Journal of Cleaner Production 144 (2017) 100–106

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

A review of Chinese land suitability assessment from the rainfall-waterlogging perspective: Evidence from the Su Yu Yuan area

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ARTICLE INFO

Article history:
Received 17 September 2016
Received in revised form
16 November 2016
Accepted 30 December 2016
Available online 2 January 2017

Keywords:
Land suitability assessment
Rainfall-waterlogging risk
China

ABSTRACT

Land suitability assessment is a fundamental process in various types of space control planning and land development, due to its effects on proper land use and reasonable urban layout. However, this form of assessment has also received much criticism for its theoretical and empirical deficiencies. This study aims to review Chinese land suitability assessment from the perspective of rainfall-waterlogging focusing on the Su Yu Yuan area in Changsha. It finds that more than half of the land in the Su Yu Yuan area that is assessed as (very) suitable for urban development has high risk of rainfall-waterlogging. The prevailing Chinese land suitability assessment method is therefore deficient as it cannot accurately reflect the rainfall-waterlogging risk of land use. To refine the land suitability assessment, it is suggested that either (1) the indictor “inundation degree of flood” is replaced with “rainfall-waterlogging risk” or (2) rainfall-waterlogging risk assessment results are superimposed onto land suitability assessment results for regions with plentiful rainfall and low-lying terrain.

1. Introduction

Land suitability assessment is the process that determines the fitness of a given tract of land for a defined use (Steiner et al., 2000). This assessment can guide the spatial organization of land with high efficiency and optimum benefits, and evaluate the relative potential of development and refine zoning (Fan et al., 2011). Land suitability assessment has become a basic tool in urban and rural space control planning and land development (FAO, 1993; Shi et al., 2007; Soltani et al., 2013). It has also been extensively applied in the assessment of agricultural land (Feizizadeh and Blaschke, 2013), land habitats for animal and plant species (Store and Kangas, 2001), landscape evaluation and planning (Girvetz et al., 2008), and environmental impact assessment (Marull et al., 2007; Rojas et al., 2013).

Its extensive utilization has made it the focus of numerous research works by many scholars (for example, Ouyang and Wang, 1995; Jiang and Eastman, 2000; Malczewski, 2006; Du et al., 2007; Azizi et al., 2014; Zabihi et al., 2015), and much has been contributed to its improvement. Land suitability assessment is a multi-indicator system that typically consists of dozens of natural, ecological, social, and economic indicators (FAO, 1976; Jafari and Zaredar, 2010). To acquire more accurate assessment results, scholars have focused on indicator selection guidelines and research has progressed in several areas, including natural environment–social economy combinations (Du et al., 2007; Li et al., 2013; Mao et al., 2013), resistance-motivation combinations (Fan et al., 2011; Peng et al., 2012), and potentiality constraint force combinations (Zong et al., 2008; Peng et al., 2015).

Research also focuses on the weight assignment of each indicator, and includes the ecological niche suitability model (Ouyang and Wang, 1995), weighted linear combination (WLC) (Dai et al., 2001), the weighted potential-constraint method (Zong et al., 2008), analytic hierarchy process (AHP) (Javadian et al., 2011; Park et al., 2011), analytic network process (ANP) (Azizi et al., 2014), ordered weighted averaging (OWA) (Jiang and Eastman, 2000; Malczewski, 2006), ideal point method (IPM) (Ekmekçioglu et al., 2010), and land suitability index model (Marull et al., 2007).

In addition to methodological discussions on indicator selection and weight assignment, scholars have examined the proper indicators that can better reflect the actual land situations. In the hydrology aspect of land suitability assessment, the literature has

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http://dx.doi.org/10.1016/j.jclepro.2016.12.162
0959-6526/

introduced new factors such as precipitation, ground water table, watershed order. For example, Li et al. (2007) chose water resource density as the hydrological factor in their assessment. Fontes et al. (2009) proposed evaluating land suitability by using the GeoTec index, and the hydrological index is determined by the potential and actual amounts of evapotranspiration and water surplus, or the excess of precipitation over evapotranspiration. Gong et al. (2012) conducted a rating of surface water regions in the land suitability assessment system. Zabihi et al. (2015) favored annual precipitation as the rating criterion of hydrological factors. Bozdağ et al. (2016) selected precipitation and the phreatic line as indicator of hydrological analysis.

Specifically focusing on rainfall-waterlogging risk related indicators in the aspect of hydrology aspect, Yu et al. (2009) used non-flooding areas as an indicator by combining the digital elevation model (DEM) and historical flood disaster analysis. Rodriguez-Gallego et al. (2012) evaluated flood frequency based on terrain altitude in the assessment process. In China, the flood inundation degree is selected as the rainfall-waterlogging risk indicator in prevailing land suitability assessment, following the Standard of Urban and Rural Land Assessment (CJJ132-2009). This indicator is calculated based on historical inundation height. However, it has received criticism for its omission of the horizontal flow character of rainfall and flood (Marsh, 2005).

