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System-dynamic analysis on socio-economic impacts of land consolidation in China

Xiaobin Jin [a, b, *], Xiaoxiao Xu [c], Xiaomin Xiang [a], Qing Bai [b], Yinkang Zhou [a, b]

[a] *School of Geographic and Oceanographic Sciences, Nanjing University, Nanjing 210023, China*
[b] *Natural Resources Research Center of Nanjing University, Nanjing 210023, China*
[c] *School of Civil Engineering, Shenzhen University, Shenzhen 518060, China*

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ABSTRACT

China has been conducting large-scale land consolidation (LC) programs since the late 1990s to ensure national food security, stabilize farmland patterns and coordinate urban and rural development. LC activities, as an essential type of public investment, show significant impacts on national/regional social and economic progress. However, it is difficult to analyze a specific impact, especially a socio-economic one, of an LC program due to its' diversified, far-reaching, and inter-correlated influencing factors. This paper establishes a system dynamics model to simulate the functional mechanism motivated by implementing an LC program, and an LC project in a rural area of mid-eastern China is used as the study case. Four subsystems are included in the proposed system dynamics model, namely the capital input-output subsystem, land use subsystem, agricultural production subsystem and social impact subsystem. All of these four subsystems are connected with each other and each of them is affected by its own "inputs", those being engineering inputs and resource inputs. The simulation result shows that the proposed system dynamics model can effectively incorporate all influencing factors and demonstrate the desired characteristics (such as systematic, complex, feedback-reenter, long-term and dynamic) of socio-economic impacts of an LC program. The system dynamics model, considering the feedbacks and dynamic nature of LC, can function as a novel method to effectively evaluate the socio-economic impacts of LC.

1. Introduction

Since the reform and opening-up policy was put in place in China in the late 1970s, unprecedented urbanization coupled with the conversion of farmland to forest (i.e., "Grain for Green") has led to the increase of built-up areas, the shrinkage of farmland and the degradation of farmland quality (Deng, Huang, Rozelle, & Uchida, 2006; Gao & Liu, 2010). Meanwhile, China also faces a structural imbalance of land uses, wasteful uses of land resources and other serious problems (Long, Liu, Li, & Chen, 2010). A massive population and relatively scarce land resources are the tough reality in China (Bennett, 2008; Tilman, Cassman, Matson, Naylor, & Polasky, 2002) where 19.78% of the world's population needs to be with products from only 7.63% of world farmland (He et al., 2013; Zhu, 2004). These concerns have urged Chinese governments to uphold land consolidation (LC) programs since 1998 to promote both farmland protection and the rational use of land resources.

LC is an important means to promote rural development, crack the current land use contradictions and problems, and guard the channel for reasonable and orderly urban and rural land resources, assets and capital flow (Wang, Zhang, & Cheong, 2014; Yan, Xia, & Bao, 2015). By developing farmland reserves, improving farmland quality, promoting the scale of agricultural production, realizing industrialization management, adjusting the land utilization structure and layout, breaking agricultural modernization constraints, etc., LC exerts extensive and far-reaching impacts on controlling land fragmentation (Niroula & Thapa, 2007; Sklenicka, 2006), increasing land use efficiency (Yan et al., 2015), reducing soil erosion (Mihara, 1996), dealing with nature conservation and environmental issues (Uhling, 1989), ensuring rural development (Sklenicka, 2006; van Dijk, 2007), and promoting rational urban development (Gonzalez, Alvarez, & Crecente, 2004). Moreover, it is of great significance in establishing a foundation for national food security, boosting agricultural infrastructure conditions, improving

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* Corresponding author. 163 Xianlin Avenue, Nanjing 210023, China.
E-mail address: jinxb@nju.edu.cn (X. Jin).

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the utilization efficiency of production factors, and structuring a platform for urban and rural harmonious development (Archer, 1994; Mobrand, 2006; Xu, Tang, & Chan, 2011).

According to “the National rural land consolidation monitoring and regulation system” maintained by the Ministry of Land and Resources in China (MLR), during a period from 2006 to 2012, more than 152,000 LC projects had been deployed and the allowance of 327.4 billion RMB (1 USD = 6.5 RMB) had been invested. By the end of 2012, 8.28 million ha of farmland had been renovated and 2.72 million ha farmland had been newly added (Guo et al., 2015). Proposed in “the National land consolidation plan (2011–2015)”, 26.7 million ha of prime farmland (about 22% of total national farmland) should have been built up by the year 2015, while an additional 26.7 million ha shall be built up by 2020 (Ministry of Land and Resources, 2012).

