AN ECOSYSTEM SERVICE VALUE ASSESSMENT OF LAND-USE CHANGE ON POYANG LAKE BASIN UNDER 3S TECHNOLOGY, CHINA

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ABSTRACT:

Ecosystem services generally mean the processes that natural ecosystems support and maintain humans' survival and the living conditions. As the global problems of ecosystems and environment, such as forest areas sharply decreasing and temperature warning up in the global area, become more and more severe, people have to pay more attention to the research on ecosystem services. Both domestic and overseas scientists have conducted many researches on ecosystem process, ecosystem services, valuing systems methods and value structure. In this study, we used mathematical simulations to estimate the annual economic value of ecosystem services provided by Poyang Lake Basin, China. We used Geographic Information System (GIS) techniques to determine land-use change within the study area because the research benefits of GIS approaches have been demonstrated by many ecological studies, but such approaches have seldom been used for ecological economic valuations. We conclude that future land-use policy formulation can influence the conservation of ecosystems, and that further land reclamation should be based on rigorous environmental impact analyses.

1. INTRODUCTION

Economic valuation of ecosystem services is becoming more widely used to understand the multiple benefits provided by ecosystems (Guo et al., 2001). Ecosystem services represent the benefits that living organisms derive from ecosystem functions that maintain the Earth's life support system. In Costanza et al. (reprinted Costanza et al., 1997) a value for the world's ecosystem services is posited as a point of departure for further discussion of ecological-economic valuation techniques, potentials and pitfalls. The authors calculate average global values of ecosystem services across 17 distinct types of services and 16 biomes. Peters et al. (1989) presented an assessment of the economic value of a tropical Amazon rainforest in Brazil, and proposed a strategy for sustainable use of rainforest in the region. Tobias and Mendelsohn (1991) have also discussed the values of tropical forests. Andrew et al. (2000) assessed the ecosystem services of the Pantanal sub-region Nhecolandia. Guo et al. (2001) estimated the economic value of some ecosystem services by forest ecosystems in the Xingshan County. Serkan (2005) discussed the method that based on contingent for valuation of the non-use benefits.

In this study, we conducted mathematical simulations to estimate the annual economic value of ecosystem services on Poyang Lake Basin, China. We used Geographic Information System (GIS) techniques to determine land use change within the study area.

2. METHODS

2.1 Study area

Poyang Lake Basin consists of Ganjiang, Xiushui, Xingjiang, Raohe and Fuhe. Its whole area is 162 225 square kilometer, which is 97.2 percent Jiangxi Province area. Poyang Lake now is the biggest fresh water lake in China, and is one of the nation-protected natural zones, and has been listed into the category of important wetlands in the world. In Poyang Lake Basin, farming, waters, forest, residential area and grassland constitute a complete amphibious ecosystem.

2.2 Data collection and preparation

We gained the land-use map of the study area from Data Center for Resources and Environment Sciences of Institute of Geographic Sciences and Natural Resources Research, CAS. The data was extracted from LANDSAT Thematic Mapper (TM) images obtained in 1988 and 1995, and LANDSAT Enhanced Thematic Mapper (ETM) image obtained in 2000.

2.3 Land use classification

Based on the characteristics of prevailing land cover and land use in Poyang Lake Basin, the six generic land categories that we identified in the study area included: orchard/plant nursery, grassland, water-supply and aquaculture pond, wetland, settlement, and farmland. Wetland consist of various types of marshes and swamps, while water-supply and aquaculture ponds are managed open water bodies used for producing fisheries food products and water supply. Farmlands are managed for growing various green food items, orchards/plant nurseries consist of managed green areas including trees and other plants, and grassland including a mixture of grass. Finally, settlements consist of commercial and residential areas and their associated transportation surfaces.

2.4 Assignment of ecosystem service value

In order to obtain ecosystem services values for each of the six land-cover categories, each category was compared with the 17 biomes identified in ecosystem services valuation model. The most representative biome for each category was used as the proxy for the category. The total value of the ecosystem services represented by each land-cover category was obtained by multiplying the estimated size of each land category by the value coefficient of the biome used as the proxy for that category:

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

where ESV is the estimated ecosystem service value, Ak the area and VCk the value coefficient ($/ha/yr) for land use category 'k' . The change in ecosystem service values was estimated by calculating the difference between the estimated values for each land- cover category in 1988, 1995 and 2000.

