

# Evaluation and Analysis of Provincial Differences in Resources and Environment Carrying Capacity in China

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**Abstract:** Resources and environment carrying capacity is central to not only regional sustainable development but also major function-oriented zoning. This paper presents an evaluation index system for resources and environment carrying capacity based on four aspects of carrying capacity (i.e., water resources, land resources, the environment, and ecosystems) by using a square deviation decision-making method, and on the basis of above effort evaluates the resources and environment carrying capacity across 31 provincial regions in China (not including Hong Kong, Macau and Taiwan regions of China). In addition, this paper evaluates the current state of socio-economic development, and analyzes the spatial distribution of resources and environment pressure. The results showed that distinct spatial differences in resources and environment carrying capacity and pressure across provincial regions. Resources and environment pressure is affected by both comprehensive resources and environment carrying capacity and socio-economic development. Regions subjected to lower degrees of resources and environment pressure will be restricted by resources and environmental problems through future courses of development owing to excessively low carrying capacities. By contrast, regions with higher comprehensive resources and environment carrying capacity will be subjected to excessively high levels of resources and environment pressure because of rapid socio-economic development. Both of resources and environment carrying capacity and pressure must therefore be considered in the allocation of country-binding targets to provincial regions.

**Keywords:** carrying capacity; square deviation decision-making method; evaluation index system; China

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## 1 Introduction

Over the past thirty years, China has achieved considerable economic and urban growth. However, such development has also contributed to complications in territorial development, and the spatial structure of some urbanizing and industrializing areas has been unordered and uncontrolled. In several rapidly developing areas, substantial conflict exists between the demands of socio-economic development and the carrying capacity of the resource-environment system (Lu *et al.*, 2011). Mean-

while, several ecologically fragile regions have undergone severe ecological degradation owing to population growth and natural resource over-exploitation, even though the speed of development is more gradual in these areas. Other regions have not achieved their full development potential because they lack sufficient infrastructure. At the start the 21st century, major function-oriented zoning (MFOZ) was proposed by the Chinese government to address these issues. The strategy classified territorial space in China into four types: optimized development region, priority development re-

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gion, restricted development region, and forbidden development region. These four regional classifications are designed to identify major regional functions, to define clear development orientations, to control development intensities, to promote ordered development, and to improve development policy. The strategic aim is to develop a spatial development plan through which population and economic growth are coordinated with resource-environment system.

In MFOZ, resources and environment carrying capacity is considered paramount; coordination development of among population, resources, and the environment is emphasized; and the improvement of ecological environments is deemed an important assessment goal (Fang and Ding, 2008). Resources and environment carrying capacity is central to not only regional sustainable development but also MFOZ (Gao, 2007a; 2007b; Zhang and Li, 2007). In MFOZ, resources and environment carrying capacity must be considered as important criterion for sustaining coordinated man-land development (Wang *et al.*, 2012). Resource limitations and increasingly severe environmental problems have always restricted economic development (Zhang and Guo, 2006).

From the start of the 1970s, research on the resources and environment carrying capacity of Earth's ecosystem has been conducted internationally (Deng, 2010). Less than 30 years, resources and environment carrying capacity has been widely adopted in environment management and spatial planning departments worldwide (Alexis, 2000; Furuya, 2003; Eko Budi Santoso *et al.*, 2012; United States Environmental Protection Agency, 2002; Zheng *et al.*, 2015). In China, research in this field was first conducted in the 1990s, with a focus on single factor analysis. However, because of constant changes in regional development application requirements, the single factor analysis approach began to present limitations. Meanwhile, regional-scale research on comprehensive resources and environment carrying capacity expanded considerably: comprehensive resources and environment carrying capacity was formally defined (Liu, 1995), and expeditions took place in oases, the Bohai Rim, the Changjiang (Yangtze) River Delta, and areas of urban agglomeration (Mao and Yu, 2001; Zhang *et al.*, 2002; Liu and Fang, 2008; Liu, 2012). After the Wenchuan Earthquake occurred in 2008, the government proposed to the evaluation of resources and envi-

ronment carrying capacity as the prerequisite and basis of post-disaster restoration and reconstruction plans (Fan, 2009). It is the first time that resources and environment carrying capacity evaluation has been considered as a basic technology research to support 'the balance between the population, resources, and the environment' in China. Thereafter, scientific evaluations of regional resources and environment carrying capacity have been applied not only in the post-quake restoration and reconstruction plans of the Yushu Earthquake of 2010 and Zhouqu Earthquake of 2011, but also increasingly in the national territory development plan and the national economic and social development plans (Fan *et al.*, 2013).

Therefore, on the basis of primary research, this paper presents an index system for the comprehensive resources and environment carrying capacity evaluation of 31 provincial regions of China (not including Hong Kong, Macau and Taiwan regions of China) based on MFOZ principles, and examines the coordinated degree of resource, environment and socio-economic development. The results will inform a method for assigning countrywide resources and environment carrying capacity targets to provincial regions. This will benefit to the implementation of evaluation indicators for MFOZ performance, which will transform provincial and municipal economic development patterns, thus finally promoting green, transformative development.

