ISSN 2522-3488 Vol. 7, Issue 7: 40-46, DOI: 10.25236/IJNDES.2023.070706

Spatial and temporal characteristics of the coordinated development of urbanization and resource and environmental carrying capacity in Guangxi

Xing Anyu[a,*], Chen Tao[b]

School of Economics and Management, Guangxi Normal University, Guilin, China
[a]Xing17837297574@163.com, [b]chentaozzz@126.com

Abstract: *This paper uses Guangxi as a case study to establish a comprehensive evaluation index system for urbanization and resource and environmental carrying capacity. It analyzes the spatial and temporal disparities in the coordinated development between urbanization levels and resource and environmental carrying capacity in Guangxi from 2008 to 2020, employing the entropy value method and coordination degree model. The results show that the comprehensive urbanization index exhibits a continuous upward trend during the study period. There are two core cities, Liuzhou and Nanning, which display a significant disparity when compared to the surrounding prefectural cities. Meanwhile, the resource and environmental carrying capacity index demonstrates a fluctuating upward trend, creating a spatial pattern of varying development levels, characterized as "one main city and six sub-cities, " resulting in a "concave" spatial distribution pattern. Furthermore, when considering the coordination aspect, the study period has seen an improvement in the coordination between urbanization and resource and environmental carrying capacity, shifting from barely coordinated to primarily coordinated. This shift is spatially represented as a "low-high-low-high" distribution trend from west to east.*

Keywords: *Urbanization; Guangxi; Resource and Environmental Carrying Capacity; Coupled Coordination*

1. Introduction

Since the initiation of economic reforms and opening-up policies, China's urbanization rate has increased from 17.92% in 1978 to 63.89% in 2020, and the traditional urbanization development in the past consumed large-scale natural and social resources. The resource and ecological environment problems have become increasingly serious, with serious urban environmental degradation and resource depletion occurring in some areas. The escalating concerns of environmental issues, namely air pollution, dwindling water resources, biodiversity depletion, and resource mismanagement, have attained increasing gravity within contemporary discourse.[4]These problems are exacerbating, highlighting the growing conflict between economic and social development on one hand and resource, ecological, and environmental considerations on the other. The direct cause of this series of problems is that China has neglected the resource and environmental carrying capacity in the pursuit of rapid urbanization, specifically, the neglect of the interplay between urbanization and resource and environmental sustainability.

Resource and environmental carrying capacity usually refers to the ability of natural resources and environment, mainly water, land, atmosphere, energy, etc., to support socioeconomic development in a specific geographical area, provided that the natural ecological environment maintains a good ecosystem [2]. In previous studies, many scholars have discussed the definition and connotation of resource and environmental carrying capacity. Ye et al. [3]defined resource and environmental carrying capacity as the socioeconomic pressure that can be applied to the ecological environment under the premise that the natural ecosystem can uphold a stable structure and complete functionality.

The existing studies are primarily concentrated in the eastern and central provinces with better development, and there are fewer studies on the less developed provinces. In contrast, the differences between different provinces in China in the level of urbanization development and resource and environmental conditions are large. These regional differences in coupling and coordination characteristics lead to a lack of universality in research findings and policies. Therefore, investigating the coupling and coordination of urbanization and resource and environmental carrying capacity in Guangxi is important. Studying the coupling and coordination relationship between urbanization and resource and environmental carrying capacity in Guangxi is significant. Since the reform and opening up, China's urbanization rate has increased from 17.92% in 1978 to 63.89% in 2020, and the traditional urbanization development in the past consumed large-scale natural and social resources. The resource and ecological environment problems have become increasingly serious, with severe urban environmental degradation and depletion in some areas. The problems of air pollution, water resource shortages, loss of biodiversity, and resource waste have become more serious[4]. Problems are becoming more and more serious, and the contradiction between economic and social development and resources, ecology, and the environment is becoming more and more prominent. The direct cause of this series of problems is that China has neglected the resource and environmental carrying capacity in the pursuit of rapid urbanization, namely, the relationship between urbanization and resource and environmental carrying capacity has been overlooked.

