their economic value. At the same time, researchers are deeply aware that human activity is constantly changing the composition, structure, and function of ecosystems and thereby weakening their service function [16-17]. Therefore, current research on ecosystem services is focused on elucidating the relationship between ecosystem structure, processes, and services, and clarifying the mechanisms behind such ecosystem services to provide a better scientific basis for the assessment of ecosystem services and the management of ecosystems.

The present paper is a step in that direction and is based on the study of the Fuping basin of the Daqing River. Our paper examines the changes in the structure of that ecosystem and in the value of the services it offers by means of remote sensing and a value-assessment model, respectively, and discusses the relationship between ecosystem structure and ecosystem service.

Materials and Methods

Overview of Study Area

The Fuping basin of the Daqing River lies in the transition zone that extends from the Taihang Mountains to the North China Plain, and is in the western part of Baoding city in Hebei Province (114°8'27"-115°58'98"E, 38°10'37"-39°19'45"N, Fig. 1). The study area is 8369.50 km². The basin is part of the temperate monsoon region. Mean annual precipitation is 500-700 mm, the mean annual temperature is 12.2ºC, and the frost-free period lasts for about 200 days. Given the proximity to the ocean and the undulating terrain, the annual precipitation varies a great deal, concentrated mostly in the form of rainstorms in July and August, with hardly any precipitation recorded in winter and spring.

This study area offers major ecological services to the surrounding region and the downstream region. Xiong'an New District may prove to be the most important district in China in the coming decades. The area sees intense human activity, either protective or disruptive, reflected in such initiatives as the greening of the Taihang Mountains and the family contract responsibility system. Because of a combination of natural factors and anthropogenic disturbance, the structure of the ecosystem and the services it offers have changed tremendously, making the ecosystem ideally suited to studying the impact of such changes on ecosystem services value.

Data Sources and Processing

The data set for the present study includes Landsat-TM (thematic mapper) or ETM (enhanced thematic mapper) remote sensing images for 1985, 1990, 1995,

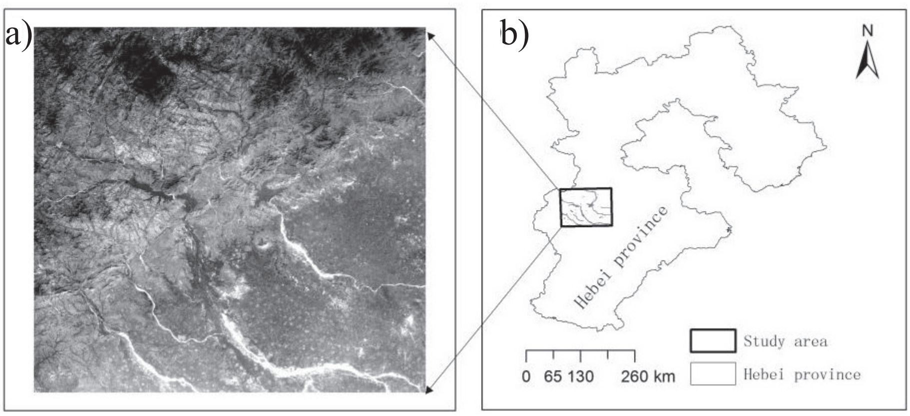

Fig. 1. Location of the study area: a) remote sensing images of study area (display in RGB) and b) location of the Daqing River Fuping basin.

Table 1. Equivalent value per unit area under different ecosystems.

