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Conflict or coordination? Assessing land use multi-functionalization using production-living-ecology analysis

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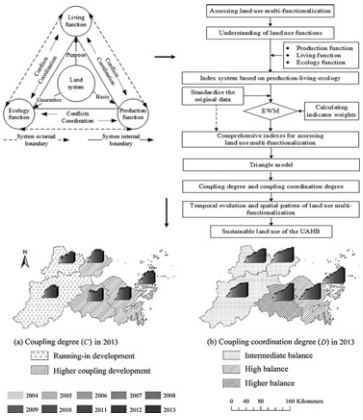
HIGHLIGHTS

- Land use multi-functionalization (LUMF) promotes coordinated urbanization.
- A production-living-ecology based index system is proposed for LUMF assessment.
- LUMF assessment was conducted in a six-city urban agglomeration in eastern China.
- Land use sub-functions displayed strong spatial and temporal variabilities.

GRAPHICAL ABSTRACT



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ABSTRACT

Land use multi-functionalization (LUMF) promotes efficient and sustainable land use, reduces land pressures from limited land resources, and elevates urbanization quality in the midst of the increasingly tense relationship between humans and nature. In this study, we propose a new conceptual index system using system science, entropy weight method, triangle model, and coupling coordination degree model for LUMF assessment as well as an analysis of the relationship among land use sub-functions. This framework was applied to six cities in the urban agglomeration around Hangzhou Bay (UAHB) in eastern China's Zhejiang Province using twenty-two indicators in terms of production-living-ecology analysis during 2004–2013. The UAHB LUMF level increased over the past ten years, being affected by the designated functions and the "planning effect" for the six cities in the UAHB. The relationships among land use sub-functions in the six cities displayed strong variabilities at the spatial and temporal scales. The overall patterns of the relative importance of these sub-functions also differed from each other. Our research also shows that urban development in the UAHB had focused more on economic growth than on ecological protection and the regional development in the UAHB's six cities was unbalanced. Therefore, we suggest urban and land use management need to embrace more integrated planning and design in order to maintain efficient and sustainable land use.

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1. Introduction

A land use system can be described by the system's structure and functions (Costanza, 2012; Zhou et al., 2015). A healthy land use system not only has structural integrity, but also functional continuity and additivity (Schluessel et al., 2008). A system's functions reflect the system's nature, behavior, and the relationships between the system and its external environment (Zhou et al., 2015).

A land use system is composed of economic, social and ecological subsystems (Bach et al., 2015; Verstegen et al., 2016) that generally perform production, living, and ecology functions (Fig. 1). Land use multifunctionality, reflecting the status and performance of a regional land use, is an important set of concepts and methods for assessing land use changes and effects on sustainable land use. Land use multifunctionality refers to functions that provide products and services through different land use types (Zhang, 2005).

Land use functions evolve in a complex process from a single function into coordinated multi-function land use. Sustained and brisk economic growth requires diversified land use types or patterns, or land use multifunctionalization (LUMF), which, however, is marred with land use function conflicts (or land use conflicts) (Montanari et al., 2014; Tudor et al., 2014). Land use function optimization therefore aims to solve land use function conflicts and improve land use quality. Production-living-ecology analysis is an approach for assessing the coordination or conflict of land use functions (Ma et al., 2014; Zhang et al., 2015).

China experienced rapid urbanization over the past 30 years, conveying accelerated socioeconomic development and improved quality of life. Nevertheless, rapid urbanization also caused a number of development constraints, (Lian and Lejano, 2014; Pan, 2012; Wei and Ye, 2014; Zhu, 2013; Zhu, 2012), such as sudden increase in population, excessive land uses (Gao et al., 2016; Ge et al., 2016), environmental damage (Wang et al., 2008a, 2008b; Yang and Chen, 2015), and loss of biodiversity (Yao et al., 2015a, 2015b; Yi et al., 2014).

Development constraints including those between production and living spaces (Wang et al., 2015a, 2015b; Yang et al., 2012; Ye et al., 2014; Zhang and Fung, 2013), economic development and ecological protection, (Adam et al., 2015; Wang et al., 2008a, 2008b; Wei and Ye, 2014; Zhu, 2013; Zhu, 2012), urban expansion and cultivated land protection (Jian et al., 2013; Li et al., 2015; Liu et al., 2015), and supply and demand of land-water resources (Ho, 2014; Nath et al., 2015; Xu et al., 2011), will last for an extended time in China and continue to be regional issues manifested as "functional conflicts of land use". Multifunctional land use (or mixed land use) is an important path to solving these conflicts by coordinating social and economic development (Steinhäußer et al., 2015) and promoting efficient and sustainable land use.

