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IMPACTS OF LAND COVER CHANGE AND SOCIOECONOMIC DEVELOPMENT ON ECOSYSTEM SERVICE VALUES

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Abstract

Social and economic development can cause land cover changes that significantly affect ecosystem services and functions. This study investigated the temporal variation in ecosystem service values in response to land cover changes caused mainly by human activities in Harbin City, one of the fastest growing metropolitan areas in northeast China. The aim was to provide guidance for regional sustainable development. An evaluation method for ecosystem service values based on land cover change was applied in 1996 and 2008. Sensitivity analysis was used to discuss driving forces triggering the change of land cover and ecosystem service values. The results showed that the total ecosystem service value increased from 20945.53 million $ in 1996 to 21030.83 million $ in 2008, mainly due to the increasing areas of woodland, water body and urban green land. Over 97% of the total value was attributable to woodland, farmland and water body. Hydrological regulation and biodiversity maintenance were the two largest service functions, contributing about 30.62% of the total value. Population growth, urban expansion, and economic development were three major driving forces for the change of land cover and ecosystem service value. The results suggest that future land use planning should emphasis on protecting woodland, water body and urban green land that have the highest ecosystem service values, and continue the policy of ecological protection, to achieve regional sustainable development.

Key words: driving forces, ecosystem service value, land cover, sensitivity analysis

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1. Introduction

Ecosystem services can be defined as the goods and services provided by ecosystem which contribute to human welfare, both directly or indirectly, including material goods such as food, fuel, and fibre, regulation services such as climate and flood regulation, and nonmaterial spiritual or aesthetic benefits (Costanza et al., 1997; Daily, 1997; Millennium Ecosystem Assessment, 2005). The capability of ecosystems to provide services is determined by changes in land cover, socio-economic characteristics, biodiversity, atmospheric composition and climate, and so on (Metzger et al., 2006; Yoshida et al., 2010). As the closest link between human and nature, land cover and cover change significantly affect ecosystem structure and function, which lead to the variation of ecosystem service value (Foley et al., 2005; Fürst et al., 2011, 2012; Glavan et al., 2012; Gren and Isacs, 2009; Hu et al., 2008; Li et al., 2010; Liang, 2013; Koschke et al., 2012; Sutton and Costanza, 2002; Volk et al., 2009). On the other hand, land cover change results from the alteration of the earth's surface by human beings. Human's behaviours play key roles in land

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cover change and furthermore influence the aspects of earth ecosystem function.

Demographic factor, economic factor, sociopolitical factor, technology, and lifestyle can indirectly affect ecosystem services (Millennium Ecosystem Assessment, 2005). Some researchers quantitatively assessed the relationship between ecosystem service and driving factors using the eco-economic harmony index (*EEH*) (Wu et al., 2007), by the coordination degree between environment and economy (*CDEE*) (Su and Zhang, 2009), using the STIRPAT model (Sun et al., 2009), using canonical correspondence analysis (*CCA*) (Zhang et al., 2010), by sensitivity analysis (Yao and Liu, 2010), and with a quantitative analysis of the sensitivity and the correlation (Li et al., 2012).

As the capital of Heilongjiang Province, Harbin City has been one of the fastest growing metropolitan areas with relatively developed economy and large population in northeast China. In recent decades, complex changes in land cover have occurred because of human activities and a policy of converting poor farmland to woodlands and grasslands, which are likely to significantly affect ecosystem services and functions in this area (Cheng et al., 2011). Comprehensive studies on the variation of ecosystem service value in response to land cover change and socioeconomic change are very scarce for Harbin City.

The objectives of this study are the following: (1) to explore the change characteristics of land cover; (2) to estimate changes of ecosystem services value as a result of land cover change; (3) to discuss the major driving forces triggering the change of land cover and ecosystem service value; and (4) to provide guidance and advice to support regional sustainable development policies.

2. Materials and methods

2.1. Study area

Harbin City is located in the south central part of Heilongjiang Province, northeast China, from 44°04′N to 46°40′N and from 125°42′E to 130°10′E, with a total area of 53068 km^2 (Fig. 1).