## 2 Materials and Methods

### 2.1 Data sources

Socio-economic and environmental data for 2010 are used, and the majority of the original data are drawn from *China Statistical Yearbook 2011* (National Bureau of Statistics of China, 2012) and *Zhongguo Guotu Ziyuan Tongji Nianjian 2011* (Ministry of Land and Resources of China, 2011). Some data are obtained from the calculation results of original data for other years. For instance, the area of construction land for 2010 is calculated from National Land Investigation data for 2008 and construction land examination and approval data for 2009 and 2010. In addition, Forest Coverage Rate data are drawn from the National Land Investigation of 2008. The National Land Investigation of 2008 includes data on construction land, cultivated land, and unused land. Unused land here includes tidal flats, de-

serts, the Gobi Desert, glaciers, and limestone, and available land refers to the sum of cultivated land and construction land (i.e., the land area deducted by the unused land area).

## 2.2 Evaluation index system

In the selection of resources and environment carrying capacity indicators for MFOZ, priority must be given to resource and environment measures that affect regional sustainable development: land resource carrying capacity, water resource carrying capacity, ecosystem carrying capacity, and environmental capacity. An evaluation index system must promote more intensive and efficient resource use, more effective environmental pollution prevention and control, and greater ecosystem stabilization. In addition, such an index must consider relevant indexes that are already used in national and regional planning. Further, the method should be both scientifically supported and feasible in order to guide, monitor, and evaluate the degree of realization in different regions. On the basis of these principles, this paper presents a resources and environment carrying capacity

evaluation index system that includes four subsystems and 16 indicators (Table 1).

## 2.3 Evaluation method

In this study, a multi-index comprehensive evaluation method is applied. The determination of weight factor is central to the evaluation process. In general, when different sources of original data are used, weight determination may involve subjective and objective weight methods. Objective weight methods involve the use of observed indicator values to statistically determine weights, and original data are drawn from an evaluation matrix. In this study, square deviation decision making is applied to evaluate carrying capacity indicators objectively and comprehensively. This conventional objective weight method involves four basic steps. First, regarding the use of evaluation indicators as random variables, the dimensionless attribute value of scheme  $A_j$  under indicator  $B_i$  is deemed the value of the random variable. Second, the mean square errors of the random variables are calculated. Mean square errors are then normalized, and the resulting value is the indicator weight coefficient.

**Table 1** Evaluation index system of resources and environment carrying capacity

Subsystem	Indicator	Indicator definition	Property	Weight
Water resource carrying capacity	$W_1$ : per-capita available water resource quantity ( $m^3/\text{person}$ )	Measures current and potential supply of available regional water resources	Positive	0.0503
	$W_2$ : unit land area available water resource quality ( $m^3/\text{ha}$ )	Measures supply of regional water resources	Positive	0.0469
	$W_3$ : unit gross regional production water consumption ( $m^3/10^4 \text{ yuan (RMB)}$ )	Efficiency of water resource utilization	Negative	0.0541
	$W_4$ : unit added value of agricultural water consumption ( $m^3/10^4 \text{ yuan (RMB)}$ )	Agricultural water usage efficiency	Negative	0.0685
	$W_5$ : unit added value of industrial water consumption ( $m^3/10^4 \text{ yuan (RMB)}$ )	Industrial water usage efficiency	Negative	0.0677
Land resource carrying capacity	$L_1$ : per-capita available land resource quantity ( $\text{ha/person}$ )	Abundance of land resources	Positive	0.0484
	$L_2$ : proportion of construction land to total land area (%)	Intensity and nature of land resource utilization	Positive	0.0662
	$L_3$ : per-capita cultivated area ( $\text{ha/person}$ )	Land potential for food cultivation; utilization of cultivated land	Positive	0.0630
	$L_4$ : unit construction land area production value ( $10^4 \text{ yuan (RMB) /ha}$ )	Land output efficiency	Positive	0.0511
	$L_5$ : unit cultivated area grain output ( $\text{kg/ha}$ )	Cultivated land efficiency and feeding potential	Positive	0.0727
Environmental carrying capacity	$E_{I1}$ : water Chemical Oxygen Demand (COD) capacity	Environmental water assimilative capacity	Positive	0.0667
	$E_{I2}$ : water $\text{NH}_3\text{-N}$ capacity	Environmental water assimilative capacity	Positive	0.0662
	$E_{I3}$ : sulfur dioxide environmental capacity	Environmental atmospheric assimilative capacity	Positive	0.0755
	$E_{I4}$ : nitrogen oxide environmental capacity ( $10^4 \text{ t}$ )	Environmental atmospheric assimilative capacity	Positive	0.0755
Ecological carrying capacity	$E_{C1}$ : forest coverage rate (%)	Ecological construction status	Positive	0.0785
	$E_{C2}$ : wetland proportion (%)	Ecological restoration and conservation	Positive	0.0487

