Change in Ecosystem Service Value Arising from Land Consolidation Planning in Anhui Province

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Abstract The evaluation of change in ecosystem service value arising from land consolidation planning is an important aspect of environmental impact assessment of land consolidation. By estimating the change in ecosystem service value before and after the implementation of land consolidation planning, it is able to quantitatively describe the change in ecosystem service value arising from land consolidation planning, so as to provide a quantitative basis for the environmental impact assessment of land consolidation. Taking the case of Anhui Province, the authors developed the equivalency factor table of ecosystem service value, to determine the economic value of single equivalency factor of ecological service value in the study area, calculate per unit area of ecological service value of land ecosystem in the study area, and research the change in ecosystem service value before and after the implementation of land consolidation planning in Anhui Province. The results show that after the implementation of a new round of land consolidation planning in Anhui Province, the total ecosystem service value may decrease to some extent, the farmland ecosystem service value substantially increases, while water body ecosystem service value greatly decreases.

Key words Ecosystem service value, Land consolidation planning, Anhui Province

1 Introduction

As an important aspect of environmental impact assessment (EIA), the land consolidation planning is intended to control ecological and environmental problems arising from land consolidation planning at the source, and it is one of the most effective means of improving science of land consolidation planning[1]. In 2012, the *National Land Consolidation Planning* (2011 – 2015) was approved by the State Council. The prominent point of this plan is to improve the ecological environment. Negligence of policy makers in economic quantization of the ecosystem service value will no doubt harm sustainable development of human beings in biosphere[2].

The evaluation of change in ecosystem service value arising from land consolidation planning is an important aspect of EIA of land consolidation. By estimating the change in ecosystem service value before and after the implementation of land consolidation planning, it is able to quantitatively describe the change in ecosystem service value arising from land consolidation planning, so as to provide a quantitative basis for the EIA of land consolidation. Change in ecosystem service value arising from land consolidation planning is becoming a hot issue among domestic scholars. Zheng Huimin *et al.* (2007), on the basis of analyzing significance of the ecosystem service value in the EIA of land consolidation planning, built a mathematical model and took Dajian Township in Xiangshui County of Jiangsu Province as an example to assess the land consolidation project[3]. Zhang Zhengfeng (2008), from typical cases of three land consolidation projects in eastern, middle and western regions of China, estimated changes in ecosystem service value arising from land consolidation activities, and compared and analyzed laws of changes in single ecosystem service function[4]. Yang Xueting *et al.* (2008) measured increase and decrease of ecological benefits in land consolidation project areas with changes in ecosystem service value through combining three land consolidation projects in Ya'an City of Sichuan Province[5]. Fu Guanghui *et al.* (2010) established an economic model for assessing regional land consolidation ecological benefits on the basis of the theory of ecosystem service value introduced by Costanza, and by taking Nanjing City as an example, they assessed changes of ecosystem service value before and after implementation of land consolidation project, and believed that land consolidation project should properly protect and increase land types that have higher value of ecological service[6]. Liang Shushu *et al.* (2011), using the equivalency factor table of ecosystem service value put forward by Xie Gaodi *et al*, assessed the ecosystem service value of Wangmuying land consolidation project area in Yangqing District of Beijing, and analyzed reasons for changes in the ecosystem service value before and after the implementation of land consolidation project[7].

In recent years, domestic scholars study the changes in ecosystem service value arising from land consolidation planning mainly from the perspective of land consolidation project, and some have made a lot of achievements through combining local practice. From the perspective of land consolidation planning at provincial level and in combination with relevant research achievements, we took the case of Anhui Province and analyzed changes in ecosystem service value before and after land consolidation planning, in the hope of providing reference for preparation and implementation of a new round land consolidation plan.

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2 General information of study area

Anhui Province (114°54′E to 119°37′E and 29°41′N to 34°38′N) extends about 450 km from east to west and stretches about 570 km from south to north. The terrain in Anhui Province is high in the southwest and low in northeast, and greatly different between the southern and northern areas. Yangtze River and Huai River flow through the whole province and divide Anhui into three natural regions, namely, Huaibei Plain, hilly area between Yangtze River and Huai River, and mountainous area in southern part. Situated in the transition area of subtropical zone and temperate zone, with Huai River as the boundary, the northern area has temperate semi-humid monsoon climate, while the southern area has subtropical humid monsoon climate. The mean annual temperature of Anhui Province is 14 to 16℃ (with 2 ℃ difference between the south and north); mean annual hours of sunshine up to 1 800 to 2 500 hours; average frost-free period up to 200 to 250 days; and average precipitation of 800 to 1 600 mm[8].

