



# Index system of urban resource and environment carrying capacity based on ecological civilization



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## ABSTRACT

'Ecological Civilization' is a Chinese characteristic concept. It is an important pathway for China to achieve sustainable development and has become a key strategy to address China's serious resource and environmental issues. To solve the disparity between resources and the environment, an index system of urban resource and environment carrying capacity (URECC) based on ecological civilization should be established. This study explored the new connotations of URECC, and constructed an evaluation index system that contains 18 indicators selected from water carrying capacity, land carrying capacity, atmospheric environmental carrying capacity, energy carrying capacity, and environmental carrying capacity of solid waste. The index system fully embodies the supporting and restraining function to resources and environment for human development and reflects the dynamic change of URECC. We used URECC of Tianjin from 2007 to 2015 as a case study. The results reveal that the index system is not only able to reflect the current status of URECC, but also reflects the changes of increment to the original carrying capacity, so that economic and social development can be constrained within URECC. It provides a reference for future research on the carrying capacity index system of the city, and also has important practical significance to guide the sustainable development of the city.

## 1. Introduction

China's rapid economic growth has generated high levels of environmental pollutions, such as water and air pollution, energy shortages, and biodiversity losses (Fang & Kiang, 2006). These environmental problems have seriously affected China's sustainable development, and even have health risks. In order to achieve sustainable development goals and solve the disparity between resource, environment and socio-economic development, China has developed the 'Ecological Civilization' concept for its sustainable development framework (UNEP, 2015). The 17th National Congress of Communist Party of China (CPC) proposed a new requirement for ecological civilization construction, and made it an important requirement of building to ensure a moderately prosperous society with a good ecological environment by 2020. At the 18th National Congress of CPC, the government incorporated ecological civilization into an overall layout of "Five-in-One", to determine the strategy and path of promoting sustainable development in China. The overall layout of "Five-in-One" is that the ecological civilization construction was added to the construction of economic, political, cultural and social. The "Five-in-One" is an organic whole, and the ecological civilization construction is the

foundation of economic construction, political construction, cultural construction and social construction, which has been put on a prominent position and carry out all aspects and the whole process of economic, political, cultural and social construction.

Ecological Civilization is one of multiple pathways to sustainable development, with Chinese characteristics to deal with China's complex environmental problems in the process of development (UNEP, 2015). China's former leader, Hu Jintao, defined ecological civilization as "a resource efficient and environmental-friendly society, based on the carrying capacity of the environment, observing the law of nature and aimed at realizing sustainable development". In order to attain resource efficient economic growth that stays within the resource and environment carrying capacity (RECC), China's Ecological Civilization should focus on conservation of natural resources and ecosystem conservation and environmental protection (UNEP, 2016). To accelerate the construction of ecological civilization, the key is to set up using bottom lines that establish and strictly observe the environmental quality baseline, resource utilization ceiling, and ecological red line, and limit all kinds of development activities within resource and environment carrying capacity (CPC Central Committee and the State Council, 2015). The red line system is important to promote suitable design of

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ecological civilization construction, and the ecological bottom line system for each zone is based on its environmental carrying capacity. As a result of the disparity between resources and the environment, the RECC has become the key for the implementation of the ecological civilization concept.

The RECC is the basis for urban planning and layout design, and a scientific and reasonable index system is required for the quantitative evaluation of RECC to promote the construction of ecological civilization. Early research on carrying capacity was predominantly related to population increase using Malthus' population theory, and the main function of carrying capacity was to emphasize the environmental pressures caused by exponential growth (Seidl and Tisdell, 1999). Likewise, the human carrying capacity was meant to the maximum size of population that the world can support without damaging the environment (Wei et al., 2015). With the rapid development of both industry and cities, the concept of carrying capacity was extended to ecological changes due to excessive exploitation of human resources and over-destruction of the environment. Some studies have proposed that the carrying capacity is “the limit of growth or development of each and all hierarchical levels of biological integration, beginning with the population, and is shaped by processes and interdependent relationships between finite resources and the consumers of those resources” (Monte-Luna et al., 2004). Indicators such as ecological footprint, energy/exergy, human development index, and environmental vulnerability index are used to evaluate the sustainability index of city (Mori & Christodoulou, 2012). Research on carrying capacity has gradually begun to focus on particular areas, such as coastal zones (Navarro et al., 2013; Wei et al., 2014), tourism carrying capacity (Coccosis & Mexa 2004; Jurado et al. 2012), land-use planning (Lane, 2010), water resources (Mei, 2010), forest resources (Martire et al., 2015), water environment (Yang et al., 2015), and marine ecosystems (Ma et al., 2017). Moreover, the use of models to calculate and evaluate the carrying capacity has begun to emerge, greatly promoting the quantitative assessment and calculation of carrying capacity. Relevant studies have begun to evaluate the urban ecological carrying capacity with grey relational analysis (Xu et al., 2010), urban population carrying capacity based on GIS (Shi et al., 2013), urban carrying capacity load number with a spatial model (Tehrani and Makhdoum, 2013), and carrying capacity with a logistic regression and favorability function as a cost-efficient tool (Munoz et al., 2015).

