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Response of ecosystem services to land use and cover change: A case study in Chengdu City

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ABSTRACT

Land use and cover change is an important factor reflecting the resource footprints of the human race. Studies related to land use and cover change with ecosystem services value can provide a good reference for research on human resource footprints. In this study, through the interpretation of remote sensing images of Chengdu from 2000 to 2015, we obtained data on land use and cover change. Based on the analysis of the equivalent factor table for land use and cover change and ecosystem services value, we used the CPI accumulation coefficient and marginal value coefficient to modify the evaluation model of ecosystem services value, thus calculating the value of ecosystem services for Chengdu. The results show that the area under farmland and grassland continued to decrease, while the area covered by forest land, water area, construction land and unused land continued to increase in general. The ecosystem services value of Chengdu increased from 2.86×10^{10} RMB yuan in 2000 to 5.02×10^{10} RMB yuan in 2015, indicating a 75.46% increase. From this study, we determined that the development of Chengdu during 2000–2015 is sustainable, with reasonable land use, and will provide an important reference for economic development and land use policy in Chengdu in the future.

1. Introduction

Land is the basis for human survival, providing resources and foods (Deng et al., 2014). For a long time, land use patterns varied, depending on both land bearing capacity and production capacity. Throughout human history, land use has always been significant, regardless of how advanced the social productivity was (Zhan et al., 2010).

Land use and cover change are important factors reflecting the resource footprints of humans, being a popular topic with widespread public concern. However, with the improvement in the productivity of human society, the use and transformation of land by humans is becoming increasingly frequent, leading to a series of ecological and environmental issues (Zhan et al., 2013). The effective evaluation of land use and cover change has become an urgent issue. Therefore, many methods have been proposed to evaluate land use and cover change, for example, land use dynamic degree (Pontau et al., 2015; Zhen et al., 2007), land use transfer matrix (Konig et al., 2013; Zhen et al., 2014), ecological footprint (Gao and Xu, 2014; Mancini et al., 2016), ecosystem services (Pei et al., 2015; Peng et al., 2016; Xie et al., 2010) and so on. Among them, ecosystem services are commonly used by many researchers, especially in the construction of ecological civilization for China. Some scholars have been undertaking researches related to land use and cover change, as well as ecosystem services (Deng et al., 2013; Song and Deng, 2015). Many methods have been developed to assess the response of ecosystem services to land use and cover change, which can be used on a global (Costanza et al., 1997; Sutton and Costanza, 2002), national (Hausner et al., 2015; Lawler et al., 2014), regional (Brauman et al., 2015; Dupras et al., 2016), and basin scale (Deng et al., 2015; Shi et al., 2015). Based on land use and cover change, Costanza et al. (1997) divided ecosystem services into 17 categories, calculating the value of global ecosystem services function, which was published in Nature. During the course of the study in Amazon rainforest, Portela and Rademacher (2001) suggested a dynamic model, which included the driving force of deforestation, land use and cover change, ecosystem services and ecosystem assessment. This model reflects the different land use patterns that reduce the value of ecosystem services. In the study of ecosystem services and land use vulnerability, Metzger et al. (2006) pointed out that the ability of an ecosystem to provide a series of important services

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for society was influenced by climate change, social and economic characteristics, land use, biodiversity, atmospheric composition. A large number of domestic scholars also used the Chinese terrestrial ecosystem services value equivalent factor table, which was developed by Xie et al. (2003) to study the response of ecosystem services to land use and cover change.

As far as China is concerned, Chengdu plain is an important commodity grain production base, where the contradiction between food security and ecological civilization is particularly prominent (Lu et al., 2011). Studying the response of ecosystem services to land use and cover change in Chengdu has a strong practical significance with regard to ensuring food security while protecting the ecological civilization in China (Peng et al., 2016). Moreover, it can provide a valuable reference for research related to human resource footprints. In this paper, with the interpretation of remote sensing data from 2000 to 2015, Chengdu city is taken as the study area to obtain data on land use and cover change. These data are combined with ecosystem services value equivalent factor table to calculate the ecosystem services value of Chengdu. And we use the CPI accumulation coefficient and the marginal value coefficient to revise and improve the ecosystem services value evaluation model, which considers the actual situation in Chengdu, and compared GDP, urbanization rate, Engel coefficient of Chengdu with the national level in China. We believe that this will make the model more accurate and applicable to Chengdu.