Before this calculation, indicators with units must be rendered dimensionless in the index system. Depending on the different effects on the comprehensive resources and environment carrying capacity, the indicators are defined as positive or negative indicators. In this study, 13 positive indicators and three negative indicators are used, as shown in Table 1. The dimensionless formula for positive indicators is  $Z_{ij} = (y_{ij} - y_{\min}) / (y_{\max} - y_{\min})$ , and the dimensionless formula for negative indicators is  $Z_{ij} = (y_{\max} - y_{ij}) / (y_{\max} - y_{\min})$ , where  $i = 1, 2, \dots, n$ ,  $n = 16$ ;  $j = 1, 2, \dots, m$ , and  $m = 31$ ;  $y_{\min}$  and  $y_{\max}$  refer to minimum and maximum values, respectively, for the 16 resources and environment carrying capacity indicators across the 31 provincial regions;  $Z_{ij}$  refers to the 16 indicators  $y_{ij}$  for the 31 provincial regions following the dimensionless treatment; and  $y_{ij}$  refers to indicator values before the dimensionless treatment.

The square deviation decision-making approach is conducted as follows:

① Calculate the mean value  $E(B_i)$  of variable  $Z_{ij}$

$$E(B_i) = \frac{1}{m} \sum_{j=1}^m Z_{ij} \quad (1)$$

② Calculate the weight coefficient  $W(B_i)$  of  $Z_{ij}$

$$\delta(B_i) = \sqrt{\frac{1}{m} \sum_{j=1}^m (Z_{ij} - E(B_i))^2} \quad (2)$$

$$W(B_i) = \frac{\delta(B_i)}{\sum_{i=1}^n \delta(B_i)} \quad (3)$$

where  $\delta(B_i)$  is the mean square value of variable  $Z_{ij}$  (the 16 indicators for the 31 provincial regions) and  $W(B_i)$  refers to the different weight values for the 16 indicators  $Z_{ij}$ . Table 1 presents the calculation results for the weight value of each indicator.

③ Evaluate the carrying capacity of the four subgroups

The resources and environment carrying capacity evaluation formula for various subgroups is as follows:

$$F_j = \sum Z_{ij} W(B_i) \quad (4)$$

where  $F_j$  refers to the carrying capacity index for water resources, land resources, the environment, and ecosystems for the 31 provincial regions;  $Z_{ij}$  refers to indicator values following standardization; and  $W(B_i)$  is the weight coefficient for each indicator.

④ Determine the comprehensive resources and environment carrying capacity index

The comprehensive resources and environment carrying capacity index is the sum of carrying capacity indexes for the four subsystems. The index is calculated with Equation (5):

$$F_Z = \sum_{j=1}^n F_j \quad (5)$$

where  $F_Z$  is the comprehensive resources and environment carrying capacity index for resources, the environment, and ecosystems;  $F_j$  is the carrying capacity index for various subgroups (i.e., water resources, land resources, the environment, and ecosystems).

### 3 Results

#### 3.1 Spatial resources and environment carrying capacity heterogeneity patterns

With the ArcGIS platform and the Natural Breaks Method, provincial regions are classified into five categories according to the index value for water resource carrying capacity, land resource carrying capacity, environmental carrying capacity, ecological carrying capacity, and comprehensive resources and environment carrying capacity. Carrying capacity levels are categorized as very high, high, moderate, low, and very low. The evaluation results are presented in Table 2.

##### 3.1.1 Water resource carrying capacity

Spatial variations in water resource carrying capacity are remarkable, largely owing to the utilization efficiency of water resources. Sixteen provincial regions in the eastern, central, and western China exhibit very high and high water resource carrying capacity values. By contrast, areas of lower water resource carrying capacity are mainly located in the southwestern, northwestern, and central China. In descending order, the weight coefficients of the five indicators are 0.0685 ( $W_4$ ), 0.0677 ( $W_5$ ), 0.0541 ( $W_3$ ), 0.0503 ( $W_1$ ), and 0.0469 ( $W_2$ ). These results indicate that water resource utilization efficiency has the most significant effect on water resource carrying capacity levels. In addition, per-capita available water resource levels are higher while water resource carrying capacity levels are lower in the northwestern and southwestern catchment areas, and per-capita available water resources are lower while water resource carrying capacity levels are higher in Beijing, Tianjin, Shandong,

