

## Research Article

### Impacts of Land Use Change on Ecosystem Services Value in Agro-pastoral Zone-Yanchi County of Ningxia, China

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**Abstract:** Based on TM image data in 1989, 1995, 1999, 2003, 2006 and 2009 of Yanchi County of Ningxia, the land use data of Yanchi County in each year were extracted supporting by RS and GIS technology and the dynamic change of land use was analyzed. The change of ecosystem services values caused by the land use change of Yanchi County were estimated using the evaluation method of China terrestrial ecosystem services value. The results showed that the change of land use were significant from 1989 to 2009. The area of forest land and construction land had an increasing tendency, while grassland area first reduced and then increased; while cultivated land and unused land area first increased then reduced, while water area fluctuated slightly. The ecosystem services value of Yanchi County had an increasing tendency from 1989 to 1995, because the increasing forest land area had played the major role in raising the total ecosystem services value. The grassland accounted for a large proportion of the total ecosystem services value of Yanchi County, with its contribution rate from 49.8 to 60.4%. And the composition of the ecosystem services value of Yanchi County came up a benign change for the increasing contribution rate of woodland. The ecosystem services value sensitivity index of each land use type was less than 1, which indicated that the ecosystem services value of Yanchi County lacks flexibility on its service value index, research results were reliable.

**Keywords:** Ecosystem services value, land use change, Yanchi County of Ningxia

## INTRODUCTION

Ecosystem good and services represent the benefits human population derive, directly or indirectly, from ecosystem functions (Costanza *et al.*, 1997), which are the material foundations and basic conditions for the survival and development of human being. The estimation of ecosystem services value is the hot issue in the ecology research worldwide and big advancements have been obtained in the theory, estimation and accounting of ecosystem services (Daily *et al.*, 2000; Ouyang *et al.*, 1999a, b; Chen and Zhang, 2000; Xie *et al.*, 2001a, b, 2003). Land use change plays crucial role in the maintenance of ecosystem services, because it can change the structure and function of ecosystem (Turner *et al.*, 1998). Therefore, the research of change of ecosystem services under the background of land use change is very important for the realization of sustainable use of land resources and coordinated development of the economy and environment. In recent years, many quantitative researches about the change of ecosystem services values caused by regional land use change have been conducted in the ecosystem of river (Wang and Zhang,

2004; Xu *et al.*, 2005; Du *et al.*, 2008, 2010), city (Wu *et al.*, 2006; Anonymous, 2007; Ye and Zhang, 2008), dry-hot valley (Zhou *et al.*, 2008), oasis (Wang and He, 2011; Ye *et al.*, 2010; Xu *et al.*, 2009), etc. But there were limitations in the time scale, emphasizing on the comparison of two periods and the research on county scale was weak (Xiong *et al.*, 2008; Su *et al.*, 2008).

Agro-pastoral zone is the area that both agricultural management and graze management exist, which is the transitional zone from plains and hills to plateaus and mountainous area and it is also the transitional area from semi-humid and semi-arid area to arid area. The area is vulnerable because of the special climate condition which is easily influenced by natural and human activities. The land use change in that area is dramatically, which is significantly influence the economic output of the area. As a matter of fact, the land use change in that area is the change of the ratio of the agricultural management and graze management. Reasonable allocation of the two managements is the precondition of the sustainable development of the agro-pastoral zone. So the effect of the allocation can be reflected by the change of ecosystem services due to the change of land use.

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Yanchi County is located in the boreal agropastoral zone. The natural resources are diverse and the ecological environment is tender because of the distinct location, makes it a main zone of desertification. Driven by the natural and human factors, such as climate change, human activities, policy regulations, the land use change in Yanchi County is very significant, subsequently affect the ecosystem services. Conservation of ecological environment, maintenance of ecological balance is critical to the ecological security and sustainable development of this area. The studies have been conducted in Yanchi County mainly focused on the land use change (Zhou and Zhao, 2005; Zhang, 2005), dynamics of desertification (Qi *et al.*, 2003; Yang, 2008), government effect of desertification combating (Zhang *et al.*, 2004; Shen *et al.*, 2007), etc. Based on the analysis of land use change dynamics of 6 periods, this study is intend to investigate the rule of impact of land use change on ecosystem services value, subsequently provides reference for decision making.

