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Quantitative analysis of agricultural land use change in China

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ABSTRACT

This article reviews the potential impacts of climate change on land use change in China. Crop sown area is used as index to quantitatively analyze the temporal–spatial changes and the utilization of the agricultural land. A new concept is defined as potential multiple cropping index to reflect the potential sowing ability. The impacting mechanism, land use status and its surplus capacity are investigated as well. The main conclusions are as following;

1. During 1949–2010, the agricultural land was the greatest in amount in the middle of China, followed by that in the country's eastern and western regions. The most rapid increase and decrease of agricultural land were observed in Xinjiang and North China respectively, Northwest China and South China is also changed rapid. The variation trend before 1980 differed significantly from that after 1980.
2. Agricultural land was affected by both natural and social factors, such as regional climate and environmental changes, population growth, economic development, and implementation of policies. In this paper, the effects of temperature and urbanization on the coverage of agriculture land are evaluated, and the results show that the urbanization can greatly affects the amount of agriculture land in South China, Northeast China, Xinjiang and Southwest China.
3. From 1980 to 2009, the extent of agricultural land use had increased as the surplus capacity had decreased. Still, large remaining potential space is available, but the future utilization of agricultural land should be carried out with scientific planning and management for the sustainable development.

1. Introduction and background

Arable land is essential for food security and sustainable development of society. Changes in the coverage, utilization, and bioenergy potentials have received much attention recently (Wang et al., 2013; Hiironen and Niukkanen, 2014). National statistic shows a generally decreasing trend in the amount of arable land in China especially after 1957. Such long-term reduction has a significant impact on national food security and agriculture development. Meanwhile the negative effect of reduced arable land on total grain output has been gradually balanced by the warming climate and improved farming techniques (Zhang et al., 2013). As the result it is not sufficient and adequate just to understand the spatial–temporal variations of arable land, along with the evaluation of its utilization and sustainability of arable land. The assessment of the status of food security could be significantly biased (Ainsworth and Ort, 2010).

Since the change in crop land is determined by both the availability of the arable land and the multiple cropping index. The multiple cropping index is calculated by dividing the total area of cultivated land by the total area of annual crops sown in percentage, reflecting not only the impact of arable land availability on grain output, but also the effects of climate change and technological development on the degree of utilization of agricultural land. Consequently the effect of decreasing arable land on the total grain output can be fully assessed (Yang and Li, 2000; Huang and Liu, 2006).

When analyzing the driving mechanisms of the quantitative agricultural land change, the Index of crop sown area is more scientific than that of a crop arable area. Taking urbanization for example. Since the multiple cropping index differs for region to region, the effects of urbanization on agricultural land use may be assumed to be varying in different cropping systems. Even under the same condition of cropping systems, high index areas are heavily affected by urbanization, while low index areas are comparatively less affected. Assessing the effect of urbanization on sown area change can provide improved supplementary information, so as to better

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validate the change in national arable area. The assessment of the effects of urbanization can be used as a tool for analyzing agricultural land use as well.

Recently the researches of agricultural land use mainly focus on the change in cropping system, the spatial–temporal variation of land resource, and assessment of the surplus capacity. Both observation (such as national survey/statistic, remote sensing data) and model outputs from crop growth model and economical model are used in agricultural land use study. Combining the effects of natural, climatic, agricultural and economic factors, Shen et al. (1983) classified the Chinese multiple cropping system, based on which agro-climatic regionalization of China was established. Liu and Han added the administrative regions' integrity at the country level (Liu and Han, 1987). Zhang (2000) analyzed the possible impacts of climate change on Chinese cropping system (Zhang, 2000). By using the remote sensing data, efforts have been made to improve the agro-climatic regionalization of Chinese in both accuracy and detail (Yan et al., 2005; Sun et al., 2008). Attention has also been put to multiple cropping index (Liang, 2007), the effects of climate change on cropping system and crop sown area (Yang et al., 2011; Fu et al., 2014).

In this paper, the impact of urbanization and surplus capacity on agricultural land is investigated using the index of crop sown area. The quantitative changes of China's agricultural land and arable land use are analyzed.

Based on the index of crop sown area, this article analyzes the quantitative changes of China's current agricultural land and arable land use. This research focuses on the controlling factors underlying both the spatial and temporal trends of crop sown area in China with particular attention is given to the empirical impacts of urbanization and regional warming. The current status and future potential availability of Chinese arable land use are assessed as well, which provides unique insight and scientific support for the national agricultural development and management, as well as the policies making.

