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Accounting of Ecosystem Service Value in Chengdu-Chongqing Double Circle

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Abstract: With the rapid development of urbanization and the rapid progress of economy and society, high-intensity development and utilization activities have brought frequent disturbances to natural ecosystems, seriously weakened the supply capacity of ecosystem services such as climate regulation, hydrology regulation, soil conservation and biodiversity maintenance, and thus posed no small threat to regional ecological security and sustainable development. Chengdu-Chongqing Economic Circle plays an important role in promoting the construction of the Yangtze River Economic Belt and consolidating the ecological barrier in the upper reaches of the Yangtze River. However, the advancement of industrialization and urbanization has also led to the shrinkage of natural ecological space and degradation of ecosystem service functions in this region to a certain extent. Therefore, it is particularly urgent to conduct in-depth research on ecosystem services. Therefore, this paper takes the Chengdu-Chongqing Economic Circle as the research object, and uses the equivalent factor method to calculate the ecosystem service value of different land types and different service types in 2005, 2010, 2015 and 2020. The results showed as follows: 1) Cultivated land and forest land were the main land types in Chengdu-Chongqing urban agglomeration. 2) From the perspective of ecosystem service value contribution of different land types, the ranking order is: forest land > cultivated land > water area > grassland > unused land. 3) From the perspective of the value of ecosystem services at each level, the regulation services > support services > production services > cultural services.

Keywords: Chengdu-chongqing double circle, Ecosystem services, Value accounting.

1. Introduction

At present, China has entered a new stage of development, and it is clearly pointed out in the 14th Five-Year Plan and the Outline of Vision Goals 2035 that it is necessary to promote the growth of urban clusters and metropolitan areas, scientifically guide the development direction and construction priorities of various cities, and optimize the production, living and ecological space of rural areas. In order to form a reasonable layout, efficient coordination, perfect function of urban and rural spatial structure. Since the 1990s, China has launched a series of planning strategies for land use with different functions, such as "three-line" demarcation, cultivated land trial zoning, main function zoning, etc., although these plans focus more on economic benefits within the time series. However, with the increasing attention of the country to ecological civilization, from the development requirements of production, ecology and living space proposed in the report of the 18th National Congress, to the formulation of the National Land Planning Outline and the rural revitalization strategy, to the scientific planning of the "three life" space layout in the Land Management Law, All of them reflect that the way of our country's territorial space development is gradually turning to the new mode of "three and life" spatial coordination [1-3].

Chengdu-chongqing area, as an important engine of western economy, has been continuously improving its development process and status. From the concept of Chengdu-Chongqing economic zone, to the issuance of the development plan of Chengdu-Chongqing urban agglomeration, to the rise of the Chengdu-Chongqing twin city economic circle as a national strategy, this region plays a pivotal role in promoting the high-quality economic development of the western region and even the whole country. However, rapid industrialization and urbanization have also brought a series of challenges, such as the rapid expansion of urban and rural construction land, the loss of cultivated land resources, and the squeeze of ecological land, especially the development pattern of "dual-core dominance and edge collapse", has become a bottleneck restricting high-quality economic development [4-5]. The traditional single-objective planning method also leads to the disconnection between the social economy and the ecosystem, the homogenization of industry, the shortage of resources, and the decline of environmental quality [6-8].

Under the background of the construction of Chengdu-Chongqing Economic Circle

and the ecological barrier in the upper reaches of Yangtze River, the agglomeration and growth of population and industry factors have great potential. The process of urbanization will profoundly affect the use mode and efficiency of production, life and ecological space, and then put forward higher requirements for land use efficiency and ecological environment quality. Therefore, exploring the path of territorial space optimization and accounting the value of ecosystem services is of vital significance for the realization of high-quality economic development of Chengdu-Chongqing economic circle.