The gigantic LC investment is not only manifested in the scale of LC projects, but is also demonstrated in its continuous impacts on agricultural production and related social issues. Studies of LC impacts (mostly benefits) focus on its effects on the national economy (Guan, Jin, Zhou, Zhou, & Yang, 2013), resources (Zhang, Zhao, & Gu, 2014), society (Crecente, Alvarez, & Fra, 2002), landscape (Bonfanti, Fregonese, & Sigura, 1997), and ecosystem (Shuai, Chao-Fu, Xin-Yue, & You-Jin, 2011). Research methodologies include fuzzy evaluation, input-output analysis, analytic hierarchy process, ecosystem service evaluation, and cost and benefit analyses. For example, Guo et al. (2015) identified and measured the effect of LC on the multi-functionality of cropland ecosystems via set pair analysis and fuzzy assessment, finding that the widespread implementation of LC projects has a great impact on the crop production system. As found by Guan et al. (2013) from the perspective of input-output, the total multiplier of LC project investment on the national economy is about 2.08 and the direct driving effect is remarkable. By using the analytic hierarchy process, Shuai et al. (2011) studied ecological compensation measures and ecological effects and concluded that the eco-design in LC projects is beneficial to the coordinated development of economy, ecology and society. By carrying out a cost and benefit analysis of LC projects, Papousek (2011) found that land accessibility measures in LC projects are critical for the dynamic and sustainable development of rural regions. To evaluate the effects of LC on ecological connectivity, Wang et al. (2015) developed coefficients of ecosystem service values and found that LC has certain negative impacts on ecosystem services. Although having made some progress in impact analysis, most previous studies are mainly focused on specific indicators, while leaving out the dynamic nature and relations between indicators, which may imply that these studies can only attain static results. It is well acknowledged that socio-economic impacts of an LC project may persist for a certain period even after an LC project has been implemented and their intensities may change over time. In addition, there is a multitude of feedback during the implementation period and the benefit period of an LC project (Van Huylenbroeck, Coelho, & Pinto, 1996). These render these researches to be comprehensive and effective.

This study is therefore proposed to establish a comprehensive model by using system dynamics to simulate the functional mechanism motivated by implementing an LC project. The novelty and strength of our study is mainly reflected in two perspectives: (1) incorporating feedback and dynamics of socio-economic impacts during the implementation period and the benefit period of LC projects into project evaluation, which is vital but has been utterly neglected by previous studies; (2) conducting scenario simulation, which is highly valuable to investment decisions before initiating the project implementation but has been largely untouched in previous studies.

With an LC project in rural areas of mid-eastern China as the study case, a system dynamics model has been fulfilled by using Vensim PLE® software. The model is expected to combine key nodes, transmissions, and feedbacks to better the understanding of the mechanism of the LC’s socio-economic impacts.

2. Methodology and data

In this study, an LC project exists from its establishment to its benefits-exhausted status, that is, the life of a project that mainly consists of two phases: the implementation period and the benefit period. Generally, the implementation period is from a project’s establishment to its construction completion and acceptance, which usually takes two to three years. The benefit period is from a project’s completion and acceptance to the end of its engineering’s life time, which is generally around 15 years (*as prescribed by the standard of well-facilitated capital farmland construction*, *TD/T 1033–2012*).

2.1. Model summary

There are many socio-economic influencing factors in an LC project and relationships among these factors are extremely complicated. Moreover, socio-economic impacts may persist for a certain period even after an LC project has been implemented and their intensities may change over time. This renders it especially difficult to consider research based on benefit evaluation to be comprehensive and effective. A system dynamics model is convenient in dealing with all these issues.

Based on feedback-control theory and computer simulation technology, a system dynamics model focuses on the structure of a complex system and relationships between functions and dynamic behaviors (Forrester, 1961). These have been widely applied in fields such as economic development (Tauheed & Wray, 2006), energy and resources management (Ansari & Seifi, 2013), urban planning (Shen et al., 2009), ecological environment management (Guan, Gao, Su, Li, & Hokao, 2011), macro-economic policy impact analysis (Wu, Huang, & Liu, 2011), and socio-economic impact analysis (Wei, Yang, Song, Abbaspour, & Xu, 2012).

Generally, the setting up of a system dynamics model consists of four steps (Forrester, 1961): (1) confirming the research problem, which includes tasks to define problems that need to be solved, defining the boundary and sorting out all variables; (2) conducting causality analysis, which requires the explaining of intrinsic relationships among factors in the system, and constructing causal-loop diagrams; (3) drawing stock-flow diagrams, which aim to establish mathematical equations and reveal relationships among variables based on just derived stock-flow diagrams; and (4) validating the model to establish function relationships, inputting raw data, and conducting computer simulation.

2.2. Study area

Our study case is an LC project in Fulin Town located in the northeast of Changsha County, Hunan province. The area is characterized by a long history of agricultural production (Fig. 1). Rice is the main crop and other economic crops include tea, fruit and vegetables. Confined by the space requirement of this paper, all necessary information about the study area has been listed in detail in Supplementary material S1.

2.3. Data sources

Official data sets, field investigation and expert consultation are employed to collect data for the study.

Official data sources include Changsha City Statistical Yearbook,