Study on the response of ecosystem services to land use

LiLi Zhao*

College of Urban and Rural Construction, Shaoyang University, Shaoyang, 422000, China

*Corresponding author e-mail: 3810@hnsyu.net

Abstract: In recent years, the urbanization process in counties has been accelerated due to the support of national policies. The depth and breadth of land use changes in counties have been strengthened, and the value of ecosystem services has been significantly degraded. In order to realize the sustainable development of county ecological environment, it is especially urgent to grasp the impact of different land use types in the county on the value of ecosystem services within a certain period of time. Based on the interpretation of remote sensing satellite images to obtain county land use classification data, the changes in the value of ecosystem services in Nanping City between 1995 and 2015 were explored in depth. The results of the study showed that the total value of ecosystem services in each region changed significantly in different time periods, among which, in 1995, the total value of ecosystem service types in Jian'ou City was the highest. In 2015, the value of ecosystem services in Songxi County decreased the most, amounting to 13.98 billion yuan, while other regions had different degrees of increase. Each regional service type has the highest value of functions such as soil formation and protection, water conservation, gas regulation and biodiversity conservation, while all the food production functions have the lowest value.

1. Introduction

Land use is closely related to human survival, and with the current rise in population and the accelerated urbanization of counties, it will inevitably have an impact on land use changes and the surrounding environment. The study of the impact of land use changes on the value of ecosystem services is of great significance for the coordinated development among population, land and environment. Land use changes are essentially a change in the area and spatial location of land use types [1]. Ecosystem services are the products and services of life that are supported directly or indirectly through the structure, processes, and functions of ecosystems [2], and land use changes and changes in ecosystem service functions develop synergistically [3-4]. Therefore, it is important for regional ecosystem conservation to study the changes in the value of its ecosystem services based on data related to land use changes.

In recent years, under the influence of national policies, the urbanization rate of counties has been accelerated, which makes the ecological security problems more prominent due to the rapid economic development in counties with weak awareness of ecological protection, and environmental disasters such as the continuous decrease of biodiversity and the increase of heat island effect intensity occur frequently. Therefore, many scholars have conducted many studies on this aspect. For example, Dai et al. [5] studied the spatial and temporal evolution of land use functions and ecosystem service values in Fuzhou new district from 2000 to 2015 by using remote sensing satellite image data and the "three living" land use dominant function classification system. Long et al. [6] accounted for the value of nine types of ecosystem services in different subsidence periods in the Hegang mining area of
Heilongjiang Province. The findings of the existing studies show that the research on the impact of land use change on ecosystem service values is relatively mature, but the empirical evidence is mostly gathered at large and medium scales, and empirical analysis at the county scale is still rare. Therefore, 10 counties (districts and cities) in Nanping City were selected as the study area, and remote sensing image data of two periods (1995 and 2015) were used to study the changes of county ecosystem service values based on ENVI and ArcGIS software platforms, using the modified ecosystem value per unit area equivalent factor method. This study is intended to provide a reference for the construction of ecological civilization and the sustainable development of ecological environment in Nanping County and even in Fujian Province and the surrounding areas.

2. Overview of the study area
Nanping City is located in the northern part of Fujian Province, with a total land area of 2.63×10⁴ km², accounting for about one-fifth of the total area of Fujian Province, and is the largest prefecture-level city in Fujian Province, known as "Min Bang Zou Lu" and "Dao Nan Li Ku". Nanping City has 2 municipal districts, 5 counties and 3 county-level cities, including Yanping District (Yp), Jianyang District (Jy), Shunchang County (Sc), Pucheng County, (Pe) Guangze County (Gz), Songxi County (Sx), Zhenghe County (Zh), Shaowu City (Sw), Wuyishan City (Wys), and Jian'ou City (Jo) (Figure 1) Nanping City is influenced by the topography by tectonic movements, the mountainous area is vast, and the land is mostly distributed in the northwest, northeast and southwest of the study area. It has the Wuyishan Airport, the main stream of the Min River, Jianxi and Futun Creek, and other air routes and waterways. At the end of 2019, Nanping's road mileage reached 1.60×10⁴ km, including 1,045 km of high-speed kilometers, with a total household population of 318.26×10⁴ and a resident urban population of 113.92×10⁴.

