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ORIGINAL RESEARCH PAPER

Effects of the land use change on ecosystem service value

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ABSTRACT: The impacts of land utilization change on the ecosystem service values in Daqing during 1995 to 2015 were analyzed based on unit area ecosystem service value of Chinese territorial ecosystem from Mr. Xie Gaodi and ecosystem service value calculation formula from Costanza. Results showed that the ecosystem service value of Daqing decreased from US $4343.1559m in 1995 to US $3824.327m in 2015, with the ecological value of US $518.8289 m decreased during the past 20 years. Wetland and water body were the two main land utilization types with the greatest contributions to the ecosystem service value. Ecosystem services value of per capita decreased 23.52%. The sensitivity coefficient of eco-service values of all types of land utilization to their value coefficients were all less than 1 in Daqing area. The sensitivity coefficients followed that wetland > water body > woodland > unutilized land > pasture land> cultivated land in 2015, which indicating that the changes of the land utilization are lack of flexibility to the changes of the ecosystem service value.

KEYWORDS: *Ecosystem service value (ESV); Land utilization; Northeast China area; Sensitivity index; Urbanization.*

INTRODUCTION

The ecosystem service function means the natural environment conditions and their effectiveness for maintaining the existence of the human being, which is formed by the ecosystem and ecological processes (Daily, 1997). According to their functions and utilization situations, the ecological service function values can be divided into four categories: direct utilization value, indirect utilization value, selection value and existence value (Bi and Ge, 2004). The analysis and evaluation of the ecosystem service function value are the hot research points in the field of ecology and ecological economy. Land is the carrier of various terrestrial ecosystems. The utilization of land is an indispensable activity for the existence and development of the human beings. The variation of the land utilization and the resulting changes in the land coverage patterns not only change the structure of the ecosystem, make biodiversity loss and decrease the productivity of the ecosystem but also lead to the changes of the function of the ecosystem. So, the land utilization change plays a decisive role (Daily, 1997; Costanza *et al*., 1997; Ge *et al*., 2000; Long *et al*., 2014; Song *et al*., 2015) in maintaining the service function of the ecosystem. There is very close relationship between the types of ecosystem and types of land utilization. So, the study of the impact the land utilization change to the regional ecosystem service value (ESV) has very important significance. The research of evaluation of the changes of the ecosystem service value according to the changes of the land utilization is developed extensively in recent years (Li *et al*., 2007; Cai *et al*., 2006; Min *et al*.,

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2006; Xiao *et al*., 2003; Muellera *et al*.,2016;Song *et al.,*2015; Yirsaw *et al*., 2016; Valdez *et al*., 2016; Feng *et al*., 2014; Lopes *et al*., 2015; Vejre *et al*.,2010; Costanza *et al*.2014). Based on the changes of the land utilization in Daqing during the years of 1995 to 2015, the author evaluated the evolutionary law of the ecosystem service value brought by the changes of the land utilization (Wang *et al*., 2006; Yu *et al*., 2011; Valdez *et al*., 2013; Zhang *et al*., 2012; Zhang *et al*., 2015; Lautenbach *et al*., 2011).The purposes of this research are to provide the scientific basis for the sustainable utilization of the land resources, for the eco-environmental protection, for the maintenance of the ecological balance and for the promotion of coordinated development of the regional resources and environment in Daqing area in 1995-2015.

MATERIALS AND METHODS

Study area

Daqing is located in the middle of the Songnen plain. Its latitude is from 45°46′ to 46°55′ N, its longitude is from 124°19′ to 125°12′ E (Fig.1). It is 150 km in its southeast direction away from Harbin City, which is the capital of Heilongjiang Province, and is 139 km in its northwest direction away from QiQihar. The territory of the city is flat. Its average elevation is 146 meters. Through Binzhou rail road, it can reach to Mongolia and Russia. Through the golden waterway of Songhua River, it can reach to Russia directly. The territorial and geographical advantages are very obvious. Daqing is the transfer station of the Eurasian continental bridge also is the transfer hub of Heilongjiang, Jilin and Inner

