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Changing characteristics of land use and ecological service value in the water source region of the Middle Route of South-to-North Water Transfer Project

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Abstract. Research on changing characteristics of land use and ecological service value (ESV) can guide the regional land use planning and promote the rational use of environmental resources. On the basis of four phases of land-use data (2000, 2005, 2010 and 2015), this research analysed the changing characteristics of land use and ESV in the water source region of the Middle Route of South-to-North Water Transfer Project (SRMRP). The results showed that forest, grassland and cultivated land were the major land-use types in the SRMRP. During 2000~2015, forest, grassland, farmland and wetland decreased. Construction land and bare land had increased, and the annual increase rates reached 3.6% and 8%, respectively. After the implementation of the water transfer project in 2003, water area was also increasing. The total ESV in the SRMRP is about 196 billion CNY, and mainly comes from the contributions of forest, grassland and farmland. During 2000~2015, farmland shrinks led to the declines in value from supply service. With increasing in water and construction land, value from entertainment and cultural service increased. During the early stage of the water transfer project, value from regulation and support services increased due to the increase in water. With the decreasing in wetland and the increasing in construction land, the negative effects on the regulation and support services were increasing, and value from regulation and support services were therefore decreasing. During the process of resource exploitation and management, more attentions should be paid to the total control of construction land and wetland protection in the SRMRP.

1. Introduction

The ESV refers to the profits that human can directly or indirectly obtain from the ecosystem, including importing the useful material and energy into the economic and social system, transforming the human waste from economic and social system, and providing ecological services (such as air, water and other resources) to human beings [1]. Quantitative evaluation of the ESV is of great practical significance to provide a scientific basis for the restoration, protection and rational utilization of ecosystem resources. Therefore, ESV evaluation becomes the research frontier and hot topic of the global ecosystem management and sustainable development [2-4].

In recent years, evaluations of ESV mainly focus on different ecosystems (forest, grassland, wetland, farmland and so on) at the local, basin and regional scales [5, 6]. Regional land use and ESV are interrelated, mutual influence and constraint. Changes in land use are seldom been considered in



these research. Evaluation results are therefore difficult to reflect the response characteristics of ESV. Due to the impact of human activities and climate change, regional land use and ESV have been in a state of dramatic changing process. Understanding the variations in land use and ESV can guide the regional land use planning and promote the rational use of environmental resources. Therefore, there is an urgent need to perform research on changing characteristics of land use and ESV.

Taking the SRMRP as the case study, on the basis of four phases of land-use data (2000, 2005, 2010 and 2015), this research analyzes the changing characteristics of land use and ESV in the SRMRP. Research results are expected to provide technical support and theoretical basis for water resources utilizations and protections in the SRMRP.

2. Study area

The SRMRP includes Danjiangkou reservoir and the upper reaches of the Hanjiang basin (figure 1). Danjiangkou reservoir supplies water for middle and western parts of Huang-Huai-Hai Plain. The SRMRP provides water for municipal and industrial use in Beijing, Tianjing Municipalities, Hebei and Henan Provinces. The SRMRP also gives consideration to the need of agricultural water and ecological water in these regions. Average annual temperature of the SRMRP is about 12.2 °C, and average annual evapotranspiration is 854 mm. Average annual precipitation is 873.3 mm. Precipitation and runoff are uneven distributed throughout the year, and about 80 percent of the annual precipitation and runoff are concentrated in rainy season.

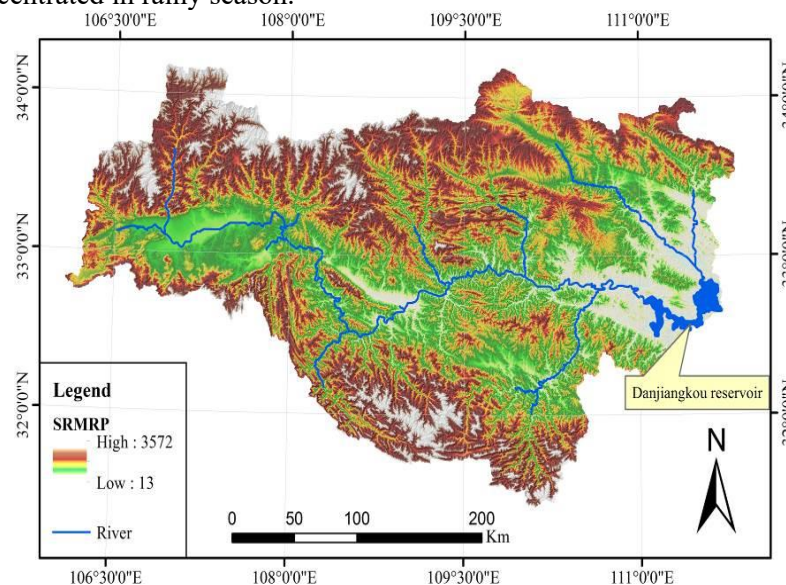


Figure 1. Sketch map of the study area.