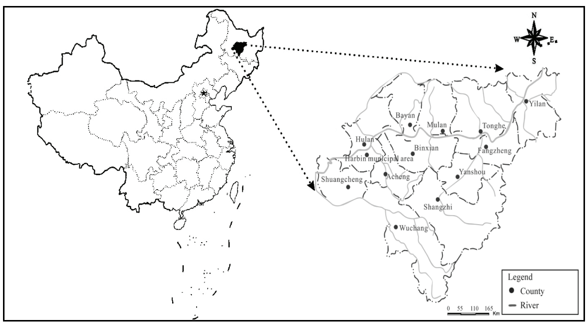

Fig. 1. The study area

The topography is higher in the northeast hills and lower in the southwest plains. The Songhua River runs across the middle of Harbin City from west to east. The climate belongs to the mid temperate continental monsoon climate. The mean annual precipitation is 400-600 mm and 80% of rainfall occurs between May and September. The frost-free period is 110-150 days and accumulated temperature is 2500-3100 °C. The land is fertile for agricultural production, which is one of the major grain production bases in China.

The study area is one of the most densely populated areas in China, with a population of 9.90 million and population density of 186.53 persons/sq. km in 2008. The *GDP* is 41302.34 million $ and per-capita *GDP* 4178$ in 2008. Growing population, increasing economy, rapid urban sprawl and a policy of returning farmland to woodland and grassland have resulted in dramatic land cover changes that are more obvious in Harbin City than in other Chinese cities (Tang, 2012). These combined factors make Harbin City appropriate case study for estimating the change of ecosystem service value.

2.2. Data collection and land cover classification

The land cover data of Harbin City in 1996 and 2008 are from Harbin Municipal Bureau of Land and Resources. These data were extracted mainly by aerial photograph interpretation supplemented by ground survey and former land cover maps. They are reliable and legal data for government planning. The original land cover categories were classified by national standard types.

This study readjusted land cover types according to their ecosystem services function. In construction land, a large proportion of the land used for water conservancy facilities are reservoirs. Considering reservoir can provide the ecosystem function of water supply and regulation, this study merged the land data of water conservancy facilities into that of water body. Moreover, in view of playing an important role in maintaining and improving urban ecological system, urban green land was separated from construction land as an ecological land cover type. As a result, this study reclassified land data in Harbin City into eight categories, including farmland, orchard, woodland, grassland, water body, urban green land, construction land, and unused land (Table 1).

Table 1. Land covers type in Harbin City

Types	*Definition*
Farmland (FL)*	Glebe field, irrigable land, paddy field, and vegetable field
Orchard (OH)	Plantations of fruit, mulberry, tea, and rubber trees
Woodland (WL)	Forest land, shrub land, open woodland and other woodland
Grassland (GL)	Natural grassland and manmade grassland
Water body (WB)	Rivers, lakes, wetland, fishery, and reservoirs

Urban green land (UGL)	Urban parks and green land
Construction land (CL)	Land for residential, commercial, industrial, and transportation use
Unused land (UL)	Land unused or difficult for using

*Notes: * The abbreviations are used hereafter in tables.*

2.3. Model of land covers change

The quantity change of land cover can be represented by the single land cover dynamic index, which denotes the change rate of a certain land cover type for a specific period of time. By analyzing the dynamic of land cover, the extent and rate of land cover change can be compared quantitatively (Wang and Bao, 1999) (Eq. 1):

$$K = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\% \tag{1}$$

where K is the single land cover dynamic index; U_a and U_b are the areas of a certain land cover class at time a and time b respectively; T is the time span from time a to time b.

When T is in a unit of year, then K is the annual rate of change in area for this land cover type. K ranges from -1 to 1. $K < 0$ means that land cover type is in a state of depletion. The larger the absolute value of K, the more intensively land has been depleted. $K \geqq 0$ means just the opposite.

