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**Research Article**

# Ecosystem Services Estimation Based on Food Production in Xinjian County of Nanchang City, East China

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**Abstract:** This study investigated estimation on ecosystem services value based on food production in Xinjian County of Nanchang City, East China. We used two Landsat TM data sets (1996, 2004) to estimate changes in the size of seven land use categories and we used the most recently published value equivalent to estimate changes in the values of ecosystem services. The total value of ecosystem services in Xinjian County was 4588.2 million Yuan in 1996 and 4587.8 million Yuan in 2004, with a decrease of 340.8 thousand Yuan mainly due to the relatively biggish decrement in values of ecosystem service functions for waste treatment, hydrology regulation and food production, although the values for all the other six ecosystem service functions showed an escalating trend from 1996 to 2004. We concluded that future local land use plan should give priority to the conservation of these reductive ecosystems, in order to promote and maintain the balance of local ecosystem.

**Keywords:** Ecosystem services, food production, land use, value estimation, Xinjian county

## INTRODUCTION

In recent literature, the links between nature and economics are often described through the concept of ecosystem services and their values (Camacho-Valdez *et al*., 2014). Ecosystem service valuation has been a hot topic in ecological economic research since the 1990s. Ecosystem services are essential to human well-being. They provide vital goods and services, such as food provision, carbon sequestration and water regulation that support economic prosperity, social well-being and quality of life (Costanza *et al*., 1997; Costanza, 2008). Land Use and Cover Change (LUCC) is likely the single most important factor affecting the conservation of natural environments (Nahuelhual *et al*., 2014). With the rapid increase in the human population and the excessive use of natural resources, the demands for ecosystem services often surpass their provisioning capacity (Bennett *et al*., 2005; Larondelle and Haase, 2013; Hu *et al*., 2013). If there is insufficient understanding of and care for these ecosystem services, anthropogenic transformation could seriously aggravate the degradation of ecosystems (Bennett *et al*., 2005; Hu *et al*., 2013).

Since Costanza *et al*. (1997) reported his research in nature about ecosystem service value in 1997, the valuation method on ecosystem service value has made some progress (Kreuter *et al*., 2001; Li *et al*., 2010a; Zhang *et al*., 2010). In China, Xie *et al*. (2008) modified twice (in 2002 and 2007) the value equivalent or coefficients of Chinese ecosystem based on Costanza's parameters (Li *et al*., 2010b). In his study, Xie considered the second value equivalent are more accurate than the first or Costanza's with time history. However, only some researchers have been conducted based on Xie's first value equivalent, but the research based on the second value equivalent has been reported rarely.

Xinjian County is located in the southern bank of Poyang Lake and is attached to Nanchang City, provincial capital of Jiangxi, where variation of ecosystem services value in response to land use change have taken place owing to human activity (Li-Hua and Bin, 2014). The objectives of this study were:

- To assign specific value coefficients for Xinjian County and determine whether they can be used to evaluate changes in ecosystem services in the local area
- To estimate variations in ecosystem services value in response to land use changes during the study period
- To make some preliminary policy recommendations to promote and maintain local ecosystem balance

## MATERIALS AND METHODS

**Study area:** The study was carried out in Xinjian County of Nanchang City, Jiangxi Province, China (115°31′-116°25′ E; 28°20′-29°10′ N). Administratively, Xinjian is one of the four counties