**Table 2** Single factor resources and environment carrying capacity evaluation results

Subsystem	Carrying capacity level		Province and city (municipality)
Water resource carrying capacity index	Very high	(0.1713–0.1907)	Shandong, Tianjin, Beijing, Shanghai, Liaoning, Hebei, Shaanxi, Zhejiang, Henan, Shanxi
	High	(0.1545–0.1712)	Inner Mongolia, Guangdong, Jiangsu, Jilin, Hainan, Sichuan
	Moderate	(0.1400–0.1544)	Chongqing, Fujian, Qinghai, Yunnan, Hunan
	Low	(0.1084–0.1399)	Gansu, Jiangxi, Hubei, Guangxi, Anhui, Heilongjiang, Ningxia
	Very low	(0.0763–0.1083)	Xinjiang, Guizhou, Tibet
Land resource carrying capacity index	Very high	(0.1217–0.1548)	Shanghai
	High	(0.0904–0.1216)	Jiangsu, Tianjin, Henan, Beijing, Shandong, Heilongjiang, Hunan, Jilin
	Moderate	(0.0678–0.0903)	Anhui, Jiangxi, Inner Mongolia, Tibet, Hebei, Chongqing, Hubei, Liaoning
	Low	(0.0462–0.0677)	Sichuan, Guangdong, Ningxia, Zhejiang, Fujian, Xinjiang
	Very low	(0.0336–0.0461)	Guangxi, Shanxi, Gansu, Shaanxi, Hainan, Guizhou, Yunnan, Qinghai
Environmental carrying capacity index	Very high	(0.1391–0.1775)	Xinjiang, Sichuan, Heilongjiang, Guangdong, Hunan
	High	(0.1079–0.1390)	Inner Mongolia, Liaoning, Tibet, Shandong, Henan, Jilin
	Moderate	(0.0670–0.1078)	Guangxi, Hubei, Hebei, Qinghai, Jiangxi, Anhui, Yunnan, Jiangsu, Zhejiang
	Low	(0.0236–0.0669)	Fujian, Guizhou, Shanxi, Gansu, Shaanxi, Chongqing
	Very low	(0.0001–0.0235)	Tianjin, Beijing, Hainan, Shanghai, Ningxia
Ecological carrying capacity index	Very high	(0.0626–0.0825)	Fujian, Zhejiang, Jiangxi, Hainan, Guangdong, Guangxi
	High	(0.0455–0.0625)	Heilongjiang, Hunan, Yunnan, Shanghai, Jilin, Liaoning
	Moderate	(0.0311–0.0454)	Shaanxi, Sichuan, Hubei, Chongqing, Beijing, Guizhou, Anhui
	Low	(0.0170–0.0310)	Hebei, Shandong, Jiangsu, Henan, Inner Mongolia, Tianjin
	Very low	(0.0005–0.0169)	Shanxi, Tibet, Ningxia, Gansu, Qinghai, Xinjiang

the central China, and the southern Huanghe (Yellow) River Valley. This result may be observed because areas with abundant water resources are characterized by lower water resource utilization efficiency levels, whereas areas with limited water resources are characterized by higher utilization efficiency levels.

### 3.1.2 Land resource carrying capacity

Land resource carrying capacity is closely related to land output efficiency and less affected by land resource abundance. Areas with very high and high land resource carrying capacity are mainly located in the eastern and central China, whereas the northwestern and southwestern regions are characterized by lower carrying capacities. Significant differences in land carrying capacity index values are observed across the 31 provincial regions. Shanghai is the provincial region with the highest carrying capacity index value (0.1548). This value is 4.6 times that of Qinghai, which has the smallest index value (0.0336), and 1.27 times that of Jiangsu, which has the second largest index value (0.1216). In descending order, the weight coefficient values for the five indicators are 0.0727 ( $L_5$ ), 0.0662 ( $L_2$ ), 0.0630( $L_3$ ), 0.0511 ( $L_4$ ), and 0.0484( $L_1$ ), suggesting that land carrying capacity index is closely related to land output efficiency. Land resource

abundance has a less significant effect. For example, while the per-capita available land resource values for Tibet, Qinghai, and Inner Mongolia are 25.83 ha/person, 7.824 ha/person, and 3.912 ha/person, respectively, the corresponding index values for these regions are 0.0799, 0.0336, and 0.0838, respectively.

### 3.1.3 Environmental carrying capacity

The spatial distribution of environmental carrying capacity values is highly variable, and the atmospheric environmental capacity distribution is closely related to the environmental water capacity distribution. Regarding the area classifications for environmental carrying capacity, developed and developing regions occupy both areas with high and areas with low environmental carrying capacity. Hence, the spatial distribution of environmental carrying capacity values is dispersive overall. In the process of socio-economic development, wastewater, exhaust gas, solid waste atmospheric emissions, and soil and water systems threaten the environmental system. Environmental carrying capacity values reflect the capacity for absorption into 'three wastes' and the capacity for environmental self-purification. The weight values for the four environmental carrying capacity indicators (in order) are as follows: sulfur dioxide envi-

ronmental capacity (0.0755), nitrogen oxide environmental capacity (0.0755), water Chemical Oxygen Demand (COD) capacity (0.0667), and water NH<sub>3</sub>-N capacity (0.0662). Additional analyses reveal that the spatial patterns for sulfur dioxide and nitrogen oxide environmental capacity have remained consistent and show that provincial regions with very high or high values are located primarily in the northern and coastal areas, such as Jiangsu, Guangdong, Shanghai, and Anhui. The spatial patterns for COD and water NH<sub>3</sub>-N capacity are also fairly uniform, and provincial regions with very high or high values are those with limited water resources, including the Bohai Rim Region, Shanxi, and Ningxia.

### 3.1.4 Ecological carrying capacity

The spatial distribution of ecological carrying capacity and forest coverage rates is largely uniform, with regions of very high and high values located primarily in the southeastern coastal areas and northeastern China. The results further show that the spatial distribution of ecological carrying capacity levels is dispersive. Values for the ecological carrying capacity index are high in the southeastern coastal areas and northeastern China and low in the northwestern region. The weighted values of two ecological carrying capacity indicators (in order) are as follows: forest coverage rate (0.0785) and wetland proportion (0.0487). In addition, because of the characteristics of the physical environment, forest coverage rates in the western and northeastern regions are higher than those in other areas. The spatial patterns for the forest coverage rate and ecological carrying capacity are also highly consistent. Finally, regions with very high wetland proportions are concentrated in certain provincial regions, including Inner Mongolia, Qinghai, Gansu, and Shaanxi.