### OVERVIEW OF STUDY AREA

Yanchi County is in the east of the Ningxia Hui Autonomous Region, 37°04'~38°10'N, 106°30'~107°41'E. Low-lying north high south and the average elevation is 1600 m. The south is loess hilly area; the north is Erdos gentle slope hilly area. The temperate continental climate dominates here, the average temperature is 8.1°C, the extreme high and low temperature is 34.9 and -24.2°C, respectively. The annual frost-free period is 165 days and the average annual precipitation is 250~350 mm, the potential evaporation is 5 times as much as the precipitation, the average annual wind speed is 2.8 m/sec, the average annual strong wind day is 24.2 days, the sand storm day is 20.6 days. The main soil type is sierozem, followed by heilu soil and Aeolian sandy soil and other soil types such as saline soil and albic soil. The main vegetation type includes shrub, rangeland, meadow, sand vegetation and desertification grassland vegetations.

Yanchi County is a typical transition zone which is linked with Maowusu desert in the north and connected with Loess Plateau in the south. From south to north, the Loess Plateau is transiting to Erdos dessert in topographic. The area is the transition zone from semi-

arid zone to arid zone in climate and from dry steppe to desertification in vegetation and from agricultural land to pastoral land in resources use (Zhang *et al.*, 2004). All these transitions make it the area of diversity of natural resources and vulnerability of ecological environment.

### DATA RESOURCES AND RESEARCH METHOD

**Acquisition of land use change data:** Based on the six years remote sensing imagines of 1989, 1995, 1999, 2003, 2006 and 2009 and the topographic, geomorphologic, soil, vegetation maps and field survey data, according to the “land use investigation technology procedures” released by the National Agricultural Districts Committee of China in 1984, the land use type in Yanchi County can be classified into 6 categories: cultivated land, forest land, grassland, construction land, water area and unutilized land. According to the land use classification system, the interpretation signals were constructed with the support of ArcGIS9.2, land use data of 6 periods were acquired with the combination of supervised classification and visual interpretation. Combined with the field sampling points data, accuracy test of the classification of land use was conducted with the support of ENVI4.6, the results showed that the total accuracy and Kappa index were all close to or greater than 0.8 (Table 1), the accuracy of the classification met the need of research.

Land Use Dynamic Degree (LUDD) could quantitatively describe the speed of regional land use change, which is helpful to compare the difference of regional land use change and predict the future land use change tendency (Wang and Bao, 1999). The single land use dynamic (K) refers to the change of area of a particular land use type in particular time period in the research area, the formula is:

Table 1: Accuracy assessment of land use classification in Yanchi County

Year	Sample point number	Total accuracy	Kappa index
1989	315	0.82	0.79
1995	319	0.84	0.81
1999	318	0.83	0.79
2003	321	0.81	0.83
2006	326	0.85	0.82
2009	332	0.83	0.86

Table 2: Ecosystem services value for each land use type in Yanchi County (Yuan/hm<sup>2</sup>·a)

Ecosystem services	Cultivated land	Forest land	Grass land	Water area	Unused land
Air regulation	256.50	1795.50	410.40	0.00	0.00
Climate regulation	456.57	1385.10	461.70	235.98	0.00
Water conservation	307.80	1641.60	410.40	10454.94	15.39
Soil formation and conservation	748.98	2000.70	1000.35	5.13	10.26
Waste disposal	841.32	672.03	672.03	9326.34	5.13
Biodiversity conservation	364.23	1672.38	559.17	1277.37	174.42
Food production	513.00	51.30	153.90	51.30	5.13
Raw material	51.30	1333.80	25.65	5.13	0.00
Entertainment and culture	5.13	656.64	20.52	2226.42	5.13
Total	3544.83	11209.05	3714.12	23582.61	215.46

$$K = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\% \quad (1)$$

where, K is the land use dynamic degree of particular land use in particular time in the research region and  $U_a$ ,  $U_b$  are the particular land use area in the beginning and ending of the research period, T is the length of research period, when T is settled as year, the value of K refers to annual land use dynamic degree.

**The evaluation of ecosystem services value:** Many researchers all over the world have conducted the evaluation of the ecosystem services value at global, regional and single ecosystem scale. Xie *et al.* (2001a, b) classified the ecosystem services into 9 categories and established the equivalence factor table. The economic value of one single equivalence factor of ecosystem services equals one seventh of the market value of the grain production per year. Based on the actual situation of study area, the table of ecosystem services value was revised, subsequently obtained the particular table of ecosystem services value that suited to the research region (Table 2). The average annual grain production of Yanchi County is 1324 kg/hm<sup>2</sup> from 1989 to 2009, the average annual price of the grain from 1989 to 2009 is 2.7 Yuan/kg, so the economic value of single ecosystem services equivalence factor is 513 Yuan.