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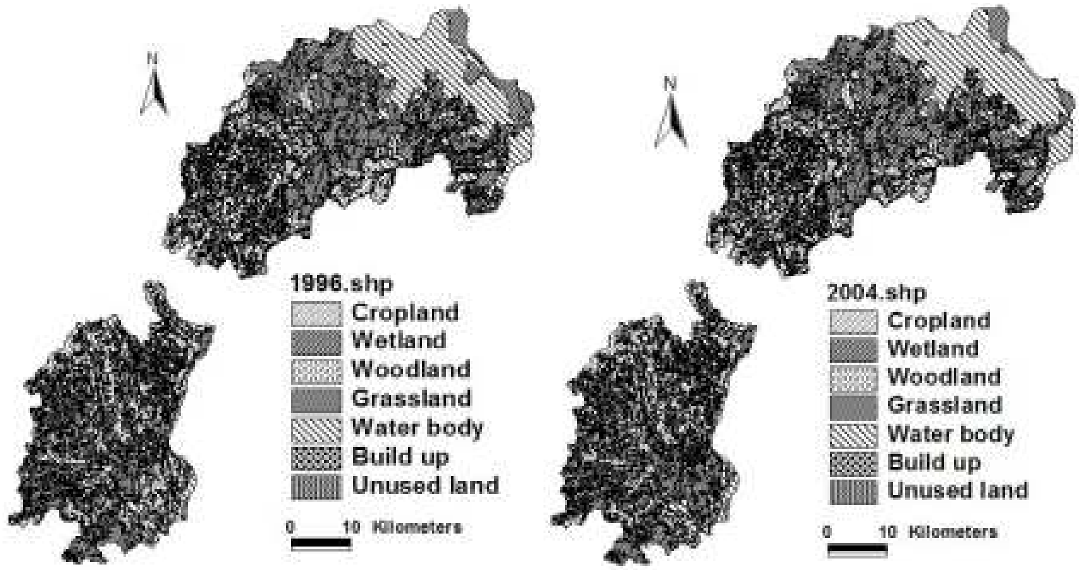


Fig. 1: Land use map in Xinjian county in 1996 and 2004

Table 1: Equivalent value per unit area of ecosystem services in China

| Ecosystem services function | Cropland | Wetland | Woodland | Grassland | Water body | Unused land |
|---|---|---|---|---|---|---|
| Food production | 1.00 | 0.36 | 0.33 | 0.43 | 0.53 | 0.02 |
| Raw material | 0.39 | 0.24 | 2.98 | 0.36 | 0.35 | 0.04 |
| Gas regulation | 0.72 | 2.41 | 4.32 | 1.50 | 0.51 | 0.06 |
| Climate regulation | 0.97 | 13.55 | 4.07 | 1.56 | 2.06 | 0.13 |
| Hydrology regulation | 0.77 | 13.44 | 4.09 | 1.52 | 18.77 | 0.07 |
| Waste treatment | 1.39 | 14.40 | 1.72 | 1.32 | 14.85 | 0.26 |
| Soil conservation | 1.47 | 1.99 | 4.02 | 2.24 | 0.41 | 0.17 |
| Biodiversity conservation | 1.02 | 3.69 | 4.51 | 1.87 | 3.43 | 0.40 |
| Aesthetic landscape | 0.17 | 4.69 | 2.08 | 0.87 | 4.44 | 0.24 |
| In total | 7.90 | 54.77 | 28.12 | 11.67 | 45.35 | 1.39 |

(Anyi, Xinjian, Nanchang and Jinxian) of Nanchang City. Xinjian has a warm and humid, subtropical monsoon climate with plenty of rainfall and sunshine. The annual average temperature is 17°C, with distinct seasonal variations and a rather large temperature difference between winter and summer. At the end of 2004, Gross Domestic Product (GDP) was Yuan 5.12 billion, with a rate of 1.1:1.94:2.08 in the three major industries.

**Land use classification:** Two cloud-free Landsat-5 TM images (collected in April, 1996 and May, 2004, respectively) were used to acquire land use change information. Based on man-machine interactive interpretation, two period vector data can be acquired. The data sets were classified into seven categories, including cropland, wetland, woodland, grassland, water body, built up land and wetland. The land use map and their corresponding attribute data were showed and analyzed in Arc GIS software for subsequent calculation of ecosystem service value (Fig. 1). By on-the-spot sampling checkup, precision of interpretation amounts to 91% and hence we can utilize these land use change information.

**Assignment of ecosystem service value:** Based on Costanza's parameters, Xie *et al*. (2008) extracted the equivalent weight factor of ecosystem services per hectare of terrestrial ecosystems in China and modified the value coefficient of Chinese ecosystem (Table 1). One factor is equal to the economic value of average natural food production of cropland per hectare per year. Generally, the natural food production is proposed to be 1/7 of the actual food production. With Xinjian County, the average actual food production of cropland was 5500 kg/ha from 1996 to 2004 and the average price for grain was 1.2 Yuan/kg in 2004. The ecosystem service value of one equivalent weight factor for Xinjian County is therefore 942.9 Yuan (Table 2).