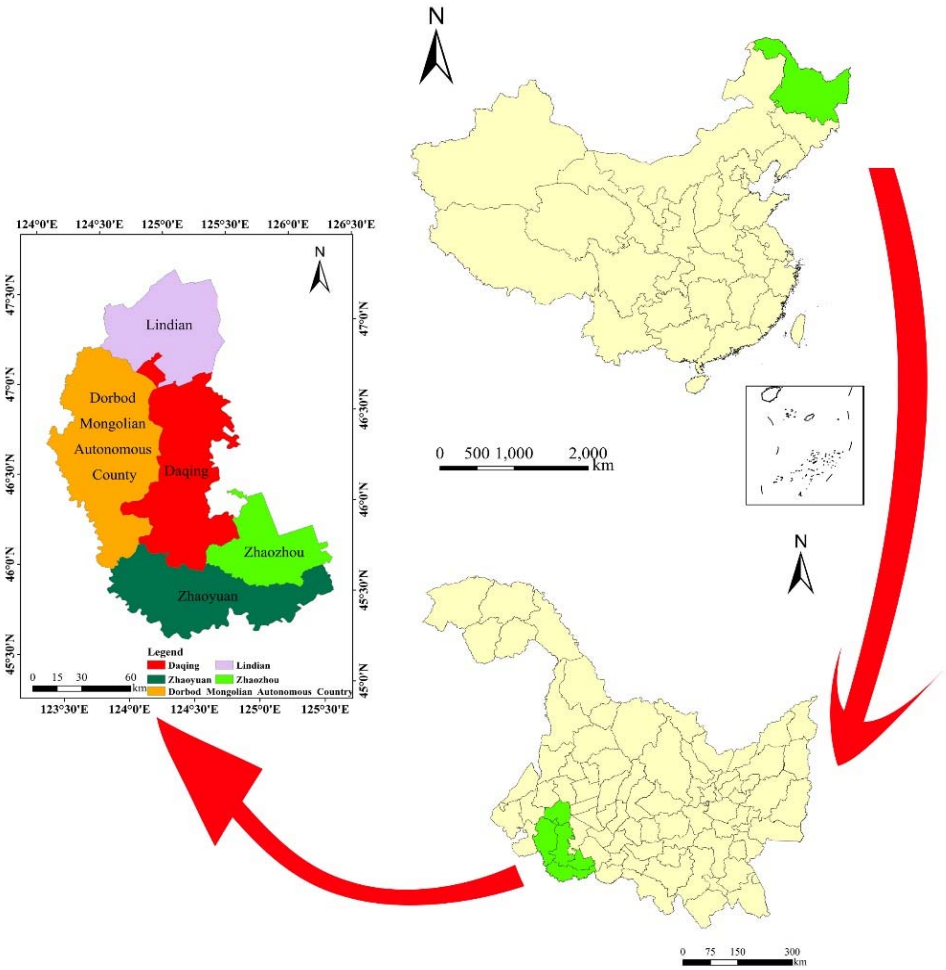

Fig. 1: The study area of Daqing in the Heilongjiang Province, northeast of China

Mongolia provinces. Daqing has jurisdiction over Saertu, Honggang, Ranghulu, Longfeng, Datong five districts and Zhao Zhou, Zhaoyuan and Lindian three counties, and Duerbote Mongolian Autonomous County. The sunshine is sufficient in Daqing area, but the rainfall is relatively less. The time of winter is longer and the weather is cold. May, in the summer and autumn time, it is cool and refreshing. Annual precipitation is between 400 mm and 550 mm, and the precipitation in the growing season is between 350 mm and 480 mm, accounting for more than 85% of the annual precipitation. Daqing has the largest onshore oilfield in China and is the important petrochemical industrial base. In fifty years, Daqing has contributed accumulatively 2 billion tons crude oil to our country, paid 1700 billion RMB tax to the government, created US $50 b of the exportation profit (Zang *et al*. 2011). The dynamic agriculture and animal husbandry and the local economy which is led by the key high tech enterprises are developing flourishingly. In the municipal comprehensive strength comparison appraising activities made by National Statistics Bureau, Daqing is ranked as No. 19 (Zang *et al*. 2011).