### 3.1.5 Comprehensive resources and environment carrying capacity

The comprehensive resources and environment carrying capacity values for the eastern and central China are higher than those for the western China. Eight regions exhibit very high level of comprehensive carrying capacity: Henan, Shandong, Guangdong, Heilongjiang, Liaoning, Hunan, Jilin, and Sichuan. Regions with high comprehensive carrying capacity include Jiangsu, Shanghai, Hebei, Inner Mongolia, Jiangsu, and Zhejiang. Regions with low and very low comprehensive carrying capacity include Gansu, Ningxia, Guizhou, Shanxi, Qinghai, Chongqing, Shaanxi, Tibet, and Hai-

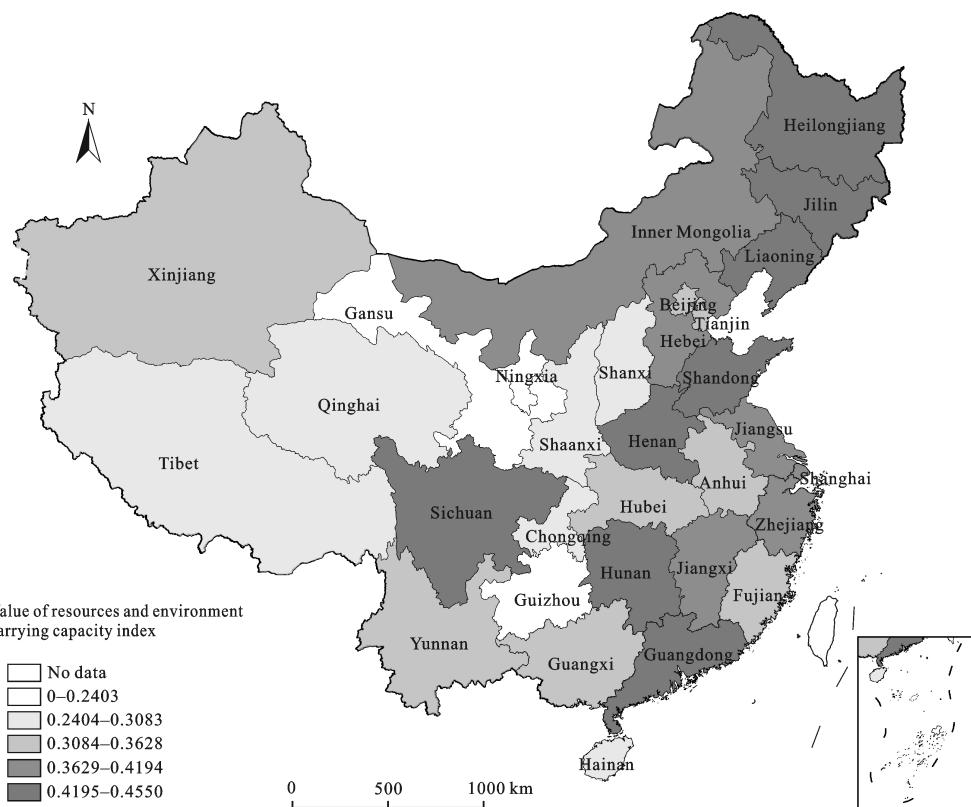
nan, and the majority of these regions are located in the western China, where the ecological environment is vulnerable (Fig. 1).

