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Cultivated land productivity potential improvement in land consolidation schemes in Shenyang, China: assessment and policy implications

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ABSTRACT

Cultivated land productivity potential improvement (CLPPI) assessment is the fundamental basis to launch land consolidation, which is one of the most important way to increase the grain productive capacity. Previous studies on CLPPI assessment have focused on factors related to natural conditions of cultivated land, but they ignored the impacts of utilization conditions, including plot characteristics and agricultural infrastructure, which account for substantial CLPPI from land consolidation. Based on the crop-growth model and Agro-ecological Zoning (AEZ) methodology, this paper proposed a modified CLPPI assessment model to estimate the improvement of land productivity potential via land consolidation. Meanwhile, the contribute rates of different factors involved in determining the CLPPI were also analysed to reveal the ideal work focus and policy direction for land consolidation. Results showed that the calculated CLPPI values had obvious spatial variety in Shenyang, of which the average was 326.18. For the consolidation case, total crop production in Shenyang could be increased by as much as 149.89 × 107 kg, 20% of the current yield. CLPPI is the comprehensive outcome of both natural and utilization qualities of land use, and the current productivity potential of cultivated land in Shenyang relied much less on natural conditions such as soil than on utilization conditions such as agricultural infrastructure. In addition, medium-productivity lands were most appropriate target areas for the implication of land consolidation projects. Actually, the arrangement of land consolidation projects should not only consider CLPPI as in the past, but also add the theoretical productivity potential into consideration. Moreover, the realization of estimated CLPPI also calls for active changes of the whole land management system. An integrated institution for the full implementation of land consolidation, proper regulations and laws on the follow-up protection of cultivated land productivity potential, economic policies to stimulate the willingness of farmers, and a transfer mechanism for cultivated land are all needed policy changes.

1. Introduction

Land-use and land-cover change (LUCC) is one of the core research topics regarding global change due to modernization (Herrick et al., 2013; Mooney et al., 2013; Rindfuss et al., 2004; Sterling et al., 2013; Li et al., 2017). Along with urbanization processes, patterns of LUCC change significantly, including a substantial loss of cultivated land (Angel et al., 2011; Poelmans and Van Rompaey, 2009; Seto et al., 2011; Torrens, 2008; Deng et al., 2015; Lambin et al., 1995), which may directly threaten the global life support system (Fang et al., 2005; Fontaine and Rounsevell, 2009; Salvati and Zitti, 2012; Tan et al., 2005). Compared to changes in the quantity of available cultivated land, quality changes due to human activities are less visible; however, they can have a vital impact on the land productivity potential, food security, and sustainable agricultural development (Foley et al., 2005; Zhang et al., 2002). The best way to simultaneously maintain global food security and ecological integrity is to increase the productivity potential of existing cultivated land resources (Foley et al., 2011; Kong, 2014).

China, with a large and growing population, yet limited cultivated land resources (Bennett, 2008; Heerink et al., 2007; Skinner et al., 2001; Yang and Li, 2000), faces the important task of protecting cultivated land, especially in recent years when the cultivated land productivity potential has been in gradual decline (Chen et al., 2011;

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Lichtenberg and Ding, 2008; Scott et al., 2003; Shen et al., 2012). Suggestions found in the literature indicate that China must introduce better policies to control the occupation of high-productivity cultivated land, as well as improve the productivity potential of available land (Kong, 2014; Jiang et al., 2010; Ding, 2003; Yun, 2011).

The Chinese government has been gradually turning attention to improving cultivated land productivity potential through activities such as the Agricultural Comprehensive Exploitation Projects, land consolidation, low-and medium-yield farmland upgrades, etc. Land consolidation is the most comprehensive land adjustment activity, addressing the goals of sustainable agriculture, rural development, eco-environmental protection, and sustainable land management (Cay et al., 2010; Crecente et al., 2002; Miranda et al., 2006; Pašakarnis and Maliene, 2010; Pašakarnis et al., 2013; Thomas, 2006; Van den Brink, 2004; Van der Molen et al., 2005). Land consolidation can improve the cultivated land productivity potential, which essentially indicates, for a given economic and technologic status, the gap between the actual and optimal cultivated land quality, however, considering cultivated land quality manifested as differences in crop yield, the study defined land productivity potential as the capacity of crop yield. The optimal yield is that obtained under optimum management practices in a given region, which can be achieved through land consolidation measures (Zhang et al., 2005; Long, 2014). The State Council of China published the "National Land Consolidation Plan (2011–2015)" in 2011, with the goal of improving the quality level of cultivated land by one grade through the process of national land consolidation. Money spent on farmland consolidation alone was more than 100 billion *Yuan* per year in 2012 (Wang and Zhang, 2012), a large and expensive endeavour for improving cultivated land productivity potential (Yun, 2011; Long et al., 2010; Deng et al., 2017). Therefore, the assessment of cultivated land productivity potential improvement (CLPPI) is vital for land consolidation project approval, and regions with concentrated cultivated land that has high productivity potential improvement are favourite places to set up consolidation projects.