Data

Major dataset used in this research includes remote sensing imagery and socio-economic information. Landsat Thematic Mapper (TM) data acquired in 1995 and 2015 were utilized to derive land utilization maps for the two years (Figs. 2 and 3). The resources of the data in this research mainly came from *Daqing Statistical Yearbook*, *China Statistical Yearbook*. The selected research area is separated according to the real situation, including mainly; 1) cultivated land, refers to the land where the crops are planted, including the newly reclaimed wasteland, fallow land,

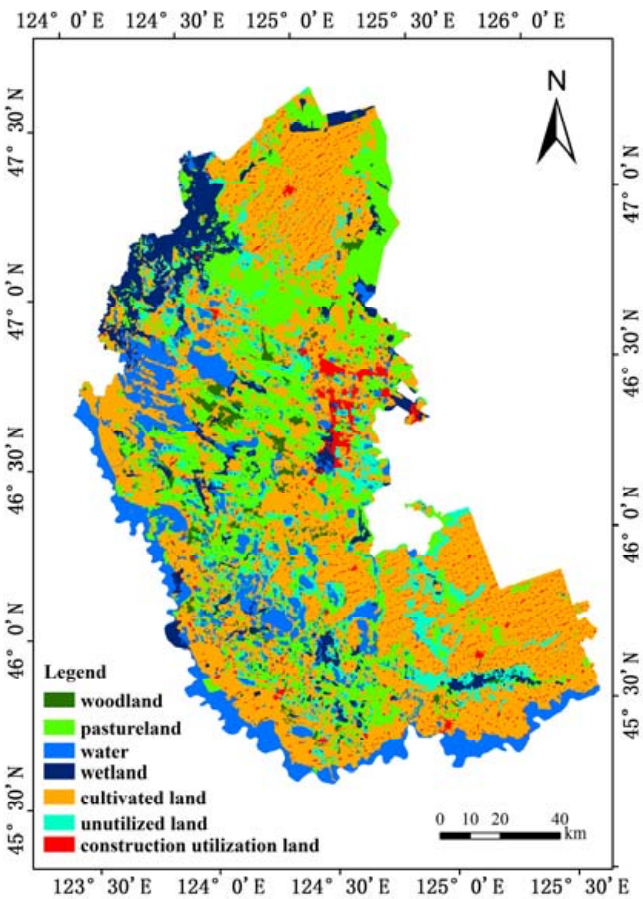

Fig. 2: Land utilization classification map for Daqing in 1995

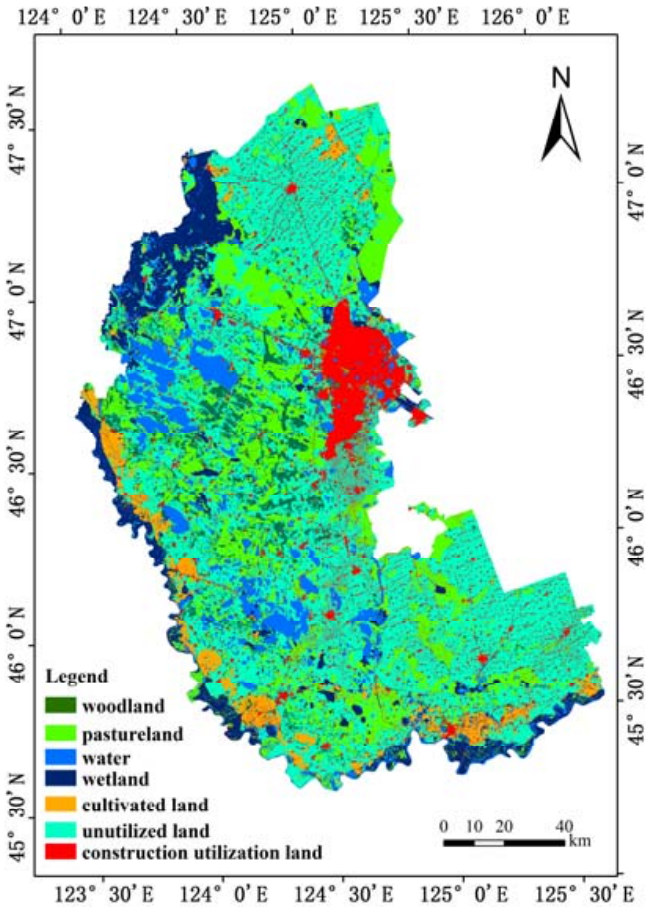

Fig. 3: Land utilization classification map for Daqing in 2015

grass and crops rotation land and cultivated fruit and forest land where the agricultural fruits and other kinds of crops are planted; 2) woodland, refers to the forest land where the shrubs, arbors and bamboo etc. are grown; 3) pastureland, refers to the land where herbaceous plants are mainly grown, including shrub grass land which mainly for the husbandry, and veld (open woodland) with the canopy density below 10%; 4) wetland, refers to low-lying, flat land, where is moist and wet in long term, the drainage is poor and the wetland plants are grown on the surface of the soil; 5) construction utilization land, refers to urban and rural residential settlement and industry, mining and transportation utilization land; 6) unutilized land, refers to the land which is unused at present time or the land which is difficult to be utilized, in Daqing area, it is mainly shown as bare land; 7) water body, refers to rivers, lakes, reservoirs and pond.

Quantitative analysis of land use change