2. Data

The coverage of arable land (1980–2009) and sown area (1949–2010) and the population data used in the paper are from National Bureau of Statistics of China, China Economic and Social Development Statistical Database, and CNKI. The actual cropping index is calculated by dividing the sown area by the corresponding arable land in different provinces. The urbanization rate index is calculated as the proportion of the urban population to the total population. The data for Hebei, Jiangxi, Fujian, Zhejiang, Shaanxi, Chongqing and Sichuan Provinces are uncompleted, and therefore not included in the study. The climate data, namely the daily accumulated temperature, is derived from the daily observation of 756 weather stations, which are operated by the China Meteorological Administration. The potential arable area, potential sown area and potential cropping index of different provinces are processed by those climate data, using the method in this paper.

3. Methods

3.1. Change and factor analysis of crop sown area of China

The potential arable area, potential sown area and potential cropping index of different provinces are calculated using the method in this paper.

Regulated by natural environmental system and socio-economic conditions, the cropping system could be used to connect environmental-socio-economic conditions and agricultural land use (Zhou et al., 2012). For a certain agricultural land, actual cropping index (referred to as *Actual_ci*), is calculated by divided the actual crop sown area by the arable land area. Actual cropping index can be viewed as the reflection of the actual sowing ability, and actual crop sown area is the determined by the sizes of arable land and the actual sowing ability. We therefore define a new concept as potential cropping index (referred to as *Potential_ci*), to reflect the potential sowing ability. The potential crop sown area (referred to as *Potential_sa*) is the product of potential cropping index and its arable area (referred to as *Potential_aa*)

$$Potential\_sa = Potential\_ci * Potential\_aa \quad (1)$$

For certain land i, its potential cropping index $Potential\_ci(i)$ reflects the latent sowing ability, represented symbolically by $Potential\_ci(i)$. The potential size of arable area $Potential\_aa(i)$ is related to the size of land i and its arable ratio. As the result, the potential sown area $Potential\_sa(i)$ is regulated by the potential cropping index $Potential\_ci(i)$, the size of land itself and its arable ratio.

Both $Potential\_ci(i)$ and the arable ratio are determined by socio-economic and natural factors, and their combined effects are represented by the index $n(i)$. $n(i)$ demonstrates the impact value of potential sowing under certain controlling factors. As the result, the potential sown area $Potential\_sa\ (i)$ can be calculated as the function of the index $n(i)$ and the size of land i.

In this paper, Chinese Grid Map is used and the resolution is $1 * 1$ degree then i is some grid on such grid graph. Considering the projection distortion, area-weighed processing is carried out. Therefore for any grid i, its $Potental\_sa\ (i)$ is as follow.

$$Potential\_sa(i) = A * \cos(Lat(i)) * n(i) \quad (2)$$

A represents the area of each grid and is a fixed value that the area of each $1 * 1$ degree grid before area-weighed processing.

Taken A as a fixed value is because that many factors made *Potential_sa* district different. Those factors have been separated out. The index of $\cos(Lat(i))$ is to revise the deviation of map projection. While the index of $n(i)$ contain the factors of temperature and urbanization. We choose to do research on the reason of sown area change in this preliminary research.

To calculate the index $n(i)$, we should first understand what is the condition for the potential crop sown area. Assuming the potential crop sown area of China are considered as arable, that is, equals to the most ideal state of sown area on the existing land, the potential crop sown area is considered as arable. Such condition does not represent the real land potential of China, but the potential crop sown area can be applicable to all sowing conditions. The change in the potential sown area under different constraint conditions reflects the effect of these conditions on the crop sown area in China.

In the paper, the regional climate change and urbanization are considered as the most important controlling factors for the change of the potential sown area. Defining $Ci\%$ as the representation of urbanization, $Potential\_ci(i)$ is the impact of climate change on cropping system, then the index $n(i)$ would be the product of $Potential\_ci(i)$ and $(1 - Ci\%)$ If only climate change is considered, $Ci\%$ is zero and then the index $n(i)$ is just the value $Potential\_ci(i)$. In Table 1, the relationship of climate, the cropping system with accumulated temperature larger than 10 °C (CAAS, 1999), and the quantitative impacts of different constraints to potential sown area $n(i)$ are displayed. The potential sown area $Potential\_sa(i)$ can be calculated on each grid point of the China Grid Map using $n(i)$.

In Table 1, the relationship of climate, the cropping system with accumulated temperature larger than 10 °C (CAAS, 1999). Cropping system with accumulated temperature larger than 10 °C is research outcome in the book of Chinese Academy of Agricultural Sciences. In this book, there are detailed and complicated instruction of 1.5 times/double cropping, double/triple cropping and triple