The Value of Ecological Assets Based on Land Cover/Use Pattern in Kunming, Yunnan Province

Meng Xu
Yunnan University of Finance and Economics
Kouqiang Zhang (zhangkouqiang@163.com)
Yunnan University of Finance and Economics
Shu'na Wei
Yunnan University of Finance and Economics

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Meng Xu[1], Kouqiang Zhang[1,*] , Shu'na Wei[1]

[1]Yunnan University of Finance and Economics, School of Urban and Environment, Kunming, 650221, China

ABSTRACT

Nowadays, the quantitative assessment of the ecological assets assessment was a hot topic and focus in the field of ecology and environmental economics. Quantitative evaluation of ecological assets can monetize the value of ecological assets, strengthen local ecological environment protection, and promote the service functions of regional ecosystems. Taking urban area as research area can clarify the value of local ecological protection and provide a scientific basis for the positioning of the functions and the construction of ecological civilization. The results showed that the value of ecological assets in Kunming was 249.858 billion yuan and 305.180 billion yuan in 2010 and 2020, respectively. Grassland made the largest contribution to ecological assets and was an important part of the composition of ecological assets, and the value of soil and water conservation occupied a large proportion in Kunming's ecological assets. The value of ecological assets in Kunming was growing in general, but a few ecological services have declined in value, so it was necessary to increase the ecological construction and strengthen the supervision and management of ecological assets.

Key words: ecological asset value; GIS; Land cover/use; Remote sensing; Kunming

Introduction

Along with the recovery of the global economy and the rapid development of the regional economy, the massive influx of people into cities has destroyed the ecosystems in urban areas[1]. At the same time, the global ecological crisis and the rapid degradation of ecosystem services have seriously threatened the sustainable development of society and economy[2,3]. Under the pressure of reality, human beings began to re-examine their own behavior, and relevant theoretical research was gradually carried out at home and abroad, resulting in the concept of ecological assets[4,5].

Nowadays, the quantitative assessment of ecological assets has gradually developed into a research hotspot and key issue in the field of ecology and ecological economics, and has been gradually incorporated into the national economic accounting system[6]. In 1997, Constanza achieved the first mapping of the value of global ecosystem services[7]. The valuation of ecosystem service functions has become the focus of academic attention and has reached a new wave of research with the establishment of TEEB (The Economics of Ecosystems and biodiversity)[8-12]. Enhancing the ability of ecosystem services and natural capital to support decision making in resource management practices has become a frontier in international ecosystem services research[13-15]. Based on research on ecosystem service valuation, the concept of ecological assets has also been gradually promoted in Chinese academia and has become to a quantitative approach to natural resource management in China. It can be considered that ecological assets are an innovation and development made by Chinese scholars based on the concept of ecosystem services and natural resources. The establishment of Ministry of Natural Resources of the People's Republic of China provides a powerful management platform for the unified management and systematic restoration of the country's natural resources. In the future, ecological asset accounting may become an important indicator for resource management performance assessment weight[16]. Although ecological asset accounting has been applied in regional sustainable development decision making, the international controversy over accounting for ecological assets has never stopped[17]. Under the premise of uncertainty in ecological

asset accounting, specific sustainable development decision states or scenarios should be further set. By refining the assessment indexes and clarifying the decision objects to find a relatively reliable accounting method, the accounting results can be used as a quantitative basis for judging the status quo or comparing scenarios.

Since 2012, the Chinese government has emphasized that "green water and green mountains are golden mountains", identifying a good relationship between economic development and ecological protection that promotes each other. In 2020, President Xi Jinping visited Yunnan Province and put forward a series of new requirements for the future development. As the capital of Yunnan Province and the central city of central Yunnan city cluster, Kunming is an important gateway and window to South Asia and Southeast Asia in China. With the advancement of urbanization and industrialization, Kunming's ecosystem has been subjected to huge stress, and the occupation of natural assets or ecological assets has become more and more serious, and the phenomenon of natural assets transferring to artificial capital in urban areas is more obvious. Although in recent years, Kunming on the ecological environment governance of bright eye, but in the economic take-off in today, in advance of Kunming urban ecological system, correct evaluation of ecological assets, clarify its future development trend, put forward the feasible measures of protection, development, and related policy making for the future city sustainable development to provide important reference value.

Study Area

Kunming is located in the southwest of China, with a total area of 21,473 square kilometers, under the jurisdiction of 7 municipal districts, 1 county-level city, 3 counties and 3 autonomous counties. According to the preliminary calculation, the GDP of Kunming in 2020 will be 673.379 billion yuan, with an average annual growth rate of 9%, and the per capita GDP will exceed 13,000 dollars. The per capita disposable income of urban permanent residents was 46,289 yuan, an increase of 7.7 percent over the previous year, and that of rural permanent residents was 16,356 yuan, an increase of 9.8 percent. The per capita disposable income of urban and rural residents reached about 48,018 yuan and 17,719 yuan respectively, narrowing the income gap from 2.97:1 in 2015 to 2.71:1.

Kunming is located in the middle of the Yunnan-Guizhou Plateau and the northern part of the Dian Lake Basin. The city center is about 1,891 meters above sea level, and most areas are between 1,500 and 2,800 meters above sea level, with the highest point at 4,247.7 meters. The topography of Kunming is located in the highlands subsidence basin and staggered valley area, from north to south in a gradual lowering of the step, the middle of the rise, the two sides lower, the ground height difference is huge, drainage conditions are complex. Kunming City is a subtropical - plateau monsoon climate, most of the area for the northern subtropical climate, the valley for the subtropical climate, the mountains for the southern temperate climate. The main vegetation type is subtropical evergreen broad-leaved forest. Influenced by the warm and humid air flow from the southwest of the Indian Ocean, Kunming has long sunshine, short frost period, obvious seasonal characteristics of precipitation, and the smallest annual temperature difference in China. It is the famous "Spring City".