## 3.2 Resources and environment pressure evaluation

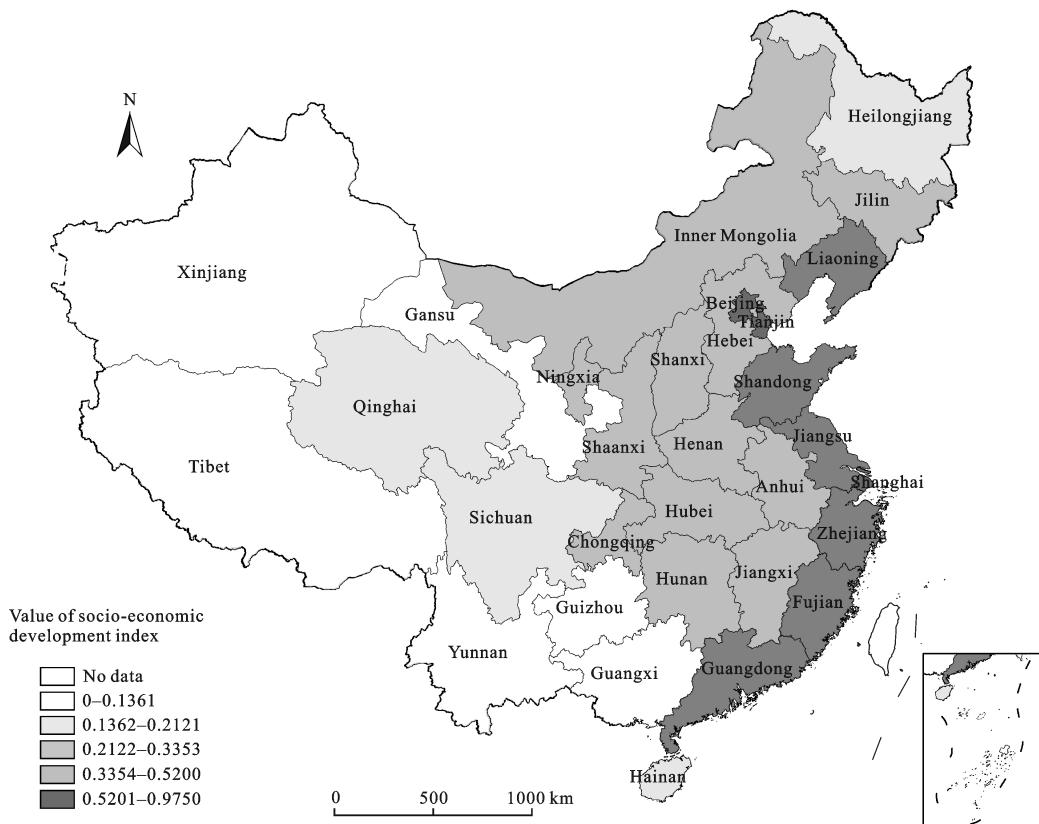
### 3.2.1 Current state of socio-economic development

Based on the resources and environment carrying capacity evaluation results, additional resources and environment pressure analyses are conducted to determine the state of resources and environment carrying capacity and regional socio-economic development and thus to identify regional variations in coordination between resource and environmental management and socio-economic development. An evaluation of the current state of socio-economic development must be conducted prior to the analyses of resources and environment pressure. Socio-economic development level indicators were selected based on Technical Schedule of Provincial Major Function Oriented Zoning indicators, including population agglomeration and the transportation superiority degree. Moreover, the urbanization rate, economic density, and the tertiary industry proportion were used as additional indicators to measure the current state of socio-economic development.

The evaluation index system that is used in this study includes the following five indicators: urbanization rate, population density, economic density, tertiary industry proportion, and traffic density. The square deviation decision-making method described above is again adopted to evaluate the socio-economic development level for the 31 provincial regions. The ArcGIS platform is also used to classify the provincial regions into five categories based on the Natural Breaks Method (Fig. 2). The results show a number of distinct trends. First, socio-economic development levels vary considerably across the 31 provincial regions. Eleven regions exhibit average index values (0.3177) that exceed the country-wide mean, and the remaining 20 regions fall below the mean. The region with the highest index value is Shanghai (0.9336), and the region registering the lowest index value is Xinjiang (0.0840). The highest value is thus 11.11 times larger than the lowest value. Second, the spatial distribution of socio-economic development shows that index values in the eastern areas are higher than those in the western areas. While Beijing, Shanghai, Tianjin, Jiangsu, Zhejiang, Shandong, Guangdong,



**Fig. 1** Resources and environment carrying capacity index value



**Fig. 2** Socio-economic development index value

Liaoning, and Fujian have very high index values, Guangxi, Guizhou, Xinjiang, Gansu, Yunnan, and Tibet in the western China have very low index values. Third, a positive correlation exists between socio-economic development and resources and environment carrying capacity (Fig. 3).

### 3.2.2 Spatial distribution of resources and environment pressure

In this study, the resources and environment pressure index is constructed as follows:

$$C_i = SE_i / F_i$$

where  $C_i$  is the resources and environment pressure index for region  $i$ ;  $SE_i$  is the socio-economic development index for region  $i$ ; and  $F_i$  is the comprehensive resources and environment carrying capacity index for region  $i$ . If  $C_i > 1$ , the resources and environment conditions for region  $i$  has reached a state of excessive pressure, and socio-economic development is not coordinated with resource and environmental management. If  $C_i < 1$ , the resources and environment conditions occupies an acceptable state, and socio-economic development is co-ordinated with resource and environmental management.

The regional resources and environment pressure index exhibits an uneven spatial pattern, with values ranging from 0.11 to 2.42. According to the pressure index, provincial regions are classified into five categories via the Natural Breaks and Manual Method avail-

able through the ArcGIS platform. Two regions occupy a state of excessive pressure, and three occupy a state of acceptable pressure (Fig. 4, Table 3).

As can be seen, the spatial distribution for the resources and environment pressure index is not the same as that of the resources and environment carrying capacity or the socio-economic development level. High-pressure regions include not only developed regions but also underdeveloped regions. As shown in Fig. 4, Shanghai, Beijing, and Tianjin occupy a state of severely excessive pressure, and Chongqing, Jiangsu, Zhejiang, and Ningxia occupy a state of excessive pressure. All remaining regions occupy a state of acceptable pressure.