Referred to the existing research results, combined with the specific situations of Yanchi County, the land use type was regarded as the most closest ecosystem type that described in (Costanza *et al.*, 1997), cultivated land, forest land, grassland, water area, unused land were regarded as farmland, forest, grassland, water body, desertification, respectively. The value of ecosystem services of the construction land was not considered. The value coefficients of ecosystem services of different land use types that corresponded to the ecosystem types were calculated as Table 2. The formula described by Costanza *et al.* (1997) to calculate the ecosystem services is as follows:

$$ESV = \sum (A_k \times VC_k) \quad (2)$$

where,

ESV : The ecosystem services value (Yuan)

$A_k$  : The area of the land use type k (hm<sup>2</sup>)

$VC_k$  : The value coefficient of ecosystem services (Yuan/hm<sup>2</sup>/a)

Currently, constrained by the factor of time, location, research scale, etc., the methods to assess the value of ecosystem services need to be improved, the results of the assessment are not accurate enough. But there are still some practical meanings in the management of ecosystem (Ouyang *et al.*, 1999a). For example, continuous assessment of ecosystem services for particular region could tell the change trend with time, that partially reflects the conditions and potential

problems of the ecosystem, subsequently provides suggestions for the ecological construction, environment protection and sustainable use of land resources.

**Assessment of sensitivity:** In order to identify the extent of which ecosystem services value coefficients dependent on the ecosystem services value, (Du *et al.*, 2010; Wu *et al.*, 2006; Ye and Zhang, 2008) chose the concept of elasticity coefficient to illustrate Coefficient of Sensitive (CS) of ecosystem services value coefficient. If the  $CS > 1$ , it means that ESV is sensitive to the change of VC; if  $CS < 1$ , it means ESV is not sensitive to the change of VC, the larger the CS, the more accurate of the assessment results. In this study, the authors changed the ESV up and down for 50% respectively. The formula for the CS is as follows:

$$CS = \left| \frac{(ESV_j - ESV_i) / ESV_i}{(VC_{jk} - VC_{ik}) / VC_{ik}} \right| \quad (3)$$

where,  $ESV_i$ ,  $ESV_j$  are the initial ecosystem services values and the values that after the adjustment of VC.

## RESULTS AND ANALYSIS

**Land use change:** During the research period, the area of grassland was the largest and most distributed widely, the area of the water was the smallest, the cultivated land mainly distributed in the south and north, the distribution of forest land was disperse, the unused land mainly distributed in the north central of the area and decreased significantly as Table 3 and Fig. 1 shows.

The land use of Yanchi County changes significantly during the period of 1989-2009. The cultivated land area increased gradually at a small annual variable ratio from 1989 to 1999, from 1999 to 2009 the cultivated land area decreased at a relative high annual variable ratio. The previous stage mainly caused by the rapid growth of population and the relative low agricultural productivity that human need more cultivated land to feed themselves. The change of cultivated land in the following stage from 1999 to 2009 mainly caused by the policy of returning the cultivated land to forest land or grassland that implemented by the government of China, the rapid development of agricultural technology and the wave of farmers getting into the factories, which all reduced the demand of cultivated land. The area of forest land increased at a relative high annual variable ratio from 1989 to 2009, especially in the period of 1995-1999, the annual variable ratio reached 68.50%. The changes of forest land area mainly caused by the eco-environment construction (e.g., Three North Shelterbelt Program, Natural Forest Conservation Program, Grain for Green Program) and the enclosure of the hills for natural afforestation, which made the vegetation recover