Ecosystem Service	Forest land	Grassland	Cultivated land	Water body	Unused land	Construction land
Food production	0.33	0.43	1.00	0.53	0.02	0.00
Raw material production	2.98	0.36	0.39	0.35	0.04	0.00
Gas regulation	4.32	1.50	0.72	0.51	0.06	0.00
Climate regulation	4.07	1.56	0.97	2.06	0.13	0.00
Hydrological regulation	4.09	1.52	0.77	18.77	0.07	−7.51
Waste disposal	1.72	1.32	1.39	14.85	0.26	−2.46
Soil conservation	4.02	2.24	1.47	0.41	0.17	0.17
Biodiversity protection	4.51	1.87	1.02	3.43	0.40	0.40
Entertainment	2.08	0.87	0.17	4.44	0.24	0.24

Note: reference research [12] and [18]

2000, 2005, 2010, and 2015; an administrative map of Hebei Province; and agricultural statistics of the study area. The Landsat-TM/ETM data were downloaded from the United States Geological Survey (USGS; https://glovis.usgs.gov/) at a resolution of 30 m, band number of 124/33, and a cloud cover of less than 0.5%; the Hebei map was provided by the Hebei Bureau of Land and Resources; and the agricultural statistics were obtained from the Hebei statistical yearbook (http://www.hetj.gov.cn/res/nj2015/indexch.htm). The processing of remote sensing images included correction for radiation, delineation of the research area, and classification of the images by the maximum-likelihood method. The classification system comprised six types of land: forest, grass, cultivated, water body, unused, and construction. The accuracy of the classification was evaluated by random sampling; the overall classification accuracy was 85.68% for 1985, 87.32% for 1990, 81.25% for 1995, 83.41% for 2000, 89.32% for 2005, 85.12% for 2010, and 88.56% for 2015.

Methods of Analysis

Valuating Ecosystem Services

Changes in the ecosystem services value (ESV) were measured based on Costanza's theory of ecosystem service value [1] and Xie's equivalent value per unit area of ecosystem services in China [12].

The first step was to establish the equivalent value per unit area for all six ecosystems and for nine ecosystem services (e_{ij}) based on the research of [12] and [18] (Table 1). Currently, most research on the assessment of ESV is only confined to natural ecosystems: the ESV of artificial ecosystems is taken as zero. However, artificial ecosystems also have positive or negative ESVs [19]. The present study takes into account the services value of construction land and takes the equivalent value per unit of construction area from Li's research. In Table 1, (e_{ij}) is the ecological service function of food production expressed as the ecological service function per unit of the farmland ecosystem in ecosystem types i and j, with i the type of ecosystem service and j the type of ecosystem.

The second step was to calculate the economic value per unit area of services provided by the farmland ecosystem (E_a), which was taken as 1/7th of the output value (in yuan RMB per 100 m^2) of the main grain crop as given in the statistical yearbook for Hebei province. To facilitate the comparison across 30 years, the (E_a) was adjusted (Table 2) to the consumer price index (CPI) by the adjustment method of Shi [20].

The third step was to calculate the value coefficients (VC_{ij}) of ESV using the following formula:

Table 2. Economic value of services per unit area provided by farmland ecosystem of Baoding city, 1985-2015.

Year	1985	1990	1995	2000	2005	2010	2015
Cultivated area/104 hm²	6.06	16.33	120.03	122.99	118.11	121.70	121.58
Economic output value/108 yuan	1.12	3.10	119.06	138.29	202.24	334.12	469.06
E_a/Yuan·hm–²	264.05	271.28	1416.97	1606.38	2446.03	3922.20	5511.39
Consumer Price Index (CPI)	100.00	165.10	281.40	314.00	343.00	403.50	464.00
E_a after adjustment/Yuan·hm–²	264.05	164.31	503.54	511.59	713.13	972.05	1187.80

Table 3. Changes in area under different ecosystems, 1985-2015.