Provincial regions in a state of severely excessive pressure include three municipalities with very high or high socio-economic development index values. Of these municipalities, Shanghai has a high comprehensive resources and environment carrying capacity index value, and Beijing and Tianjin have moderate values. These results indicate that these three municipalities have reached a mature level of economic and social development, as the base level and potential for regional development are relatively higher. However, in these municipalities, the consumption of resources such as water and soil is excessive because of rapid economic growth, and intensified human activity has led to severe ecological degradation. Although ecological and environmental recovery and rehabilitation efforts in these

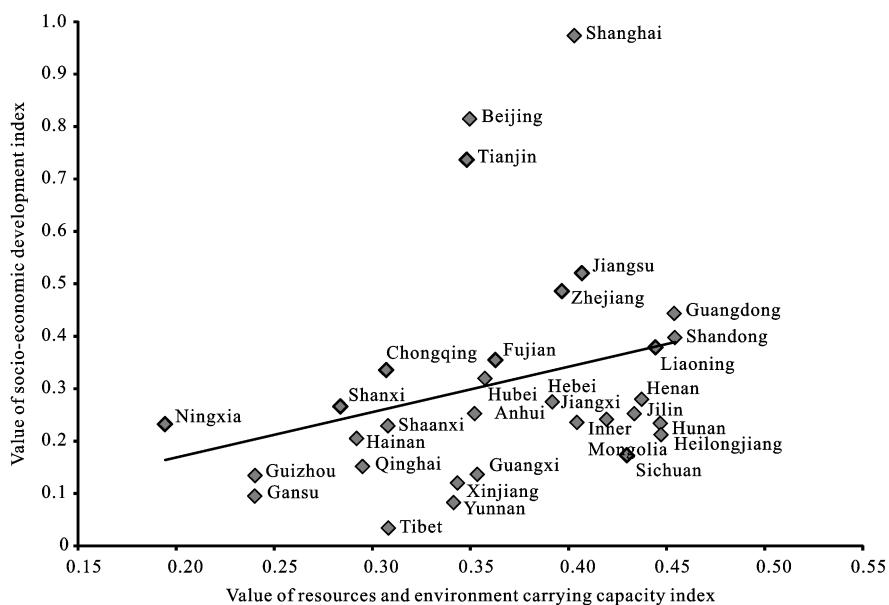
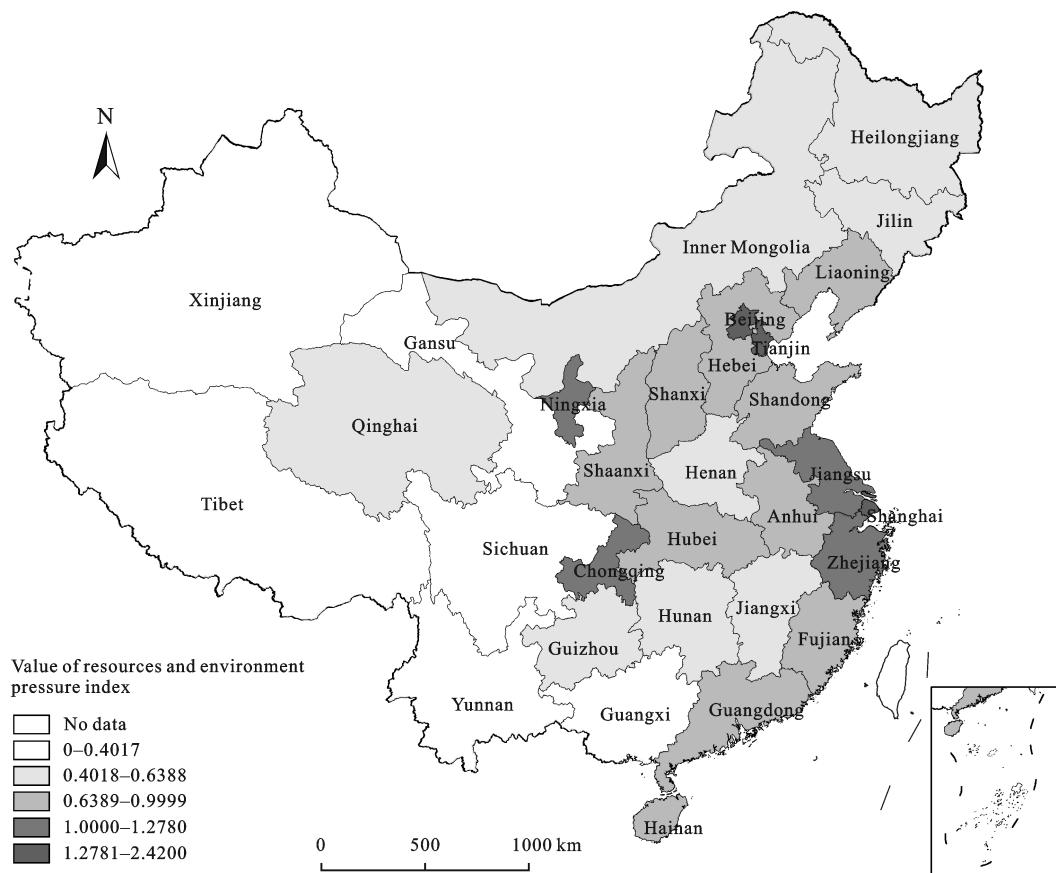


