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Management of trade-offs between cultivated land conversions and land productivity in Shandong Province

Xiangzheng Deng [a, b, *], John Gibson [c], Pei Wang [d]

[a] Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China
[b] Center for Chinese Agricultural Policy, Chinese Academy of Sciences, Beijing, 100101, China
[c] Department of Economics, The University of Waikato, Private Bag 3105, Hamilton, Waikato, New Zealand
[d] School of Business Administration, Zhongnan University of Economics and Law, Wuhan, 430073, China

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A B S T R A C T

This study aims to analyze the trade-offs between cultivated land conversions and land productivity using data fusion. First, 1-km area percentage data model, which integrates advantages of grid data and vector data, is applied to detect cultivated land conversion in each 1 km × 1 km grid cell in Shandong Province. Then land productivity in the study area is assessed with the Estimation System of Land Production (ESLP) model based on agro-ecological zones, which integrates multi-source data, including land use data, climatic data, radiation parameters, soil properties. Estimation result shows that the average land productivity of the whole study area is 7509 kg hm^{-2} during 1985–2010, while land productivity of built-up land and water areas with low vegetation is zero. Furthermore, results of comparative analysis on cultivated land conversion and land productivity shows that land productivity in Shandong Province is unevenly distributed, which is higher in the west part of the study area, and lower in the regions where cultivated land conversion occurs. And the overall trend of land productivity is in a decreasing trend during 2003–2010. The measures of management of this trade-off should be focused on preventing cultivated land conversion.

1. Introduction

Land resource for cropping is one of the key determinants of agricultural production, and the report released by FAO (2011) has revealed that the increasing population is expected to cause additional 70% increase in global demand for agricultural production with current cultivated land by 2050. It is well known that China's cultivated land area per capita ranked as one of the lowest worldwide, and the second national land survey has showed that the cultivated land area per capita is 913 m^2, less than half of the world average level (FAO, 2009). However, urbanization, economic growth and industrial transformation aggravate land conversion, which incurs the competition between cultivated land and built-up land and imposes an overriding challenge upon the food safety. The problem seems to be particularly distinct in Shandong Province, which is one of the major grain production regions in China.

Shandong Province is located on the eastern edge of the North China Plain (114°19′-122° 43′E, 34°22′-38°15′N) and at the lower reaches of the Yellow River (Fig. 1). It covers a total area of over 151, 100 km^2, 55%, 15.5% and 13.2% of which are plains, mountainous area and hilly area, respectively. Shandong Province lies in the warm-temperate zone with the continental monsoon climate, with the annual mean temperature ranging from 11 to 14 °C and the annual precipitation ranging from 550 to 950 mm.

Cultivated land conversions may create positive externalities, such as outstanding economic growth, increasing agricultural production through technological innovation and shared information (Bai et al., 2011; Song et al., 2013; Deng et al., 2013a). In Shandong Province, gross domestic product (GDP) was 3.12 trillion yuan by the end of 2008, which was 27 times higher than that of 1988 (NBSC, 1999-2009). In the same time, the industrial structure, which is represented by the ratios of primary industry, secondary industry and tertiary industry in the total GDP, changed from 3:4.4:2.6 in 1988 to 1:5.7:3.3 in 2008 (NBSC, 1999-

* Corresponding author. Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China.
E-mail addresses: dengxz.ccap@igsnrr.ac.cn (X. Deng), jkgibson.waikato@gmail.com (J. Gibson), wangpei@igsnrr.ac.cn (P. Wang).

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2009). Otherwise, cultivated land conversions generate negative externalities, such as problems in the public safety, health and social equality (Deng et al., 2008; Liu et al., 2014a), and the most significant negative effect is cultivated land loss (Huang et al., 2007; Wu et al., 2011). Along with the changes in industrial structure, there is an obvious land use/land cover change (LUCC) in Shandong Province. The built-up land area in Shandong Province increased from 34 123 km^2 to 39 110 km^2 during 1988–2008, but meanwhile the cultivated land area decreased from 83 623 km^2 to 80 135 km^2 (It is calculated by our own land use dataset used to estimate land productivity). Apparently, the cultivated land loss and built-up land expansion suggest that land conversion is caused by the increasing demand for built-up land, which is at the expense of occupying other types of land (Song and Deng, 2015). However, land resource and other natural resources are translated into food for millions of people (Fader et al., 2013), otherwise, food production exerts pressure on land and other resources (Pfister et al., 2011). Although the grain production in Shandong Province had been continuously increasing since 2003, the growth rate shows it decreases. A slow down of the growth rate of grain supply is primarily caused by land productivity degradation and cultivated land loss (Alston et al., 2009; Smith and Gregory, 2013). On one hand, cultivated land conversion is decreasing the cultivated land area for grain production; on the other hand, cultivated land conversion affects land productivity through changing its properties. As land conversion can be detected with Geographic Information System (GIS) and Remote Sensing (RS) techniques, how can the land productivity be assessed? What kind of strategies should be used to improve or remain land productivity for grain production?

