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Impact assessment of land use planning driving forces on environment

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ABSTRACT

Land use change may exert a negative impact on environmental quality. A state–impact–state (SIS) model describing a state transform under certain impacts has been integrated into land use planning (LUP) environmental impact assessment (LUPEA). This logical model is intuitive and easy to understand, but the exploration of impact is essential to establish the indicator system and to identify the scope of land use environmental impact when it is applied to a specific region. In this study, we investigated environmental driving forces from land use planning (LUPF), along with the conception, components, scope, and impact of LUPF. This method was illustrated by a case study in Zoucheng, China. Through the results, we concluded that (1) the LUPF on environment are impacts originated from the implementation of LUP on a regional environment, which are characterized by four aspects: magnitude, direction, action point, and its owner; (2) various scopes of LUPF on individual environmental elements based on different standards jointly define the final scope of LUPEA; (3) our case study in Zoucheng demonstrates the practicability of this proposed approach; (4) this method can be embedded into LUPEA with direction, magnitudes, and scopes of the LUPF on individual elements obtained, and the identified indicator system can be directly employed into LUPEA and (5) the assessment helps to identify key indicators and to set up a corresponding strategy to mitigate the negative impact of LUP on the environment, which are two important objectives of strategic environmental assessment (SEA) in LUP.
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1. Introduction

The relative shortage of land resources with increasing human demand for food or service leads to the excessive use of land, a fundamental resource to human development, resulting in considerable environmental problems on various perspectives. Thus, it is essential to plan land use patterns and distribution carefully with the consideration of these environmental challenges. Environmental impact assessment (EIA), a means to identify potential environmental and social impacts of human actions, has been widely used in various human activities including land use planning processes (Coleby et al., 2012). EIA aims to examine, analyze, and assess the planned activities to ensure environmentally sound and sustainable development (Ramanathan, 2001). To minimize the negative impacts and maximize the positive impacts on the environment, strategic environmental assessment (SEA) has been used to integrate EIA in land use and planning (Jiricka and Pröbstl, 2008), and several practical frameworks have been introduced or developed. For example, Loiseau et al. (2013) adapted a revised framework based on lifecycle assessment (LCA) to land use planning environmental impact assessment (LUPEA) with a theoretical case study of a territory; Barral and Oscar (2012) developed a methodological protocol of SEA to incorporate the value of ecosystem services in LUP and García-Montero et al. (2008) developed a screening method to rapidly evaluate the LUPEA. Other frameworks or methodologies, such as the health index/risk evaluation tool (HIRET) (Bien et al., 2004) and the land suitability index (LSI) (Marull et al., 2007), have been introduced into LUPEA as well (Bien et al., 2004; Marull et al., 2007). Some assessment methods/frameworks related to LUPEA are listed in Table 1.

Spatial land planning is a method for allocating land to different uses in the future (Sutanta et al., 2013). Land use planning considers spatio-temporal arrangement of land resources according to regional development strategies, especially at a county level. In recent years, geographical information system (GIS) techniques have been widely applied to acquire indicator values for the spatial assessment of LUP (Campagna and Matta, 2014; Chen et al., 2009a), and have provided a visual and scenario tool for LUPEA (Bishop and Stock, 2010; Bishop and Miller, 2007; Rivas Casado et al., 2014). But many early studies (e.g. Tao et al., 2007; Barral and Oscar, 2012; Geneletti, 2012; Amir et al., 1997) ignored the extended spatial influence of LUP, which is the externality of land use environmental impact. Another important but often ignored challenge in LUPEA is the dynamic impacts during the implementation of LUP. Some assessments (e.g. García-Montero et al., 2008; Barral and Oscar, 2012; Marull et al., 2007) calculated the impact after the implementation of LUP and compared it with the environmental quality in the base year, but seldom investigated the dynamic environmental states

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Table 1
Summary of assessment methods/framework of land use environmental impact assessment.