Fig. 3 Resources and environment carrying capacity and socio-economic development index scatter plot



**Fig. 4** Resources and environment pressure index value

**Table 3** Resources and environment pressure classification

Classification		Province and city (municipality)
Severely excessive pressure	(1.278 1–2.420 0)	Shanghai, Beijing, Tianjin
Excessive pressure	(1.000 0–1.278 0)	Jiangsu, Zhejiang, Ningxia, Chongqing
Acceptable pressure	I (0.638 9–0.999 9)	Guangdong, Fujian, Shanxi, Hubei, Shandong, Liaoning, Shaanxi, Anhui, Hainan, Hebei
	II (0.401 8–0.638 8)	Henan, Jiangxi, Jilin, Inner Mongolia, Guizhou, Hunan, Qinghai, Heilongjiang, Sichuan
	III (0–0.401 7)	Gansu, Guangxi, Xinjiang, Yunnan, Tibet

regions have partially mitigated these negative effects, resources and environment pressure still limits future regional development.

Provincial regions in a state of excessive pressure include Chongqing, Jiangsu, Ningxia and Zhejiang. Jiangsu and Zhejiang in the eastern coastal region exhibit high resources and environment carrying capacity and socio-economic development levels. Further, Ningxia and Chongqing in the western China exhibit very low and low resources and environment carrying capacity levels, respectively, but moderate socio-economic development. All these regions have excessively high resources and environment pressure values, suggesting

that coordination between socio-economic development and resource and environmental management is poor in these regions. Hence, binding targets should be deemed higher in these provincial regions than in other regions.

Provinces occupying an acceptable state of pressure exhibit various characteristics. Socio-economic development indexes for provinces with higher resources and environment carrying capacity values largely fall above the moderate level, although Heilongjiang and Sichuan present lower values. Socio-economic development indexes for the provinces with lower resources and environment carrying capacity values largely fall below the moderate level. Provinces presenting the lowest re-

sources and environment pressure index values exhibit the lowest degree of socio-economic development, and the resources and environment carrying capacity values for these regions fall below moderate levels. Although the pressure indexes for Tiber, Shaanxi, Qinghai, Hainan, Shanxi, Guizhou, and Gansu exhibit acceptable levels, the resources and environment carrying capacity values are lower, and the natural environment is vulnerable in these regions. Hence, in these regions, socio-economic development will be constrained by resources and environment limitations.

The above analyses show that the resources and environment pressure index is affected by both comprehensive resources and environment carrying capacity and socio-economic development levels. Low-resources and environment pressure regions will continue to be restricted by resources and environment problems through future courses of development owing to the presence of excessively low resources and environment carrying capacity values. By contrast, regions characterized by higher comprehensive resources and environment carrying capacity values will encounter excessively higher resources and environment pressure levels brought about through rapid socio-economic development. Therefore, both resources and environment carrying capacity and resources and environment pressure values must be considered in the allocation of resources and environment carrying capacity binding targets to provincial regions.

#### 4 Conclusions

According to the theoretical method, this paper presents an evaluation index system for resources and environment carrying capacity based on water resource, land resource, environmental, and ecological carrying capacity, and through using square deviation decision-making method, the comprehensive evaluation analysis on resources and environment carrying capacity for 31 provincial regions in China was carried out. In addition, this paper also evaluates the current socio-economic development of these 31 regions, and the results reveal regional variations in coordination between resource and environmental management and socio-economic development. The following conclusions are drawn.

First, spatial variations in resources and environment carrying capacity are evident. The utilization efficiency for water and land resources has the greatest effect on

water resource carrying capacity. Further, the spatial distribution of environmental carrying capacity is relatively dispersed: ecological carrying capacity levels are high in the southeastern coastal areas and northeastern China, and comprehensive resources and environment carrying capacity levels in the eastern and central China are higher than those in the western China.

Second, the resources and environment pressure index is affected by both comprehensive resources and environment carrying capacity and socio-economic development levels. On one hand, rapidly developing regions such as Shanghai, Beijing, and Tianjin lack coordination between socio-economic development and resource and environment management, as intensified human activities generate enormous resources and environment pressure levels. In addition, regions in a state of excessively high resources and environment pressure include not only developed regions, such as Jiangsu, Zhejiang, and Chongqing, but also developing regions, such as Ningxia. On the other hand, while less-developed regions, such as Tiber, Shaanxi, Qinghai, Hainan, Shanxi, Guizhou, and Gansu, exhibit an acceptable state of pressure, given the fragile natural environments in these areas, these regions will face resources and environment constraints over the course of their socio-economic development.

Finally, countrywide binding targets for resources and environment carrying capacity must be allocated to provincial regions for an evaluation of MFOZ performance to realize more comprehensive resource utilization, more effective pollution control, and greater ecosystem stabilization. This study demonstrates that the spatial distribution of resources and environment pressure, which reflects the degree of human-land coordination, differs from the spatial distribution of resources and environment carrying capacity in China. Therefore, both resources and environment carrying capacity and resources and environment pressure should be considered in the allocation of countrywide binding targets for resources and environment carrying capacity to provincial regions.

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