2.4. Assignment of value coefficients

Costanza et al. (1997) classified the global biosphere into sixteen biomes and seventeen ecosystem services and then estimated the global value of ecosystem services, but their results have been questioned by many researchers (Heal, 2000; Serafy, 1998; Wilson and Howarth, 2002) because of the over-estimation on ecosystem service value of wetland and the underestimation on ecosystem service value of farmland, and so on. Moreover, it has been turned out that there are several shortcomings in direct adoption of the Costanza's value coefficients into Chinese ecosystem. For example, some ecosystem services have been insufficiently valuated or even ignored (Xie et al., 2008). To fill this gap, Xie et al. (2008) modified the value coeficient of Chinese ecosystem based on Costanza et al. (1997) method. They reclassified Chinese ecosystem into six types of ecosystems and nine types of service functions (Tables 2, 3). Thereinto, climate regulation includes climate regulation and disturbance regulation of Costanza et al. (1997) classification; soil retention includes erosion control and sediment retention, soil formation and nutrient cycling of Costanza et al. (1997) classification; and biodiversity maintenance includes pollination, biological control, refugia and genetic resources of Costanza et al. (1997) classification.

The value of food production of cropland was defined as the equivalent weight factor. Xie et al. (2008) investigated the relative importance of six biomes and nine ecosystem services with respect to the equivalent weight factor from about 500 Chinese ecologists in 2007. Then they established a new value system of unit area of ecosystem services of terrestrial ecosystems in China on the basis of the responses of expert interviews with structured questionnaire in 2007. The results were listed in Table 2. It has been found that the value system based on expert knowledge can reflect the process of production, consumption and value realization of ecosystem services more accurately. Therefore, Xie et al.'s method is considered more feasible and has been widely applied in valuing Chinese ecosystem services (Li et al., 2010; Liu et al., 2012; Wu et al., 2013).

Table 2. Equivalent value per unit area of land ecosystem services in China (Xie et al., 2008)

	Forest	***Grassland***	***Cropland***	***Wetland***	***River/Lake***	***Barren land***
Food production	0.33	0.43	1	0.36	0.53	0.02
Raw materials production	2.98	0.36	0.39	0.24	0.35	0.04
Gas regulation	4.32	1.5	0.72	2.41	0.51	0.06
Climate regulation	4.07	1.56	0.97	13.55	2.06	0.13
Hydrological regulation	4.09	1.52	0.77	13.44	18.77	0.07
Waste treatment	1.72	1.32	1.39	14.4	14.85	0.26
Recreation and culture	2.08	0.87	0.17	4.69	4.44	0.24
Soil conservation	4.02	2.24	1.47	1.99	0.41	0.17
Biodiversity maintenance	4.51	1.87	1.02	3.69	3.43	0.4
Total	28.12	11.67	7.9	54.77	45.35	1.39

Table 3. Classification of ecosystem services (Xie et al., 2010)

	Definition
Food production	Edible plant and animal goods transformed from solar energy
Raw materials production	Raw materials derived from solar energy that can be used as construction materials or alike
Gas regulation	Maintenance of atmospheric chemical composition balance, absorbing SO_2, fluoride and N_xO_y
Climate regulation	Regulation of regional climate, i.e., increase precipitation and decrease temperature
Hydrological regulation	Fresh water filtration, retention, storage and supply
Waste treatment	Removal or breakdown of excess of nutrients and compounds, dust agglutination

Recreation and culture	Potentials in Providing recreational, cultural and artistic values
Soil conservation	Accumulation of organic materials, function of root and biological materials in soil retention, nutrient cycling and accumulation
Biodiversity maintenance	Sources of genes for wild animals and plants, habitats for wild animals and plants

The equivalent value per unit area of ecosystem services listed in Table 2 can be applied to different regions across China by localizing the average natural food production (Xie et al., 2008). The equivalent weight factor is equal to the economic value of average natural food yield of cropland per hectare per year (Li et al., 2010). The natural food yield is used to be presumed as 1/7 of the actual food yield in common calculation (Li et al., 2010; Xiao et al., 2003; Xie et al., 2008). From 1996 to 2008, the average actual food production from Harbin City farmland was 6339 kg/ha; the average purchasing price for unprocessed food grain was 0.24 \$/kg. Therefore, the ecosystem service value of one equivalent weight factor for Harbin was 217.89 \$/ha (6339×0.24/7).