Land cover land use categories	Equivalent biome	Ecosystem service coefficient($/ha/y)
Orchard/plant nursery	Forest	969
Grassland	Grassland	232
Water-supply and aquaculture pond	Lakes/rivers	8498
Wetland	marsh/floodplains	14785
Settlement	Urban	0
Farmland	Cropland	92

Table 1 Costanza et al. (1997) biome equivalents for the six land-use categories, and the corresponding ecosystem values

Land cover land use categories	1988 (ha)	1995 (ha)	2000 (ha)	1988-1995 (ha)	1995-2000 (ha)	1988-2000 (ha)
Orchard/plant nursery	10352428.92	10387966.76	10377397.56	35537.84	-10569.20	24968.64
Grassland	754614.68	733450.90	728500.56	-21163.80	-4950.34	-26114.10
Water-supply and Aquaculture pond	523317.74	460427.72	511080.16	-62890.00	50652.44	-12237.60
Wetland	244593.00	266809.84	261558.40	22216.84	-5251.45	16965.40
Settlement	268600.04	284100.88	286150.83	15500.84	2049.95	17550.79
Farmland	4550424.37	4561050.77	4529264.93	10626.41	-31785.80	-21159.40

Table 2 Land-use/land-cover change in Poyang Lake Basin from 1988 to 2000.

3. RESULTS

3.1 Land use change detection

The changes in the study area of each of the six generic land categories are presented in Table.2. The most affected category was Water-supply and aquaculture pond, which shrank in area from 523318 ha in 1988 to 460428 ha in 1995, and increased to 511080 ha in 2000. The second most affected category was Orchard/plant nursery, which increased from 10352429 ha in 1988 to 10387967 ha in 1995, but declined to 10377398 ha in 2000. The area of other four categories also had change during this 10-year period. Grassland declined in area from 754615 to 728501 ha, Wetland increased in area from 244593 to 261558 ha, Settlement increased in area from 268600 to 286151 ha, Farmland declined in area from 4550424 to 4529265 ha.

3.2 Estimation of changes in ecosystem services

Using the estimated change in the size of each land-cover category together with the ecosystem service value coefficients reported by Costanza et al. (1997), we found that land-use change in our study area resulted in increased from $19274.7 million in 1988 to $19438.161 million in 2000(Table3). From the table 3, we can see the ecosystem service value in the study area declined from 1988 to 1995, and then increased from 1995 to 2000. By adding the ecosystem service increased during these two periods, we obtained a cumulative ecosystem increased of $163.466 million. Settlement land was assigned no ecosystemservice value (which may underestimate its actual ecological value derived from plants in residential and urban areas).

We also estimated the impacts of land-use change on individual ecosystem functions within the study area. The values of services provided by individual ecosystem functions were calculated using the following equation:

$$ESV_f = \sum (A_k \times VC_{fk})$$

where ESVf is the estimated ecosystem service value of function f, Ak is the area (ha) and VCfk the value coefficient of function f for land-use category 'k' (Table 4).

The contributions of ecosystem functions to overall value of ecosystem services in each year of analysis were ranked based on their estimated ESVf in 1988, 1995 and 2000, while the overall ranking of each function was based on the average value of each ESVf across the three years of analysis. The shift in the contribution of each ecosystem function to the total value of the ecosystem services is presented in Table 4 by an upward arrow for increasing contribution, downward arrow for decrease in contribution.

Land cover land use categories	ESV(US＄×10^6/yr)			1988-1995	1995-2000	1988-2000
	1988	1995	2000	＄×10^6	＄×10^6	＄×10^6
Orchard/plant nursery	10031.504	10065.940	10055.698	34.436	-10.242	24.194
Grassland	1110.304	1112.896	1105.141	2.592	-7.755	-5.163
Water-supply and aquaculture pond	4447.154	3912.715	4343.159	-534.439	430.444	-103.995
Wetland	3616.308	3944.784	3867.141	328.476	-77.643	250.833
Settlement	0	0	0	0	0	0
Farmland	69.425	67.477	67.022	-1.948	-0.455	-2.403
Total	19274.700	19103.812	19438.161	-170.883	334.349	163.466

Table 3 Total ecosystem service value (ESV in US＄×106/yr) estimated for each land cover category in the study area using Costanza et al. coefficients, and the overall change and rate of change between 1988, 1995 and 2000.

The contribution of nutrient cycling to total value of ecosystem services increases over the 10-year period, it continues to be the dominant ecosystem function, contributing 19.273-19.389% of the total value. Waste treatment, water regulation, erosion control, climate regulation, raw materials, disturbance regulation, water supply, recreation, food production and cultural each contributed an average of more than 1% to the value of total ecosystem services, while the contribution of other ecosystem functions was minimal. Among the 11 top-ranked ecosystem functions, the contribution of nutrient cycling, water treatment, erosion control, climate regulation, raw materials, recreation, food production and cultural increased over the 10-year period of our study, while the contribution of water regulation, disturbance regulation, water supply decreased during the same time period.