As the capital of Yunnan Province and the central city of central Yunnan city cluster, Kunming has always been at the forefront in the construction of ecologically livable cities, ecosystem protection and ecological civilization system reform. In terms of ecosystem protection, with the control of the Dian Lake as the focus, the water quality of the whole lake has improved from poor to good, achieving the best water quality in the past 30 years. In the reform of ecological civilization system, laws, regulations and normative documents related to environmental protection and the Dian Lake governance have been introduced one after another. Many environmental management systems are of pioneering significance in the whole country.

Data used and Methodology

Data used

Based on the timeliness and availability of data, the main data used in this study include: (1) Landsat TM remote

sensing image data of Kunming City in 2010 and 2020 (pixel size: 30 m×30 m). (2) Data of administrative divisions of Kunming. (3) The digital elevation model (DEM) data, data from National Earth System Science Data Center, National Science & Technology Infrastructure of China (http://www.geodata.cn). (4) Soil data from Harmonizes World Soil Database (HWSD). (5) The meteorological data are from China Meteorological Data Network (http://data.cma.cn/). Other relevant statistical data are from Kunming Statistical Yearbook.

In order to meet the accuracy of ecological asset value accounting in the study area, the Landsat TM remote sensing images of Kunming City in 2010 and 2020 were cropped with the vector data of administrative divisions to obtain the remote sensing image data of Kunming City. According to the classification system of ecosystem services proposed by Costanza[7] and the revised national standard Land Use Status Classification (2017), the maximum likelihood method is used in the ENVI software to supervise the classification. Combined with the actual land cover situation in the study area and the needs of ecological asset assessment, The land cover types in the study area were divided into six categories: forest, cultivated land, grassland, water body, building land and bare land, and the land cover thematic map data in the study area was obtained with a spatial resolution of 30 m.

The establishment of ecological assets assessment model

Natural resource value

The natural resource values calculated in this paper are mainly accounted for from the perspective of returns, and the data are sourced from the total output value of agriculture, forestry, animal husbandry and fishery in the current year.

Ecological service value

(1) Organic production value

Organic matter production refers to the conversion of inorganic matter into organic matter by solar energy, which is an important link in ecosystem services. Net Primary Production (NPP) is an important indicator to measure the value of organic matter, which can be regarded as fixed carbon in the ecosystem. This article fixed capacity replacement method was adopted to calculate the net primary productivity (NPP) in the study area, and the market price of standard coal was used to represent the price of organic matter. The research estimated NPP by referring to the Miami model established by H.Lieth. The model is as follows:

$$NPP_t = 3000/(1+e^{1.315-0.1196t})$$
$$NPP_r = 3000\times(1+e^{-0.000684r}) \tag{1}$$

In this formula, NPP_t and NPP_r represents the net primary production of vegetation calculated with temperature and rainfall, respectively. The value with A lower value was selected as A_i, (i.e., annual net production dry weight) and its value was calculated by converting it into energy based on the market price. The calculation formula was as follows:

$$V(x) = \frac{P\times A_i\times S\times Q_1}{B\times Q_2} \tag{2}$$

In this formula, V(x) represents the value of organic material; A_i represents net production dry weight; S represents area; P represents the price of standard coal; B represents the mass coefficient of coal; Q_1 and Q_2 represents the amount of heat converted under dry weight of biomass and the amount of heat converted from standard coal respectively.

(2) Nutrient Recycling Value

Based on the calculation of NPP, this paper estimated the annual absorption amount of nitrogen, phosphorus and potassium in the ecosystem and converted it into the corresponding amount of fertilizer, and then multiplied by the market value of fertilizer to get the nutritional recovery value. The calculation formula was as follows:

$$V(x) = V_N(x) + V_P(x) + V_K(x) \tag{3}$$

In this formula, V represents the value of nutrients absorbed in the study area every year; V_N, V_P and V_K represent the annual absorption value of nitrogen, phosphorus and potassium, respectively.

In this article, the calculation method of the three nutrient elements is the same. Taking nitrogen as an example, the calculation formula is as follows:

$$N(x) = NPP(x) \times r_1 \times r_2 \times M \tag{4}$$

In the formula, $V_N(x)$ represents annual absorption of nitrogen value at pixel x (yuan); NPP(x) represents annual produced organic at pixel x; r_1 represents distribution rate of nitrogen in organic material in different ecosystem; r_2 represents ratio of pure nitrogen converted into fertilizer (79/14); M represents the average price of nitrogen fertilizer; V_N represents annual absorption nitrogen value in the region.

(3) Water conservation value

Water resource is an important carrier of ecological resources, and water resource conservation is the focus of ecosystem service function, which is mainly manifested in water resource regulation. In this article, the value of water conservation by the ecosystem is estimated by multiplying the project cost per unit reservoir by the precipitation storage volume per unit area. The calculation formula is as follows:

$$V(x) = Q(x) \times V_{sk} \times S \tag{5}$$

In the formula, V(x) represents the value of water conservation; Q(x) represents the annual precipitation storage volume per unit area; V_{SK} represents unit reservoir engineering cost; S represents the study area.

(4) Soil Conservation Value

Soil conservation function of ecosystem estimates mainly from three aspects including protection of soil fertility, reduced topsoil loss and reduced sediment deposition. The calculation formula is as follows:

$$V = V_1(x) + V_2(x) + V_3(x) \tag{6}$$

In the formula, V(x) represents annual soil conservation value; $V_1(x)$ represents annual value of protection of soil fertility; $V_2(x)$ represents annual value of reduced topsoil loss; $V_3(x)$ represents annual value of reduced sediment deposition; In the estimation process, adopting soil erosion amount of non-forest land to estimate reduced soil erosion amount in the ecological system, in order to estimate the value of the reduced topsoil loss, maintain soil fertility and the amount of sediment deposition.