3. Research Methodology

3.1. Data sources
The basic research data used Landsat-5 TM in 1995 and Landsat-7 ETM in 2015 with strip processing, and the spatial resolution of all three phases of remote sensing image data was 30 m. With reference to China's land use classification system and combined with the geographical characteristics of Nanping City and fieldwork information, the land use types of Nanping City were classified into forest land, grassland, construction land, water area, cultivated land and unused land. The images were subsequently processed using ENVI and ARCGIS software, and the area of each land use type was substituted into the equations in the research method to calculate the ecosystem service values of...
different service types.

3.2. Research Methodology

3.2.1. Selection of ecosystem service indicators and calculation of unit area value. With reference to previous studies [7], nine ecosystem service indicators were selected in this paper, including gas regulation, climate regulation, water conservation, soil formation and protection, waste treatment, biodiversity conservation, food production, supply of raw materials, and recreation and culture. At the same time, the equivalence table developed by Xie et al. [8] was slightly modified to make a table of equivalence factors for the value of ecosystem services per unit area in Nanping City, see Table 1.

The value per unit area of food production services in farmland ecosystems, with the following equation.

\[ E_a = \frac{1}{7} \cdot T_a \cdot T_b \]  

(1)

where \( E_a \), \( T_a \) and \( T_b \) represent the unit area value of farmland ecosystem services (Yuan/ hm²), the average benchmark grain yield in Nanping City (kg/ hm²) and the national average grain price (Yuan/kg), respectively.

Value of other ecosystem services per unit area \( CV_{ij} \) (yuan/hm² year) is calculated as follows.

\[ CV_{ij} = E_a \cdot f_{ij} \]  

(2)

Where \( f_{ij} \) represents the first \( i \) land use type of the \( j \) equivalence factor of the value of ecosystem services.

Table 1. Equivalent value per unit area of terrestrial ecosystem services in Nanping City.

| Types                      | Woodland | Cultivated land | Water area | Unused land | Grassland |
|----------------------------|----------|-----------------|------------|-------------|-----------|
| gas regulation             | 3.50     | 0.50            | 0.00       | 0.00        | 0.80      |
| climate regulation         | 2.70     | 0.89            | 0.46       | 0.00        | 0.90      |
| water conservation         | 3.20     | 0.60            | 20.38      | 0.03        | 0.80      |
| soil formation and protection | 3.90   | 1.46            | 0.01       | 0.02        | 1.31      |
| waste treatment            | 1.31     | 1.64            | 18.18      | 0.01        | 1.95      |
| biodiversity conservation  | 3.26     | 0.71            | 2.49       | 0.34        | 1.09      |
| food production            | 0.10     | 1.00            | 0.10       | 0.01        | 0.30      |
| supply of raw materials    | 2.60     | 0.10            | 0.01       | 0.00        | 0.05      |
| recreation and culture     | 1.28     | 0.01            | 4.34       | 0.01        | 0.04      |

3.2.2. Total value of ecosystem services. The formula for calculating the total value of ecosystem services in the county is as follows.

\[ ESV = \sum_{i=1}^{n} \sum_{j=1}^{m} A_i \times CV_{ij} \]  

(3)

where \( ESV \), \( A_i \) and \( CV_{ij} \) represent the total value of ecosystem services, the area of the \( i \) land use type, and the area of the \( i \) land use type \( j \) the unit area value of ecosystem services.

