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# Changes resulting from a land consolidation project (LCP) and its resource–environment effects: A case study in Tianmen City of Hubei Province, China

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ABSTRACT

Land consolidation (LC) is essential for ensuring rural development and for increasing land use effectiveness. LC has been implemented in China since the mid-1990s in an attempt to increase available cropland area, reduce fragmentation and promote agricultural production capacity. The purpose of this study is to identify the changes resulting from the land consolidation project (LCP) implementation, and to develop a parametric approach to assess the resource–environment effects. This study could promote the LCP planning, and provide the support for the decision-making of the LC authorities. The Tianmen land consolidation project in Hubei Province of China was chosen as a case study. The results of the case study showed LCP implementation results in great changes in land use types and their proportions, connectivity of field-roads, irrigation systems and drainage systems, plot numbers, plot shape and plot size. These changes bring both positive and negative effects to region environmental and economic system. Positive effects were demonstrated in agricultural production capacity and agricultural production cost and the negative effects were expressed by the ecosystem services value, landscape diversity and human disturbance intensity.



## Introduction

Land consolidation (LC) is a tool for improving the effectiveness of land cultivation and for supporting rural development (Sklenicka, 2006; Van Dijk, 2007). It is also a useful tool for facilitating environmental management (Van Lier, 2000; Crecente et al., 2002; Gonzalez et al., 2004) and other social and economic issues related to managing the development of rural areas (Wittlingerova and Kriz, 1998).

In China, The Household Responsibility System (HRS), which means production and management are entrusted to individual farming households through long-term contracts, replaced the less efficient Commune System in the late 1970s. Although the HRS greatly improved agricultural production capacity in the early years (Tan et al., 2006), it has, more recently, resulted in land fragmentation due to the high population in the rural areas and the limited availability of arable land. Land fragmentation also results in low efficiency in irrigation water management because of the irregular shape of numerous plots, and also causes time loss in travel and inconvenience in agricultural management (Nguyen et al., 1996). In order to increase cropland area, reduce fragmentation, rationalize plot size and shape, renovate agriculture infrastructure and promote agricultural production capacity, LC has been implementing in China since the mid-1990s. The goals of LC are carried out by executing the land consolidation projects (LCPs) which can be divided into government-funded projects and enterprise-funded projects. The first set of the government invested LCPs started in 2001. From 2006 to 2010, 124,085 LCPs funded by the national and provincial government were approved and the total areas of these projects were 110,600 $km^2$. Meanwhile, 115,127 LCPs were competed and the total areas of these projects were 61,300 $km^2$, resulting in an increased cropland area of 20,800 $km^2$ which exceeded the areas damaged by disasters and the areas occupied by urbanization during the same period.

LCPs are most often associated with land, irrigation and drainage and road reconstruction which have been found to bring wide and profound impacts to the agricultural system, environmental and economic system (Coelho et al., 1996; Van Dijk, 2000; Coelho et al., 2001; Crecente et al., 2002; Miranda et al., 2006; Zhang, 2008; Yaslioglu et al., 2009; Yu et al., 2010; Reerink and van Gelder, 2010; Zhang and Zhao, 2011). Effects are positive or desirable if they contribute positively to goal realization and negative in the opposite

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case (Van Huylenbroeck et al., 1996). Bonfanti et al. (1997) and Mihara (1996) concluded that land consolidation had impact on the number of patches, the area occupied by different land-uses, the size of patches and the erosion processes. According to Coelho et al. (2001), the changes resulting from LC included farm size, farm-road quality and distance between field plots and farm buildings, irrigation water management system, drainage system and cropping system. Miranda et al. (2006) proved LC influenced property structure in rural areas, land usage, agricultural production and the population size of rural areas. Yaslioglu et al. (2009) found that successfully implemented LCPs increase farmers' satisfaction, promote affinity to agriculture, and consequently contribute to sustainable farm management.

The evaluation of LCP effects was initiated in several European countries and was carried out from three sectors generally: economic, social and environmental evaluation, usually comparing consolidated and non-consolidated areas. Zhang and Zhao (2011) quantified the direct and indirect economic effects of LCPs. Goodale and Sky (1998) proposed how social variables can be introduced in the LCP planning process. Yu et al. (2010) identified and classified the ecological risks in land consolidation, and to develop a framework of theory and method to assess the change of ecological risk degree before and after land consolidation. Usually, several methods can be used to quantify the effects. Cost–benefit analyses (CBA) can be used to quantify LCP contribution to economic growth, while Environmental Impact Assessment (EIA) measures the influences on the environment and Social Impact Studies (SIS) focus on the social effects (Crecente et al., 2002). In addition, in order to carry out the integrated LCP effects evaluation, some researchers focused on developing simulation models or building parametric evaluation approaches to quantify these effects. Coelho et al. (2001) presented a simulation model that incorporated methods for the evaluation of the performance of the agricultural system before and after the transformations proposed in the LCP. Sklenicka (2006) defined the evaluation criteria for the LCP effects on the basis of the size, shape and juxtaposition of the plots, on the basis of natural and social conditions, and on the basis of the economic benefits of the LC process in the Czech Republic. Miranda et al. (2006) also construct a set of criteria and indicators to assess the LCP effects within the general EU guidelines for project evaluation and with the aid of GIS-assisted analyses.