(5) Fixing Carbon and Releasing Oxygen Value

The ecological value of maintaining atmospheric balance mainly considers the value of fixing carbon dioxide and releasing oxygen in the ecosystem. Based on the ecosystem biomass and NPP, this paper indirectly calculated the ecological value of maintaining atmospheric balance based on the reaction equations of photosynthesis and respiration. The unit economic value was calculated by referring to the Swedish carbon tax rate and the price of industrial oxygen production. The calculation formula was as follows:

$$V_{O_2}(x) = 1.2 \times NPP(x) \times R_{O_2}$$
$$V_{CO_2}(x) = 1.62 \times NPP(x) \times R_{CO_2} \tag{7}$$

In the formula, $V_{O2}(x)$ represents the value of O_2 released annually in the study area; Represents the unit mass value

of oxygen in the carbon tax law; $V_{CO2}(x)$ represents the value of CO_2 absorbed every year in the research area. R_{CO2} represents the unit mass value of CO_2 in the carbon tax code.

(6) Air Purification Value

The air purification value of ecosystem mainly considers two parts: absorption of SO_2 and residual dust.The amount of air purification value in the study area can be obtained by multiplying the amount of SO_2 and dust absorption by unit treatment cost. The calculation formula is as follows:

$$\begin{aligned} V(x) &= V_s + V_d \\ V_s &= Q_s \times W_s \times S \\ V_d &= Q_d \times W_d \times S \end{aligned} \tag{8}$$

In the formula, V(x) represents the total value of air purification, V_s and V_d represent the value of SO_2 absorption and dust retention, respectively. Q_s represents the amount of SO_2 absorbed by vegetation. W_S means to reduce the average overhead cost of SO_2; Q_d represents the total amount of dust retained by vegetation; W_D represents the residual dust treatment cost.

(7) Cultural Service Value

Ecosystems can meet human needs for sightseeing and recreation, while the scientific and cultural benefits of research such as basic science research, applied development research, teaching internships, and cultural promotion provided by ecosystems cannot be underestimated.

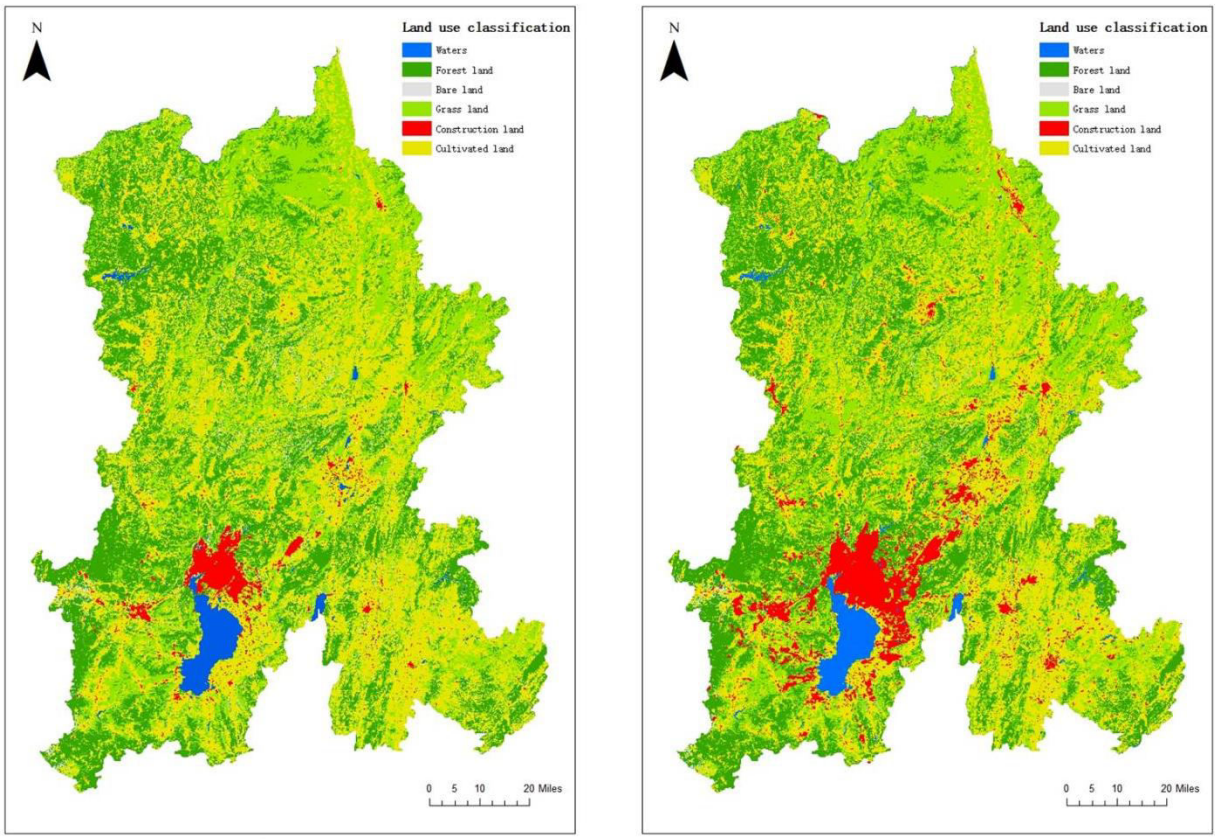
$$V(x) = V_1 + V_2 \tag{9}$$

In the formula, V(x) represents the value of cultural service, V_1 represents research and cultural value, V_2 represents leisure and recreation value.

Results and Discussion

The change of land use type in Kunming from 2010 to 2020

In terms of spatial distribution(Fig.1,table 1), the north area of Kunming is dominated by woodland and grassland. The central part is dominated by cultivated land and grass land, at the same time, a small part of construction land is distributed near rivers and lakes. Kunming central urban area is concentrated in the southwest with a high level of urbanization, and construction land and water body are the main land use types.