2. Overview of the Study Area and Data Sources

2.1. Overview of the Study Area

2.1.1. Geographical Location

The Chengdu-Chongqing Twin City Economic Circle, located at the intersection of the "Belt and Road" and the

Yangtze River Economic Belt, is not only the starting point of the new land and sea passage in the west, but also an important bridge connecting the southwest and northwest, and connecting East Asia with Southeast Asia and South Asia by virtue of its unique geographical location. This region has superior natural conditions, abundant energy and minerals, dense urban distribution, diverse customs and customs, and can be called the leader of China's western region. It has the highest population density, strong industrial foundation, outstanding innovation ability, broad market space and leading degree of openness, so it occupies a pivotal strategic position in the overall development of the country. Specifically, the Chengdu-Chongqing Economic Circle covers the central city of Chongqing and a number of districts and counties, as well as a number of cities in Sichuan province, with a total area of 185,000 square kilometers. Within this region, the number of permanent residents reached 96 million in 2019, and the regional GDP was close to 6.3 trillion yuan, accounting for 1.9%, 6.9% and 6.3% of the national share respectively.

2.1.2. Social Economy

Located at the intersection of the Yangtze River Economic Belt and the "One Belt, One Road" strategy, the research area is not only the most prosperous area of social and economic development in the western region, but also plays an irreplaceable role in promoting the implementation of various national strategies. According to statistics, the total population of the study area reached 974.948 million in 2018, and its regional GDP was as high as 5,581.637 billion yuan. Among them, the primary industry contributed 468.301 billion yuan, accounting for 8.39% of the total GDP of the study area, while the tertiary industry accounted for 48.19% with an output value of 26900.47 billion yuan. Compared with the three major urban agglomerations in eastern China, the socio-economic level of the study area still has some room for improvement, but its ecological performance is quite excellent. The research area is located in the core area of the Yangtze River Basin, especially Chongqing, as the core area of the Three Gorges Reservoir area, its ecological status is second to none in the upstream provinces. In addition, the research area is also rich in natural resources, including water resources, forest resources, minerals and natural gas, which are among the best in the country. Therefore, the study area plays an important role in the construction of an important ecological barrier in the upper reaches of the Yangtze River and even in the national ecological protection pattern.

2.1.3. Land Use Area

From 2005 to 2020, the land use structure of the study area is mainly concentrated in cultivated land and forest land. Specifically, the share of arable land in these years was stable at about 62%, while forest land accounted for about 27%. In contrast, grassland, water area and construction land are also distributed, but the proportion is relatively small; The proportion of unused land is the smallest. The total area of the study area is 208515.96km^2, of which cultivated land, as the dominant land use type, accounts for more than 61% from 2005 to 2020. However, because arable land is mostly located in flat and easily accessible areas, it is also more vulnerable to human activities. In the past 20 years, the cultivated land area has shown a downward trend year by year, from 116193km^2 in 2005 to 114,067 km^2 in 2020, with a decrease of 1.83%, equivalent to a decrease of 2126km^2. On the other hand, as another important part of the land use structure, the proportion of forest land has stabilized at more than 26% for many years. Under the influence of policies such as returning farmland to forest and human activities, the woodland area showed an overall rising trend during the study period, increasing by 1474km^2, with an increase rate of 2.99%. At the same time, the area of grassland showed an overall decrease trend, decreasing by 2320km^2. The water area showed a steady upward trend and showed signs of stabilization in recent years. It is worth noting that construction land is the land use type with the largest change during the study period. From 2005 to 2020, the area of construction land increased by 3,355 km^2, an increase of 90.16%. Especially in the period from 2005 to 2010, the growth rate of construction land is particularly significant. In contrast, the change of unused land is very small, and the proportion of the last four periods has hardly changed. For details on the area of each land use type, see Table 2-1.

Table 2-1. Land use area by type from 2005 to 2020 (km^2)

Land use type	2005	2010	2015	2020
plowland	116193	115450	114228	114067
Forest land	49259	49859	49542	50733
meadow	12171	10702	10561	9851
waters	2805	2987	3109	3190
Construction land	3721	5064	6635	7076
unutilized	125	210	199	199

2.2. Data Sources

The production and other data required in this paper are mainly from China Statistical Yearbook, Sichuan Statistical Yearbook, Chongqing Statistical Yearbook, National Cost and Compilation of Agricultural Products, statistical yearbook and government work report of prefecture-level cities in Sichuan Province. Based on the national land use classification standard body, the land use types in Chengdu-Chongqing double circle are divided into six categories as shown in Table 2-2.