For cities, environmental quality is an abstract concept, due to factors of human and nature in different spatial ranges (Nichol & Wong, 2005). Nowadays, the issue of urban carrying capacity over-development has produced different kinds of problems owing to the great changes in population and social economy in different cities (Barrett & Odum, 2000). Consequently, for urban planners and managers, it is not easy “to provide inhabitants with a good quality of life in their cities” (Shen et al., 2011).

To solve these environmental problems and construct ecological cities, many studies have focused on the assessment, planning, and management of urban ecosystems. The urban ecosystem can be divided into three subsystems that is population subsystem, economy subsystem and resources and environment subsystem, and a theoretical framework of urban ecological carrying capacity is established based on an analysis of three subsystems (Fang et al., 2017). And services and infrastructure are one of the important urban design guidelines derived to achieve optimum carrying capacity (George and Kini, 2016). In a lot of research, the urban ecosystem development is based on the interactions of carrying capacity among environment, resource, society, economy, etc. (Graymore et al., 2010; Xu and Xie, 2012; Wei et al., 2015), such as a systems analysis of sustainable development associated with economic, social and environmental problems (Kondyli, 2010), and a comparison of environmental capacity concept based on strategic environment assessment instruments and the basic principles of carrying capacity within the spatial plan (Santoso et al., 2014). The urban carrying capacity concept have contributed to the management, construction and

resource allocation, to solve the huge demand of the growing urban population, thereby suiting the needs of urban development (Rengasamy, 2009).

Different from a traditional natural ecosystem, an urban ecosystem is mainly related to humans, whose activities may have an impact on the ecosystems, therefore, the study of urban resource and environment carrying capacity (URECC) should focus on the support capability of urban ecosystems for human beings and their activities, and more research is required on URECC from the perspective of population or economic and social development. Furthermore, evaluations of carrying capacity should also focus on key characteristics of urban ecosystem, urban resources, urban ecological security, urban ecological activities, and other potential impacts (Xu and Xie, 2012). Except a good comprehensive assessment on URECC, the development of a city is determined by the lowest resource or environment carrying capacity, and it is very important to find the “short plank” of URECC (Wang et al., 2017). However, at present, the research on URECC mainly concentrates on one field with one environmental factor or one type of economic activities, lack of a comprehensive evaluation with environmental quality and human activities.

By combining the research progress made in the existing carrying capacity index system with the requirements of ecological civilization, this study explores a new connotation of URECC. Using the expert scoring method and the Analytic Hierarchy Process (AHP), an evaluation index system of URECC was constructed based on the concept of ecological civilization. The URECC is dynamic and is reflected by the environmental quality conditions, and its changes are mainly related to human activities. The index system is formulated specifically for the quantitative evaluation of URECC, and the criteria layer is set up according to the major environmental factors, which contains 18 indicators selected from water carrying capacity, land carrying capacity, atmospheric environmental carrying capacity, energy carrying capacity, and the environmental carrying capacity of solid waste. At each level of the environmental factor, the indicators not only reflect the background of present situation of resource and environment, but also reflect the changes of the carrying capacity increment to the original capacity, to help us correctly evaluate the current status of URECC and take appropriate measures that conform to the law “Respecting nature, conforming to nature, and protecting nature” to improve URECC. The results of the index system evaluation are very important for the promotion of urban ecological civilization construction and sustainable development. This study used the URECC of Tianjin from 2007 to 2015 as a case study. In theory, it provides a reference for future research on the carrying capacity index system of a city, whilst also having important practical significance for the sustainable development of a city.

## 2. Methods

### 2.1. Construction of an urban resource and environment carrying capacity (URECC) index system

As the center of human economic and social activities, the relationships among the various system elements of a city are interwoven, overlapping, and co-functioning. Therefore, the construction of an index system for URECC is based on the characteristics of a city, taken as a unit, which integrates the concept of ecological civilization into the entire index system construction process.

According to the concept of ecological civilization, the aim of an URECC index system is to realize the harmonious development between man and nature by “respecting nature, conforming to nature, and protecting nature”, rather than simply discussing environmental protection and resource conservation related to resources and the environment. “Respecting nature, conforming to nature, and protecting nature” is an important part of the ecological civilization theory system. Respecting nature defines the basic attitude of humans to nature, and it emphasizes that human behavior should be restricted by other natural

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