Since the year of 2001, lots of LCPs have been initiated in China. However, there are currently few researches focused on the integrated effects of land consolidation projects. The aim of this paper is to identify the changes resulting from land consolidation projects implementation and further to quantify the resource–environment effects which could measure performances against objectives, and also support the decision-making processes of the LC authorities. This paper firstly presents the changes resulting from the LCP implementation from six main categories and explains the calculations of the resource–environment effects of LCPs. Then, we provide a detailed analysis of changes and resource–environment effects resulting from a land consolidation project and discuss the results obtained. And finally, we report the conclusions of this study briefly.

## Materials and methods

### *Study area*

The study area is situated in Tianmen City of Hubei Province in Central China (Fig. 1). The region of this LCP can be characterized as hilly landscape, with an average elevation of 82.8 m above mean sea level and an average annual precipitation of 1108 mm. The project region involved a total area of 691 ha with a cropland area of 427 ha. The annual income per capita is US$ 508.

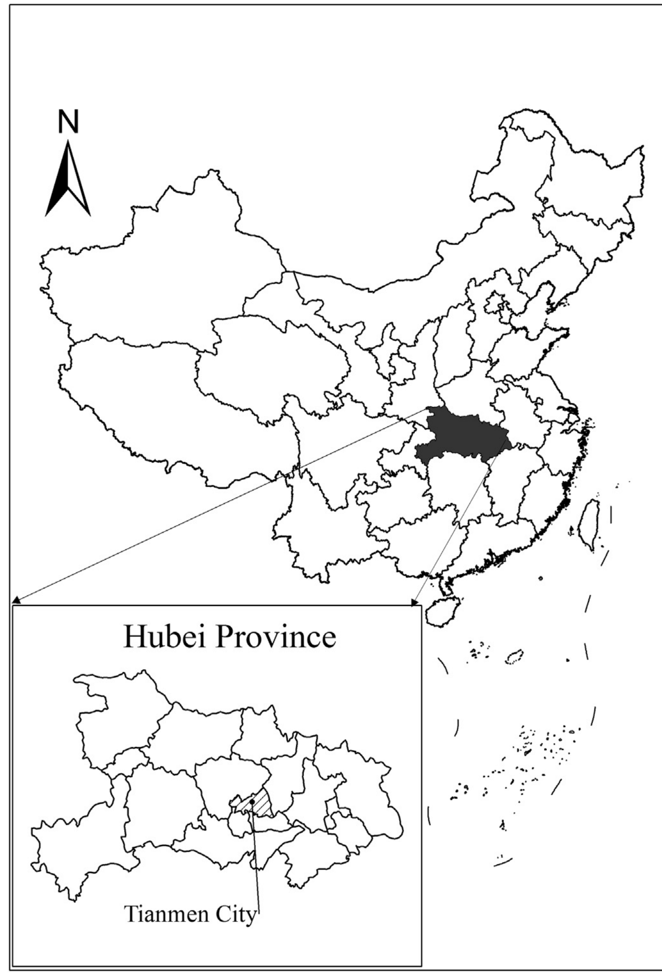


**Fig. 1.** Location of study area.

This LCP of Tianmen City was funded by Land Consolidation Center of Hubei Province in 2003 and was accomplished in 2006. Due to the LCP implementation, cropland area increased from 427 to 546 ha in the consolidation region.

### *The changes resulting from the LCP implementation*

In China, LCPs are most often associated with government-funded engineering works and fall into four general categories. The first type is to amalgamate small plots into large plots by taking out the small ridge of earth that typically divides plots of land. This increases the available cropland area and removes obstacles to the use of agricultural machinery. The second type of engineering work is the construction of agricultural irrigation and drainage systems. The third type is the construction of field- roads. The fourth type plants trees to protect the fields from wind erosion. These techniques have been found to bring changes to the project region. Meanwhile, as referred above, HRS resulted in land fragmentation, i.e. plots belonging to each household were scattered over numerous non-continuous plots. Land fragmentation leads to plots belonging to one production unit being enclosed in that of another, which also increased the number of land property disputes. Land reallocation activities, one of the most important activities of LC, gather the scattered plots and reduce the numbers of mosaic plots after LC. Generally, the changes resulting from the LCP implementation can be split into six main categories:

- available cropland area;
- plot size and plot shape;