**Calculation of ecosystem service values:** Once the ecosystem service value of one unit area for each land use category has been extracted, the service value for each land use category, each service function and total ecosystem services are given in the following Eq. (1) to (3):

$$ESV_k = \sum_f A_k \times VC_{kf} \tag{1}$$

$$ESV_f = \sum_k A_k \times VC_{kf} \tag{2}$$

Table 2: Value coefficients of ecosystem service function in Xinjian county (VC, Yuan/ha/a)

| Ecosystem services function | Cropland | Wetland | Woodland | Grassland | Water body | Unused land |
|---|---|---|---|---|---|---|
| Food production | 942.90 | 339.44 | 311.16 | 405.45 | 499.74 | 18.86 |
| Raw material | 367.73 | 226.30 | 2809.84 | 339.44 | 330.02 | 37.72 |
| Gas regulation | 678.89 | 2272.39 | 4073.33 | 1414.35 | 480.88 | 56.57 |
| Climate regulation | 914.61 | 12776.30 | 3837.60 | 1470.92 | 1942.37 | 122.58 |
| Hydrology regulation | 726.03 | 12672.58 | 3856.46 | 1433.21 | 17698.23 | 66.00 |
| Waste treatment | 1310.63 | 13577.76 | 1621.79 | 1244.63 | 14002.07 | 245.15 |
| Soil conservation | 1386.06 | 1876.37 | 3790.46 | 2112.10 | 386.59 | 160.29 |
| Biodiversity conservation | 961.76 | 3479.30 | 4252.48 | 1763.22 | 3234.15 | 377.16 |
| Aesthetic landscape | 160.29 | 4422.20 | 1961.23 | 820.32 | 4186.48 | 226.30 |
| In total | 7448.90 | 51642.64 | 26514.35 | 11003.64 | 42760.53 | 1310.63 |

Table 3: Area changes of land use in Xianjian county, Poyang lake basin

| | 1996 | | 2004 | | 1996-2004 | | |
|---|---|---|---|---|---|---|---|
| Land use categories | ha | (%) | ha | (%) | ha | (%) | %/year |
| Cropland | 101026.30 | 43.21 | 99131.61 | 42.40 | -1894.69 | -1.88 | -0.24 |
| Wetland | 38465.49 | 16.45 | 38376.02 | 16.71 | -89.47 | -0.23 | -0.03 |
| Woodland | 35284.39 | 15.09 | 36519.00 | 15.71 | 1234.61 | 3.50 | 0.44 |
| Grassland | 26153.30 | 11.19 | 26391.06 | 10.99 | 237.76 | 0.91 | 0.11 |
| Water body | 14391.76 | 6.16 | 14065.67 | 6.10 | -326.09 | -2.27 | -0.28 |
| Build up | 10491.20 | 4.49 | 13629.00 | 5.83 | 3137.80 | 29.91 | 3.74 |
| Unused land | 7972.13 | 3.41 | 5672.21 | 2.26 | -2299.92 | -28.85 | -3.61 |
| In total | 233784.57 | 100 | 233784.57 | 100 | 0 | 0 | 0 |

$$ESV = \sum_k \sum_f A_k \times VC_{kf} \tag{3}$$

where, $ESV_k$, $ESV_f$ and $ESV$ refer to the ecosystem service value of land use category "$k$", value of ecosystem service function type "$f$" and the total ecosystem service value, respectively. $A_k$ is the area (ha) for land use category "$k$" and $VC_{kf}$ the value coefficient (Yuan/ha/a) for land use category "$k$", ecosystem service function type "$f$".

Since uncertainties exit in the value coefficients, sensitivity analyses were conducted to determine the dependence of temporal changes in ecosystem service values on the applied value coefficients. The ecosystem value coefficients for cropland, woodland, grassland, water body, wetland and unused land categories were each adjusted by 50%. In each analysis, the Coefficient of Sensitivity (CS) was calculated using the following Eq. (4):

$$CS = \frac{(ESV_j - ESV_i)/ESV_i}{(VC_{jk} - VC_{ik})/VC_{ik}} \tag{4}$$

## RESULTS AND DISCUSSION

**Land use change:** Through overlay analysis of two land use images and attribute data calculation within Arc GIS soft, the area of land use change was obtained (Table 3). There was an obvious land use change in Xinjian County during the study period. The areas of woodland, grassland and build up land increased from 1996 to 2004. On the contrary, the areas of cropland, wetland, water body and unused land decreased.

