The 18th Biennial Conference of International Society for Ecological Modelling

Scenarios of changes in the spatial pattern of land use in China

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Abstract

Land use changes affect many aspects of Earth System functioning, for example in impacting global carbon cycle, contributing to climate change, or increasing soil erosion. The simulation of land use change is important in environmental impact assessment and land use planning. We assessed the land use scenarios of China in the next 100 years based on the SMLC (surface modelling of land cover change) model and Dyna-CLUE (dynamic conversion of land use and its effects) model. Three SRES scenarios were evaluated: Global Economy (A1FI): lean government, strong globalization; Continental Markets (A2a): lean government, regional culture and economic development; Regional communities (B2a): much government intervention, regional cultural and economic development. Ten land cover types were simulated, which are cultivated land, woodland, grassland, built-up land, water area, wetland, nival area, desert, bare rock and desertification land. The SMLC model was used to calculate changes in area for each land use types in the future at country level while the spatially explicit land use model Dyna-CLUE was used to simulate land use pattern at 2 km^2 resolution based on the country level areas demands for each land cover type. The results show that the cultivated land would decrease in all of the three scenarios, while in the A2a scenario, the cultivated land would decrease with the lowest rate because of the high population growth, high level of market protection and low agricultural efficiency; in the B2a scenario, it would decrease with the highest rate caused by the decreased population numbers and increased crop productivity. The nival area would decrease with the highest rate in the A1FI scenario since the rapid introduce of new technology and the energy system is fossil intensive, which would discharge more greenhouse gas than other two scenarios. The area of natural ecosystems such as wood land, grassland, water area and wet land would increase significantly in the B2a scenario because this scenario puts more weight on environmental sustainability. The land use spatial pattern in China under the B2a scenario is simulated. The results are important to identify hotspots of land use change that need specific attention by the governments and the researchers.

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Introduction

Land cover change has important effects on climate change, biodiversity, biogeochemical cycling and socioeconomic situation [1-6]. Accurate land use change information is needed for land use policy making and scientific research. Therefore, scientists and policy makers realized the need to assess the land use change dynamics and related impacts. Scenarios provide a methodology for ordering perceptions about alternative future environments in which today's decisions might be played out [7]. The foresight of land use change can provide useful advice for policy decisions.

Recently a large number of studies on future land use change have been conducted at regional or national scale [8-13]. Verburg et al. [14] simulated future land use change for European union used global economic and integrated assessment models and a spatially explicit land use change model based on scenarios differ in worldview, ranging from enhanced global cooperation towards strong regionalization on one hand and strong to weak government intervention on the other. Results show that the impact of abandonment of agriculture land and urbanization on European landscape is large.Schulp et al. [15] assessed how future land use change can influence future carbon sequestration in the EU under four SRES scenarios used a high-resolution land use change model and a carbon bookkeeping approach. Their results show that clear differences are found in the spatial distributions of sinks and sources between the scenarios, illustrating that land use is an important factor in future carbon sequestration changes that cannot be ignored. Tappeiner et al. [16] analysed the effects of future scenarios of land use on the carbon stocks present in the vegetation.Verburg et al. [17] simulated the spatial pattern of land use conversions in China caused by urbanization, desertification and afforestation for a scenario based upon a trend analysis of present land use dynamics.

As mentioned above, a number of scenarios were developed and used in the study of future land use change. The most well-known examples include the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emission Scenarios (SRES). The SRES is based on possible developments during the 21st century, which are arranged around the level of globalization and different values [18-19]. In this study, we assessed the land use change in Chinaunder three HadCM3 climatic scenarios in the next one hundred year.

1. Data and methods

1.1. HadCM3 climatic scenarios

The HadCM3 climatic scenarios used in this study were developed by A1FI, A2 and B2 experiments [20]. In the A1 scenario, increased productivity, increased production and rapid economic growth is expected. Global population peaks in mid-century and declines thereafter. New and more efficient technologies are introduced rapidly. The A1FI group in the A1 scenario describes that technological change in the energy system is fossil intensive [12]. In the A2 scenario, the world is very heterogeneous with high level of market protection; the population growth is more rapid than A1 but the economic growth is slower than A1. The B2 storyline describes a future world in which population number decrease and crop productivity increase. B2 assumes a relatively high level of regulation, including specific spatial and agricultural policies.

1.2. Surface modeling of land use scenario

We assessed the spatial pattern of land use change in China between 2005 and 2099 for three scenarios. An overview of the methodology is shown in figure 1. Ten land cover types were estimated, which are cultivated land, woodland, grassland, built-up land, water area, wetland, nival area, desert, bare rock and desertification land. The land use classification was conducted by a combination of remote sensing data and geographic data sets [21]. The Changes in the required areas for the ten land use types at the national level are simulated using the SMLC model, the detailed description of the SMLC model is given in another paper [12]. The changes in national level land use claims are spatially allocated using the Dyna-CLUE model [22]. Dyna-CLUE model is a spatially explicit model which downscale the national scale land use requirements for different land use types to individual grid cells. The model has been widely used and validated in different studies [23-26]. The spatial allocation is based on the rules specified based on empirical analysis, user-specific decision rules and neighbourhood characteristics. The methodology of land use change allocation through is illustrated in more detail in [14, 22, 27].