This study answers these questions by exploring the trade-offs between cultivated land conversions and land productivity by using 1-km area percentage data model and Estimation System of Land Production (ESLP). Firstly, literature review shows the context of land productivity and big data technology, with priorities of combining both vector data and grid data. Secondly, this study utilizes 1-km area percentage data model to simulate cultivated land conversion. Thirdly, land productivity is estimated by Estimation System of Land Production (ESLP) model, which integrates multi-source data into different forms of indices to calculate land productivity. Fourthly, cultivated land conversion data and land productivity data in 1 km × 1 km grid cells are compared to analyze their trade-offs. Finally, a concise conclusion is provided.

2. Literature review

2.1. Land productivity

Land productivity refers to the capacity of agricultural land to produce plant biomass under the constraints of each agro-ecological zone (FAO, 2003; Barrios, 2007). Pieri (1995) and Dengiz and Sağlam (2012) defined land productivity as "the condition and capacity of land, including its soil, climate, topography and biological properties, for purpose of production, conservation, and environmental management". Driving mechanism of land productivity should be accordingly clarified before the assessment. Dynamics of land productivity is induced by diverse factors, involving both geographic forces and socio-economic forces (Holden et al., 2001; Datta and De Jong, 2002; Holden and Shiferaw, 2002; Song and Pijanowski, 2014). Barrios (2007) concluded that soil biota directly and indirectly affected land productivity via ecosystem services, which actually referred to provisioning services and natural flow, as it stated that soil organism community had an influence on crop yield and participated carbon and nutrients cycles. Research on soil erosion and land productivity indicated that soil erosion as one of the most serious determinants for degradation of land productivity was often neglected or treated as a loss of infrastructure rather than a loss of production capacity (Bakker et al., 2005; Larney and Janzen, 2012; Power et al., 2014). Documentation of Blaschke et al. (2000) manifested that surface-erosion-induced loss of land productivity emphasized the issue of decreasing crop yield. Aside from the geographic forces for assessing land productivity, the relationship between socio-economic forces and land productivity was widely investigated in the field of economy. For example, Chand et al. (2011) showed that the farm size was closely associated with land productivity. Dyer (2014) argued that land productivity tended to drop in a long run with smaller farms as smaller households intended implement intensive cultivation of land to maintain the labor productivity.

The assessment of land productivity is to obtain the optimal production capability of agriculture for human's requirement in a certain premise of climate condition, soil property, land use intensity and management measures (Deng et al., 2013b). Land productivity can be estimated for any unit area, ranging from pixels, plots to countries, and even the global scope (Fischer et al., 2000, 2008; Atehnkeng et al., 2008). There are diverse methodologies for assessing land productivity, but a common step is to stepwise correct the target index. Original FAO Agro-ecological Zones Project

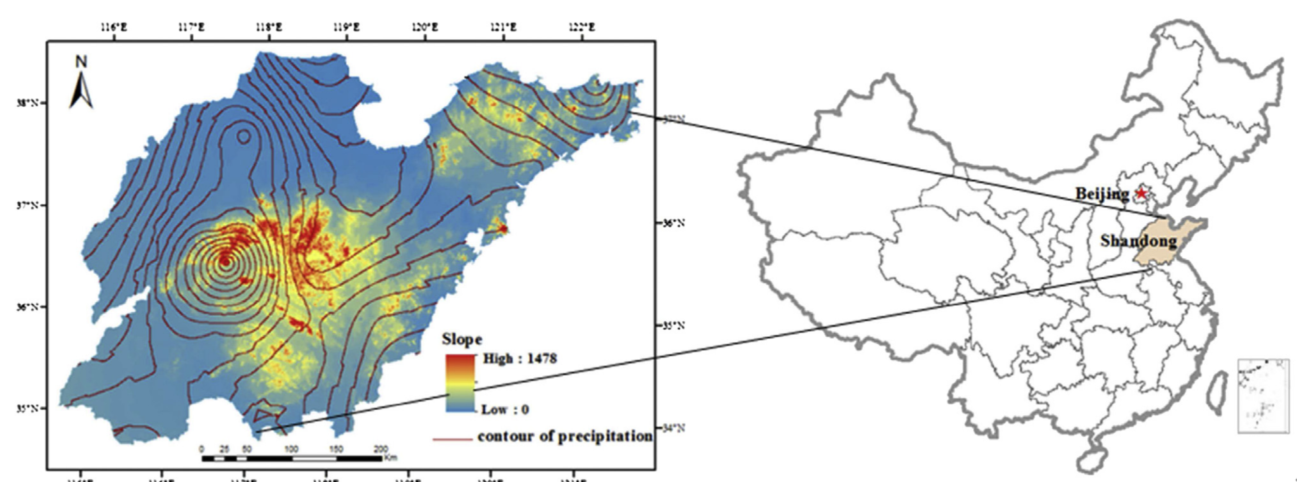

Fig. 1. Location and mean annual rainfall of the study area of Shandong Province.

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