The land use with larger area was cropland (over 40%) and woodland (about 16%), as a result of traditional agricultural county with hill cover. However, their change direction was opposite. Cropland decreased from 101026.3 ha to 99131.61 and woodland showed a rising tendency, increasing from 35284.39 to 36519 ha during the study period. Although the area of unused land (about 3%) was the least, followed by build up land (about 5%), the greater area changes was also build up land and unused land. The difference was that build up land increased with 3137.8 ha, with an incremental rate of 29.91% in total and 3.74%/year. However, the unused land decreased with 2299.92 ha, with a decrease ratio of 28.85% in total and 3.61%/year. The probable reason for the change of cropland, build up land and unused land was as a result of urbanization and industrialization. The areas of aquatic ecosystem including wetland and water body amounted to about 23% of the total area and their variation trends were the same, with a decrease from 38465.49 to 38376.02 ha and from 14391.76 to 14065.67 ha, respectively. With decline of water body and wetland, the area of grassland increased 237.36 ha, from 26153.3 ha in 1996 to 26391.06 ha in 2004. The possible causes for the decrease of water body and wetland were climate warming and environment disruption.

**Change of ecosystem services value:** By utilizing the value coefficients and areas of land use categories (Table 2 and 3), the ecosystem service value of land use category "$k$", value of ecosystem service function type "$f$" and the total ecosystem services value of Xinjian in 1996 and 2004 were obtained according to the formulas (1)-(3). These results are shown in Table 4 and 5. The total ecosystem services value of Xinjian was about 4588.2 million Yuan in 1996 and 4587.8 million Yuan in 2004, with a reduction of 340.8 thousand Yuan.

Table 4: Values of ecosystem service for land use category in 1996 and 2004 ($ESV_k$ in $10^4$ Yuan/year)

| | 1996 | | 2004 | | 1996-2004 | | |
|---|---|---|---|---|---|---|---|
| Land use categories | $ESV_k$ | (%) | $ESV_k$ | (%) | $ESV_k$ | (%) | Rank |
| Cropland | 75253.48 | 16.40 | 73842.15 | 16.10 | -1411.33 | -1.88 | 3 |
| Wetland | 198645.94 | 43.30 | 198183.90 | 43.20 | -462.04 | -0.23 | 1 |
| Woodland | 93554.27 | 20.39 | 96827.75 | 21.10 | 3273.48 | 3.50 | 2 |
| Grassland | 28778.15 | 6.27 | 29039.77 | 6.33 | 261.62 | 0.91 | 5 |
| Water body | 61539.93 | 13.41 | 60145.55 | 13.11 | -1394.38 | -2.27 | 4 |
| Unused land | 1044.85 | 0.23 | 743.42 | 0.16 | -301.43 | -28.85 | 6 |
| In total | 458816.62 | 100 | 458782.54 | 100.00 | -34.08 | -0.01 | - |

Table 5: Values of ecosystem service functions in 1996 and 2004 ($ESV_f$ in $10^4$ Yuan/year)

| | 1996 | | 2004 | | 1996-2004 | | |
|---|---|---|---|---|---|---|---|
| Ecosystem service function | $ESV_f$ | (%) | $ESV_f$ | (%) | $ESV_f$ | (%) | Rank |
| Food production | 13723.99 | 2.99 | 13569.72 | 2.96 | -154.27 | -1.12 | 9 |
| Raw material | 15892.64 | 3.46 | 16156.48 | 3.52 | 263.84 | 1.66 | 8 |
| Gas regulation | 34408.09 | 7.50 | 34766.97 | 7.58 | 358.88 | 1.04 | 6 |
| Climate regulation | 78665.44 | 17.15 | 78795.08 | 17.17 | 129.64 | 0.16 | 3 |
| Hydrology regulation | 98959.60 | 21.57 | 98626.55 | 21.50 | -333.05 | -0.34 | 1 |
| Waste treatment | 94792.71 | 20.66 | 94139.75 | 20.52 | -652.96 | -0.69 | 2 |
| Soil conservation | 40802.80 | 8.89 | 40992.12 | 8.93 | 189.32 | 0.46 | 5 |
| Biodiversity conservation | 47670.81 | 10.39 | 47832.19 | 10.43 | 161.38 | 0.34 | 4 |
| Aesthetic landscape | 33900.54 | 7.39 | 33903.68 | 7.39 | 3.14 | 0.01 | 7 |
| In total | 458816.62 | 100 | 458782.54 | 100 | -34.08 | -0.01 | - |