4. DISCUSSION AND CONCLUSION

We used Costanza et al.'s (1997) ecosystem-service values to analyze our study area, they represented the most comprehensive set of valuation coefficients available to us. Nevertheless, in order to analyze the kind of ecosystem-service that we considered it should become more meaningful for policy formulation affecting land use, it is imperative to obtain value coefficients for ecosystem services that more accurately reflect local conditions. One approach to implement this in a pragmatic way would be to identify benchmark ecosystem service values for dominant ecosystem types within a region and then to evaluate the ecosystem services provided at specific locations relative to the representative benchmark (Kreuter et al., 2001). Because ecosystem services are generally not traded directly, indirect valuation techniques (such as contingent valuation, hedonic values, and travel cost methods) will be needed to obtain location specific values for ecosystem services. Once such coefficients are determined, the values of ecosystem services can be calculated through GIS tools. In using such an approach, it is important to realize that absolutely accurate coefficients are often less critical for land-use change analyses than time-specific analyses of the value of ecosystem services because coefficients tend to affect estimates of directional change less than estimates of the magnitude of ecosystem values at a specific point in time.

The most important ecological feature in Poyang Lake Basin is its Water-supply and aquaculture pond. This zone has provided valuable fisheries and water supply for thousands of years, now lake and river are being declined in Poyang Lake due to the valuable land resources. But in concordance with Jiangxi Province land use policy, no large-scale land reclamation for agriculture, fisheries, and other uses, especially in Poyang Lake Region, so Water-supply and aquaculture pond area is increased between 1995 and 2000.

Based on the estimated size of six land-cover categories and using Costanza et al.'s (1997) ecosystem services values for related biomes, we determined that the total annual ecosystem service values in Poyang Lake Basin to have increased $163.466 million between 1988 and 2000. This increase in ecosystem services is largely attributable to the Forest increased and the water-supply and aquaculture pond increased between 1995 and 2000. At the same time, Grassland declined due to the Jangxi Province land use police which advocate tree planting. The increased of wetland due to the Shanjiang Lake Project in Jiangxi Province which have availability protect on the wetland.

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Ecosystem function	*1988*			*1995*			*2000*			*Overall rank*	*Tendency*
	ESV_f	%	Rank	ESV_f	%	Rank	ESV_f	%	Rank		
Nutrient cycling	3737.227	19.389	1	3750.056	19.630	1	3746.241	19.273	1	1	↑
Waste treatment	2666.219	13.834	3	2721.214	14.244	2	2729.277	14.041	3	2	↑
Water regulation	2883.821	14.963	2	2541.488	13.305	3	2817.174	14.493	2	3	↓
Erosion control	2055.249	10.663	4	2143.393	11.220	4	2121.501	10.914	4	4	↑
Climate regulation	1459.692	7.573	5	1464.703	7.667	5	1463.213	7.528	5	5	↑
Raw materials	1454.562	7.546	6	1461.822	7.652	6	1459.906	7.511	6	6	↑
Disturbance regulation	1130.912	5.867	8	1231.826	6.448	7	1207.968	6.214	7	7	↓
Water supply	1142.267	5.926	7	1009.531	5.284	8	1116.501	5.744	8	8	↓
Recreation	953.221	4.945	9	953.775	4.993	9	961.760	4.948	9	9	↑
Food production	874.854	4.539	10	879.060	4.601	10	876.941	4.511	10	10	↑
Cultural	236.291	1.226	11	255.835	1.339	11	251.288	1.293	12	11	↑
Genetic Resources	165.639	0.859	12	166.267	0.870	12	166.038	0.854	12	12	↑
Biological control	143.475	0.744	13	143.283	0.750	13	142.412	0.733	13	13	↓
Pollination	124.355	0.645	14	124.395	0.651	14	123.431	0.635	14	14	↓
Soil formation	108.075	0.561	15	108.541	0.568	15	108.403	0.558	15	15	↑
Habitat/refugia	74.456	0.386	16	81.210	0.425	16	79.514	0.409	16	16	↑
Gas regulation	64.384	0.334	17	67.413	0.353	17	66.592	0.343	17	17	↑
Total	19274.700	100	–	19103.813	100	–	19438.160	100	–	–	–

Table 4 Estimated annual value of ecosystem functions