Table 2-2. Classification of land use

Primary classification	implication
plowland	Refers to the land where crops are grown, including cultivated land, newly opened land, fallow land, rotation land, grass field rotation crop land; Agricultural fruit, agricultural mulberry, agricultural and forestry land mainly used for growing crops; Tilling beaches and sea flats for more than three years.
Forest land	Refers to the growth of trees, shrubs, bamboo, and coastal mangrove forest and other forestry land.
meadow	Refers to all kinds of grassland mainly growing herbaceous plants and covering more than 5%, including shrubland grassland mainly grazing.
Construction land	Refers to urban and rural residential areas and other industrial, mining, transportation and other land.
waters	Refers to natural land waters and water conservancy facilities.
unutilized	Refers to large, medium and small cities and counties and towns above the built-up areas of land.

The land use data mainly comes from the Resources and Environmental Sciences and Data Center of the Chinese Academy of Sciences. The remote sensing interpretation data

of land use in the four phases of Chengdu-Chongqing urban agglomeration can be obtained by querying the website, with a resolution of 30m, including the years 2005, 2010, 2015 and 2020. Based on the "Classification of Land Use Status" and referring to this standard, the land use types of Chengdu-Chongqing double circle were divided into the following six categories by ArcGIS software, namely: cultivated land, forest land, grassland, water area, construction land and unused land.

3. Accounting of the Value of Eco-System Services in Chengdu-Chongqing Double Circle

3.1. Estimation of Ecosystem Service Value Kernel with Standard Equivalent Factor

The estimation of ecosystem service value is mainly based on the equivalent of ecosystem service value per unit area of Chinese ecosystem proposed by Xie Gaudi [9]. This equivalent factor actually reflects the contribution of different types of ecosystems to ecological service functions. In determining the value of ecological services, a core problem is how to determine the value of standard equivalent factors. The so-called standard equivalent value here refers to the economic value of a hectare of farmland with the national average yield, which can be produced by its main grains (such as rice, corn and wheat) in a completely undisturbed state. In practice, however, it is almost impossible to completely rule out the effects of man-made perturbations. Therefore, for the calculation of standard equivalent, two main methods have been proposed. The first method is to use the statistics in the National Agricultural Product Cost-Benefit Data Collection by calculating the product of the sown area of rice, wheat and corn and their average net profit per unit area. The second method is based on the data of the Statistical Yearbook, through the product of grain yield per unit area and sown area, and consider the cost-benefit ratio of grain cultivation. Since the net profit involved in the first method is greatly affected by labor cost and other factors, this paper prefers to choose the second method for calculation. The calculation formula is:

$$D = \frac{1}{7} \times P \times Q$$

Where D is the value of an equivalent factor, that is, the ecological service value per unit area, 1/7 is the ratio of consideration of grain income and cost, P is the grain output per unit area, which is obtained by dividing grain output by grain cultivated land area, and Q is the grain price.

According to the Statistical Yearbook of Sichuan Province and the Statistical Yearbook of Chongqing in the fourth issues of 2005, 2010, 2015 and 2020, the average grain yield per unit area of Chengdu-Chongqing urban agglomeration in the fourth period was calculated to be 5277.00kg/hm^2 (Table 3-1). Since the annual grain price is affected by social demand, in order to reduce calculation errors and comparability of data, the grain price adopts the national average price of 2.45 yuan /kg in 2020, and the value of an equivalent factor is calculated to be 1846.95/hm^2.