Table 6: Percentage change in estimated total ecosystem service value and Coefficient of Sensitivity (CS) resulting from adjustment of ecosystem Valuation Coefficients (VC)

| | 1996 | | 2004 | |
|---|---|---|---|---|
| Change in value coefficient | (%) | CS | (%) | CS |
| Cropland VC±50% | ±5.70 | 0.011 | ±2.19 | 0.003 |
| Wetland VC±50% | ±32.26 | 0.619 | ±28.55 | 0.608 |
| Woodland VC±50% | ±11.53 | 0.045 | ±13.75 | 0.053 |
| Grassland VC±50% | ±1.96 | 0.003 | ±2.13 | 0.003 |
| Water body VC±50% | ±3.68 | 0.004 | ±1.73 | 0.002 |
| Unused land VC±50% | ±0.79 | 0.001 | ±0.64 | 0.001 |

Because of the highest value coefficient and the second large area, the value of ecosystem services produced by wetland was the highest among the six land use categories, accounted for about 43% (Table 4) of the total value, far more than 16% (Table 3) of its proportion in land use. Rank 2nd and 3rd in values of ecosystem service for land use were woodland and cropland (Table 4), for the value coefficients of woodland was far better than cropland although the area of cropland was greater than woodland. Water body and grassland generated fewer service values owing to their small area, though they have the relatively higher value coefficients. Comparatively speaking, due to the value coefficient of water body were nearly 4 times greater than that of grassland, in spite of the area of water body being less than grassland, the values of ecosystem service for water body were still more than that of grassland. Unused land has the smallest area and the lowest value coefficient and hence the value of ecosystem services was the least.

The Ecosystem Service Values ($ESV_f$) provided by individual ecosystem functions were shown in Table 5. In general, the changes in the contribution of each ecosystem function to the total ESV were small, with all the change rates lower than 1.7%. Owing to the relatively biggish decrement in values of ecosystem service functions for waste treatment, hydrology regulation and food production, the total ecosystem service value still lower down, although the values for all the other six ecosystem service functions showed an escalating trend from 1996 to 2004. The overall rank order for each ecosystem function based on their contributions to the overall value of ecosystem services was as follows, from high to low, hydrology regulation, waste treatment, climate regulation, biodiversity conservation, soil conservation, gas regulation, aesthetic landscape, raw material and food production. The cause for the rank order likely resulted from the high ability of aquatic ecosystem (wetland and water body) to regulate hydrology and treat waste and the high capacity of woodland and grassland to regulate climate and protect biodiversity.

**Ecosystem services sensitivity analysis:** As shown in Table 6 the percentage change in estimated total ecosystem service value and the coefficient of sensitivity resulting from a 50% adjustment in the value of the coefficient, were calculated using formula (4). In all cases, CS was far less than unity and often near zero, indicating that the total ecosystem services value estimated in this study area was relatively inelastic with respect to the value coefficients. CS for wetland was the highest and showed declining tendency, from 0.619 in 1996 to 0.608 in 2004, because of the large area and high service value coefficient. However, CS for woodland showed slightly increasing trend from 0.045 in 1996 to 0.053 in 2004. Besides woodland, the CS for all the other land uses reduced slightly or remained constant. That is to say, CS for cropland or water body decreased while that for grassland or unused land relatively remained constant. The sensitivity analysis indicated that the estimation in this study area was robust in spite of uncertainties on the value coefficients.

## CONCLUSION

By analyzing and discussing the changes of ecosystem service value based on land use in Xinjian County from 1996 to 2004, we came to the conclusions as follows:

- The areas of woodland, grassland and build up land increased, yet the areas of cropland, wetland, water body and unused land decreased.
- The total ecosystem services value of Xinjian County was about 4588.2 million Yuan in 1996 and 4587.8 million Yuan in 2004. The net decline in ecosystem service value was about 340.8 thousand Yuan from 1996 to 2004, which was caused by the decreasing areas of cropland, wetland, water body and unused land. Some measures should be taken to protect their land use so as to maintain the balance of ecosystems.
- Owing to the high ability of wetland and water body to regulate hydrology and treat waste and the high capacity of woodland and grassland to regulate climate and protect biodiversity, the relatively higher values for each ecosystem function were hydrology regulation, waste treatment, climate regulation, biodiversity conservation.

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