Year	Area	Forest land	Grassland	Cultivated land	Water body	Construction land	Unused land
1985	Area (km²)	941.51	2162.45	2317.15	70.38	510.26	2367.76
	Percentage(%)	11.25	25.84	27.69	0.84	6.10	28.29
1990	Area/km²	1024.36	2060.80	2649.82	70.22	775.13	1789.17
	Percentage(%)	12.24	24.62	31.66	0.84	9.26	21.38
1995	Area/km²	1088.71	853.23	3847.77	115.49	684.08	1780.23
	Percentage(%)	13.01	10.19	45.97	1.38	8.17	21.27
2000	Area/km²	1784.97	1099.51	4106.33	91.13	682.18	605.38
	Percentage(%)	21.33	13.14	49.06	1.09	8.15	7.23
2005	Area/km²	1647.62	1255.39	3453.46	73.73	977.53	961.76 ~~861.59~~
	Percentage(%)	19.69	15.00	41.26	0.88	11.68	11.49 ~~10.29~~
2010	Area/km²	1885.21	1059.08	3205.63	68.62	995.12	1155.83
	Percentage(%)	22.52	12.65	38.30	0.82	11.89	13.81
2015	Area/km²	1795.10	974.79	3911.13	74.99	1222.41	391.07
	Percentage(%)	21.45	11.65	46.73	0.90	14.61	4.67

Note: The remote sensing image come from USGS (https://glovis.usgs.gov/), the classification of the images by the Maximum-Likelihood Method

$$VC_{ij} = e_{ij}E_a \tag{1}$$

…where i is the type of ecosystem service and j is the type of ecosystem.

Finally, the ESV and of the ecosystem of the Fuping basin were calculated using the following formulae:

$$ESV = \sum(A_k \times VC_k) \tag{2}$$

$$ESV_f = \sum(A_k \times VC_{fk}) \tag{3}$$

…where ESV is the total ecosystem service value, A_k is the area (hm²) under the K-class land use in the study area, VC_k is the value coefficient (in yuans per hm² per year) of the K-class land use, ESV_f is the value (in yuans) of a single ecosystem service, and VC_{fk} is the individual service value coefficient (in yuans per hm² per year).

Sensitivity Index Analysis

Sensitivity index (SI) refers to the response of the total ESV to the change in service value coefficient [21] and is calculated using the following formula:

$$SI = \left|\frac{(ESV_j - ESV_i)/ESV_i}{(VC_{jk} - VC_{ik})/VC_{ik}}\right| \tag{4}$$

…where ESV_j is total ESV after adjusting for the ecological value coefficient, ESV_j is total ESV before adjusting for the ecological value coefficient, VC_{jk} is the ecological value coefficient of K-class land use after the adjustment, and VC_{jk} is the ecological value coefficient of the same land use before the adjustment. If SI is greater than 1, ESV is flexible and changes with the value coefficient (VC), indicating that the ESV is not particularly accurate; if SI is less than 1, ESV is not affected by VC, indicating that ESV is more accurate.

Results and Discussion

Analysis of Changes in Ecosystem Structure

Changes in Ecosystem Area

Over a 30-year period (1985-2015), the ecological structure of the Fuping basin significantly (Table 3). The main change was the decrease in the extent of unused land, followed by the increase in the extent of cultivated land. In 1985, unused land accounted for 2367.76 km², or 28.29% of the total study area; in 2015, land under that category had decreased to 391.07 km², or merely 4.67% of the total study area. The corresponding numbers for cultivated land – which recorded increased area – were 2317.15 km² (27.69%) and 3911.13 km² (46.73%). However, in terms of the amplitude of change, the most dramatic change was in the construction area (Table 4), which increased by 139.57% during 1985-2015, followed, in that order, by forest land (increase of 90.66%) and unused land (decrease of 83.48%).

Table 4. Amplitude of change (%) in area under different ecosystems, 1985-2015.