According to survey data of land change in 2010, Anhui Province covers an area of 14.01 million hectares, accounting for 1.46% of the national total land area. In the land use structure of Anhui Province, 42.08% is cultivated land (5.9 million hectares); 26.96% is forest land (3.78 million hectares); 13.23% is water and water conservancy facility land (1.85 million hectares); 11.19% is township villages and industry and mining land (1.57 million hectares); 2.53% is garden land (0.36 million hectares); 2.21% is transport and communication land (0.31 million hectares); 0.57% is grass land (0.08 million hectares); and the rest 1.23% is other types of land.

3 Changes in ecosystem service value arising from land consolidation planning in Anhui Province

3.1 Preparing the equivalency factor table of ecosystem service value The equivalency factor of ecosystem service value is the relative contribution potential of ecosystem services. It is defined as the economic value of annual natural grain yield in 1 hm^2 average-yield farmland. Through comprehensive comparison and analysis and with reference to research achievements of Robert Costanza, Xie Gaodi and other scholars, we determined that the economic value of one ecological service value equivalency factor is about 1/7 of the market value of national average unit yield in that year[2,9], as listed in Table 1.

Table 1 Coefficient for unit area ecosystem service value of land ecosystem in Anhui Province

	Forest	Grassland	Farmland	Wetland	Water area	Land difficult to be used
Gas regulation	3.5	0.8	0.5	1.8	0	0
Climate regulation	2.7	0.9	0.89	17.1	0.46	0
Water supply conservation	3.2	0.8	0.6	15.5	20.38	0.03
Soil formation and protection	3.9	1.95	1.46	1.71	0.01	0.02
Waste disposal	1.31	1.31	1.64	18.18	18.18	0.01
Bio-diversity protection	3.26	1.09	0.71	2.5	2.79	0.34
Food production	0.1	0.3	1	0.3	0.1	0.01
Raw material production	2.6	0.05	0.1	0.07	0.01	0
Amusement and recreation	1.28	0.04	0.01	5.55	4.34	0.01

In Table 1, the forest ecosystem corresponds to the forest land in the national land classification; grassland ecosystem corresponds to meadow; farmland ecosystem corresponds to cultivated land and garden land; wetland ecosystem corresponds to marshland; water area ecosystem corresponds to rivers, lakes, reservoirs, ponds and mud flats; ecosystem of land difficult to be used corresponds to residential area, industry and mining land, traffic and transportation land and unused land.

3.2 Determining economic value of equivalency factor of single ecosystem value in the study area On the basis of sown area of grain crops, grain yield per unit area and average price of grain crops, we calculate the economic value with equation (1):

$$E_a = 1/7 \sum_{i=1}^{n} \frac{m_i p_i q_i}{M} (i = 1, 2, \cdots, n) \quad (1)$$

where E_a is the economic value of crop production service provided by farmland ecosystem per unit area (yuan/hm^2); i is crop type; p_i signifies national average price of the i-th crop (yuan/kg); q_i stands for per unit area yield of the i-th crop (kg/hm^2); m_i refers to planting area of the i-th crop (hm^2); M is the total planting area of the i-th crop (hm^2); 1/7 means that the economic value of crop provided by natural ecosystem without human input is 1/7 of the economic value of the crop provided by existing unit area of farmland.

According to the *National Economic Statistical Yearbook of Anhui Province in* 2010, major grain crops of Anhui Province include maize, wheat, rice, beans and tuber crops. According to their unit price, per unit area yield and sown area data in 2010, we calculated the economic value for one ecosystem service value equivalence factor of Anhui Province, Ea = 1 274.56 yuan/hm^2.

3.3 Determining the unit area economic value of ecosystem service in the study area According to Table 1 and the economic value of unit area food production service provided by farmland ecosystem in the study area, we can obtain the unit area ecological service value of other types of ecosystems in Anhui Province:

$$E_{ij} = e_{ij} E_a (i = 1, 2, \cdots, 9; j = 1, 2, \cdots, 6) \quad (2)$$

where E_{ij} signifies the unit price of the i-th ecological service function of the j-th ecosystem (yuan/hm^2); E_a = 1 274.56 yuan/hm^2; e_{ij} refers to the equivalence factor of the i-th ecological service function of the j-th ecosystem relative to the unit price of ecological service provided by farmland ecosystem (shown in Table 3 – 1); i

is the type of ecosystem service function, including gas regulation, climate regulation, water supply conservation, soil formation and protection, waste disposal, bio-diversity protection, food production, raw material production, amusement and recreation; j stands for ecosystem type, including forest, grassland, farmland, wetland, water area and land difficult to be used. According to this, we can calculate the unit area annual economic value E_{ij} of ecosystem service function for every types of land use in Anhui Province.