4. Results and Analysis

The changes in the values of the nine service types of the county ecosystems in Nanping are shown in Tables 2 to 4. The values of each service type of the ecosystem in 1995 are shown in Table 2. In
In general, the total value of the ecosystem service types in Jian’ou City was the highest at 329.00 billion yuan in 1995, compared to the lowest total value of each service type in Songxi County at 72.68 billion yuan. In terms of the value of each ecosystem service type, Jian’ou City had the highest service functions of gas regulation, climate regulation, water conservation, soil formation and protection, biodiversity conservation, raw materials and recreation and culture, with values of 49.94, 39.26, 51.22, 56.65, 48.07, 36.24 and 18.99 billion yuan, respectively. In contrast, the value of all nine service types in Songxi County is lower than that of other regions, which is closely related to the fact that Jian’ou City has the largest area among the 10 regions, while Songxi County has the smallest area. On waste disposal, Yanping District has the highest service value with a value of 34.94 billion yuan, followed by Jianyang District and Jian’ou City with 27.44 and 26.34 billion yuan, respectively. On food production capacity, Pucheng County has the highest service value with 3.14 billion yuan, Shaowu City is the next highest with 2.59 billion yuan, Jianyang District and Jian’ou City are on par, both with a service value of 2.30 billion yuan.

From the value ranking of each service type in each region, the value ranking of each service type in Shunchang County, Pucheng County, Wuyishan City and Jian’ou City is exactly the same, which are: soil formation and protection > water conservation > gas regulation > biodiversity protection > climate regulation > raw materials > waste treatment > recreation culture > food production; Songxi County, Zhenghe County and Shaowu City have the same value ranking of each service type as: soil formation and protection > gas regulation > biodiversity protection > water conservation > climate regulation > raw materials > waste treatment > recreation culture > food production. Yanping District has a large difference in the ranking of each service type compared with other regions, among which, the value of waste treatment ranks second in the value of nine service types, with a value of 34.94 billion yuan.

Table 2. Value of each ecosystem service type by region in1995 (billion yuan).

| Type                  | Yp  | Jy  | Sc  | Pc  | Gz  | Sx  | Zh  | Sw  | Wys | Jo  |
|-----------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Gas Regulation        | 24.25 | 41.17 | 21.62 | 38.72 | 27.31 | 10.70 | 18.96 | 34.72 | 33.21 | 49.94 |
| Climate regulation    | 19.70 | 32.67 | 17.56 | 31.14 | 21.73 | 8.86 | 15.57 | 27.78 | 26.50 | 39.26 |
| Water conservation    | 49.46 | 48.32 | 23.36 | 40.07 | 26.83 | 10.44 | 18.21 | 33.12 | 33.47 | 51.22 |
| Soil formation and conservation | 27.66 | 47.01 | 25.48 | 45.18 | 31.47 | 12.93 | 22.72 | 40.34 | 38.39 | 56.65 |
| Waste disposal        | 34.94 | 27.44 | 14.03 | 22.60 | 14.21 | 6.83 | 10.92 | 17.69 | 18.18 | 26.34 |
| Biodiversity Conservation | 26.29 | 40.28 | 21.09 | 37.71 | 26.14 | 10.66 | 18.35 | 33.19 | 32.17 | 48.07 |
| Food production       | 1.38 | 2.30 | 2.02 | 3.14 | 1.78 | 1.25 | 2.14 | 2.59 | 2.28 | 2.30 |
| Raw Materials         | 17.57 | 29.86 | 15.34 | 27.71 | 19.62 | 7.31 | 13.29 | 24.83 | 23.83 | 36.24 |
| Entertainment Culture | 14.42 | 16.91 | 8.23 | 14.51 | 10.00 | 3.69 | 6.63 | 12.42 | 12.31 | 18.99 |
| Total                 | 215.67 | 285.97 | 148.72 | 260.79 | 179.09 | 72.68 | 126.79 | 226.68 | 220.33 | 329.00 |

As shown in Table 3, the total value of ecosystem services decreased in 2015 in Pucheng, Guangze, Songxi and Zhenghe counties, with the largest decrease of 13.98 billion yuan in Songxi County and increases of varying degrees in the other regions. Among the regions where the value increased, the increase in total value mainly came from the value of service types such as gas regulation, climate regulation, soil formation and protection, biodiversity conservation, raw materials and recreation and culture.