Ecosystem	1985-1990	1990-1995	1995-2000	2000-2005	2005-2010	2010-2015	1985-2015
Forest land	8.80	6.28	63.95	−7.69	14.42	−4.78	90.66
Grassland	−4.70	−58.60	28.86	14.18	−15.64	−7.96	−54.92
Cultivated land	14.36	45.21	6.72	−15.90	−7.18	22.01	68.79
Water body	−0.23	64.48	−21.10	−19.09	−6.93	9.28	6.55
Construction land	51.91	−11.75	−0.28	43.30	1.80	22.84	139.57
Unused land	−24.44	−0.50	−65.99	58.87 ~~42.32~~	20.18 ~~34.15~~	−66.17	−83.48

The changes in areas under different ecosystems showed a different pattern. As shown in Table 3, the area under forest land increased slowly from 1985 to 1995 and rapidly from 1995 to 2000, from 13.01% in 1995 to 21.33% in 2000, and remained stable thereafter. The increase in forest land is closely related to the Taihang Mountain Greening Project, which was implemented in 1994 and covered the mountainous area in the northern part of the study area. By 2000, 16805.3 km² had been afforested, the area under forests had doubled, and forest land accounted for 22.6% of the total area [22-23]. The Taihang Mountain Greening Project increased the rate of afforestation in the Taihang mountains significantly, and the improvement in the ecology of the area was clearly apparent. The overall area under grassland decreased from 1985 to 2015, the decrease during 1990-1995 being the most marked, from 24.62% in 1990 to 10.19% in 1995, and was followed by a slight increase during 2000-2010 and a slight decrease during 2010-2015. The overall area of cultivated land increased rapidly from 1985 to 1995; reached its peak in 2000; decreased during 2000-2010; and increased again during 2010-2015. The area of cultivated land increased rapidly during 1985-1995, mainly at the cost of grassland and unused land. The change was closely related to the family contract responsibility system introduced in the late 1980s, which encouraged farmers to bring more and more land under cultivation – the result of which was large-scale destruction of original grassland and forest ecosystems [24]. The increase in the area of water body was probably due either to the increase in forest land, which preserves water sources, or to precipitation, although the relationship between such aspects of climate as temperature and precipitation and ecosystem

Table 5. Transfer matrix of land use, 1985-2015 (km²).

1985 / 2015	Forest land	Grassland	Cultivated land	Water body	Construction land	Unused land	Total area	Transferred in
Forest land A	695.11	622.67	25.97	4.56	15.35	431.45	1795.10	1099.99
B%	73.83	28.80	1.12	6.48	3.01	18.22	—	—
Grass land A	72.30	422.78	38.07	3.36	36.39	401.89	974.79	552.01
B%	7.68	19.55	1.64	4.78	7.13	16.97	—	—
Cultivated land A	105.70	831.41	1772.92	10.68	126.92	1063.50	3911.13	2138.21
B%	11.23	38.45	76.51	15.18	24.87	44.92	—	—
Water body A	1.46	9.02	3.79	44.06	3.34	13.30	74.99	30.92
B%	0.16	0.42	0.16	62.61	0.66	0.56	—	—
Construction land A	18.97	188.09	441.91	2.95	310.98	259.51	1222.41	911.43
B%	2.02	8.70	19.07	4.19	60.95	10.96	—	—
Unused land A	47.96	88.48	34.49	4.76	17.27	198.11	391.07	192.96
B%	5.09	4.09	1.49	6.77	3.39	8.37	—	—
Total area	941.51	2162.45	2317.15	70.38	510.26	2367.76	—	—
Transferred out	246.40	1739.67	544.23	26.31	199.27	2169.65	—	—

Note: A_{ij} represents the area (km²) under land use type *I* transferred into type *J* from 1985 to 2015 and B% represents the percentage of land use type *I* in 1985 converted to type *J* $B_{ij} = A_{ij}/\sum_n^n A_i \times 100\%$.

structure is not examined in the present study. As research continues to increase our understanding of global climate change and its impact on land use on different scales, which, in turn, indirectly affects global climate change, the complexity of global processes becomes more and more apparent [25-26]. The area under construction land increased slowly but steadily, and that under unused land decreased during 1985-2000 and remained stable thereafter.

