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Land use, total carbon emissions change and low carbon land management in Coastal Jiangsu, China

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ABSTRACT

Given the background of global warming, carbon emission reduction has become a topic of global importance. Land use change not only influences carbon storage in terrestrial ecosystems directly, but it also indirectly affects anthropogenic carbon emissions, which occur more frequently in coastal regions. Based on data of energy consumption, industrial products, waste, soil organic carbon, and vegetation, together with land use images of five typical years, this paper calculated the total carbon emissions in coastal Jiangsu, China, assigned the detailed carbon emission items to different land use types, and optimized land use structure to low carbon emissions using the Linear Programming Model. It was found that carbon emission intensity in coastal Jiangsu was much higher than the average for China as a whole, and that energy consumption contributed most to local carbon emissions with the contribution from animals second. Urban land accounted for the most concentrated and highest intensity of carbon emissions. Between 1985 and 2010, the transfer of cropland to built-up land accounted for the largest percentage of the total transferred area and contributed most to the increase of carbon emissions. In particular, the limitation of urban land will play a key role in carbon emission reduction. Our optimized land use structure can control and decrease carbon emissions effectively and thus, it is an important tool worth the consideration of land managers and policy makers.

1. Introduction

The problem of global warming worsens continuously and has brought significant damage (Wallace et al., 2014). Carbon emission in China is ranked the highest in the world and it is increasing rapidly (Chuai et al., 2012; Mu et al., 2013), which has attracted the attention of the rest of the world. Under the global imperative for the development of low carbon economies, China is under great pressure to reduce carbon emissions (Chuai et al., 2012). According to the greenhouse gas inventory of the Intergovernmental Panel on Climate Change (IPCC), sources of total carbon emissions are usually divided into four sectors: 1) energy consumption, 2) industrial processes, 3) forestry, agriculture, land use, land use/cover change (LUCC), and 4) waste. The IPCC method provides detailed carbon emission coefficients, and according to the amount and type of energy consumption, waste, and industrial production, the amount of carbon emissions can be calculated. It provides a simple and practical method for the calculation of large-scale carbon emissions and it has been used widely throughout the world. In China, most of the studies have been performed with regard to carbon emissions from energy consumption, because this accounts for about 90% of China's total carbon emissions (Lai, 2010). Many of the studies focused on national (Chang, 2010; Mu et al., 2013; Zhou et al., 2013) and provincial scales (Zhang and Wang, 2013; Chuai et al., 2012; Zhang and Huang, 2012). However, carbon sources and sinks of terrestrial ecosystems have also been active areas of research in China with investigations undertaken in single ecosystems, such as forests (Wang et al., 2013), and wetlands (Zhang et al., 2013). It has been recognized that land use change can significantly affect carbon storage because of the different capacities of differing land use types to accumulate carbon (Jaiarree et al., 2011; Bailis and McCarthy, 2011); something that has caused obvious carbon emissions from

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both vegetation and soil (Houghton, 2008; Xie et al., 2007; Van Minnen et al., 2009). China still lacks the comprehensive carbon emissions inventory proposed by the IPCC. However, our research group selected five typical years from the 1980s to 2009 and completed a carbon emissions inventory on a provincial scale according to the IPCC's method to make it comparable internationally (Lai, 2010). Furthermore, we attempted to extend it to local scales as a guide to carbon emissions for local government (Zhao, 2011).

The effects of human activity, for example, carbon emissions, differ greatly depending on land use type and land surface characteristics and functions. For example, industrial energy consumption is concentrated on the industrial land use type, but the scale of the industrial land use may greatly affect the carbon emissions from industrial energy consumption (Lai, 2010). Human activity can affect regional carbon emissions through changes of land use patterns, which in turn alter energy consumption patterns and ultimately, influence the amount and rate of carbon emissions (Lan et al., 2012). Although anthropogenic carbon emissions are often deemed derived from social and economic factors, such as the growth of both the economy and population (Dhakal, 2009), they are always reflected in the extent of the expansion of built-up land. Therefore, we can say that social and economic factors, land use change, and carbon emissions are interactional, and that changes in total carbon emissions can be reflected by land use change. Thus, we can conclude that land use change not only causes carbon emissions from terrestrial ecosystems directly, but it also indirectly affects anthropogenic carbon emissions. Therefore, land use change might have an even more profound influence on total carbon emissions, although carbon emissions might not change linearly according to land use change. Similar results were obtained following a study by Zhao (2011) in Nanjing, which showed that land use change clearly influences carbon emissions, and other researchers have used this method to analyze both the carbon emissions characteristics of different land types and the influence of land use change (Shi et al., 2012). Further research has investigated reducing carbon emissions by optimizing land use structure; however, the studies only discussed carbon in terrestrial ecosystems (Tang et al., 2009; Zhong et al., 2006), and the influence of anthropogenic carbon emissions was only discussed superficially (Chuai et al., 2013).