2010 2020

Figure 1. land use map in Kunming from 2010 to 2015

Land use type	2010		2020		Change area(km^2)	Annual rate(%)
	Area(km^2)	Ratio(%)	Area(km^2)	Ratio(%)		
Water body	154.59	0.74	137.82	0.66	-16.77	-10.85
Wood land	5713.18	27.19	5601.85	26.66	-111.34	-1.95
Unused land	3564.36	16.96	3407.11	16.21	-157.25	-4.41
Land for Construction	54.46	0.26	158.36	0.75%	103.91	190.80
Cropland	1181.00	5.62	1291.17	6.14	110.16	9.33
Grassland	10344.94	49.23	10416.23	49.57	71.29	0.69
Total	21012.54	100.00	21012.54	100.00		

Table 1. The area of each land use type in Kunming from 2010 to 2020

Table 1 shows the area and proportion of various types of land use in Kunming from 2010 to 2020. The area of construction land increased the most during the decade, but by 2020, grassland and woodland were still the most important land use types, accounting for 49.57% and 26.66%, respectively. Then unused land and cultivated land accounted for 16.21% and 6.14%, respectively. The smallest land use types were land of construction and water body, which were 0.75% and 0.66%, respectively. During the ten years, the area of grassland increased slightly, only by 0.69%, the area of cropland increased by 9.33%, but due to the rapid development of urbanization, the area of construction land increased by 190.80%. However, the area of water body, wood land and unused land decreased by 10.84%, 1.95% and 4.41%, respectively. Among them, the unused land decreased the most, mainly because of the rapid development of urbanization and the promotion of ecological civilization construction, the unused land area in Kunming gradually decreased.

Dynamic evaluation of ecological assets value in Kunming

natural resource value analysis

From 2010 to 2020, the value of products provided by all ecosystems will increase, from 19.386 billion yuan to 50.112 billion yuan, an increase of 158.5%. Among them, the value of products provided by forest land increased the most, reaching 202.96%, which was mainly due to the increase in the value of forest products. In the past 10 years, Kunming has focused on industrial restructuring and improving quality and efficiency, vigorously developing the dominant forestry industry with advantages, and promoting industrial transformation and upgrading. As of 2020, Kunming has become the largest forest product distribution center and consumer market in Yunnan Province. Through the implementation of the project of returning farmland to forest, 1.21 million forest farmers have directly benefited. Secondly, the value of products provided by arable land has also increased significantly, with an increase of 179.82%. In recent years, Kunming has closely followed in the footsteps of the country, fully fulfilled its responsibilities for arable land protection, strictly abided by the red line of arable land protection, and improved the level of science and technology and the advancement of agricultural scale (Table 2).

Item		Grassland	Cropland	Unused land	Land for Construction	Wood land	Water body	Total
Provide product value ($\times 10^8$yuan)	2010	75.03	107.06	-	-	7.44	4.33	193.86
	2020	170.88	299.58	-	-	22.54	8.12	501.12
	Increase	127.75%	179.82%	-	-	202.96%	87.53%	158.50%

Table 2. Natural resource values of various ecosystems in Kunming from 2010 to 2020

ecological service value analysis

(1) Production value of organic matter

In the 10 years from 2010 to 2020, the value of organic matter production increased from 11.111 billion yuan to 12.784 billion yuan, an increase of 15.06%. The order of the organic matter production value of each ecosystem type is as follows: grassland>woodland>bare land>cultivated land>water body>building land. The energy fixed replacement method converts the ecological value that is difficult to calculate into an economic value that can be calculated. The energy value calculated by the algorithm takes all the organic matter produced in the area into account, and its value is more approximate to the limit value. In life, the value of organic matter flows along the food chain in the ecosystem, and energy consumption is generated during the flow. Therefore, the actual production value of organic matter will be lower than the calculated value. (Table 3).

Item		Grassland	Cropland	Unused land	Land for Construction	Wood land	Water body	Total
Production value of organic matter ($\times 10^8$yuan)	2010	54.70	6.25	18.85	0.29	30.21	0.82	111.11
	2020	63.37	7.86	20.73	0.96	34.08	0.84	127.84
	Increase	15.85%	25.76%	9.97%	231.03%	12.81%	2.44%	15.06%

Table 3. Value of organic matter production in various ecosystems in Kunming from 2010 to 2020

(2) Climate regulation value

The climate regulation value of Kunming in 2010 and 2020 will be 46.069 billion yuan and 53.003 billion yuan, an increase of 15.05%. The order of climate regulation value of each ecosystem type is as follows: grassland>woodland>bare land>cultivated land>water body>construction land. Forests, grasslands and cultivated land ecosystems contribute significantly to Kunming's climate regulation services (Table 4).

Item			Grassland	Cropland	Unused land	Land for Construction	Wood land	Water body	Total
Climate regulation value ($\times 10^8$yuan)	Carbon sequestration	2010	165.33	18.87	56.97	0.87	91.31	2.47	335.82
		2020	191.53	23.74	62.65	2.91	103.01	2.53	386.37
	Oxygen release	2010	61.47	7.02	21.18	0.32	33.95	0.92	124.87
		2020	71.22	8.83	23.29	1.08	38.30	0.94	143.66
	Total	2010	226.81	25.89	78.15	1.19	125.26	3.39	460.69
		2020	262.75	32.57	85.94	3.99	141.30	3.48	530.03
		Increase	15.85%	25.80%	9.97%	235.29%	12.81%	2.65%	15.05%

Table 4. Value of climate regulation in various ecosystems in Kunming from 2010 to 2020