The ecosystem service values per unit area for each land cover category in Harbin City per unit area was then assigned, based on the nearest equivalent ecosystems suggested by Xie et al.'s table (2008). For example, farmland equates to cropland; woodland equates to forest; orchard equals the average value of forest and grassland combined; water body equates to river/lake; unused land equates to barren land; and construction land is zero. In addition, urban green land is made up of trees, lawns and waters. With reference to the research of the structure of urban green land, this study assumed that the ration of trees, lawns and waters was 5:4:1 (Cheng et al., 2011); then equivalent value per unit area of ecosystem services of urban green land was adjusted by Eq. 2:

$$VC_{UGL} = VC_{WL} \times 0.5 + VC_{GL} \times 0.4 + VC_{WB} \times 0.1 \quad (2)$$

where VC_{UGL}, VC_{WL}, VC_{GL}, and VC_{WB} are the value coefficients for urban green land, woodland, grassland, and water body, respectively.

In addition, urban green land mainly provides recreational places for city residents, and not raw materials and food. Therefore, this paper let the service value per unit area for recreation and culture of urban green land equal that of water body, and let the service values per unit area for food production and raw material production equal those of barren land (Cheng et al., 2011). The adjusted ecosystem service value of unit area of different land cover type in Harbin City was shown in Table 4. This study assumed that ecosystem service value of unit area of different land cover type was consistent in different years.

2.5. Calculation of ecosystem service value

After the ecosystem service value of per unit area for each land cover category has been extracted, the following equations were used to determine the ecosystem service value for each land cover category, each service function, and the total ecosystem service value (Eqs. 3-5):

$$ESV_i = \sum_{j=1}^{m} VC_{ij} \times A_i \quad (3)$$

$$ESV_j = \sum_{i=1}^{n} VC_{ij} \times A_i \quad (4)$$

$$ESV = \sum_{i=1}^{n} \sum_{j=1}^{m} VC_{ij} \times A_i \quad (5)$$

where ESV_i, ESV_j and ESV refer to the ecosystem service value of land cover category "*i*", value of ecosystem service function type "*j*", and the total ecosystem service value, A_i is the area (ha) for land cover category "*i*", respectively. VC_{ij} (\$/ha) is the value coefficient for land cover category "*i*", ecosystem service function type "*j*", *i*=1,2,…,n, *j*=1,2,…,m.

2.6. Method of sensitivity analysis

Sensitivity analysis was introduced to reflect the dependence of ecosystem service value on human factors. The coefficient of sensitivity (CS) is calculated by the standard economic concept of elasticity as follows (Kreuter et al., 2001; Yao and Liu, 2010; Woinaroschy and Radu, 2014):

$$CS = \left| \frac{(ESV_b - ESV_a)/ESV_a}{(IF_b - IF_a)/IF_a} \right| \quad (6)$$

Table 4. Ecosystem service value of unit area of different land cover type in Harbin City (\$/ha)

	FL	*OH*	*WL*	*GL*	*WB*	*UGL*	*UL*	*CL*
Food production	217.89	82.80	71.90	93.69	115.48	4.36	4.36	0
Raw materials production	84.98	363.88	649.31	78.44	76.26	8.72	8.72	0
Gas regulation	156.88	634.06	941.28	326.84	111.12	612.49	13.07	0
Climate regulation	211.35	613.36	886.81	339.91	448.85	624.25	28.33	0
Hydrological regulation	167.78	611.18	891.17	331.19	4089.80	987.04	15.25	0
Waste treatment	302.87	331.19	374.77	287.61	3235.67	626.00	56.65	0
Recreation and culture	37.04	321.39	453.21	189.56	967.43	967.43	52.29	0
Soil conservation	320.30	682.00	875.92	488.07	89.33	642.12	37.04	0