Land use changes were assessed by comparing the areas occupied by each land use type in each period. For each study period, the total area lost or gained by each land use type was calculated. In this study, two indices, the land use dynamic index (Hao *et al*., 2012) and land use dynamic degree (Liu *et al*., 2010; Wang *et al*., 1999) were employed to analysis of land use changes in the area of Daqing. These indices can be assessed as Eq. 1.

$$K = \frac{S_b - S_a}{S_a} \times \frac{1}{T} \quad (1)$$

Where K is the land use dynamic index of a certain land use type, S is the area for a certain land use type, "a" and "b" are the initial and final areas, respectively, and "T" is the study period. If "T" is 1 year, then K is the annual rate of change of a certain land use type.

Evaluation methods of the service value of ecosystem

During the calulation of the ecosystem service value of in Daqing area (Sawut *et al*., 2013), considering the real situation of the researched areas, some modifications are made in the reference. The residential settlement, transportation and water conservancy facilities belong to the construction utilization, referred to research results of Costanza (Costanza *et al*., 1997). The parameter of their ecological value is 0; the unutilized land is divided as: the saline-alkali land, marsh, sand, mud flat and reed shallows, wild grass ground, and bare rocks in the land utilization plan. With the reason of short of the statistical data of their real utilization, they are considered together as unutilized land. Their ecological value is the average of the desert and grassland (Xu *et al*., 2008). The calculation formula of the ecosystem service value is as Eq. 2.

$$ESV = \sum_{i=1}^{n} (VC_i \times A_i) \quad (2)$$

Where in Eq. 1, ESV refers to the total value of the ecosystem service function of the research region, VC_i is the unit area ecosystem service value with type i land utilization (US $/ha), using unit area ecosystem service value of Chinese Territorial ecosystem made by (Xie *et al*., 2003)and his partners (Table 1). A_i is the area of type i land utilization in the research region (ha), n refers to the number of the types of the land utilization.