Currently, CLPPI assessment is usually calculated as the gap between the actual and standard cultivated land quality (with the standard being the highest found within the region) (Chen et al., 2011). It also can be regard as the method to increase comprehensive agricultural productivity through agricultural or elemental inputs. Studies have assessed relationships among natural resources such as climate, water, and landforms (Bindraban et al., 2000; Bouma, 2002; Dumanski, 2000; Ochola and Kerkides, 2004; Rahmanipour et al., 2014; Rossiter, 1996; Tesfahunegn et al., 2011) as potential inputs for improving the agricultural system. Socio-economic resources like labour, technology, and capacity for agricultural production have also been studied (Passioura, 2006; Wheeler et al., 2000; Mondal and Basu, 2009; Pretty et al., 2003). Others emphasized aspects of high-productivity, efficient cultivation, and light utilization of crops (Agam et al., 2012; Sadras et al., 2005; Kiniry et al., 2004; Thirtle et al., 2003; Kho, 2000).

All of these studies have ignored the role of land consolidation in improving land productivity by enhancing plot characteristics (size, shape, flatness) and agricultural infrastructure (roads, shelterbelts) (Guo et al., 2010; Zhang et al., 2013). Land consolidation projects improvements to cultivated land would include flattening fields to create larger and better shaped parcels, building irrigation-drainage infrastructure, perfecting field roads to increase accessibility, and constructing shelterbelts as windbreaks to prevent soil erosion (Bian et al., 2009; Crecente et al., 2002; Demetriou et al., 2012; Niroula and Thapa, 2007; Pa & akarnis and Maliene, 2010; Sklenicka, 2006). Moreover, the assumed plot quality could reach the highest value for all plots after effective land consolidation. Limitations related to agricultural infrastructure are relatively easy to improve, while some limitations related to soil conditions cannot be changed quickly. Assuming the ideal situation would therefore overestimate land quality and CLPPI.

Meanwhile, assessment models for CLPPI are often constructed using the method of multiple-factor weighted summation, which neglects the various mechanisms that change cultivated land quality. These assessment results neglect the contribution rate of land quality factors to CLPPI, thereby limiting the available policy tools. Therefore, establishing one CLPPI assessment model based on work mechanisms between land consolidation projects and land quality, and building the relationship between the model results and policy directions, will improve the scientific foundation of land consolidation and strengthen the cultivated land management.

With Shenyang City in China as the study area, this paper attempts to address three research objectives: 1) distinguish different impacts of land consolidation on different factors, and construct an indicator system for assessing the quality of cultivated land consolidation; 2) construct a quantitative CLPPI assessment model; and 3) analyse the rates of contribution for different types of assessment factors; 4) propose the policy implications of land consolidation work by identifying which factors will lead to the greatest improvements. The results from this work will not only enrich the theory of CLPPI assessment, but can also help solidify approval for land consolidation projects and management in practice, and provide policy tools for land consolidation performance appraisal.

2. Study area

Shenyang City is located in the middle of Liaoning Province, northeast China, covering the area of 122°25'9"E to 123°48'24"E and 41°11'51"N to 43°2'13"N (Fig. 1). It includes nine districts, one county-level city and three counties. In 2011, Shenyang's total registered population was 7.196 million, of which 5.154 million 71.6% were in the districts.

Shenyang is a famous agricultural city in China. Its counties such as Faku, Kangping, Liaozhong, Xinmin, and Sujiatun are major grain producing regions and the main target areas for constructing national high-standard farmland. The major crops here are rice and corn, and the cropping system is one crop per year. Crop planting here was 0.65 million ha in 2011, which brought a final harvest of 3.25 billion kg and a total value of 44.49 billion Yuan, a net income of 10,022 Yuan per farmer.

Located at the junction of west Liaodong Upland and Liaohe Plain, Shenyang City inclines slightly from northeast to southwest with an average altitude of 50 m. Its major terrain consists of flat plains, accompanied by some hilly areas. Influenced by a temperate continental monsoon climate, the annual average temperature and rainfall are respectively 8.3 °C and 700 mm. The climate, as well as soil types of brown, meadow, and rice soil, makes it an ideal place for agriculture. The existing cultivated land is 0.77 million ha, accounting for 60.02% of the total land. However, due to the long-term producing mode in which "high yield but low input" was pursued, agricultural infrastructure systems, including rural roads, and power and water supply, have fallen into disrepair. Land degradation has also caused problems such as desertification, saline-alkalization, and water erosion, making cultivated land in Shenyang badly in need of land consolidation to improve its productivity potential.

3. Modelling methodologies

In essence, CLPPI reflects the gap in productivity potential prior to and following consolidation. These changes can be expressed through qualitative and quantitative assessment of changes in factors related to productivity potential before and after consolidation (Zhang et al., 2005; Zhang and Chen, 2002).

Based on the light-temperature (climatic) productivity potential, we designed a modified CLPPI assessment model covering both natural land and unitization factors that accounts for the influence of land consolidation. Using the ArcGIS 10.2, the current productivity potential of each cultivated land plot (the basic assessment unit) was calculated. Land consolidation to the extent improved various selected factors, and