2. Results

2.1. Area changes of land cover types

The area of cultivated land would decrease in all the periods from 2000 to 2039, from 2039 to 2069, and from 2069 to 2099 under all the three scenarios (figure 1). Under B2a Scenario, the cultivated land would decrease with the highest speed because of the population numbers decreased and the crop productivity increased. In the A1FI scenario, in combination with increased global trade of agricultural commodities the agricultural area also decreased significantly. The A2a scenario describes a future world of high population growth, high economic growth, high level of market protection and low agriculture efficiency, so the demand for cultivated land is high, which lead to the lowest speed of decrease.
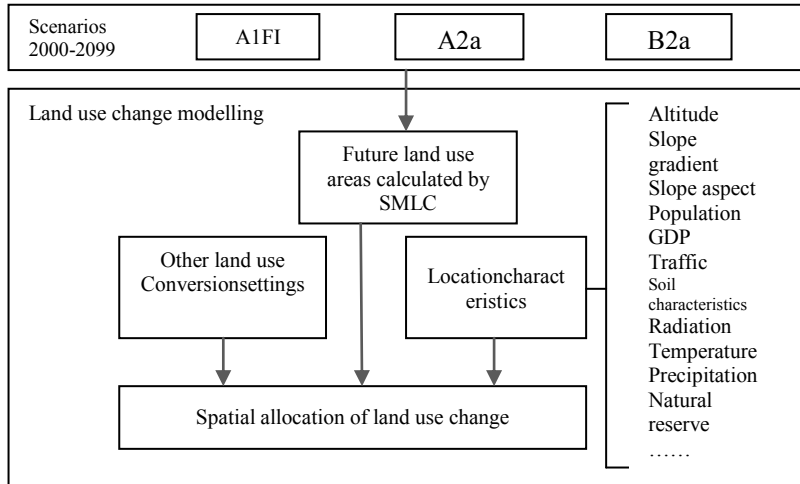
Figure 1 Schematic represent of the simulation approach

Nival area would decrease in all the three periods under all the three scenarios (figure 3). The speed is fastest in A1FI scenario, which describe a future world with rapid introduce of new technology and fossil intensive energy system. The decrease speed in A2a scenario is lowest because of the slow technology growth.

In this study, the nature land includes wood land, grassland, water area and wetland. The area of nature land would increase under all the scenarios in all the three periods except a decrease in the period from 2069 to 2099 under the A1FI scenario. Especially in B2a scenario, the nature area increased significantly, due to the emphasis on environmental sustainability.
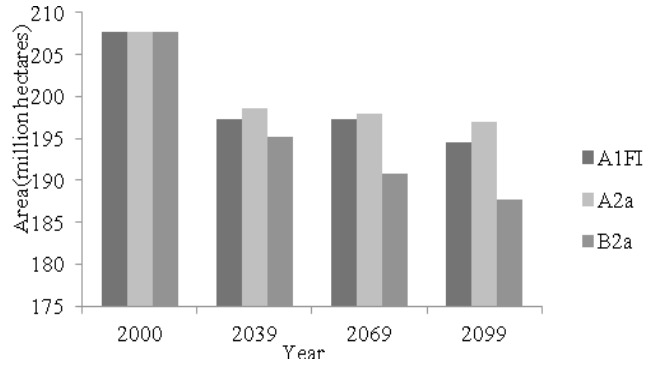
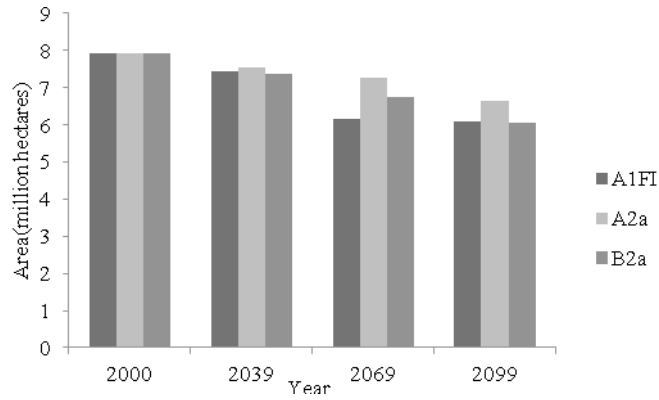Figure 2 Trend of Cultivated land area in three scenarios