From the value ranking of each service type in the county, the value ranking of each service type in Jianyang District, Shaowu City and Wuyishan City are consistent as follows: soil formation and protection > gas regulation > water conservation > biodiversity protection > climate regulation > raw materials > waste disposal > recreation and culture > food production. The value ranking of each service type in Pucheng, Guangze, Songxi County and Jian’ou City is basically the same as above, and only the ranking of water conservation and gas regulating ability is interchanged. In terms of the value of each ecosystem service type, Jian’ou City was in the first place among the 10 regions in 2015 in terms of the value of nine service types. In contrast, Songxi County had the lowest value of each service type among all regions.
Table 3. Value of ecosystems by service type by region in 2015 (billion yuan).

| Type                        | Yp  | Jy  | Sc  | Pc  | Gz  | Sx  | Zh  | Sw  | Wys | Jo  |
|-----------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Gas Regulation              | 31.80 | 46.36 | 25.36 | 42.31 | 28.95 | 12.88 | 18.80 | 35.46 | 37.83 | 47.50 |
| Climate regulation          | 25.03 | 36.23 | 20.04 | 33.44 | 22.85 | 10.14 | 14.92 | 27.99 | 29.63 | 37.78 |
| Water conservation          | 37.63 | 44.48 | 34.96 | 47.33 | 30.68 | 13.84 | 23.74 | 34.44 | 37.75 | 50.26 |
| Soil formation and conservation | 35.94 | 52.32 | 28.60 | 48.17 | 32.94 | 14.62 | 21.40 | 40.47 | 42.78 | 54.68 |
| Waste disposal              | 20.87 | 21.30 | 20.90 | 25.73 | 16.45 | 7.26  | 13.98 | 17.55 | 18.62 | 26.77 |
| Biodiversity Conservation   | 30.97 | 43.90 | 25.26 | 40.91 | 27.87 | 12.41 | 18.56 | 33.83 | 36.21 | 45.69 |
| Food production             | 1.37 | 1.84 | 1.08 | 2.23 | 1.42 | 0.63  | 0.96  | 1.86  | 1.62  | 3.22  |
| Raw Materials               | 23.21 | 33.74 | 18.55 | 30.82 | 20.92 | 9.39  | 13.64 | 25.58 | 27.58 | 34.60 |
| Entertainment Culture       | 13.22 | 17.03 | 11.62 | 16.95 | 11.17 | 5.05  | 8.08  | 12.98 | 14.22 | 18.36 |
| Total                       | 220.04 | 297.21 | 186.37 | 287.90 | 193.25 | 86.22 | 134.09 | 230.16 | 246.24 | 318.86 |

5. Conclusion

Based on the remote sensing interpretation data of land use in Nanping City in two periods of 1995 and 2015, the study made an ecosystem service unit area value equivalent factor table conforming to Nanping City, and quantitatively explored the value changes of different service types of ecosystems in Nanping County during 20 years. The results of the study showed that:

(1) In general, the value of ecosystem services in each region changed significantly in different time periods. In 1995, the total value of ecosystem service types in Jian’ou City was the highest. In 2015, Songxi County had the largest decrease in ecosystem service value, amounting to 13.98 billion yuan, while other regions had different degrees of increase.

(2) In terms of the value ranking of the service types in 1995, the value ranking of each service type in Shunchang County, Pucheng County, Wuyishan City and Jian’ou City was exactly the same: soil formation and protection > water conservation > gas regulation > biodiversity conservation > climate regulation > raw materials > waste treatment > recreation culture > food production. In 2015, the value ranking of each service type in Jianyang District, Shaowu City and Wuyishan City was consistent as follows: soil formation and protection > gas regulation > water conservation > biodiversity conservation > climate regulation > raw materials > waste treatment > recreation and culture > food production, and the value ranking of each service type in Pucheng County, Glossy County, Songxi County and Jian’ou City was basically the same as above, and only the water conservation and gas regulation ability ranking were interchanged.

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