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 study 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 decline 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.

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].

| Supply service | Farmland | Forest | Grassland | Water | Wetland | Construction land | Bare land |
|----------------|----------|--------|-----------|-------|---------|-------------------|-----------|
| 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 |
| Regulation service | 802.3 | 4813.7 | 1671.4 | 568.3 | 2685.4 | -2005.7 | 66.9 |
| Gas regulation | 1080.9 | 4535.1 | 1738.3 | 2295.4 | 15098.5 | -1626.8 | 144.9 |
| Climate regulation | 858.0 | 4557.4 | 1693.7 | 20915.0 | 14975.9 | -7309.7 | 78.0 |
| Hydrological regulation | 1548.8 | 1916.6 | 1470.8 | 16547.1 | 16045.6 | -791.1 | 289.7 |
| Environment purification | 1638.0 | 4479.4 | 2496.0 | 456.9 | 2217.4 | -1114.3 | 189.4 |
| Support service | 1136.6 | 5025.4 | 2083.7 | 3822.0 | 4111.7 | -334.3 | 445.7 |
| Soil conservation | 189.4 | 2317.7 | 969.4 | 4947.4 | 5226.0 | 1114.3 | 267.4 |
| Biodiversity conservation | 4.2. Changing characteristics of ESV in the SRMRP

Table 2. Areas of different land use types in the SRMRP. (10^2 hm^2)

| 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.](image)

| 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 leaded 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.

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