Biodiversity maintenance	222.25	695.07	982.68	407.45	747.36	729.06	87.16	0
Total	1721.33	4334.92	6127.07	2542.78	9881.31	5068.78	302.87	0

Notes: FL-Farmland, OH-Orchard, WL-Woodland, GL-Grassland, WB-Water body, UGL-urban green land, UL-Unused land, CL-Construction land.

where ESV_a and ESV_b are the ecosystem service value at time a and time b, respectively; IF_a and IF_b are the impacting factors at time a and time b, respectively. If CS is less than one, the estimated ecosystem service value is inelastic with respect to that impacting factor, but if CS is greater than one, the estimated ecosystem service value is considered to be elastic.

3. Results and discussion

3.1. Dynamic change of land cover

Table 5 summarizes the land cover changes in Harbin City during 1996-2008. Woodland comprises the largest portion of the total area, 2,619,277 ha in 1996, and 2,632,093 ha in 2008, over 49% of the total area. During the study period, the decrease in area was greatest for farmland, followed by unused land. The largest increase in area was for woodland, followed by construction land.

The single land cover dynamic index (K) was greatest for urban green land, followed by construction land; on the contrary, K was smallest for grassland. Overall, woodland and farmland were the primary land cover types in both 1996 and 2008, contributing to over 83% of the total land cover area in Harbin City. From 1996 to 2008, orchard, woodland, water body, urban green land and construction land tended to increase in area while farmland, grassland and unused land tended to decrease.

3.2. Change of ecosystem service value

The ecosystem service values for each land cover category and the total value for each study year (1996 and 2008) were calculated using the value coefficients (Table 4) and the area of each land cover type (Table 5). The results are shown in Table 6.

As shown in Table 6, the ecosystem service value of woodland was the highest among the seven land cover categories in Harbin City, about 76% of the total service value. Because of the large area, the ecosystem service value of farmland accounted for over 14% of the total service value. Although the area of water body was only about 2% of the total area, it had the highest value coefficient and generated enormous ecosystem service value, which was over 6% of the total ecosystem service value. The aggregated ecosystem service value of woodland, farmland and water body was over 98% of the total service value, indicating that these land cover categories play important roles in ecosystem services and should be paid close attention in ecological protection and construction.

The total ecosystem service value in Harbin City was about 20945.53 million \$ in 1996 and 21030.83 million \$ in 2008 (Table 6). From 1996 to 2008, the ecosystem service value of orchard, woodland, water body and urban green land increased by 0.60 million \$, 78.52 million \$, 18.58 million \$ and 32.59 million \$, with an increasing rate of 1.18%, 0.49%, 1.35% and 173.74%, respectively. While the ecosystem service value of farmland, grassland and unused land decreased by 34.96 million \$, 8.47 million \$ and 1.56 million \$, with a decreasing rate of 1.12%, 4.24% and 1.22%, respectively.

As a result, the net increase in the total ecosystem service value was 85.30 million \$, with an increasing rate of 0.41% from 1996 to 2008.

The ecosystem service values of individual ecosystem functions were also calculated in Table 7. The contribution of each ecosystem function to the total ecosystem service value was greatest for hydrological regulation, followed by biodiversity maintenance, contributing about 30.62% of the total value, which likely resulted from the high ability of water body, and high-cover woodland in Harbin City to supply water and provide habitat for wild animals and plants. From 1996 to 2008, the ecosystem service value of food production was decreased while those of other ecosystem functions were increased, especially for hydrological regulation.

Considering farmland mainly provide ecosystem function of food production, water body mainly provide ecosystem function of fresh water filtration, storage and supply, the results coincided with the land cover changes in decreased farmland and increased water body. In general, the changes in the share of each ecosystem function to the total ecosystem service value were small in 1996 and 2008.