Method/framework	Researcher	Major achievement	Study area/case
Health index/risk evaluation tool (HIRET)	Bien et al. (2004)	Dynamic human health risk assessment in long-term period related to land use planning was spatially performed within a GIS framework.	A site contaminated by benzene.
Land Suitability Index (LSI) assessment tool	Marull et al. (2007)	Quantitative and cartographic assessment of the suitability for land development is executed with GIS calculation.	The municipal urban plans in the Barcelona Metropolitan Region (BMR).
Environmental screening tool	García-Montero et al. (2008)	With the usage of GIS raster screening model, the critical environmental areas to limit the area involved in the land use plans were` identified.	Spanish Transport Infrastructure Plan (PIT 2000–2007) guidelines.
Integrated methodology containing SEA procedure, sustainable assessment framework, and an SEA management system	Chen et al. (2009)	The comprehensive impacts of six possible scenarios by 2011 on ecology, society, and economy are simultaneously assessed.	Golf Course Installation Policy in Taiwan
A fuzzy matter-element model and factor-overlay method in eco-environmental sensitivity assessment for LUP.	Zhang et al. (2011)	Categorized eco-environmental sensitivity was spatially figured out with GIS based factor-overlay.	Yicheng City in China
Ecosystem services valuation based methodological protocol	Barral and Oscar (2012)	Achieve the ecosystem services provision and assessed the ecological contribution of lands.	Balcarce, Southeast Pampas Region (Argentina)
Life cycle assessment (LCA) embedded in LUPEA	Loiseau et al. (2013)	Achieve the environmental impacts and the goods and services of associated land use scenario.	A theoretical case study of territory
State–impact–state (SIS) model	Chen et al. (2014)	Obtain the spatial and multi-temporal assessment of LUP environmental impact.	Zoucheng County in China.
Minimum indicator set with value-function based approach	Recatalá and Sacristán (2014)	Be capable to predict environmental impacts on natural resources at low cost.	Valencian region, a representative area of the European Mediterranean Region.

impacted by the implementation of LUP, resulting in the incompleteness of process evaluation in LUPEA.

We developed a state–impact–state (SIS) model as an easy tool for both theoretical analysis and the application of LUPEA (Chen et al., 2014). Table 2 describes the procedure of LUPEA using the SIS model and the function/purpose of each step. To apply the SIS model to the LUPEA of other regions, one should explore the impact from LUP on the environment before constructing the indicator system and identifying the scope of land use environmental impact in target areas. The driving forces from LUP (LUPF) on the environment require to be systematically analyzed to guide its application to other areas.

The assessment of LUPF helps to build the indicator system and provide the impact scope of individual environmental elements and indicator value for LUPEA. With SEA embedded in LUP, the indicator system and indicator values can be directly employed into LUPEA, and the SEA scope can be obtained based on the overlay of individual environmental elements. The LUPF assessment is also capable of identifying key indicators and of formulating corresponding strategies to mitigate the negative impact on the environment, the two important issues that need to be dealt with in SEA. In this study, we first explored the theory of LUPF, including its conception, components, types, and scope, and then assessed the environmental LUPF by a case study in Zoucheng County, China, to test the feasibility of the model.

2. Conceptualizing the LUPF on the environment

Chen et al. (2014) introduced a SIS model to be integrated into LUPEA. This model is a conceptual framework describing the structure and object transformation from one state to another under certain LUP impacts. For example, a regional environment is an object with several elements, such as atmosphere, water, soil, and landscape, and has a function to purify the pollutant and guarantee the development of society. Object can be described and assessed based on certain temporal states and the transform between states. Each state is described and analyzed based on the contribution of individual interior elements, in other words, it is described as an overall assessment of a system containing several characteristics/indicators. In practice, GIS techniques provide a power tool for the assessment of LUPF. The spatial and dynamic impacts of LUPF on the environment can be determined using spatial analysis, 3D, and collaborative virtual analysis (Bishop and Stock, 2010; Bishop and Miller, 2007; Rivas Casado et al., 2014).

Table 2
The procedure of LUPEA using the SIS model and the function/purpose of each step.
Chen et al. (2014)

Steps	Function & purpose
Analysis of LUP impact on the environment	The analysis is based on the LUP scheme and regional environmental features. The LUPFs on the environment and the environmental concerns are figured out in this step. It aims at building the basis for constructing environmental structure with the environmental elements.
Identification of impacted environmental elements	The environmental concerns due to LUPFs help to identify the impacted environmental elements. The major impacted elements are identified and corresponding indicators reflecting the quality of individual elements are developed in this step.
Definition of the environmental states in the base year and different planning years.	Based on the concerns of relevant participants or criterions, the environmental states are defined using the SIS model. The states usually contain a base year and different planning years. It sets the checking time for LUPEA.
Calculation of selected indicator values	Selected indicator values in each checking time are assessed. They provide the data base for LUPEA to obtain integrated and comprehensive results. The major impacted indicators and correlated elements can be identified in the steps.
Assessment of LUP environmental impact	This step obtains the final assessment of LUP on the environment. With the comparison of each result in individual states, the environmental change and its spatio-temporal dynamics are figured out.
Identification of key indicators, development of environmental mitigation measures and alternative LUP scheme.	This step is optional since the assessment is obtained in the previous step. However, identification of key indicators, development of environmental mitigation measures and even the development of alternative LUP scheme are rather important to mitigate the environmental impact.

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