Contemporary land managers and users have started to realize that economic production is not the only function of land use that a piece of land can provide; the same piece of land also provides social, environmental, and ecological functions (Liang et al., 2013; Peng et al., 2016). Gradually, land use management has moved away from focusing on one single production function to consideration of multi-functional land use (Song et al., 2013). Recently, more studies are paying close attention to "multi-functionality of land use or mixed land use" (Barnaud et al., 2013; Brown and Castellazzi, 2014; Delgado-Matas et al., 2015; Peng et al., 2015; Shi and Yang, 2015; Song et al., 2015; Song et al., 2012; Torre and Darly, 2014). This opened up a new research direction on sustainable land use.

Previous studies on LUMF mainly focus on the functions of agricultural and cultivated lands (Gao et al., 2012; Song et al., 2015), however, most land use changes occurred in areas with rapid urbanization (Deng et al., 2009; Deng et al., 2015; Lian and Lejano, 2014; Wei and Ye, 2014). Other studies were mainly interested in mixed land use planning and mapping (Galletti and Myint, 2014; Hara et al., 2010), mixed land use environment effects (Ge et al., 2016; Jacobs-Crisioni et al., 2014; Liang et al., 2013; Pacheco and Sanches Fernandes, 2016; Pacheco et al., 2014; Qiu and Wang, 2014; Valera et al., 2016; Valle Junior et al., 2015; Valle Junior et al., 2014a; Valle Junior et al., 2014b), and mixed land use spatial evolution (Shi and Yang, 2015).

The Report on the Government's Work delivered by Chinese Premier Li Keqiang at the Fourth Session of the Twelfth National People's Congress on March 5, 2016 (Li, 2016) emphasized that the objectives of land use and consolidation in China should focus on integrated development for production, living, and ecology. We propose a conceptual index system for LUMF assessment in terms of three aspects of land use functions of production-living-ecology in a land use system. Secondly, we demonstrate the use of the proposed LUMF assessment index system in the six rapidly urbanized cities of the urban agglomeration around Hangzhou Bay (UAHB) using entropy weight method (EWM), triangle model, and coupling coordination degree model (CCDM). The workflow of our study is shown in Fig. 2.

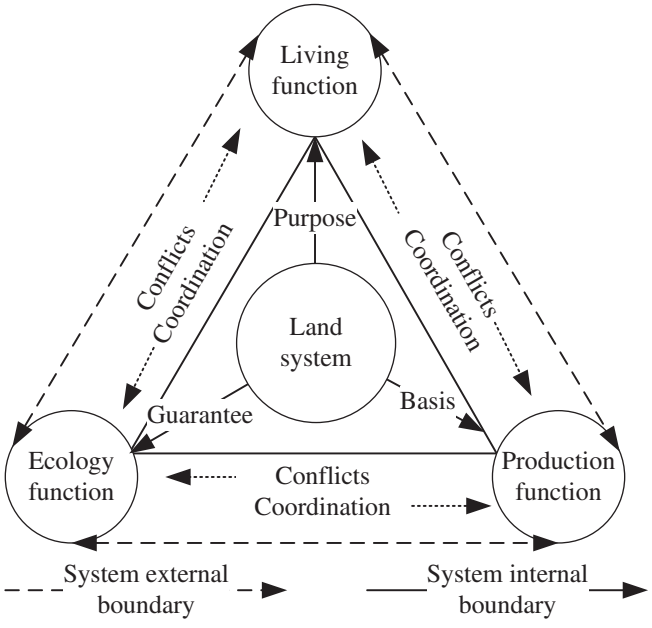

Fig. 1. Relationship and conflicts among three fundamental functions in a land use system.

2. Materials and methods

2.1. Conceptual index system

Fig. 1 illustrates the relationships among production, living, and ecology functions of a land use system. The production functions are the system's basis, the ecology functions are the system's guarantee, and the living functions are the system's ultimate purpose.

The production functions are the foundation of a land use system and they are the outputs of the production and operation activities in a land use system. These activities include material supplies for human activities, transportation and trade, and other production and business operation activities. In this study, the production functions include agricultural production function, economic growth function, and transportation function.

The ecology functions are the support of a land use system. They refer to a series of natural conditions that support high-quality human production and life. In this study, the ecology functions mainly consist of resources security and ecological balance. Although the ecological functions of a land use system cannot provide material output, they provide a safeguard for human production and livelihood.

The living functions are the ultimate purpose of a land use system. Improvement is achieved through production functions and ecology functions. The living functions of a land use system provide employment, housing, consumption, and leisure entertainment for humans.