Calculation for the changes of the ecological service value per capita

In order to show out the relationship of ecosystem service value with human beings, it must calculate out the ecological service value per capita. The changes can show the relationship of the ecosystem service function with the population according to the Eq. 3.

$$Ave(ESV) = \frac{ESV}{N} = \sum_{i=1}^{n} \frac{VC_i}{N} \times A_i \quad (3)$$

Where in Eq. 2, *Ave(ESV)* is the amount of ecological service per capita; N is population; the definitions of the other parameters in the formula are the same as those in Eq. 2.

The calculation of the sensitivity index of the ecological value

In this article, the concept of flexibility coefficient which is frequently used in the economy (Kreuter *et al.,* 2001; Mankiw, 1999) is applied to calculate the sensitivity index of the coefficient of value. The purpose is to determine the dependence level of the change of the ecosystem service value with the time upon the coefficient of value, and also to verify the representativeness of the above types of ecosystem to the types of the land coverage and to verify the accuracy of the coefficient of value provided by Costanza too. Flexibility coefficient refers to the ratio of the percentage of the changes of the dependent variables to the percentage of the changes of the independent variables, when CS < 1, it shows that the value of ecosystem is short of flexibility, when CS>1, it shows the value of the ecosystem is flexible. The high value of CS declares the ecosystem service value is flexible compared with the coefficient of value. Further, it also illustrates the significance of the accuracy of the ecosystem value factor to the evaluation of the ecosystem service value. The calculation is based on Eq. 4.

$$CS = \left| \frac{(ESV_j - ESV_i)/ESV_i}{(VC_{jk} - VC_{ik})/VC_{ik}} \right| \quad (4)$$

Where in Eq. 4, j and i represent the value of the

Table 1: Table of Unit area ecological service values of Different Chinese Territorial Ecosystems (US $/ha)

Types of service	Cultivated land	Forest	Grassland	Desert	Unutilized land	Wetland
Air regulation	63.84	446.90	102.15	0.00	51.07	229.83
Climate regulation	113.64	344.75	114.92	0.00	57.46	2183.39
Water conservation	76.61	408.59	102.15	3.82	52.99	1979.10
Soil formation and protection	186.42	497.96	248.99	2.55	125.77	218.34
Waste treatment	209.41	167.27	167.27	1.27	84.27	2321.30
Biodiversity conservation	90.65	416.25	139.18	43.41	91.29	319.22
Food production	127.69	12.77	38.31	1.27	19.79	38.31
Raw materials	12.77	331.98	6.38	0.00	3.19	8.93
Entertainment	1.28	163.43	5.11	1.27	3.19	708.64
Total Value	882.29	2789.90	924.46	53.59	489.03	8007.06

initial situation and the value after the coefficient is modified.

RESULTS AND DISCUSSION

Analysis of the changes of land utilization in Daqing area

According to the need of the research, the land in Daqing area is separated into seven categories, e.g. the cultivated land, woodland, pasture land, residential land and construction land, unutilized land, wetland and water body classified from remote sensing imagery (Table 2).

Data in Table 2 shows that the main type of the land utilization in Daqing in 1995 is cultivated land, followed with pastureland and water body; while, the main type in 2015 is unutilized land, up to 9 thousand square km, following is the pasture land.

Large changes happened with the land utilization during 1995-2015. The overall trend is that the water body, pasture and cultivated land is decreasing, in which the cultivated land reduced the most, up to 8779.85 square km, with the rate of change is -91.32%, and the dynamic degree is -4.57%. The proportion of cultivated land decreased from 45.65% to 3.95%. Water body decreased by 1022.45 square km, with the rate of change is -35.92%, and the dynamic degree is -1.8%. The proportion of cultivated land decreased from 13.51% to 8.64%. Pasture land decreased by 532.34 square km, with the rate of change is -11.88%, and the dynamic degree is -0.59%. The proportion of cultivated land decreased from 21.27% to 18.7%. The unutilized land and woodland increased the most. Unutilized land increased by 7652.08 square km, with the rate of change is 524.67%, and the dynamic degree is 26.23%. Woodland increased by 1261.21 square km, with the rate of change is 342.94%, and the dynamic degree is 17.15%. Meanwhile, Construction utilization land and wetland increased, with the dynamic degrees of 8.37% and 0.72%, respectively. Daqing oil industry rapidly developed during the period of 1995-2015, which resulted in construction utilization land increased rapidly. Especially the implementation of the strategic decision of "Ha-Da-Qi industrial corridor" in 2005, the development of Daqing regional economy and population was promoted, and also the development of the oil industrialization process was derived. The increased of woodland is due to the implementation of returning farmland to forest policy, which promoting the construction of protection forest system in northeast China. The increased of artificial forest prevented the excessive exploitation of oil field caused by soil erosion. At the same time, because the area is closed flow area, poor drainage, unreasonable land exploitation and utilization of land salinization,