Table 5. Quantity changes of land cover in Harbin City in 1996 and 2008

Land cover type	***1996***		***2008***		***Change (1996-2008)***	
	Area(ha)	***%***	***Area(ha)***	***%***	***Area (ha)***	***K (%)***
Farmland	1,812,832	34.16	1,792,520	33.78	-20,312	-0.09
Orchard	11,804	0.22	11,943	0.23	139	0.10
Woodland	2,619,277	49.36	2,632,093	49.60	12,816	0.04
Grassland	78,637	1.48	75,306	1.42	-3,331	-0.35
Water body	139,518	2.63	141,398	2.66	1,880	0.11
Urban green land	3,701	0.07	10,131	0.19	6,430	14.48

Construction land	218,219	4.11	225,761	4.25	7,542	0.29
Unused land	422,808	7.97	417,644	7.87	-5,164	-0.10
Total	5,306,796	100	5,306,796	100		

Table 6. Total ecosystem service values for each land cover types in Harbin City in 1996 and 2008

	1996		*2008*		*Change (1996-2008)*	
	ESV($10^6$$)	*%*	***ESV($10^6$$)***	*%*	***ESV($10^6$$)***	*%*
Farmland	3120.48	14.90	3085.52	14.67	-34.96	-1.12
Orchard	51.17	0.24	51.77	0.25	0.60	1.18
Woodland	16048.49	76.62	16127.01	76.68	78.52	0.49
Grassland	199.96	0.95	191.49	0.91	-8.47	-4.24
Water body	1378.62	6.58	1397.20	6.64	18.58	1.35
Urban green land	18.76	0.09	51.35	0.24	32.59	173.74
Unused land	128.05	0.61	126.49	0.60	-1.56	-1.22
Construction land	0	0	0	0	0	0
Total	20945.53	100	21030.83	100	85.30	0.41

Table 7. Values of ecosystem service functions for Harbin City in 1996 and 2008

	1996		*2008*		*Change (1996-2008)*	
	ESV($10^6$$)	*%*	***ESV($10^6$$)***	*%*	***ESV($10^6$$)***	*%*
Food production	609.65	2.91	606.07	2.88	-3.58	-0.59
Raw materials production	1879.60	8.97	1886.14	8.97	6.54	0.35
Gas regulation	2806.37	13.40	2818.32	13.40	11.96	0.43
Climate regulation	2816.83	13.45	2827.57	13.44	10.74	0.38
Hydrological regulation	3252.33	15.53	3273.28	15.56	20.95	0.64
Waste treatment	2034.91	9.72	2042.46	9.71	7.55	0.37
Recreation and culture	1433.60	6.84	1445.84	6.87	12.24	0.85
Soil conservation	2951.85	14.09	2959.15	14.07	7.29	0.25
Biodiversity maintenance	3160.88	15.09	3173.35	15.09	12.46	0.39
Total	20945.53	100	21030.83	100	85.30	0.41

3.3. Driving factors of change in ecosystem service value

To explore the socio-economic driving factors of change of ecosystem service value, this study selected three variables as proxies for the explanatory factors because detailed information for all factors could not be found. For example, "population" could be the representative of the "the utilization degree of resources and environment", "urbanization" could be the representative of the "urban expansion", "the gross domestic production (*GDP*)" could be the representative of "human economic activities" (Yao and Liu, 2010). According to *Harbin Statistics Yearbook,* the values of population, urbanization, and *GDP* were 9.46 million, 44.32%, and 9754.48 million $ in 1996, and 9.90 million, 48.18%, and 41302.34 million $ in 2008, respectively. Therefore, the coefficients of sensitivity (*CS*) of total ecosystem service value to population (CS_p), urbanization (CS_u) and *GDP* (CS_e) during the period 1996-2008 were calculated by Eq. (6) (Table 8).