2. Overview of the study area

Chengdu is located between 102°54′E–104°53′E and 30°05′N–31°26′N, in the hinterland of Chengdu plain (Fig. 1). Chengdu is one of the most historically important cities in China. It is the capital city of Sichuan Province, serving as a political, industrial and cultural center on a provincial level, in addition to being a major economic center for southwest China (Qin, 2015). There belongs to the sub-tropical zone, with annual average temperatures of 15–18 °C, annual precipitation of approximately 1000 mm, annual sunshine hour between 1000 and 1600 h, which is the lowest in China (Zheng et al., 2010). Additionally, Chengdu is a significant ecological buffer zone in the upper reaches of the Yangtze River Basin, due to the certain impact on the ecological balance of the Yangtze River Basin (Peng et al., 2016).

Chengdu is a typical mega city in China, with the total land area of 12119 km^2, and the urban land area of it is 862.19 km^2. There are 9 districts, 6 counties and 4 county-level cities in Chengdu (Chen et al., 2016). The population of Chengdu was 12.28 million, with a GDP of 1.22 trillion yuan in 2016, which have soared by nearly 7.7% compared with last year, ranking first in the sub-provincial cities of China. There is a complex topography, diverse natural ecological environment and rich biological and mineral resources in Chengdu. However, the associated rapid increase in resource consumption has caused resource inefficiencies (Zhang et al., 2014). The conflict between economic development and environmental protection in Chengdu has become severe.

3. Data and methodology

3.1. Data preparation

The data regarding land use and cover change are based on the Landsat TM/ETM remote sensing images of Chengdu from 2000, 2005, 2010 and 2015, which were obtained from the website of United States Geological Survey. After pretreatment, the land types of Chengdu were divided into six types, which are farmland, forest land, grassland, water area, construction land and unused land. Farmland includes dry land and paddy fields, while the water area includes rivers, lakes, reservoirs and ponds. Construction land includes residential areas, industrial and mining land, transportation land and land for water conservation facilities.

3.2. The model of ecosystem services value calculation

At present, there are many methods to assess the value of ecosystem services in China and abroad. Ecosystem services were classified into 17 types by Costanza et al. (1997), who set the equivalent factor of services value, drawing a single value equivalent factor. Based on this, he calculated the ecosystem services value of every item using Eq. (1) and obtained the year of global ecosystem services value. Since then, research on global ecosystem services value evaluation has been developing (Brown, 2013). However, the value of equivalent factor put forward by Costanza is based on the global ecosystem, which is not entirely applicable to China (Zhang et al., 2012). Therefore, based on the research by Costanza, the classification method of ecosystem services in China was proposed by Xie et al. (2003). Using the questionnaire scoring method, he analyzed the views of domestic scholars on the ecosystem services in China and formulated the "Chinese land ecosystem services value equivalent factor table". Based on the evaluation method of ecosystem services value of Costanza and in accordance with ecosystem services value equivalent factor table, we used the CPI accumulation coefficient and marginal value coefficient to modify the evaluation model of ecosystem services value, thus calculating the ecosystem services value for Chengdu.

In this paper, we used the "Chinese land ecosystem services value equivalent factor table", with the farmland, grassland, forest land, water area and unused land in Chengdu corresponding to the farmland, grassland, forest land, river and lake, and desert land in the "Chinese terrestrial ecosystem services value equivalent factor". Due to the lack of data, the equivalent factor of construction land was not within the scope of our consideration. Hence, we set its factor as 0. Therefore, we get the equivalent factor of ecosystem services value in Chengdu (Table 1).

The economic value of the average yield per hectare of farmland across the entire country is determined by the economic value of the natural grain yield per year, which is the value of grain production in the field of farmland ecosystem for a year. Therefore, based on the value of the equivalent factor and the conclusion that the value of a single equivalent factor is equal to 1/7 of the value of grain per unit area, we calculated the economic value of the food production service provided by the municipal unit of farmland ecosystem in Chengdu by Eq. (1), which is the unit equivalent factor value E_t. Subsequently, based on the Chinese consumer price index (CPI) statistics of 1979–2015 announced by the National Bureau of Statistics, we introduced the CPI cumulative index correction factor CPI_t to correct it, thus obtaining the corrected unit equivalent factor value E'_t which is shown in Eq. (2). Here, we take the CPI index cumulative value from 1979 as the reference, transforming the economic value of each year into the economic value of 2015 to eliminate the impact of inflation.

$$E_t = \frac{1}{7} \times \frac{Q_t}{M_t} \quad ,(1)$$

$$E'_t = \frac{1}{7} \times \frac{Q_t}{M_t} \times CPI_t \quad ,(2)$$

where Q_t is the total output value of major food crops in the year t; M_t is the cultivation area of main grain crops in the year t.

The calculation of the total value of ecosystem services proposed by Xie and others is shown in Eq. (3) and Eq. (4):

$$ESV = \sum_{k}^{n} A_k U_k \qquad (n = 1, 2, \ \ldots\ldots, 6) \quad ,(3)$$

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