Table 2 The unit area economic value of ecosystem service function in Anhui Province in 2010 (yuan/hm^2)

	Forest	Grassland	Farmland	Wetland	Water area	Land difficult to be used
Gas regulation	4 460.98	1 019.65	637.28	2 294.22	0.00	0.00
Climate regulation	3 441.32	1 147.11	1 134.36	21 795.05	586.30	0.00
Water supply conservation	4 078.61	1 019.65	764.74	19 755.75	25 975.63	38.24
Soil formation and protection	4 970.80	2485.40	1860.86	2 179.51	12.75	25.49
Waste disposal	1 669.68	1669.68	2090.29	23 171.58	23 171.58	12.75
Bio-diversity protection	4 155.08	1389.28	904.94	3 186.41	3 556.04	433.35
Food production	127.46	382.37	1274.56	382.37	127.46	12.75
Raw material production	3 313.87	63.73	127.46	89.22	12.75	0.00
Amusement and recreation	1 631.44	50.98	12.75	7 073.83	5 531.61	12.75

3.4 Changes in ecosystem service value before and after the implementation of land consolidation planning in Anhui Province To facilitate comparison, we assume that the economic value of unit area ecosystem service keeps not changing in the base period (2010) and the end of period of planning (2020). According to land area changes of every types of ecosystem before and after implementation of land consolidation planning in Anhui Province, we can obtain changes of ecosystem service value Dbefore and after the implementation of planning.

Total value of ecosystem service within the area can be calculated with the following equation:

$$ESV = \sum_{i=1}^{m}\sum_{j=1}^{n} A_j E_{ij} \ (m = 1, 2, \cdots a;\ n = 1, 2, \cdots, 6) \qquad (3)$$

where ESV is the total value of ecosystem service value within the area; A_j signifies the area of the j-th type land ecosystem; i stands for the type of ecosystem service; E_{ij} refers to the unit price of the i-th ecological service function in the j-th ecosystem (yuan/hm^2).

The value of ecosystem service function of a certain type of land within the area is calculated by following equation:

$$ESV_f = \sum_{j=1}^{n} A_f E_{ij} \ (n = 1, 2, \cdots, 6) \qquad (4)$$

where ESV_f is the total value of ecosystem service of the f-th type land; A_f is the area of the f-th type land ecosystem; E_{ij} refers to the unit price of the i-th ecological service function in the j-th type ecosystem (yuan/hm^2).

Table 3 Changes of land area of ecosystems before and after the implementation of land consolidation planning in Anhui Province (hectare)

	Forest	Grassland	Farmland	Wetland	Water area	Land difficult to be used
2010	3 777 630.75	385.37	6 251 697.89	128 099.64	1 404 673.20	1 983 468.40
2020	3 776 605.04	322.84	6 365 930.53	127 261.93	1 246 393.16	1 937 044.25

Table 4 Changes in ecosystem service value before and after the implementation of land consolidation planning in Anhui Province (108 yuan)

		Forest	Grassland	Farmland	Wetland	Water area	Land difficult to be used	Total
Before the implementation of planning (2010)	Gas regulation	168.52	0.00	39.84	2.94	0.00	0	211.30
	Climate regulation	130.00	0.00	70.92	27.92	8.24	0	237.08
	Water supply conservation	154.07	0.00	47.81	25.31	364.87	0.76	592.83
	Soil formation and protection	187.78	0.01	116.34	2.79	0.18	0.51	307.60
	Waste disposal	63.07	0.01	130.68	29.68	325.49	0.25	549.18
	Bio-diversity protection	156.96	0.01	56.57	4.08	49.95	8.6	276.17
	Food production	4.81	0.00	79.68	0.49	1.79	0.25	87.03
	Raw material production	125.19	0.00	7.97	0.11	0.18	0	133.45
	Amusement and recreation	61.63	0.00	0.80	9.06	77.70	0.25	149.44
	Total	1 052.04	0.04	550.60	102.39	828.39	10.62	2 544.08
After the implementation of planning (2020)	Gas regulation	168.47	0.00	40.57	2.92	0.00	0.00	211.96
	Climate regulation	129.97	0.00	72.21	27.74	7.31	0.00	237.23
	Water supply conservation	154.03	0.00	48.68	25.14	323.76	0.74	552.35
	Soil formation and protection	187.73	0.01	118.46	2.77	0.16	0.49	309.62
	Waste disposal	63.06	0.01	133.07	29.49	288.81	0.25	514.69
	Bio-diversity protection	156.92	0.00	57.61	4.06	44.32	8.39	271.30
	Food production	4.81	0.00	81.14	0.49	1.59	0.25	88.28
	Raw material production	125.15	0.00	8.11	0.11	0.16	0.00	133.53
	Amusement and recreation	61.61	0.00	0.81	9.00	68.95	0.25	140.62
	Total	1 051.76	0.03	560.66	101.72	735.05	10.37	2 459.59

