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Reviews on land use change induced effects on regional hydrological ecosystem services for integrated water resources management

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ABSTRACT

This paper proposed to provide valuable information for integrated water resources management through evaluating the research on the interaction mechanism among land use changes, regional hydrological ecosystem services and human well-being. Firstly, the driving mechanism of land use and land cover changes was introduced in this paper. Secondly, the overview of the interaction mechanism among land use and land cover changes, regional hydrological ecosystem services and human well-being was given. Based on the meta-analysis, land use changes have a profound influence on regional hydrological ecosystem services, and the variation of hydrological ecosystem could benefit or impair human well-being. Finally, two suggestions were emphasized for managers or policy makers for the future integrated water resources management: (1) Proper land use makes for the water resource management; (2) Blindly pursuing the provisioning services weakens other services of hydrological ecosystem.

1. Introduction

There is growing concern that water crisis caused by human activities is severely threatening human survival and impairing the law of nature (Schindler and Donahue, 2006; Bakker, 2012). It poses challenges on managers or policy makers for developing scientific and proper plans for preserving water resources or saving water use and leads to the recognition that the management of water resources requires a holistic approach. Integrated water resources management (IWRM), an empirical concept built up from the on-the-ground experience of practitioners, is now the dominant paradigm for relieving the water-related issues (Calizaya et al., 2010). The UN provided the most-quoted definition (1992): a process to promote the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. Therefore, IWRM can be enhanced through water resource modeling and land use planning. With the exploration on the interconnections between Land Use and Land Cover Changes (LUCC) and regional hydrological ecosystem services or water-land coupling system, the solutions for improving water environment are no longer limited to study water itself, and the research on the interaction mechanism of LUCC and hydrological ecosystem services could offer another accessible path for integrated water resources management.

The dynamics of LUCC and their resulting consequences are one of the central themes of global change research (Lambin et al., 2001; Turner et al., 2007). With the development of theory and methodology of the dynamics of land system change and the establishment of the Global Land Project (Liu et al., 2014), researchers have increasingly realized the close relationships among natural environmental evolution, terrestrial ecosystem processes, human production activities and the dynamics of LUCC (Deng et al., 2014). LUCC considered as an important driving force for the hydrological ecosystem change, enormously alters the structure of the earth surface system as well as its material and energy flows. In the past decades, aside from the study on the process and driving

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mechanism of LUCC at different spatial scales, the investigation upon the externality of LUCC, especially the effects of land use changes on regional hydrological ecosystem services, was another hotspot, due to the awareness of water as an increasingly scarce yet essential resource for sustainable development (Wu et al., 2014). As the enhanced land use intensity and growing land cover diversity dramatically varies the biogeochemical circulation, hydrological process and landscape of the earth surface, these variations affect the status, characteristics and functions of the regional hydrological ecosystem (Deng et al., 2013a).

The Millennium Ecosystem Assessment (MA) synthesizes and analyzes the theory and methodology of ecosystem services framework, and makes plenty efforts to illustrate its widespread importance and strengthen recognition and knowledge of societal dependence on ecosystems (Van Kamp et al., 2003; Pejchar and Mooney, 2009; Smith et al., 2013). Hydrological ecosystem services are just one category of diverse services providing tremendous beneficial interests for people. As human well-being varies with ecosystem services change reported by Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Service (IPBES) in 21st century, hydrological ecosystem services involving freshwater supply, spiritual uses and flood damages have both negative and positive impacts on human-well-being. Thus, the IWRM is required to governance the consequences induced by alteration of hydrological ecosystem services for optimizing the human benefits. Of course, there is a large amount of evidences to clarify the internal and external mechanism of the changes of hydrological ecosystem services for integrated water resources management (Daily and Matson, 2008; Polasky and Segerson, 2009; Gascoigne et al., 2011).

What is the driving mechanism of dynamics of LUCC in terms of natural conditions and socio-economy? How does the LUCC act on regional hydrological ecosystem services? What are the impacts of regional hydrological ecosystem services on human well-being? And how does the IWRM do to improve the human well-being based on the effects of LUCC upon hydrological ecosystem services? This paper gives the answers in tandem with an investigation on the interaction among LUCC, regional hydrological ecosystem services and human well-being. Then the remainder will introduce the IWRM through land use regulating in the context of research on the impacts of LUCC on hydrological ecosystem services. Last but not least, conclusions and expectations of relevant study on LUCC and regional hydrological ecosystem services and IWRM —will be given.