Table 3: Area change and annual rate change of land use in Yanchi County

Year		Cultivated land	Forest land	Grass land	Water area	Construction land	Unused land
1989	Area (hm <sup>2</sup> )	144630.36	36376.93	433823.59	5331.68	6276.54	48457.58
	Ratio (%)	21.43	5.39	64.28	0.79	0.93	7.18
1995	Area (hm <sup>2</sup> )	146520.07	39211.50	424240.05	5669.13	7153.90	52102.02
	Ratio (%)	21.71	5.81	62.86	0.84	1.06	7.72
1999	Area (hm <sup>2</sup> )	146992.50	66072.38	400551.18	5061.73	8638.68	47580.22
	Ratio (%)	21.78	9.79	59.35	0.75	1.28	7.05
2003	Area (hm <sup>2</sup> )	138016.37	71404.07	410742.12	4589.30	11810.69	38334.13
	Ratio (%)	20.45	10.58	60.86	0.68	1.75	5.68
2006	Area (hm <sup>2</sup> )	130120.08	80650.15	411417.02	4319.34	20989.29	27400.81
	Ratio (%)	19.28	11.95	60.96	0.64	3.11	4.06
2009	Area (hm <sup>2</sup> )	124788.40	88276.49	415466.40	5129.21	28345.66	12890.53
	Ratio (%)	18.49	13.08	61.56	0.76	4.2	1.91
1989~1995	Annual variable ratio (%)	1.31	7.79	-2.21	6.33	13.98	7.52
1995~1999		0.32	68.50	-5.58	-10.71	20.75	-8.68
1999~2003		-6.11	8.07	2.54	-9.33	36.72	-19.43
2003~2006		-5.72	12.95	0.16	-5.88	77.71	-28.52
2006~2009		-4.10	9.46	0.98	18.75	35.05	-52.96

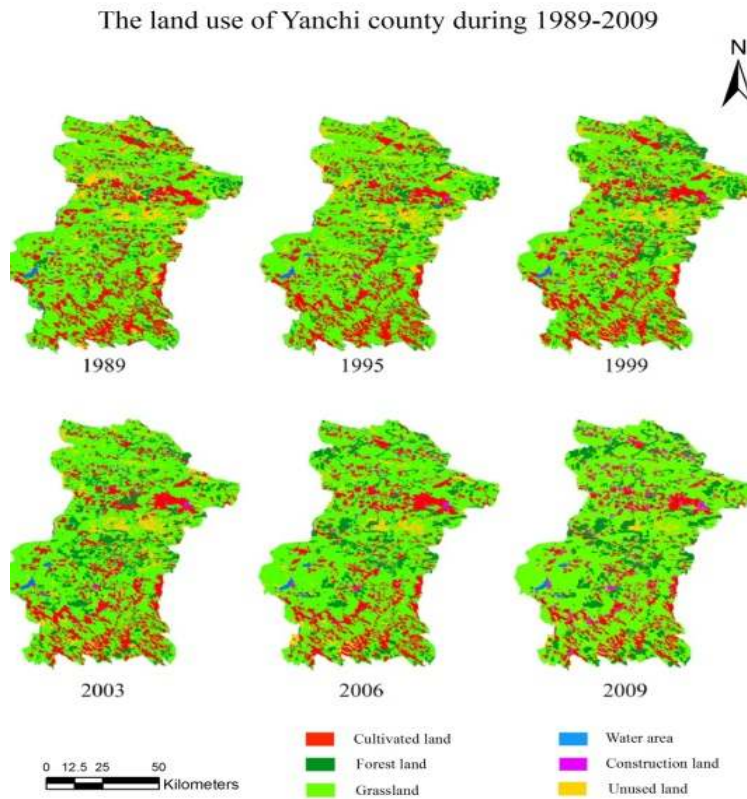


Fig. 1: The land use of Yanchi County during 1989-2009

quickly. The change of grassland area was just opposite to the change of forest land. Though the annual variable ratio was small, the change of the area was very large because the large area of grassland in Yanchi County. The change of water area was not obvious, because it was mainly affected by the factor of climate, such as precipitation and evaporation. The ratio of construction land was increasing gradually, from 0.93% in 1989 to 4.20% in 2009, turned over 4 times in the past 20 years; the annual variable ration was relative high. The

construction land was the fastest changing land use type in the three phrases: 1989-1995, 1999-2003, 2003-2006. Continuously advancing urbanization pace was the main reason for the significant change of construction land. The unused land area was increasing at a low speed before 1995 and it decreased significantly after 1995, the fastest change rate appeared during 2006-2009, the annual variable ration was -52.96%. The increase of the unused land area was caused by the conversion of grassland into mobile sand