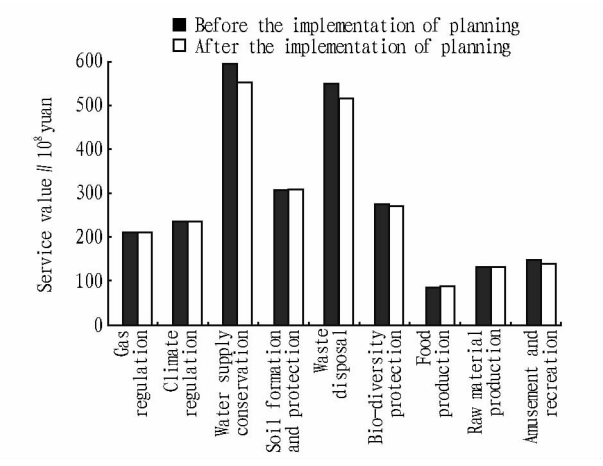

Fig. 1 Changes in value of every types of ecosystem service before and after the implementation of land consolidation planning in Anhui Province

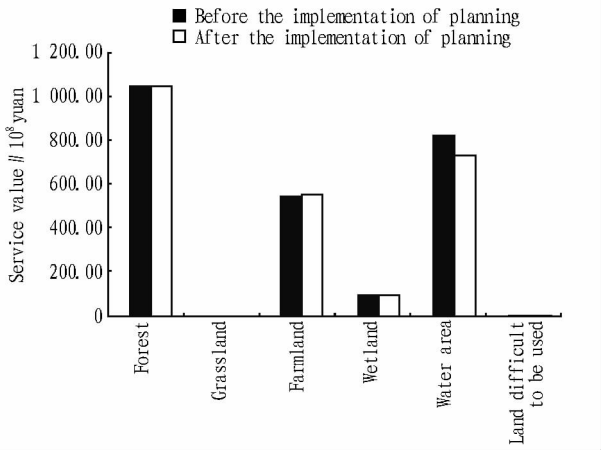

Fig. 2 Changes in service value of every types of land before and after the implementation of land consolidation planning in Anhui Province

From Table 4 and Fig. 1, it can be known that functions of gas regulation, climate regulation, soil formation and protection, food production and raw material production get improved after this round of the implementation of land consolidation planning in Anhui Province, but due to reduction of some water areas, functions of water supply conservation, waste disposal, bio-diversity protection, and amusement and recreation are falling in varying degrees.

Table 4 and Fig. 2 show that after the implementation of land consolidation planning in Anhui Province, there is a greater increase in economic value of farmland ecosystem service function, while that of water area ecosystem service function decreases a lot. This is mainly because this round of land consolidation planning renovates shallow water polluted pond into paddy field. The water area decreases, but the quality gets improved. The economic value of ecosystem service function of land difficult to be used reduces about 2.34% of the total value, bringing an increase in utilization ratio of this type of land.

4 Discussion and weak point

Compared with measuring capital of financial industry and manufacturing industry, the estimation of ecosystem service value is often neglected by policy makers. The complexity of land ecosystem also creates more difficulty to estimation of ecosystem service value. Besides, we must admit that not all land ecosystem services can be quantified in economic value, and the quantified value is only the estimation, to provide reference for planning and decision making. When establishing the coefficient for unit area ecological service value of land ecosystem in Anhui Province, we referred to scholars' country-wide researches. As to dimensional effect and cumulative effect of ecosystem, there is weak point in our study. In addition, to compare the influence of land consolidation planning on ecosystem service value, this study assumes the economic value of unit area ecosystem service keeps not changing in the base period (2010) and the end of period of planning (2020), but if it is changing, what will be the influence is a question to be considered deeply.

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