3. Methodology, data sources and processing

DEM data of the study area (90 m spatial resolution) were collected from the Computer Network Information Center, Chinese Academy of Science (<http://www.gscloud.cn>). Arcgis 10.2 software was used to splice and cut the DEM data. ArcSWAT 2012 software was used to generate the boundary of the SRMRP. Four phases of land use data (2000, 2005, 2010 and 2015) is provided by Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences (RESDC) (<http://www.resdc.cn>). Arcgis 10.2 software was used to splice the land use data by the generated boundary of the SRMRP.

Costanza et al. clearly defined the principles of ESV evaluation, and put forward the ESV evaluation method which is widely used in ESV accounting and evaluation around the world [1]. The ESV in the SRMRP is also calculated by the method recommended by Costanza et al. The formula was established as following:

$$ESV = \sum (A_k \times VC_k)$$

where ESV is ecological service value in the SRMRP; A_k and VC_k are the area of k_{th} land use type and ESV per unit area for k_{th} land use type in the SRMRP, respectively.

ESV per unit area for different land use types in the SRMRP were calculated based on equivalent weight factor of ecosystem services per hectare of terrestrial ecosystem in China and service value per hectare of food production in the SRMRP (Table 1). Equivalent weight factor of ecosystem services per hectare of terrestrial ecosystem in China referred to Xie et al. [7]. Service value per hectare of food production in the SRMRP is 1114.28 CNY [8].

Table 1. ESV per unit area for different land use types in the SRMRP. (CNY/hm²)

		Farmland	Forest	Grassland	Water	Wetland	Construction land	Bare land
Supply service	Food production	1114.3	367.7	479.1	590.6	401.1	-1671.4	22.3
	Raw material production	434.6	3320.6	401.1	390.0	267.4	-2975.1	44.6
	Gas regulation	802.3	4813.7	1671.4	568.3	2685.4	-2005.7	66.9
Regulation service	Climate regulation	1080.9	4535.1	1738.3	2295.4	15098.5	-1626.8	144.9
	Hydrological regulation	858.0	4557.4	1693.7	20915.0	14975.9	-7309.7	78.0
	Environment purification	1548.8	1916.6	1470.8	16547.1	16045.6	-791.1	289.7
Support service	Soil conservation	1638.0	4479.4	2496.0	456.9	2217.4	-1114.3	189.4
	Biodiversity conservation	1136.6	5025.4	2083.7	3822.0	4111.7	-334.3	445.7
Entertainment and cultural service	Recreation and culture	189.4	2317.7	969.4	4947.4	5226.0	1114.3	267.4

4. Results and discussions

4.1. Changing characteristics of land use in the SRMRP

Forest, grassland and farmland are the main land use types, and account for more than 99% area of the SRMRP. The contributions of six types of land use in the SRMRP ranked as follows: forest > grassland > farmland > water > construction land > wetland > bare land (Table 2). During 2000~2015, farmland had been reduced. Compared with 2000, farmland in 2015 decreased by 42500 hm². Forest and grassland increased firstly and then decreased. Water area was increasing. Compared with 2000, water area in 2015 increased by 17200 hm², and the change rate amounted to 29.9%. After the implementation of the south to North Water Diversion Project in 2003, elevation of the Danjiangkou reservoir dam leveled from 162 m to 176.6 m, and it may be the main reason for the increase of water area. Compared with 2000, the wetland in 2015 decreased by 3900 hm². Compared with 2000, the construction land and bare land in 2015 increased by 24700 and 600 hm², and the annual increasing rate reached to 3.6% and 8%, respectively.

Table 2. Areas of different land use types in the SRMRP. (10² hm²)

Land use type	2000	2005	2010	2015
Farmland	21242	20973	20945	20819
Forest	43400	43457	43464	43369
Grassland	28558	28672	28666	28626
Water	575	676	687	747
Wetland	272	235	230	233
Construction land	455	489	510	702
Bare land	5	5	5	11

4.2. Changing characteristics of ESV in the SRMRP

Total ESV in the SRMRP is about 196 billion CNY (figure 2). The value is slightly lower than the ESV evaluation results from the previous research [8]. The research did not calculate the ESV from the construction land. Considering the negative effects of construction land on ESV, evaluation result in this research was reasonable. ESV of the SRMRP was mainly from the contribution of forest, grassland and farmland ecosystems (Table 3). During 2000~2005, ESV of the SRMRP had an increasing of 0.32 billion CNY. During 2005~2015, ESV of the SRMRP had a decreasing of 0.48 billion CNY (figure 2).

