Improving eco-efficiency for the sustainable agricultural production: A case study in Shandong, China

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ABSTRACT

With rapid economic growth and urbanization in China affecting agricultural land, it is of great importance to improve eco-efficiency for sustainable agricultural development to ensure food security. Shandong, as a key agricultural production base in China that experiences accelerated urbanization, was chosen as our case study area. Supported by a large scale natural and socioeconomic data, we estimated land productivity in Shandong, China during 1990–2010 using the Estimation System of Land Production, then analyzed the eco-efficiency based on Stochastic Frontier Analysis. The results showed that land productivity was unevenly distributed in Shandong, with relatively lower values in regions covered by built-up area. The regional eco-efficiency in Shandong was mostly over 0.9, expect for cities located far from the political or economic centers. The results indicated there exists trade-offs between agricultural production and urbanization, and it is necessary to adjust its agricultural technological measures according to local specific conditions to improve eco-efficiency for sustainable agricultural development in Shandong.

1. Introduction

China is the most populous nation in the world, and it currently feeds approximately 22% of world population with only 7% of the global cultivated land. Rising population is expected to lead to a 70% increase in demand for agricultural production globally by 2050 with current cultivated land not increasing over current levels (FAO, 2015; Guilpart et al., 2017; Tirlapur and Mundinamani, 2015). It is notable that China’s cultivated land area per capita is one of the lowest worldwide (Deng et al., 2010). For example, the second national land survey showed cultivated land area per capita in China was 913 m², which was less than half of the world average level (Song and Deng, 2015). Based on this background, tracking changes in cultivated land area and analysing its impacts on agricultural productivity in China are prerequisites for the better safeguarding of national food security. However, rapid urbanization in China, along with implementations of various land policies and ecological protection campaigns, has resulted in changes in the quantity and quality of cultivated land (Gingrich et al., 2015; Wu et al., 2011). The total area of cultivated land in China showed a decreasing trend from 1990 to 2010 (Fig. 1).

Along with detailed research on land use change, there is growing awareness that eco-efficiency is one of the fundamental factors for ecosystem services improvement and sustainable agricultural production (Deng et al., 2016). The concept of eco-efficiency was introduced as ‘a business link to sustainable development’ by Schaltegger and Sturm (1990). Regional eco-efficiency is the efficiency with which ecological resources within an area are used to meet human needs (Mickwitz et al., 2006), expressing how efficient the economic activity is regarding nature’s goods and services (Zhang et al., 2008). Eco-efficiency can be improved by reducing environmental impacts and natural resources use while maintaining or increasing the value of the output produced (Mickwitz et al., 2006). Scientific estimation and analysis of eco-efficiency is needed to analyze the impacts of socio-economic development on ecosystem services, with the aim of providing support for land use policy making.

In China, problems regarding land use change and sustainable development of agricultural production are particularly acute in Shandong, which is the third largest agricultural production bases in China (Fig. 2), so what happens in Shandong will affect food security and social stability in whole China. Shandong features interactions among crop production, conservation of forestry and grassland covers, and urbanization. According to the information released by the Ministry...
of Land and Resources of China, the cultivated land area per capita in Shandong was just 232 m², which is one-quarter of the average value of China in 2015. Shandong’s importance as an agricultural production base and loss of cultivated land to development justifies our choice of the region as a study area.

In this paper, we first evaluated land productivity in Shandong based on the Estimation System of Land Production (ESLP). Within the ESLP, agricultural productivity is an indicator of the production capacity of each unit area land, taking consideration of many socio-economic factors based on land potential productivity (Deng et al., 2013; Jin et al., 2015). During the estimation of land productivity, a significant part is the support of large scale data for the inputs in the ESLP.
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