As shown in Table 8, CS_p, CS_u and CS_e for the total ecosystem service value were 0.088, 0.047 and 0.001, respectively, which indicated that the total ecosystem service value had the most sensitivity to population, and followed by urbanization and *GDP*. Similarly, the most sensitive factors with *CS* for each land cover type were population, urbanization and *GDP* in sequence. This implied that the influence on the ecosystem service value for 1% increase in population was greater than those of for 1% increase in urbanization and 1% increase in *GDP*. In other words, the influence of population growth on the ecological environment is much greater than the urban sprawl and economic development. In addition, *CS* for urban green land to population and urbanization were more than one (37.679 and 19.948, respectively), indicating that the ecosystem service value of urban green land was elastic with respect to changes in population and urbanization. As one of ecological land types, urban green land has close relations with urban residents' living and urban environment. The higher of CS_p and CS_u for urban green land, the more sensitive was urban green land to population and urbanization, which implied that urban human settlements environment is paid more and more attention in the course of city construction.

3.4. Discussions

The method used to estimate ecosystem service value was proposed by Costanza et al. (1997), and modified by Xie et al. (2008) to account for Chinese conditions, deriving ecosystem service value from multiplying the area of a given land cover category by the corresponding ecosystem value coefficient. However, as discussed in some literatures (Costanza et al., 1997; Hein et al., 2006; Konarska et al., 2002; Limburg et al., 2002; Turner et al., 2003), the ecosystem service value calculated by this method have high uncertainly due to the complex and nonlinear properties of ecosystems, and problems including double counting and scales and limitations of the economic valuation of land cover types. Land cover type can be used as a proxy measure of ecosystem services by matching the land cover types to equivalent biomes. However, the biomes used as proxies are not always perfect matches in every case (Kreuter et al., 2001).

Table 8. The *CS* of ecosystem services value to population, urbanization and *GDP* in Harbin City from 1996 to 2008

	FL	*OH*	*WL*	*GL*	*WB*	*UGL*	*UL*	*CL*	*Total*
CS_p	0.243	0.255	0.106	0.919	0.292	37.679	0.265	0	0.088
CS_u	0.129	0.135	0.056	0.486	0.155	19.948	0.140	0	0.047
CS_e	0.003	0.004	0.002	0.013	0.004	0.537	0.004	0	0.001

Note: CS_p=CS of ecosystem service value to population; CS_u =CS of ecosystem service value to urbanization; CS_e =CS of ecosystem service value to GDP; FL-Farmland, OH-Orchard, WL-Woodland, GL-Grassland, WB-Water body, UGL-urban green land, UL-Unused land, CL-Construction land

In addition, the accuracy of the modified value coefficients (Table 2) is doubtful because of ecosystem complexity. The estimation of ecosystem service value based on land cover data has been used widely in other case studies (Li et al., 2010; Liu et al., 2012; Yoshida et al., 2010). In some studies, other methods were used to calculate ecosystem service value (Koschke et al., 2012; Wu et al., 2013). Although different calculation methods may get different estimation result, leading to criticism and doubt on ecosystem service valuation, it is important to realize that the change rate of ecosystem service for time series analysis can overcome the influence on ecosystem service valuation caused by different calculating coefficients, and also can objectively reflect the change of ecosystem service value at specific points in time (Li et al., 2010).

This study primarily focused on changes in ecosystem service value over time, the results are credible, particularly in qualitative terms. By calculating the ecosystem services value in 1996 and 2008, and analyzing the changes during this time period, uncertainties and errors could thus be reduced or eliminated.

From 1996 to 2008, the total ecosystem service value increased by 85.30 million $ in Harbin City, mainly caused by the increase in value of woodland, water body and urban green land, which offset the loss of the decrease in value of other land cover types. As primary land cover type in Harbin City, the area of woodland was enlarged because of the policy of converting land to forestry since 2002, causing the increase in the ecosystem service value of woodland. The ecosystem service value of water body was increasing due to the improving of the water environment, especially the protection and rehabilitation of wetland in Harbin City.

The change rate of service value for urban green land was significantly higher than that of other land cover types. Because the statistical range of urban green land was from urban area, the area of urban green land was increased with the continuous expansion of Harbin City district area from 179.47 sq. km in 1996 to 340.33 sq. km in 2008. The effect of urban green land on the total ecosystem service value was expanding. Meanwhile, the ecosystem service values of farmland, grassland and unused land were decreased. From the single land cover dynamic index (*K*) point of view, because of the smaller proportion of grassland and unused land, the change degree of farmland is far greater than that of grassland and unused land when *K* is same.