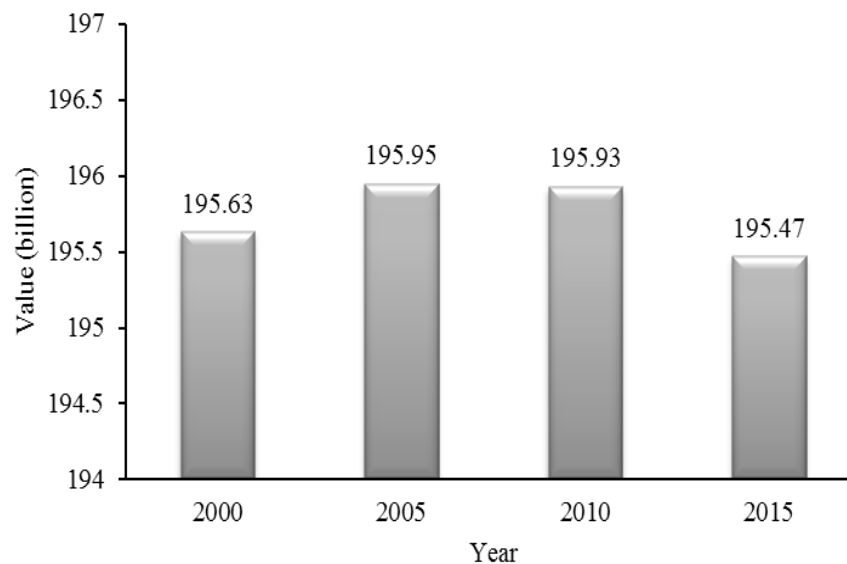


Figure 2. ESV in the SRMRP during 2000~2015.

Table 3. ESV from different ecosystems during 2000~2015. (million)

Year	Farmland	Forest	Grassland	Water	Wetland	Construction land	Bare land
2000	18698.93	135987.62	37135.82	2905.62	1659.99	-760.50	0.77
2005	18462.14	136166.22	37284.06	3416.00	1434.18	-817.32	0.77
2010	18437.49	136188.16	37276.26	3471.59	1403.67	-852.42	0.77
2015	18326.57	135890.49	37224.24	3774.79	1421.98	-1173.34	1.70

Values from different types of ecosystem service function in the SRMRP ranked as follows: regulation service > support service > supply service > entertainment and cultural service (figure 3). During 2000-2015, value from supply service declined. Supply service function is mainly provided by the farmland. Farmland shrinks may be the main reason for the decline of value from supply service. With the increasing in water and construction land, value from entertainment and cultural service increased. During the early stage of the water transfer project, value from regulation and support services increased due to the increase in water area. With the decrease in wetland and the increase in construction land, the negative effects on the regulation and support services were increasing, and value from regulation and support services were therefore decreasing. During the process of resource exploitation and management, more attentions should be paid to total control of construction land and wetland protection in the SRMRP.

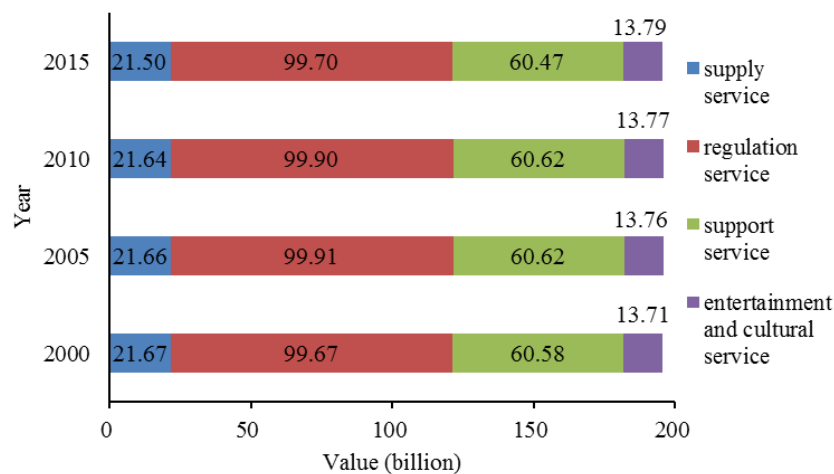


Figure 3. Values from different types of ecosystem service function in the SRMRP.

5. Conclusions

On the basis of four phases of land-use data during 2000~2015, this research analysed the changing characteristics of land use and ESV in the SRMRP. The following conclusions can be obtained:

1) Forest, grassland and cultivated land were the major land-use types in the SRMRP. Forest, grassland, farmland and wetland decreased. Construction land and bare land had increased, and the annual increase rates reached 3.6% and 8%, respectively. After the implementation of the water transfer project in 2003, water area was also increasing.

2) The total ESV in the SRMRP is about 196 billion CNY, and mainly comes from the contributions of forest, grassland and farmland.

3) Value from different types of ecosystem service function in the SRMRP ranked as: regulation service > support service > supply service > entertainment and cultural service. Declines in farmland led to the decline of value from supply service. With increasing in the water and construction land, value from entertainment and cultural service increased.

4) During the early stage of the water transfer project, value from regulation and support services increased. With the decrease in wetland and the increase in construction land, the negative effects on the regulation and support services were increasing, and value from regulation and support services were therefore decreasing.

Acknowledgments

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