Table 2: Changes of the area of each category of the land utilized in Daqing area (Unit: km2 and %)

Land utilization categories	1995		2015	
	Area (km^2)	Proportion (%)	Area (km^2)	Proportion (%)
Cultivated land	9614.34	45.65	834.4947	3.95
Woodland	367.7693	1.75	1628.982	7.71
Pastureland	4480.193	21.27	3947.85	18.70
Construction utilization land	749.1192	3.56	2003.47	9.49
Unutilized land	1458.442	6.93	9110.522	43.14
Wetland	1543.922	7.33	1767.59	8.37
Water body	2846.122	13.51	1823.668	8.64
Total	21059.91	100.00	21116.58	100.00

Table 3: ESVs in 1995 and 2015, and their changes during 1995-2015

Land use type	ESV in 1995 (US $ 10^4)	ESV in 2015 (US $ 10^4)	Values of changes (US $ 10^4)	Ratio of changes (%)	ESV per cap (US $)		Ratio of ESV per cap (%)
					1995	2015	
Cultivated land	84826.70	7362.69	-77464.01	-91.32	354.50	26.73	-92.46
Woodland	10260.38	45446.91	35186.53	342.94	42.88	164.97	284.74
Pasture land	41417.50	36496.21	-4921.29	-11.88	173.09	132.48	-23.46
Unutilized land	7132.15	44552.78	37420.62	524.68	29.81	161.73	442.60
Wetland	123622.77	141532.01	17909.24	14.49	516.64	513.77	-0.56
Water body	167056.09	107042.10	-60013.99	-35.92	698.15	388.57	-44.34
Total	434315.59	382432.70	-51882.89	-11.95	1815.06	1388.24	-23.52

therefore, unused area of explosion. Wetlands area increased was due to strengthen ecological protection.

The reason of the decreased of cultivated land were various. The speeding up of urbanization and the development of oil industry took up a lot of cultivated land. At the same time, because the land salinization is serious in Daqing area. Oilfield development reduced the number of arable land, is a profound badly effect on cultivated land quality. The pollutant derived from oilfield drilling and oil chemical industry emitted through a variety of ways such as surface runoff, spreading of harmful substances into the soil, cause the pollution of farmland, so that the cultivated land loss of productivity. The development of oil field and animal husbandry leaded to a drop in grassland area.

Analysis of the changes of the ecosystem service value in Daqing area

According to the related data in Tables 1 and 2, and the Eq. (2), it is calculated the overall value of the ecosystem service in Daqing area (Table 3). The results showed that the main types of land utilization by which the ecosystem service value in Daqing were wetland and water body, with the proportion of more than 60%. For the wetland, its ecological service value accounting for 37.01% of the total value in 2015, which related to the high ecological service value per unit area in wetland (Zorrilla-Miras *et al*., 2014). For the water body, its ecological service value accounting for 27.99% of the total value in 2015. The overall ecosystem value in the research area was decreased in 21 years with the change rate is 11.95%. The overall change of the ecological value is very large. The cultivated land reduced the most, and the loss value of ecosystems was 91.32%; while, the unutilized land increased the most. Thus, the main reason for reducing the number of Daqing city ecosystem services value is caused by a big drop in cultivated land. The period of study, six types of land use types of ecological service value and its change trend of area is consistent.