2. Driving mechanism of LUCC

The analysis on driving forces of LUCC is one of the vital contents for LUCC research (Singh and Shi, 2014), their relationship is often quantified by combining use conceptual model and mathematical model, introducing mathematical statistics methods and adopting the historical and current LUCC data (Deng et al., 2013b). The drivers of LUCC are usually divided into two major categories: natural factors and socioeconomic factors (Weng, 2002). Naveh (1995), Crow et al. (1999), Veldkamp and Verburg (2004) and Huang et al. (2007) made multiple efforts to identify the natural elements of LUCC. Natural factors often refer to natural and environmental characteristics, climate change, soil condition, vegetation succession, periodic interference, and other natural processes (Wu et al., 2013). Millette et al. (1995) and Zhen et al. (2014) made achievements on socio-economic elements. As the report of International Geosphere–Biosphere Program (IGBP) and International Human Dimensions Programme on Global Environmental Change (IHDP) stated (Xu et al., 2013), socio-economic elements include demographic change, poverty status, technological progress, economic growth, political and economic structure, and core value of the society. However, the main driving force remains uncertain due to the variation of regional characteristics.

2.1. Natural factors of LUCC

First and foremost, the differences of natural conditions determine regional heterogeneity of the LUCC in spatial and temporal, containing the heterogeneity of land suitability, natural structure of LUCC and natural condition of land system (Li et al., 2013). In the long run, the physical elements provide basic condition for LUCC, especially geology, geomorphology and soil. Except for the human activities, organism and water resource are the components of the land and also drives the natural dynamics of land through the phenomena of surface erosion, transportation and deposition acting on the formation of the land. In the natural system, climate change is usually considered as the main driver of LUCC, and their relationship is complex. Recently, the popular method is to assess the effects of future climate change on LUCC by using an economic model based on exogenous environment variables. The fourth assessment report released by Intergovernmental Panel on Climate Change (IPCC) in 2007 presented that climate change induced by human activities would bring adverse effects on society, economy and environment, even alter the way of land using, in light of the prediction for the changes of global temperature, sea level and snow cover in the next 100 years by different models. According to the results of the simulation and prediction for LUCC in different climate scenarios, land use types vary with climate change in different typical regions, such as the urbanization region and the afforestation region.

2.2. Socio-economic factors of LUCC

Socio-economic factors of LUCC are land demand, land investment, urbanization, land use intensity, land ownership, land privatization, population, technology, economic growth, policy, core value of the society, etc. The relevant research established index system for LUCC and constructed LUCC model considering the coupling characteristics of LUCC model and other global environmental change models to simulate and predict the dynamics of LUCC (Li et al., 2013). With the advances of global urbanization, growth of population, and boom of agricultural activity and industrialization, artificial influences cannot be ignored. Based on the future socio-economic development conditions and national policies of China, Deng et al. (2008) set up three scenarios, namely Usual scenario, Rapid Economic Growth scenario and Cooperate Environmental Sustainability scenario, to simulate the spatial structure of LUCC in 2005–2010 taking natural factors and socio-economic factors into account by adopting Global Change Assessment Model (GCAM), and utilized Dynamics of Land System (DLS) to analyze the future land use change in spatial and temporal in China. Several international case studies also revealed an intricate relationship between population and LUCC (Lin et al., 2014), which implies that it is not linear dependence due to the large regional differences and temporal variation. Thus, it is necessary to comprehensively understand the driving mechanism of LUCC in global range and carry on the research by conducting the case studies for comparative analysis (Lambin and Geist, 2001).

Due to heterogeneity of the way and the consequences of these factors acting on LUCC, we treat all these factors as a whole to simplified their sophisticated relationships, and reveal the processes and the evolution of inherent forces of LUCC via the research on structure, function and the material/energy flows of LUCC (Wu et al., 2014). Therefore, the research on driving mechanism of LUCC increasingly involved the integrated apply of natural and social sciences.