It has been reported that 60% of the world's population is concentrated in coastal areas and that coastal economies develop quickly, which means that land use change is frequent (Kurt, 2013), especially for urban expansion (Ellis et al., 2011). Land use in coastal regions usually involves marine characteristics, such as shallows and salt pans distributed along the coastline and thus, total carbon emission brought by LUCC will be more obvious than in inland areas and may present distinctive coastal characteristics. Under policies introduced in 2006, most coastal provinces in China have drawn up their coastal development plans and had them approved by the Chinese Government. Jiangsu Province legalized its development plan in 2009 (Chuai, 2013) and land use has changed obviously in recent years (He, 2011; Yao, 2013).

Overall, for local coastal regions, we lack the IPCC-guided examination of total carbon emissions. Land use changes frequently, but we lack analyses both of specific land use types and of detailed temporospatial total carbon emissions caused by land transitions. Quantitative research into assigning anthropogenic carbon emissions to different land use types is still at the initial stages, and there has been no research into optimizing land use structure for reducing total carbon emissions. In our study, all of these questions will be answered, such that our research will provide a meaningful resource that will aid land managers and policy makers implement the coastal development strategy in Jiangsu Province. The objectives of our study include: 1) the examination of total carbon emissions, mainly by the method of the IPCC; 2) assigning carbon emission items to different land use types; 3) the examination of temporospatial land transition and its effect on total carbon emissions; and 4) the optimization of land use structure and a discussion of its effect on reducing carbon emissions.

2. Materials and methods

2.1. Study area

The coastal region of Jiangsu has the Yellow Sea to the east and the Yangtze River to the south. The study area includes the cities of Lianyungang, Yancheng, and Nantong (Fig. 1), encompassing an area of 3.3×10^4 km^2 between latitudes 31°41′N–35°07′N and longitudes 118°24′E–121°55′E, which accounts for 35% of Jiangsu's entire land area. The total length of the coastline is 954 km. Most of the study area presents plain landforms with low hills located mainly to the north of Lianyungang. Soil types include aquic soil, paddy soil, and coastal saline soil. Cultivated land accounts for more than 70% of the entire region, but the percentages of woodland and grassland are much lower, and in recent years, because of rapid economic development, land use has changed frequently.

2.2. Data sources

Information sources used in this paper include images of land use type from 1985 (comprising several images from the late 1980s), 1995, 2000, 2005, and 2010, and data of energy consumption, amount of waste, population, gross domestic product (GDP), yields of principal crops, livestock, industrial production, soil organic carbon, forest inventory, and other empirical data related to values of carbon densities and carbon sinks for different terrestrial ecosystems.

The 100 × 100 m land use grid was produced from Landsat TM images. Here, we reclassify its land use types as cropland, woodland, grassland, water area, shallows, urban land, rural residential land, and other built-up land (including salt pan, which accounts for more than 70%, transportation land, and independent industrial and mine land). Energy consumption data were obtained from the China Energy Statistical Yearbook, and data on the amount of waste were derived from the Jiangsu Environmental Statistical Yearbook. Population, GDP, yields of principal crops, livestock, and industrial production data were obtained from the Statistical Yearbooks of Lianyungang, Yancheng, and Nantong, and the Statistical Yearbook of Jiangsu Province. Soil organic carbon data include two periods: the 1980s and 2000s. Data from the 1980s were derived from The

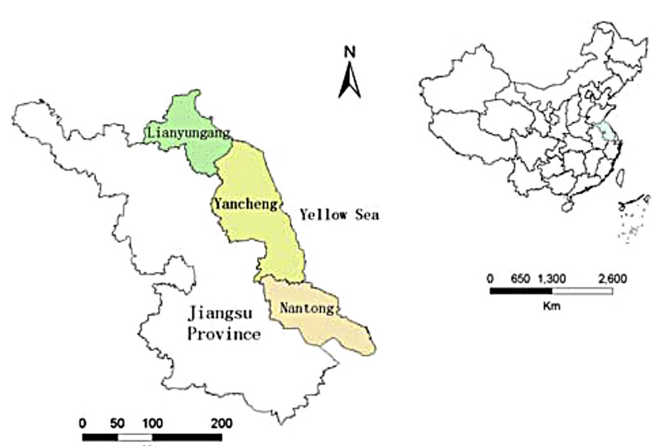

Fig. 1. Location of study area.

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