(3) Air purification value

In summary, the value of air purification in Kunming in 2010 and 2020 will be 3.320 billion yuan and 3.264 billion yuan, a decrease of 1.69%. Among them, the value of SO^2 absorption is 134 million yuan and 132 million yuan, the value of dust retention is 3.186 billion yuan, 3.132 billion yuan, and the value of dust retention is about 24 times the value of SO^2 absorption.(Table 5)

Item			Grassland	Cropland	Unused land	Land for Construction	Wood land	Water body	Total
Air purification value ($\times 10^8$yuan)	Absorb SO^2	2010	0.27	0.03	-	-	1.04	-	1.34
		2020	0.27	0.03	-	-	1.02	-	1.32
	Dust retention	2010	0.31	0.62	-	-	30.93	-	31.86
		2020	0.31	0.68	-	-	30.33	-	31.32
	Total	2010	0.58	0.65	-	-	31.97	-	33.20
		2020	0.58	0.71	-	-	31.35	-	32.64
		Increase	0.00%	9.23%	-	-	-1.94%	-	-1.69%

Table 5. Value of air purification in various ecosystems in Kunming from 2010 to 2020

(4) Water conservation value

The realization of water conservation function is mainly the process in which each ecosystem participates in regulating atmospheric water circulation. The value of water conservation in Kunming city in 2010 and 2020 is 35.059 billion yuan and 49.787 billion yuan respectively, increasing by 41.01%.(Table 6)

Item		Grassland	Cropland	Unused land	Land for Construction	Wood land	Water body	Total
Conservation of water value ($\times 10^8$yuan)	2010	172.60	19.70	59.47	0.91	95.32	2.58	350.59
	2020	246.80	30.59	80.73	3.75	132.73	3.27	497.87
	Increase	42.99%	55.26%	35.74%	312.96%	39.24%	26.60%	42.01%

Table 6. Value of water conservation in various ecosystems in Kunming from 2010 to 2020

(5) Soil and water conservation value

According to the formula, the fixed soil amount in 2010 and 2020 is 532672180.3m3, and the total value of soil and water conservation is 1282.25 billion yuan and 1288.29 billion yuan respectively, increasing by 0.47%. The value of preserving soil fertility was the highest, accounting for about 97.66% of the soil conservation value in this region. The value of reducing topsoil loss and maintaining soil fertility accounted for only 1.88% and 0.47% respectively. Soil

erosion will take away a large number of nutrients in the soil, resulting in the loss of N, P, K and other nutrient elements, resulting in the decline of soil fertility. The study area has a significant effect in maintaining soil fertility and reducing nutrient loss.(Table 7)

Item			Grassland	Cropland	Unused land	Land for Construction	Wood land	Water body	Total
Soil and water conservation value ($\times 10^8$yuan)	Reduce topsoil loss	2010	11.64	8.97	-	-	3.07	-	23.68
		2020	11.72	9.80	-	-	3.01	-	24.54
	Maintain soil fertility	2010	751.64	86.36	-	-	414.56	-	1252.56
		2020	756.82	94.42	-	-	406.48	-	1257.71
	Alleviating sedimentation	2010	3.61	0.41	-	-	1.99	-	6.01
		2020	3.63	0.45	-	-	1.95	-	6.04
	Total	2010	766.89	95.74	-	-	419.62	-	1282.25
		2020	772.17	104.67	-	-	411.44	-	1288.29
		Increase	0.69%	9.33%	-	-	-1.95%	-	0.47%

Table 7. Value of soil and water conservation in various ecosystems in Kunming from 2010 to 2020

(6) Nutrient cycle value

In 2010 and 2020, the nutritional recycling value of Kunming was 4.86 billion yuan and 5.584 billion yuan respectively, with an increase of 14.89%. The value of nitrogen accounted for 82.49% of the nutrient cycle value, phosphorus and potassium only accounted for 3.49% and 14.02% of the nutrient cycle value.(Table 8)

Item			Grassland	Cropland	Unused land	Land for Construction	Wood land	Water body	Total
Nutrient cycle value ($\times 10^8$yuan)	N	2010	24.49	2.80	8.43	-	4.25	0.12	40.08
		2020	28.37	3.52	9.27	-	4.80	0.12	46.07
	P	2010	0.25	0.03	0.09	-	1.31	0.04	1.71
		2020	0.29	0.04	0.09	-	1.48	0.04	1.93
	K	2010	4.33	0.49	1.49	-	0.49	0.01	6.81
		2020	5.01	0.62	1.64	-	0.55	0.01	7.83
	Total	2010	29.06	3.32	10.00	-	6.05	0.16	48.60
		2020	33.67	4.17	11.00	-	6.82	0.17	55.84
		Increase	15.84%	25.78%	9.98%	-	12.81%	2.57%	14.89%

Table 8. Value of nutrient cycle in various ecosystems in Kunming from 2010 to 2020

(7) cultural service value

As one of the provinces with the richest natural resources in China, Yunnan Province is rich in ecological and cultural landscapes, with a pleasant climate and spring in all seasons. It has always been an ideal place for leisure and tourism. With the popularity of the eco-tourism model, it has provided unlimited potential for the future tourism development model of Kunming. Kunming is known as the "biological gene resource bank" because of its rich natural resources. Its special geographical location and geomorphic environment make Kunming have great scientific research potential. Therefore, calculating according to the national average standard may underestimate the actual value.(Table 9)

Item			Grassland	Cropland	Unused land	Land for Construction	Wood land	Water body	Total
Cultural	Leisure	2010	4.04	0.09	0.38	0.01	5.34	0.38	10.24

service value ($\times 10^8$yuan)	value	2020	4.07	0.10	0.37	0.04	5.23	0.34	10.14
	Scientific value	2010	3.95	0.45	1.36	0.02	2.18	0.06	8.03
		2020	3.98	0.49	1.30	0.06	2.14	0.05	8.03
	Total	2010	7.99	0.54	1.75	0.03	7.52	0.44	18.27
		2020	8.05	0.59	1.67	0.10	7.37	0.39	18.17
		Increase	0.69%	9.33%	-4.41%	190.80%	-1.95%	-10.85%	-0.56%