Table 3-1. Grain data of Chengdu-Chongqing urban agglomeration

	Total production (Ten thousand tons)	Sown area (Ten thousand hectares)	Yield per unit area (Kg/ha)
2005	4577.38	900.29	5084.34
2010	4338.97	843.90	5141.57
2015	4549.49	852.01	5339.72
2020	4608.85	831.56	5542.40

3.2. Determination of the Value Coefficient Table of Ecosystem Services Per Unit Area

Table 3-2. Table of equivalent factors of ecological service value in Chengdu-Chongqing double circle

First-order type	Secondary type	plowland	Forest land	meadow	waters	unutilized
Supply service	Food production	1.31	0.33	0.43	0.53	0.02
	Raw material production	0.51	2.98	0.36	0.35	0.04
Regulating service	Gas regulation	0.84	4.32	1.50	0.51	0.06
	Climate regulation	1.13	4.07	1.56	2.06	0.13
	Wastewater treatment	1.61	1.72	1.32	14.85	0.26
	Hydrologic regulation	0.89	4.09	1.52	18.77	0.07
Support service	Soil conservation	1.71	4.02	2.24	0.41	0.17
	Maintain biodiversity	1.18	4.51	1.87	3.43	0.40
Cultural service	Aesthetic landscape	0.20	2.08	0.87	4.44	0.24

The operation of equivalent factor method is relatively simple, this paper refers to the "Terrestrial ecosystem Service Value Scale" compiled by Gaodi Xie, and revised according to the actual situation of the study area. The value coefficient of cultivated land corresponds to farmland, woodland corresponds to forest, and the value coefficient of unused land corresponds to desert. Regarding the value equivalent of construction land, Gaodi Xie et al did not discuss it at that time. Therefore, after reading relevant literature, it is decided to refer to the research results of Yan Wu et al. set the equivalent factor of construction land as 0, and obtain the scale of eco-system service value of Chengdu-Chongqing dual circle (Table 3-2) [10]. Finally, this value scale is multiplied with the standard equivalent factor value of Chengdu-Chongqing urban agglomeration to obtain the ESV unit area value coefficient table (Table 3-3).

Table 3-3. Ecological service value coefficient per unit area of Chengdu-Chongqing urban Agglomeration (yuan/hm^2)

First-order type	Secondary type	plowland	Forest land	meadow	waters	unutilized
Supply service	Food production	2419.50	609.50	794.19	978.88	36.93
	Raw material production	943.61	5503.92	664.9	646.43	73.88
Regulating service	Gas regulation	1542.57	7978.82	2770.42	941.95	110.81
	Climate regulation	2078.19	7517.09	2881.24	3804.71	240.10
	Wastewater treatment	2978.02	3176.76	2437.97	27427.22	480.21
	Hydrologic regulation	1649.7	7554.03	2807.37	34667.27	129.29
Support service	Soil conservation	3149.42	7424.74	4137.17	757.25	313.97
	Maintain biodiversity	2185.31	8329.75	3453.8	6335.04	738.78
Cultural service	Aesthetic landscape	364.22	3841.66	1606.85	8200.46	443.26

3.3. Ecosystem Service Value Assessment Model

According to the formula, combined with the coefficient of ecosystem service value per unit area of Chengdu-Chongqing double circle and the data table of land use type area in 2005, 2010, 2015 and 2020, the ecosystem service value of various types of land in the study area can be calculated. The calculation formula of ecosystem service value is as follows:

$$ESV=\sum_{k=1}^{n}(A_k \times VC_k) \quad (1)$$

$$ESVf=\sum_{k=1}^{n}(A_k \times VC_{kf}) \quad (2)$$

Where: ESV is the total value of ecosystem services; Ak is the area of land use type k; VCk is the ecosystem service value of land use type k per unit area. ESVf is the service function value of item f of ecosystem; VCkf is the service value of item f of ecosystem of land use type k per unit area.