Therefore, farmland was main reduced land resources in Harbin City, caused by the occupation of construction land, returning poor farmland to woodland, and some farmland fallen into disuse resulting from large agricultural population flocked to the cities in the process of rapid urbanization.

In the past decades, great changes in society and economy have taken place in Harbin City. However, the social and economic development is often in conflict with nature conservation. Population growth, rapid urbanization, and economic development were three major driving forces contributing to the change of land cover and ecosystem service value in Harbin City over the period from 1996 to 2008. Population growth has long been considered a major factor leading to land cover change. From 1996 to 2008, the total population increased from 9.46 million to 9.90 million.

The increase in population has led to increasing pressure on housing, traffic, town construction, and so on. It was evident that the growth of population was the most direct and basic driving force for the change in areas and service values of various ecosystems. Due to urban economic development and population concentration, construction land increased progressively with the annual rate of 0.29% from 1996 to 2008 in Harbin City, which is in accordance with increasing urbanization level from 44.32% in 1996 to 48.18% in 2008. The rapid urbanization has triggered a large amount of agricultural land to be converted into market-oriented land covered for residential areas and industrial estates in Harbin City. From 9754.48 million $ in 1996 to 41302.34 million $ in 2008, Harbin's *GDP* increased by 323.42% (base on constant currency), while the total ecosystem service value only increased by 0.25%.

It was still worth attention because the total ecosystem service value per *GDP* decreased by about 76.32% (=[2.15-0.51]/2.15) during 1996-2008. If this situation exists for a long time, it will inevitably hamper the sustainable development of regional economy. Therefore, regional planners should focus more on sustainable development and ecological protection in Harbin City, so as to maintain a balance between ecosystem health and economic development in the future.

4. Conclusions

By analyzing and discussing the changes in ecosystem service value based on land use type in Harbin City from 1996 and 2008, this study reached three primary conclusions. First, the total ecosystem service value in Harbin City was about 20945.53 million $ in 1996 and 21030.83 million $ in 2008. Woodland produced the largest proportion of the total ecosystem service value (about 76%), and combined woodland, farmland and water body accounted for over 97% of the total ecosystem service value. Second, hydrological regulation and biodiversity maintenance were the main ecological functions, accounting for about 30.62% of the total. Three, population growth, rapid urbanization and economic development play important roles in regulating the change of land cover and ecosystem service value.

Therefore, the policy of slow-down population growth, enhancement of population quality, and equitable distribution of population should be incorporated into the development strategy of "Twelfth-Five-Year Plan" in Harbin City so that a coordinated development of ecological environment and population can be reached. In addition, it is suggested that a reasonable land use plan must control construction land (e.g. for residential, commercial, or industrial use), and emphasize the protection of woodland, water body and urban green land, which have highest ecosystem service value. Furthermore, land consolidation and rehabilitation should be encouraged to realize the dynamic equilibrium of total farmland.

Moreover, Harbin City should insist on the policy of converting poor farmland to woodland and grassland in order to further improve forest coverage. Land cover type can be used as a proxy measure of ecosystem services by matching the land cover types to equivalent biomes, and then ecosystem service valuation can then be easily and conducted based on land cover data. The accuracy and reliability of the estimated results are mainly determined by the accuracy of value coefficients. Therefore, it is necessary to extract more accurate value coefficients in future research.

On the other hand, the change rate of ecosystem service for time series analysis can overcome the influence on ecosystem service valuation caused by different calculating coefficients. In other words, uncertainties and errors could be reduced or eliminated by calculating the ecosystem service value for time series and analyzing the changes over time. In addition, limited by a lack of the data of land cover of various counties in Harbin City, the spatial distribution of ecosystem service value hasn't presented. It is necessary to extract more detailed the data of land cover of Harbin City in future research.

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