Table 9. Value of cultural service in various ecosystems in Kunming from 2010 to 2020

Total value of ecological assets in Kunming

Based on the established ecological asset assessment model, this study calculated the ecological asset values of Kunming city in 2010 and 2020. Using GIS software as a platform, the ecological asset values of six types of land cover types: arable land, forest land, grassland, water bodies, construction land, and unused land were spatially analyzed to obtain the ecological asset values of various land types under various conditions, and the results of ecological asset remote sensing measurements are shown in Fig 2. During the decade, the value of ecological assets in Kunming increased from 249.858 billion yuan to 305.18 billion yuan, and the value of ecological assets per unit area increased from 11.6359 million yuan to 14.22123 million yuan, an increase of 22.14%.

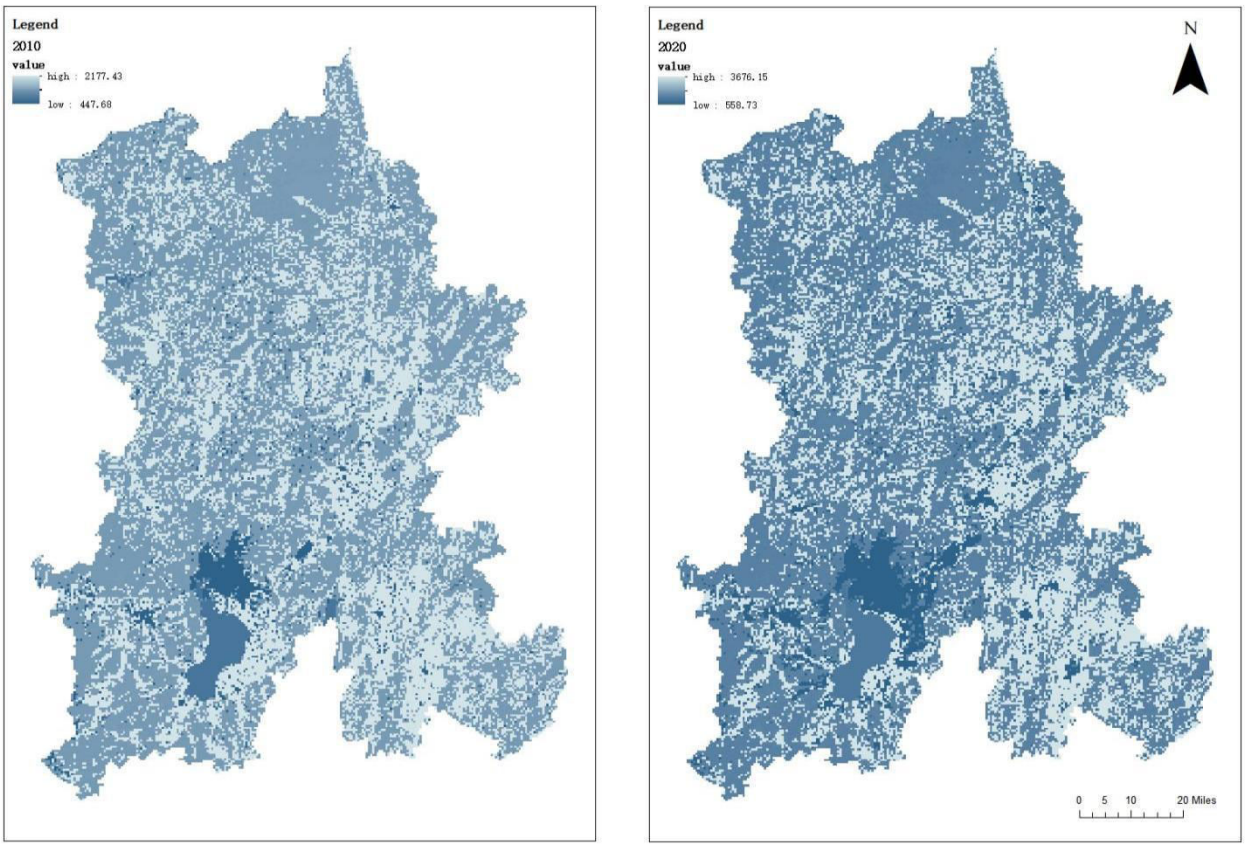


Figure 2. The spatial distribution of ecological asset value in Kunming from 2010 to 2020

In terms of different ecosystem types, the ecological asset values of all types of ecosystems in Kunming have increased year by year, with the largest change in the value of construction land, which increased by 263.35%, but only increased by 24.95% in terms of unit area value. It can be seen that the increase in ecological value of construction land is mainly due to the expansion of construction land area brought about by urbanization process. Secondly, the changes in