Transfer Matrix

The transfer matrix from 1985 to 2015 was calculated using ENVI v. 5.0 (Harris Geospatial Solutions, Broomfield, Colorado, USA) and the images for 1985 and 2015 that showed the ecosystem classification (Table 5). The ecosystems in the study area underwent frequent transformation during 1985-2015. The type or ecosystem that was transformed the most in terms of area gained was cultivated land, followed by forest land, construction land, grassland, unused land, and water body, and the transformed areas were 2138.21 km², 1099.99 km², 911.43 km², 552.01 km², 192.96 km², and 30.92 km² respectively. In terms of area lost, the ranking, in descending order, was as follows: unused land, grassland, cultivated land, forest land, construction land, and water body. Thus, cultivated land, forest land, water body, and construction land recorded a net increase in area because the area gained is larger than the area lost, whereas grassland and unused land recorded a net decrease because of the area lost being larger than the area gained.

Details of the transformation of different types of ecosystems during 1985-2015 are as follows: 622.67 km² of grassland and 431.45 km² of unused land were turned into forest land, the transfer rates being 28.8% and 18.22%, respectively; the increase in forest land was therefore mainly at the cost of grassland and unused land; 831.41 km² of grassland was turned into cultivated land and 622.67 km² of grassland turned into forest land; 1063.50 km² of unused land and 831.41 km² of grassland were turned into cultivated land; the expansion in cultivated land was therefore mainly at the cost of unused land and grassland. Changes in construction land were more marked: 441.91 km² of cultivated land and 259.51 km² of unused land were turned into construction land – over 30 years, unused land was mainly turned into cultivated land or forest land.

Analysis of Ecosystem Service Value

Changes in Ecosystem Services Value

According to Formula (2), the total ecosystem services were valued, in billions of yuan RMB, in different years was as follows: 4.429 in 1985, 4.462 in 1990, 4.465 in 1995, 5.808 in 2000, 5.171 in 2005, 5.322 in 2010, and 5.272 in 2015. Thus the total ESV of

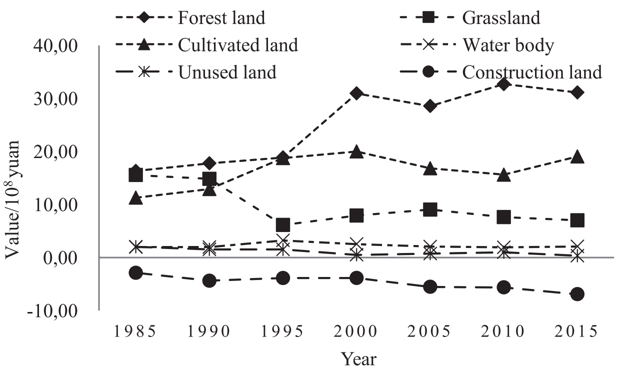

Fig. 2. Changes in service value of different types of ecosystems.

the study area kept increasing up to 2000 and declined thereafter, which indicates that there may be an upper limit on the ESV of an ecosystem. Of its components, the ESV of forest land, cultivated land, and water body kept increasing, and that of grassland, unused land, and construction land kept decreasing. The major contributors to the total ESV of the area were forest land, cultivated land, and grassland, and their ESVs changed substantially: (1) the ESV of forest land rose slowly during 1985-1995, rapidly during 1995-2000, and continued to rise slowly thereafter to peak in 2010; (2) the ESV of cultivated land increased during 1985-2000, decreased gradually during 2000-2010, only to rise rapidly again during 2010-2015 (although the highest value – 2 billion yuan RMB – was recorded in 2000); and (3) the ESV of grassland was its lowest point in 1995, but increased slowly thereafter. Water body did not record any major change in its ESV over the 30-year period (the peak appeared in 1995), whereas the ESV of unused land and construction land kept declining year after year (Fig. 2).