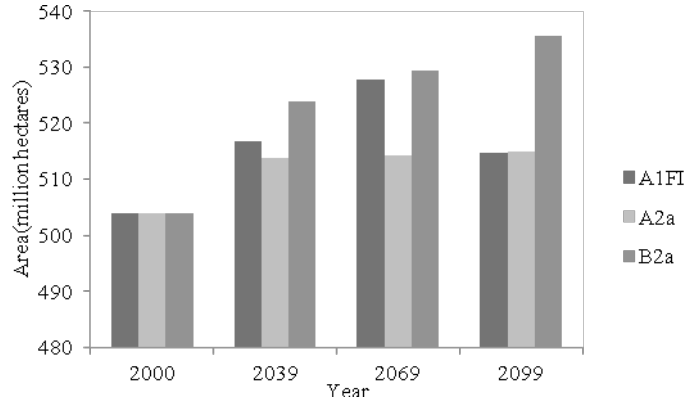Figure 3 Trend of Nival land area in three scenarios

Figure 4 Trend of Nature land area in three scenarios

2.2. Spatial distribution of land use types

According to the National Eleventh Five-Year long-term development planning, the future of China would resemble the B2 scenario. Therefore, this study estimated the spatial pattern of land use change of China under the B2a scenario (figure 5). Because of the regional variance of spatial hydrothermal distribution and the impact of the continental monsoon climate, the regional variety of land use types in China is very apparent. Woodland in the northeastern China would increase. Grassland in eastern China for example in Shandong province would turn into cultivated land, which coincide with consequence expected by Grain for Green program. However, the spatial pattern of land use types would not change dramatically in the three periods constrained by the spatial distribution pattern of rainfall, radiation, temperature, topography and so on.
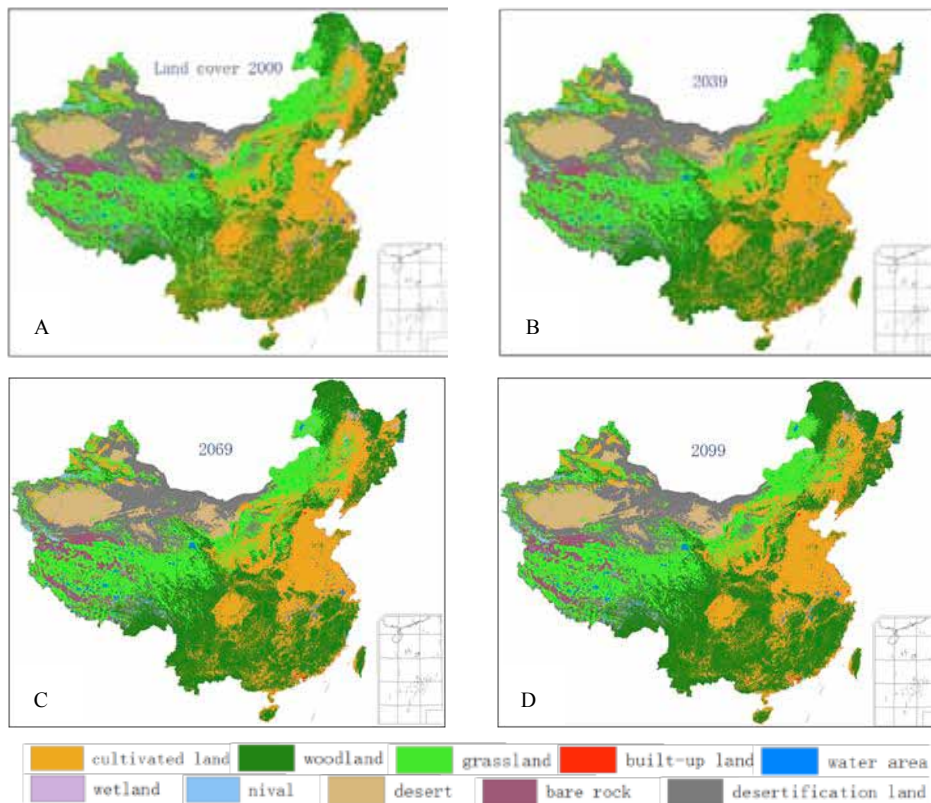

Figure 5 Spatial pattern of land use under scenario B2a in the three periods (A. land use in 2000; B. land use in 2039; C. land use in 2069; D. land use in 2099)

4. Conclusion:

In this paper, we evaluated the future land use change of China. This is one of the first Chinese-wide simulations of land use change spatial pattern taking climatic, socioeconomic and geographic factors into consideration. In the future 100 years, the area of cultivated land and nival would decrease and natural area will increase. The cultivated land would decrease with the lowest rate under the A2a scenario, while

in the B2a scenario it would decrease with the highest rate. The nival area will decrease with the highest rate in A1FI. The nature ecosystem would increase significantly in the B2a scenario. Spatial pattern of land use change is simulated for the B2a scenario, which is most similar to the future of China. The results are important to identify hotspots of land use change that need specific attention by the governments and the researchers. The results of the simulation can also be used as a tool for estimating related effects of land use change. As an example, the results can be used to assess the effect of land use change on biomass, diversity, carbon sequestration and other ecosystem services.

Acknowledgements

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