cropland (85.51%) and water bodies (38.73%) are larger. Among them, the change of ecological value of arable land is mainly due to the influence of human factors, which is the increase of ecological asset value brought by the upgrade of agricultural industry structure and the improvement of agricultural technology level. Within 10 years, the area of water bodies in Kunming has decreased by 10.85%, but the ecological value of water bodies still has a large increase. Kunming is one of the cities with serious water shortage, the per capita water resources is less than one eighth of the national per capita level, as the main source of water in the city, the Dian Lake water resources development and utilization rate has reached 60%, according to foreign experience, a country and region to use more than 20% of water resources, there may be a water crisis. In recent years, Kunming has invested a lot of money in water resources management, the Dian Lake water quality and the surrounding ecological environment has been significantly improved, but has not yet reached the desired effect, the future still needs to continue to strengthen the management efforts. The ecological value of bare land (18.94%), grassland (16.84%), and forest land (8.88%) increased at a relatively low rate, but still maintained a positive growth trend. Grassland ecosystems contribute the most to the value by 2020, accounting for about 51.06% of the total value, followed by forest land (25.81%), cropland (15.75%), bare land (6.56%), water bodies (0.53%), and building land (0.29%) in that order. The largest area of the ecosystem in Kunming is grassland (49.57%), nearly half of the total area of Kunming, followed by forest land (26.66%), bare land (16.21%) and cropland (6.14%), with smaller areas of floor space (0.75%) and water bodies (0.66%). Grasslands and woodlands have larger land area, high land vegetation cover, rich ecosystem service functions and high amount of ecological asset value, indicating that Kunming has a better ability to perform natural ecological functions. As an artificially constructed ecosystem, not naturally generated, the human factor is crucial in the process of ecosystem development. Arable ecosystems are centered on crops and need to produce a large number of cash crops each year to meet the needs of socio-economic development, so the material production capacity of arable land, i.e., the value of ecological and economic products, is high, making the value per unit area high.The value of built-up land has increased significantly over the decade, but part of this increase stems mainly from the large increase in the area of built-up land in towns and cities. The positive benefits of urban ecosystems come from urban greening, and the negative benefits are larger and usually inextricably linked to the increase in urban population and building land area, not only in countable aspects such as domestic waste and industrial pollution, but also in aspects that are difficult to assess, such as noise pollution and traffic congestion. Due to urbanization, urban areas are densely populated, with frequent human activities and fragile ecological environments, which are more vulnerable to damage and more difficult to repair, thus the contribution of ecological assets value is relatively low.(Table 10)

Land use type	**Year**	**Ecological asset value ($\times 10^8 \cdot a^{-1}$)**	**Change in value ($\times 10^8 \cdot a^{-1}$)**	**Ecological asset value per unit area ($\times 10^4 \cdot a^{-1}$)**	**Change in value ($\times 10^4 \cdot a^{-1}$)**
Water body	2010	11.72	4.54	741.90	412.59
	2020	16.26		1154.49	
Wood land	2010	723.39	64.25	1238.99	136.90
	2020	787.64		1375.89	
Unused land	2010	168.22	31.85	461.81	112.82
	2020	200.07		574.62	
Land for Construction	2010	2.42	6.38	435.58	108.68
	2020	8.81		544.26	
Cropland	2010	259.15	221.59	2147.23	1496.28
	2020	480.75		3643.52	
Grassland	2010	1333.68	224.60	1261.60	202.33
	2020	1558.27		1463.93	

Total	2010	2498.58	553.22	1163.59	257.64
	2020	3051.80		1421.23	

Table 10. Ecological asset value of various ecosystems in Kunming from 2010 to 2020

In terms of types of ecological asset values, as of 2020, soil and water conservation value (42.21%) is the most prominent, followed by climate regulation value (17.37%), natural resource value (16.42%), water conservation value (16.31%), organic matter production value (4.19%), nutrient recycling value (1.83%), air purification value (1.07%), and cultural service value (0.6%). The most significant increase was in the value of natural resources (158.5%), followed by the value of water conservation (42.01%), organic matter provision (15.05%), climate regulating value (15.05%), nutrient cycling value (14.89%), soil and water conservation value (0.47%), cultural services value (-0.56%), and air purification value (-1.68%). Kunming is a city rich in natural resources, and in 2020, agricultural value (57.5%) and livestock value (36.4%) dominate the value of natural resources in Kunming. The value of forestry accounts for 4.17% of the value of natural resources, which is related to Kunming's management measures to restrict forest logging, adhere to the priority of protection, and strive to promote the upgrading of industrial structure. The fishery value is the lowest (1.62%), which is mainly influenced by the comprehensive water resource management and protection carried out by the Kunming government after the pollution of the Dian Lake water quality. It is noteworthy that the cultural service value and air purification value of Kunming city show negative growth in the calculation of this study. Ecological assets are usually influenced by various factors such as climatic factors, soil factors, topographic factors, and human activity factors. In the of Kunming City, climatic factors should be the main influencing factor of its ecological asset value, but the negative growth of cultural service value and air purification value may be due to the influence of human factors, i.e., the expansion of the construction land area, which causes the destruction of ecological environment in a certain range.(Table 11)

		Grassland	Cropland	Bare land	Land for Construction	Forest land	Water bodies	Total	
2010	Natural Resource Value	75.03	107.06	-	-	7.44	4.33	193.86	7.76%
	Nutrient cycle value	29.06	3.32	10.00	-	6.05	0.16	48.60	1.95%
	Air purification value	0.58	0.65	-	-	31.97	-	33.20	1.33%
	Climate regulation value	226.81	25.89	78.15	1.19	125.26	3.39	460.69	18.44%
	Value of water conservation	172.60	19.70	59.47	0.91	95.32	2.58	350.59	14.03%
	Organic matter production value	54.70	6.25	18.85	0.29	30.21	0.82	111.11	4.45%
	Soil and water conservation value	766.89	95.74	-	-	419.62	-	1282.25	51.32%
	Cultural service value	7.99	0.54	1.75	0.03	7.52	0.44	18.27	0.73%
	Total value	1333.68	259.15	168.22	2.42	723.39	11.72	2498.58	100.00%
	Unit area value	1261.60	2147.23	461.81	435.58	1238.99	741.90	1163.59	
2020	Natural Resource Value	170.88	299.58	-	-	22.54	8.12	501.12	16.42%
	Nutrient cycle value	33.67	4.17	11.00	-	6.82	0.17	55.84	1.83%
	Air purification value	0.58	0.71	-	-	31.35	-	32.64	1.07%
	Climate regulation value	262.75	32.57	85.94	3.99	141.30	3.48	530.03	17.37%
	Value of water conservation	246.80	30.59	80.73	3.75	132.73	3.27	497.87	16.31%
	Organic matter production	63.37	7.86	20.73	0.96	34.08	0.84	127.84	4.19%

	value								
	Soil and water conservation value	772.17	104.67	-	-	411.44	-	1288.29	42.21%
	Cultural service value	8.05	0.59	1.67	0.10	7.37	0.39	18.17	0.60%
	Total value	1558.27	480.75	200.07	8.81	787.64	16.26	3051.80	100.00%
	Unit area value	1463.93	3643.52	574.62	544.26	1375.89	1154.49	1421.23	