In terms of the ESV of different functions – calculated according to Formula (1) – instead of that of different types of ecosystems (Fig. 3), the main function in the study area was soil conservation, followed by biodiversity protection, climate regulation, and gas regulation. The other functions showed an increasing trend other than hydrological regulation and waste

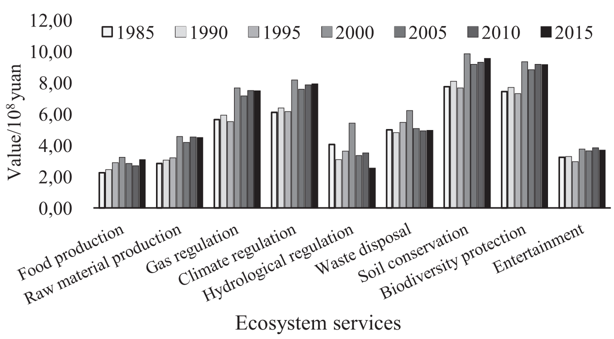

Fig. 3. Changes in ecosystem service value of different fuctions, 1985-2015.

Table 6. Coefficients of sensitivity of service value of different ecosystems.

Coefficient of ecosystem service value (±50%)	Sensitivity Index						
	1985	1990	1995	2000	2005	2010	2015
Forest land	0.426	0.369	0.395	0.438	0.429	0.509	0.513
Grassland	0.121	0.101	0.098	0.118	0.127	0.097	0.091
Cultivated land	0.403	0.357	0.392	0.395	0.407	0.368	0.347
Water body	0.045	0.038	0.043	0.047	0.039	0.047	0.046
Construction land	0.325	0.381	0.402	0.396	0.462	0.455	0.394
Unused land	0.005	0.007	0.012	0.015	0.009	0.013	0.003

disposal. The peak of every ecosystem service was reached in 2000. Over the 30-year period, the value of hydrological regulation and waste disposal services decreased, but that of all the other services increased, mainly because of the adverse impact of urbanization on hydrological regulation and waste disposal services. (The expansion of urban areas is obvious in the 139.57% increase in construction area.) Ge and his colleague found that due to the diversity of ecosystem services, the imbalance in spatial distribution (the area allocated to different land uses) and people's preferences, trade-offs between different service functions are inevitable [27]. However, the highest total ESV recorded in 2000 shows that the key to maximizing the ESV lies in optimal allocation of land to different ecosystems.

Changes in Sensitivity Index

The sensitivity index was calculated using Formula (3). The highest (0.531) SI was that of forest land and the lowest (0.003), that of unused land. All the ecosystems showed SI of less than 1 (Table 6), which indicates that the ESV is inelastic to VC, and the ecosystem service value is reliable.

Relationship between Ecosystem Service Value and Structural Changes in Ecosystem

Total Service Value and Area under Different Ecosystems

The total ESV of the study area was positively correlated to the area of forest land (the correlation coefficient was 0.929^{**}) and negatively correlated to the area of unused land (the correlation coefficient was -0.878^{**}) (Table 7). The amplitude of change in the total ESV and the amplitude of change in the area of forest land were also positively correlated (the correlation coefficient was 0.887^{**}) (Table 8).

Relationship between Different Ecosystem Service and Area under Different Ecosystems

The value of food production as a service was positively correlated to the area of cultivated land (the correlation coefficient was 0.992^{**}) (Table 9) and negatively correlated to the area of grassland (-0.841^{**}), and of unused land (-0.855^{**}). The values of other services were positively correlated to forest land and negatively correlated to unused land. The highest total

Table 7. Coefficients of correlation between total ESV and area under different ecosystems.

	Forest land	Grassland	Cultivated land	Water body	Unused land	Construction land
Pearson correlation	0.929**	−0.574	0.656	−0.095	−0.878**	0.453
Significant (both sides)	0.002	0.178	0.11	0.84	0.009	0.308

**significantly correlated at 0.01 level, *significantly correlated at 0. 05 level

Table 8. Coefficients of correlation between amplitude of change in total ESV and in area under different ecosystem.