4. Analysis of Ecosystem Service Value Results

4.1. Analysis of the Value of Ecosystem Services in Different Places

As can be seen from Table 4-1, from 2005 to 2020, the Chengdu-chongqing double circle generally presents an upward trend, increasing from 488 billion yuan in 2005 to 495.7 billion yuan in 2020, among which the growth rate of this ranges from 2005 to 2010 is the most obvious, with a total increase of 4.380 billion yuan. This is mainly due to the implementation of farmland conversion and project construction in Chengdu-Chongqing region during this period, which led to the conversion of large areas of cultivated land and grassland with low ecosystem service value to woodland with high ecosystem service value, and had a positive effect on the overall ecosystem service in the region. From 2010 to 2015, the total value of ecosystem services in the Chengdu-Chongqing city cluster declined slightly, by about 700 million yuan. This is closely related to the rapid economic and social development of Chengdu-Chongqing area. In 2011, the Regional Plan of Chengdu-Chongqing Economic Zone proposed to "strengthen regional central cities" and "expand key towns". In addition, the Master Plan of Chengdu City (2011-2020) and the Master Plan of Chongqing City (2007-2020) have both promoted the development of a large number of small and medium-sized cities in Chengdu-Chongqing area to varying degrees. The resource consumption and waste discharge brought about by population urbanization have promoted the reduction of forest biomass and oppressed the adjustment system such as wetlands. Changes in land use induced by spatial, economic and social urbanization have significantly affected the service capacity of ecosystems. Until 2016, the Development Plan of Chengdu-Chongqing City Cluster proposed to "promote the construction of ecological civilization, optimize land development space, build an ecological security pattern, and build an ecological barrier in the upper reaches of the Yangtze River", which effectively contained the deterioration of the ecological environment in Chengdu-Chongqing region and improved ecosystem services. The total value of ecosystem services increased by 4.1 billion yuan from 2015 to 2020.

Table 4-1. Value of ecosystem services in different geographical categories from 2005 to 2020

Land use type	ESV (Hundred million yuan)				Amplitude of change (%)
	2005	2010	2015	2020	2005-2020
plowland	1791	1788	1765	1750	-2.27
Forest land	2659	2717	2724	2764	3.95
meadow	187	159	157	149	-20.44
waters	242	259	270	294	21.39
unutilized	0.16	0.23	0.26	0.25	58.6
total	4880	4923	4916	4957	1.6

From the perspective of the contribution of ecosystem service value of different places, the value of forest ecosystem service continued to rank first in the study period. From 2005 to 2020, the value of forest ecosystem services continued to increase, from 265.9 billion yuan to 276.4 billion yuan, with an overall increase of 3.95%. The value of forest ecosystem services accounted for 54.50%, 55.19%, 55.41% and 55.76% of the total value of ecosystem services in each year, accounting for an increasing proportion year by year. It is the main contribution of ecosystem service value of Chengdu-chongqing double circle.

Cultivated land also plays an important role. In 2005, 2010, 2015 and 2020, the ecosystem service value of cultivated land accounted for 36.70%, 36.31%, 35.89% and 35.30% of the total value of Chengdu-chongqing double circle, respectively. The value volume decreased from 179.1 billion yuan in 2005 to 175 billion yuan in 2020, and the value volume and the contribution to the total value volume continued to decline, mainly due to the expansion of non-agricultural construction in some regions and the adjustment of agricultural structure.

The change trend of grassland ecosystem service value was consistent with that of cultivated land, showing a continuous

decreasing trend. From 18.7 billion yuan in 2005 to 14.9 billion yuan in 2020, a decrease of 20.44%. Among them, the value decreased significantly from 2005 to 2010, accounting for 73.52% of the total, and the reason for the decline was closely related to the large reduction of grassland area in this stage.

During the study period, the value of ecosystem services in water area and unused land increased by 21.39% and 58.60% respectively. The difference is that the value of water area continues to rise during the study period, while the change trend of the value of unused land is consistent with the change trend of the total value of ecosystem services, showing a trend of first increasing, then decreasing and then increasing. The main reason is that part of unused land in the study area has been managed and utilized from bare land to land use type covered by vegetation from 2015 to 2020. To a certain extent, it alleviates the decline in the value of ecosystem services in the region.

4.2. Ecosystem Service Value of Different Service Types

Based on the value of different types of ecosystem services, the value structure and change rules of ecosystem services were analyzed (Table 4-2).