Compared with the overall eco-service value, the eco-service values per capita show different change situation. It is mainly manifested as: the value per capita of unutilized land and woodland increased the most. Although wetlands ecological value has increased, but due to that it was lower than the rate of population growth, so its per capita ecological value showed a trend of decline. Cultivated land, water, and the change of per capita value of grassland and the trend are consistent with the overall value changes (Li *et al*., 2014).

Analysis of the sensitivity

According to the coefficient of sensitivity calculation Eq. 4 and for the purpose to be convenient during calculation, the author adjust the ecosystem service value coefficient (VC) up and down 50% separately in order to analyze the significance of the change of certain type of land utilization in Daqing area to the change of the ecosystem service value (Table 4). The results show that the sensitivity coefficient of eco-service values of all types of land utilization to their value coefficients are all less than 1 in Daqing area. The highest CS value is 0.285-0.370, which means when the eco-service value coefficient increases 1%, the total eco-service value will increase 0.285 to 0.370 percentages. It shows concretely as: wetland > water body > woodland > unutilized land > pasture land> cultivated land. It indicates that the ESV in the research region is short of flexibility to VC and the research result is reliable. Except that

Table 4: Sensitivity of the ecosystem service value

Type of the land utilization	Ecosystem service value (ESV) (US 10^4)		Coefficient of sensitivity (CS)	
	1995	2015	1995	2015
Cultivated land VC+50%	476728.94	386114.04	0.195	0.019
Cultivated land VC-50%	391902.24	378751.35		
Woodland VC+50%	439445.78	405156.15	0.024	0.119
Woodland VC-50%	429185.40	359709.24		
Pasture land VC+50%	455024.34	400680.80	0.095	0.095
Pasture land VC-50%	413606.84	364184.59		
Unutilized land VC+50%	437881.67	404709.09	0.016	0.116
Unutilized land VC-50%	430749.52	360156.31		
Wetland VC+50%	496126.98	453198.70	0.285	0.370
Wetland VC-50%	372504.21	311666.69		
Water body VC+50%	517843.64	435953.75	0.385	0.280
Water body VC-50%	350787.55	328911.65		

SC of wetland, unutilized land and woodland shows an increase result, all the SCs of other types of land utilization are decreased. It indicates that the change of the VC of wetland can have a magnified effect to the total eco-service value, which was agreed with the results of Valdez *et al*. (2016). Its research that wetland is very sensitive to changes in land use, these changes alter the supply of the ecosystem services and quality (Valdez *et al.*, 2014).

CONCLUSION

The changing characteristics of ecosystem service value in Daqing induced from the land utilization change during the 20 years of 1995-2015 were analyzed. Analyses of results suggest several conclusions as below:

(1) The structure of the land utilization in Daqing area had a great change during 1995 to 2015. The unutilized land increased the most, followed by constructional land and woodland, and wetland increased in a small extent. The cultivated land reduced the most, which was indicating an evitable phenomenon that large area of cultivated land will be evaded during the quick process of urbanization (Chen *et al*., 2016).

(2) Wetland and water body were the two main land utilization types with the greatest contributions to the ecosystem service value. The change trend of the ecosystem service value of the land utilization in the selected research area is consistent with that of its main components. In the quick process of the urbanization, the construction land utilization and unutilized land is increasing, while, the cultivated land, water body and pasture land is reducing. Ecosystem service value was decreased by 11.95% during the years of 1995 to 2015.

(3) The sensitivity coefficient of eco-service values of all types of land utilization to their value coefficients were all less than 1 in Daqing area. The sensitivity coefficients followed that wetland > water body > woodland > unutilized land > pasture land> cultivated land in 2015, which indicating that the changes of the land utilization are lack of flexibility to the changes of the ecosystem service value.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

ABBREVIATIONS

CS	Coefficient of Sensitivity
ESV	Ecosystem Service Value
TM	Thematic Mapper
VC	Value Coefficient

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