	Forest land	Grassland	Cultivated land	Water body	Unused land	Construction land
Pearson correlation	0.887**	0.073	0.355	−0.215	0.174	−0.695
Significant (both sides)	0.008	0.877	0.435	0.643	0.709	0.083

**significantly correlated at 0.01 level, *significantly correlated at 0. 05 level

Table 9. Correlation coefficients of values of different ecosystem services and area of different ecosystems.

Ecosystem function		Forest land	Grassland	Cultivated land	Water body	Unused land	Construction land
Food production	P	0.699	−0.841**	0.982**	0.468	−0.855*	0.427
	Sig	0.080	0.018	0.000	0.290	0.014	0.339
Material production	P	0.996**	−0.691	0.676	−0.137	−0.929**	0.688
	Sig	0.000	0.085	0.096	0.769	0.003	0.088
Gas regulation	P	0.977**	−0.530	0.550	−0.301	−0.906**	0.656
	Sig	0.000	0.221	0.201	0.512	0.005	0.110
Climate regulation	P	0.978**	−0.577	0.613	−0.227	−0.927**	0.643
	Sig	0.000	0.175	0.144	0.624	0.003	0.119
Hydrological regulation	P	0.055	−0.003	0.177	0.314	0.026	−0.655
	Sig	0.907	0.995	0.704	0.492	0.957	0.110
Waste disposal	P	0.232	−0.409	0.638	0.625	−0.311	−0.372
	Sig	0.606	0.363	0.123	0.134	0.497	0.412
Soil conservation	P	0.953**	−0.522	0.598	−0.250	−0.932**	0.622
	Sig	0.001	0.229	0.156	0.588	0.002	0.136
Biodiversity protection	P	0.975**	−0.527	0.551	-0.300	−0.905**	0.651
	Sig	0.000	0.224	0.200	0.514	0.005	0.113
Entertainment	P	0.916**	−0.323	0.313	−0.517	−0.778*	0.601
	Sig	0.004	0.480	0.494	0.234	0.039	0.154

**significantly correlated at 0.01 level *significantly correlated at 0. 05 level

ESV was reached in 2000, and the highest ESV of forest land was reached in 2010, which indicates that in the study area, the highest ESV was derived not from the higher ESV of forest land but from a more reasonable allocation of land to different ecosystems – the proportions of areas of different types of ecosystems in 2000 represented the most optimum distribution of land. However, the present research needs to be extended to take into account the relationship between overall landscape pattern and service functions, a relationship that can be examined by using patch fragmentation index and patch fractal dimension [28].

Conclusions

The following conclusions can be drawn based on the results of our study:

1. The ecological structure of the study area changed markedly during 1985-2015. The area of construction land, forest land, cultivated land, and water body increased, whereas that of unused land and grassland decreased. The increase in forest land was mainly at the cost of grassland and cultivated land, and the rapid increase occurred in 1995-2000. The expansion of construction land during 1985-2015 was mainly at the cost of cultivated land (441.91 km²) and unused land (259.51 km²).
2. Forest ecosystem services in different periods made the largest contributions to total ESV, followed by cultivated land and grassland ecosystems. Similarly, among the various functions, soil conservation made the largest contribution, followed by biodiversity protection, gas regulation, and climate regulation. In the present study, that allocation, seen in 2000, was approximately as follows: cultivated land, 49%; forest land, 22%; grassland, 13%; construction land, 8%; unused land, 7%; and water body, 1%. Globally, about 60% of ecosystem services are affected; the loss and degradation of ecosystem services is bound to have a significant adverse impact on human well-being and global ecological security. The present study confirms that trend, but also identifies possible reasons for it to further our understanding of ecosystem structures and services.
3. The overall increase in ESV from 1985 to 2015 was mainly due to the increase in forest land and the decrease in unused land. The allocation of land to different ecosystems as seen in 2000 can be considered optimal. We should therefore make full use of unused land and arrest the loss of water body and forest land.

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Conflict of Interest

We declare that there are no competing interests among authors of this manuscript. Furthermore, it is declared that the manuscript has not been submitted to any other journal.

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