Table 4-2. Ecosystem service value of different service types from 2005 to 2020

Ecosystem level service function	Ecosystem secondary service function	ESV (Hundred million yuan)			
		2005	2010	2015	2020
Production service	Food production	268	267	264	263
	Raw material production	378	383	383	386
Regulating service	Gas regulation	599	604	603	607
	Climate regulation	641	646	644	648
	Hydrologic regulation	686	697	700	714
	Waste disposal	578	584	583	590
Support service	Soil conservation	752	754	750	752
	Maintain biodiversity	706	712	710	715
Cultural service	Provide an aesthetic landscape	273	277	278	282

From the perspective of ecosystem service value structure, from 2005 to 2020, the ecosystem service value of the four services of production, regulation, support and culture in Chengdu-Chongqing double circle has not changed greatly, and is generally relatively stable. From the perspective of the value of ecosystem services at each level, the value of ecosystem services of regulation services is in the leading position, followed by support services, and then production services, and cultural services have the lowest value. It can be seen that adjustment service is the main service type of the Chengdu-chongqing double circle, that is to say, the ecosystem of the Chengdu-chongqing double circle mainly plays the role of eliminating human pollution and ensuring the stability of the ecosystem. Compared with the secondary ecosystem service value of the Chengdu-chongqing double circle from 2005 to 2020, only the food production ecosystem service value showed a downward trend, while the remaining eight ecosystem service values basically showed an upward trend, showing a high consistency with the change trend of the total ecosystem service value in the study area.

In the regulation service, the service value of each secondary ecosystem as a whole present's different amplitude changes. From 2005 to 2020, the value of gas regulation, climate regulation, hydrological regulation and waste treatment services increased by 1.34%, 1.09%, 4.08% and 2.08%, respectively. Among them, the value of gas regulation, climate regulation and waste treatment services showed a fluctuating trend of first increase and then increase, and decreased slightly from 2010 to 2015. During the study period, the value of hydrological regulation service kept rising, mainly because the water network with the Yangtze River, Jialing River, Wujiang River, Minjiang River, Tuojiang River and Fujiang River as the main body has a good self-regulation ability, which provides a strong support for the supply of hydrological regulation service in the Chengdu-Chongqing double circle.

Among the support services, soil conservation services ranked first among all secondary ecosystem service values in each year of the study period, and the service value of maintaining ecological diversity was also at a high level, and the two types of ecosystem service values increased over time. Good vegetation coverage in the study area was conducive to the natural production and reproduction of organisms. It is an important basis for maintaining biodiversity services in the region. At the same time, there are also important terrestrial ecological functional areas such as Sichuan-Yunnan Forest ecology and biodiversity functional areas and Qinin-Ba biodiversity functional areas in the region. The biodiversity of the study area is expected to be further improved.

In production services and cultural services, the value of raw material production services increased by 800 million yuan during the study period, while the value of food production services continued to decrease, with a total decrease of 500 million yuan from 2005 to 2020, with a decrease ratio of 1.76%, which is closely related to the rapid development of manufacturing and service industries in the study area. The value of aesthetic landscape service is on the rise, which is greatly affected by the changes of forest land and grassland.

5. Conclusions

(1) The main land types of Chengdu-Chongqing urban agglomeration are cultivated land and forest land, and the most prominent land use change from 2005 to 2020 is the conversion of cultivated land to construction land and forest land. In the process of accelerating urbanization, the conversion of farmland to forest and grassland is significant, but some forest land is still converted to cultivated land due to economic needs.

(2) From the perspective of ecosystem service value, the total ecosystem service value of Chengdu-Chongqing urban agglomeration showed an upward trend from 2005 to 2020. Mainly due to the implementation of farmland conversion and project construction in Chengdu-Chongqing region during this period, a large area of cultivated land and grassland with low ecosystem service value was transformed into woodland with high ecosystem service value, which had a positive effect on the overall ecosystem service in the region. From the perspective of ecosystem service value contribution of

different land types, the ranking order is: forest land > cultivated land > water area > grassland > unused land.

(3) From the perspective of different types of ecosystem service value, the ecosystem service value of the four services of production, regulation, support and culture in Chengdu-Chongqing double circle has not changed greatly, and is generally stable. From the perspective of the value of ecosystem services at each level, the regulation service > support service > production service > cultural service. Among them, except the food production ecosystem service value showed a downward trend, while the remaining eight ecosystem service values basically showed an upward trend, which was highly consistent with the change trend of the total ecosystem service value in the study area.

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