Table 11. Statistics on the value of various ecological assets by ecosystem in Kunming from 2010 to 2020

Eco-Asset Management Measures

Based on the dynamic assessment of the value of ecological assets in Kunming, this study proposes the following ecological asset management countermeasures:

(1) Ecological service supervision

As a subject with specific ecological service functions, the value of ecological assets needs to be measured from the perspective of ecological service functions, and ecological asset management also needs to start from the perspective of ecological service functions. In the process of managing the value of ecosystem services in Kunming, it is necessary to first focus on the trade-offs between multiple ecological services, for example, fertilization is good for organic matter production, nutrient cycling and soil fertility, but can lead to a decline in water quality and damage to the ecological services of water bodies; secondly, planning for ecosystem service protection zones should be carried out for Kunming, and corresponding protection measures should be implemented based on the leading functions and protection objectives of the ecological function zones. Secondly, we should plan the protected areas for ecosystem services in Kunming and implement corresponding protection measures according to the leading functions and protection objectives of ecological function areas. Finally, we should strengthen the management of natural resources, comprehensively grasp the basic data of natural resources, and establish a diversified and multi-level natural resources management system.

(2) Ecological resource conservation

Ecological assets are the basis for social and economic development and GDP growth. The value of ecological assets in Kunming has increased by 22.14%, but their proportion relative to GDP has decreased from 117.84% to 45.32%, therefore, while ensuring economic development, we should not relax the efforts of ecological assets conservation. The value assessment of ecological assets should be opened regularly and focus on the value enhancement of ecological assets. As Kunming is rich in grassland and woodland resources, forest and grass species with economic value can be developed into ecological products, and the economic benefits obtained can drive the conservation of ecological assets, forming a virtuous cycle. For the management of watershed, indirect utilization can be adopted to develop the symbiotic function of ecological assets and feed the ecological construction with the development proceeds, forming a virtuous cycle.

(3) Implementation of ecological compensation

Scientific ecological compensation priorities and ecological compensation standards should be formulated according to local conditions, and the implementation efficiency of compensation funds should be improved. Referring to international experience and combining with China's actual situation, we should establish diversified investment and financing channels, establish effective socialized supervision and evaluation mechanisms, gradually improve the basic support system for ecological compensation, and conduct regular comprehensive evaluation of the effects of ecological compensation.

Conclusions

Based on the remote sensing images of Kunming in 2010 and 2020, this paper classifies the land use types of Kunming, evaluates the ecological asset values of Kunming in 2010 and 2020 after considering the natural and human elements, and discusses the ecological asset value types and ecosystem types, and finally draws the following

conclusions：

(1) In general, with the rapid development of urbanization, the area of urban construction land in Kunming increases significantly from 2010 to 2020. As of 2020, the total value of ecological assets in Kunming accounts for about 45.32% of the total GDP of Kunming in that year. during the 10-year period, the value of ecological assets in Kunming generally tends to increase, and all ecological asset value types maintain growth, except for the value of cultural services and air regulation.

(2) There are differences in the ecological asset values of different ecosystems. During the 10-year period, the ecological asset values of arable land, forest land and grassland areas accounted for more than 90% of the total value, and ecological protection of these areas should be strengthened. Bare land and construction land are affected by human activities and have lower ecological asset values. It is necessary to further improve regional ecological values on the basis of balancing economic development and ecological protection. The value of ecological assets in the water area is limited by the water area, but as an important part of the Kunming ecosystem, the current water quality of Dianchi Lake continues to improve after 30 years of treatment, but it is still necessary to continue to strengthen the protection of the ecological environment and pollution prevention in the water area in the future.

(3) The value of different ecosystem services varies, among which the value of soil and water conservation contributes the most, followed by the value of climate regulation and water conservation. Therefore, it is necessary to balance the relationship between various ecological services in management and protection, and to develop and protect sustainably according to the dominant ecological services in different areas.

The value of Kunming's ecological assets is much higher than the value of ecosystem services alone or the apparent economic value embodied through tourism and direct products, indicating that Kunming is rich in ecological resources and high in ecological conservation value, and that the future development of the city needs to pay attention to the balance between economic development and ecological conservation.

This study takes into account the specificity of ecosystem types and quality conditions in the study area, and constructs an ecological asset value assessment system based on the connotation of ecological assets, which can reflect the spatial distribution of ecological asset values in the study area to a certain extent, but there are still some shortcomings in this study compared with similar studies:

(1) Some of the parameters in this study were difficult to obtain, so national or regional averages were selected for substitution, and no research and adjustment of parameters were conducted for the characteristics of the study area, so the assessment results may not accurately reflect the true value of ecological assets in the study area.

(2) The ecological asset value measured in this paper includes eight items: natural resource value, nutrient cycle value, air purification value, climate regulation value, water conservation value, organic matter production value, soil and water conservation value, and cultural service value. The value of natural resources is only accounted for by the gross agricultural product, and the value of natural resources itself is not fully included in the accounting. At the same time, the indicators in the value of ecological assets are not completely independent from each other, and there may be duplication in the calculation, which may lead to inaccurate estimation of the value of ecological assets in the study area.

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Author contributions statement

M.X. and S.W. conceived the article. M.X. and Z.K.wrote the main manuscript text. All authors reviewed the manuscript.

Competing interests

The author(s) declare no competing interests.

Additional information

Correspondence and requests for materials should be addressed to Z.K.

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