In China, land suitability assessment has also become a prevailing practice in space control planning and land development. To improve land suitability assessment practices, the Ministry of Housing and Urban-Rural Development issued the Standard of Urban and Rural Land Assessment (CJJ132-2009) in 2009. The standard is now an industry norm, and is widely used in land suitability assessment.

Land suitability assessment has been extensively applied to city development in China and other countries, but has also received much criticism for its theoretical and empirical deficiencies (for example, Li et al., 2007; Fontes et al., 2009; Ekmekçioglu et al., 2010; Gong et al., 2012; Zabihi et al., 2015; Bozdağ et al., 2016). Therefore, this study aims to review Chinese land suitability assessment from the perspective of rainfall-waterlogging risk, which is seldom highlighted in the literature. Su Yu Yuan, a typical hilly area in the south of China, is selected as the study area.

Apart from introduction and brief overview of literature, the remainder of this paper is structured as follows. The second section presents the study area and the methodological approach. Land suitability assessment and rainfall-waterlogging risk assessment follow in the third and fourth sections, respectively. The main research findings are then discussed and concluded in the end.

2. Research methodology

2.1. Study area

Changsha is the capital city of Hunan province and is located in the central region of China. Many rivers and lakes have watershed areas reaching as high as 11,819 km^2in Changsha. Due to the subtropical monsoon climate, the city's annual average rainfall is 1483.6 mm, concentrated in the period from April to July (Li et al., 2007). Therefore, Changsha is prone to waterlogging, particularly in low-lying areas in the rainy season.

Su Yu Yuan is located in the north of Changsha city, downstream of the Laodao River. It is a typical low-lying area surrounded by hills and embankment of the river. This area is almost undeveloped, but with the outward expansion of the city, Su Yu Yuan area has become a major development region to the north of Changsha. Due to its basin-like topography, waterlogging is a key issue in the planning and development of Su Yu Yuan area, as presented in Fig. 1.

2.2. Research questions and methodological approach

This study attempts to address the research question, i.e. can Chinese land suitability assessment accurately evaluate the rainfall-waterlogging risk of land? To solving the question, the basic methodological approach, shown in Fig. 2, is presented as follows: (1) Using the prevailing land suitability assessment (i.e., following the standard (CJJ132-2009)) to evaluate the suitability of land in Su Yu Yuan area; (2) Combining the Soil Conservation Service (SCS) model and GIS technology to evaluate the rainfall-waterlogging risk of land in Su Yu Yuan area; (3) Superimposing the both evaluation results to assess the land in terms of suitability and waterlogging risk; (4) Using the superimposition outcomes to review and improve the prevailing land suitability assessment.

3. Land suitability assessment of Su Yu Yuan area

3.1. The assessment indicators and their grade classification

According to the Standard of Urban and Rural Land Assessment (CJJ132-2009), first-level indicators of land suitability assessment include engineering geology, topography, hydrometeorology, nature and ecology, and human impact. There are 18 regular second-level indicators under these five first-level indicators, as shown in Table 1. Special second-level indicators are also included in the standard (CJJ132-2009), and can be added into the assessment of a given tract of land in consideration of certain uses.

The land in Su Yu Yuan area has no landslide, debris flow, new tectonic movement, tectonic structure causing site instability, or other adverse geological features, based on geological data and survey results. Therefore, it is unnecessary to add any second-level indicators for this site.

All second-level indicators are classified into four grades: "not suitable (0–1)," "poorly suitable (2–3)," "suitable (4–6)," and "very suitable (7–10)". The criteria for the grade classification of second-level indicators are detailed in the national standard (CJJ132-2009). However, in view of the situation in Su Yu Yuan area and the General Planning Rule for Soil and Water Conservation Control (GB/T15772-2008), the criteria for the grade classification of ground

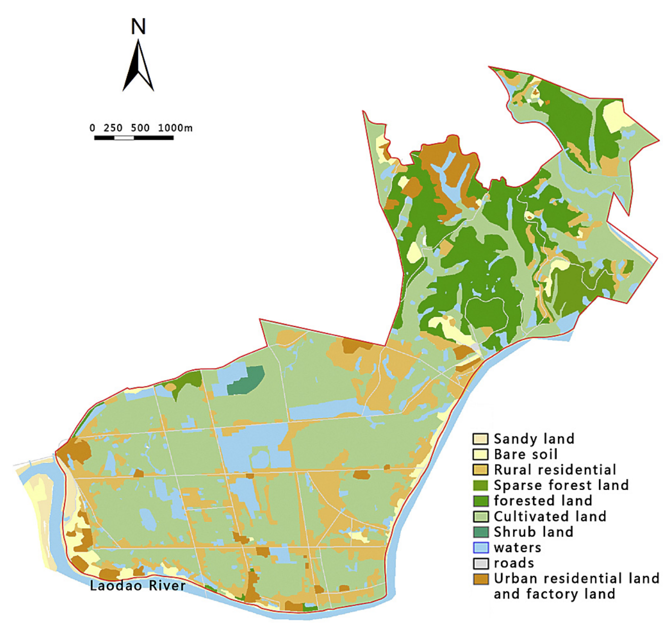

Fig. 1. Land-use map of the Su Yu Yuan area.