Table 4: The ecosystem services value of Yanchi County during 1989-2009

Year		Cultivated land	Forest land	Grass land	Water body	Unused land	Total
1989	Value (¥ 10 <sup>6</sup> /year)	512.69	407.75	1611.27	125.74	10.44	2667.89
	Ratio (%)	19.22	15.28	60.40	4.71	0.39	100.00
1995	Value (¥ 10 <sup>6</sup> /year)	519.39	439.52	1575.68	133.69	11.23	2679.51
	Ratio (%)	19.38	16.40	58.81	4.99	0.42	100.00
1999	Value (¥ 10 <sup>6</sup> /year)	521.06	740.61	1487.70	119.37	10.25	2878.99
	Ratio (%)	18.10	25.72	51.67	4.15	0.36	100.00
2003	Value (¥ 10 <sup>6</sup> /year)	489.24	800.37	1525.55	108.23	8.26	2931.65
	Ratio (%)	16.69	27.30	52.04	3.69	0.28	100.00
2006	Value (¥ 10 <sup>6</sup> /year)	461.25	904.01	1528.05	101.86	5.90	3001.08
	Ratio (%)	15.37	30.12	50.92	3.39	0.20	100.00
2009	Value (¥ 10 <sup>6</sup> /year)	442.35	989.50	1543.09	120.96	2.78	3098.68
	Ratio (%)	14.28	31.93	49.80	3.90	0.09	100.00

Table 5: VC of ecosystem services value in Yanchi County

Year	Cultivated land	Forest land	Grass land	Water area	Unused land
1989	0.19	0.15	0.60	0.05	0.004
1995	0.19	0.16	0.59	0.05	0.004
1999	0.18	0.26	0.52	0.04	0.004
2003	0.17	0.27	0.52	0.04	0.003
2006	0.15	0.30	0.51	0.03	0.002
2009	0.14	0.32	0.50	0.04	0.001

land that affected by both natural and human factors, the ecological construction at the core of control of land desertification resulted in the decreasing phrase.

**Ecosystem services value change:** The ecosystem services value of Yanchi County from 1989 to 2009 has been increasing generally as Table 4 shows, the amplification was obvious especially after 1999. The ecosystem services value increased from 2667.89×10<sup>6</sup> Yuan in 1989 to 3098.68×10<sup>6</sup> Yuan in 2009, the net growth was 430.79×10<sup>6</sup> Yuan, the amplification was 16.15%. The change of ecosystem services value of different ecosystem had obvious difference: the ecosystem services value of forest ecosystem had a significant double growth from 407.75×10<sup>6</sup> Yuan in 1989 to 989.50×10<sup>6</sup> Yuan in 2009. The ecosystem services value of grassland first decreased then increased, the extent was not very large. The ecosystem services value of cultivated land, water body and unused land showed a fluctuation decrease. The change of ecosystem services value from 1989 to 2009 derived from the change of land use in the corresponding period. The area of cultivated land and unused land decreased the area of forest land and construction land increased. Because the increase of construction land would not result the increase of ecosystem services value, so the continuous increase of ecosystem services value in Yanchi County was caused by the increase of forest land.

The grassland's ecosystem services value dominated the composition of ecosystem services value in Yanchi County with the contribution rate of 49.8-60.4%, the cultivated land and forest land came second. The ecosystem services value of cultivated land was higher than forest land in the preliminary stage of study period, that inverted in the later stage of the study period. Though the proportion of ecosystem services

value of water body was less than 5%, it could not be ignored. The ecosystem services value of unused land was the smallest in the research area, less than 1%. The significant increase of ecosystem services value demonstrated the good shift of ecosystem structure and pattern.

**Sensitivity analysis:** The results of CS calculated using Eq. (3) show as Table 5, the CS of forest land increased from 1989 to 2009 while that of cultivated land and grassland decreased, which shows that the impact of VC of forest land to ESV was amplified and the impact of VC of cultivated land and grassland to ESV was reduced. The order of the CS from high to low was grassland, forest land, cultivated land, water area, unused land. The value of grassland's CS was the highest varying from 0.5 to 0.6, which indicates that the change of grassland's VC has a great influence on ESV. The CS of water area and unused land was small varying from 0 to 0.05, which indicates that the change of VC has little impact on ESV. All the results of CS were less than 1 which indicates the total value of ecosystem services is not sensitive to the change of VC, so the values of VC are suitable and the results are credible.

## CONCLUSION

The significant changes of land use were caused by both natural and human factors and the human disturbance was predominant. The implementation of corresponding environment protection and ecological construction projects played a critical role in the change of land use structure.

Land use change is the determining factor of change of ecosystem services value. Positive measures should be taken to protect the forest land and grassland

in the process of economic construction and land development to maintain the function of ecosystem, subsequently realize the sustainable and healthy development of ecosystem.

The method adopted in the study is easy and intuitive, but also has some limitations. Every land use type adopted the same VC, which is not realistic. For every land use type consists of several ecosystem types, the main species composition of each ecosystem are different, so the ESV of the same land use type is not homogenous. The evaluation results would be closer to the real value if more accurate VC given to the more detailed land use types.

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