2. Overview of the study area

Guangxi Zhuang Autonomous Region is located on the southeast edge of the Yunnan-Guizhou Plateau, at longitude 104°26′-112°04′E and latitude 20°54′-26°24′N. It is China's only western autonomous region with a territorial sea, a vital gateway front for China to ASEAN, and the most convenient access to the sea in the southwest. Guangxi administers 14 prefectural-level cities and 111 county-level units under its jurisdiction, with Nanning as its capital. Its administrative land area covers 237,600 square kilometers, which accounts for 2.5% of the country's total land area. The region features a widespread distribution of karst landforms and a fragile ecological environment. As of 2020, the resident population stood at approximately 50.187 million, with a gross regional product of 2.21 trillion yuan and a per capita disposable income of 24,562 yuan.

In 2020, the urbanization rate of Guangxi's resident population reached 54.2%, marking a stage of rapid urbanization development. As China-ASEAN regional economic integration progresses and the rural revitalization strategy is implemented, the levels of urbanization are rapidly increasing, thereby facing severe resource and environmental pressure. With the promotion of China-ASEAN regional economic integration and the implementation of a rural revitalization strategy, urbanization is rapidly increasing, facing severe resource and environmental pressure. Consequently, it is essential to study the spatial and temporal evolution of the relationship between urbanization and resource-environmental carrying capacity, as well as their coupling and coordination in Guangxi from 2008 to 2020.

3. Data sources and research methodology

3.1. Data sources

The socioeconomic data in this paper come from Guangxi Statistical Yearbook, China Urban Statistical Yearbook, and China County Statistical Yearbook from 2008 to 2020. In cases of missing data, information has been supplemented using data from adjacent years. Land is obtained from the Globeland30 Global Surface Cover Database (http://www.globallandcover. com) with a resolution of 30 m; PM2.5 data has been acquired from the Atmospheric Composition Analysis Group of Dalhousie University, Canada (http://fizz.phys.dal.ca/~atmos/martin/?page_id=140).

3.2. Indicator system construction and research methodology

3.2.1. Indicator system

Existing studies have no consensus on the evaluation indicators of resource and environmental carrying capacity. Guangxi boasts complex geomorphological features and an extensive distribution of karst landforms. It serves as a critical ecological barrier in the Pan-Pearl River Delta region, and its resource and environmental carrying capacity underpin urbanization and sustainable economic and social development. While the selection of indicators to measure the level of urbanization is relatively well-established, the key challenge lies in selecting indicators to measure the carrying capacity of resources and the environment.

For this reason, this paper constructs a coordinated development index system for urbanization and the resource-environment composite system. This system is built upon existing literature, reviews of prior research, and relevant government reports. It also takes into account the actual urbanization situation in Guangxi. The index system comprises a total of 37 indicators distributed across the dimensions of urbanization level and resource-environment carrying capacity.

a) Construction of urbanization level evaluation index system

Drawing on the research results of existing studies [1] and combining the availability and reasonableness of data, this paper starts from the four dimensions of population urbanization: population urbanization, social urbanization, economic urbanization, and spatial urbanization. Finally, it selects 18 third-level indicators (Table 1) to evaluate the urbanization level of Guangxi.

b) Construction of resource and environmental carrying capacity evaluation index system

Previous studies have failed to reach a consensus on the measurement indices of resource and environmental carrying capacity. Most existing research has constructed the evaluation index system of resource and environmental carrying capacity from the way of resources and environment, economic society, and ecological environment protection, or the composite of multiple single elements. Since sustainable urban development is a coordinated economy, society, and environment development, the city should carry a specific capacity for economic and social activities, such as water resources, land resources, atmospheric environment, transportation, education, health care, etc. These elements are collectively referred to as the resource and environmental carrying capacity, so the resource and environmental carrying capacity can be divided into three dimensions: economic, social, and environmental. Further, this paper establishes 19 three-level indicators to represent and measure regional resource and environmental carrying capacity from the economic, social, and environmental perspectives (Table 1).

Table 1: Evaluation Index System of urbanization and Resource and environmental carrying capacity.

Tier 1 indicators	Elements	Indicators	Indicator type	Weights
UL	Population Urbanization	Population density (persons/km2)	+	0.049
		Urban population share (%)	+	0.058
		GDP per capita (yuan/person)	+	0.063
	Economic Urbanization	GDP (yuan)	+	0.090
		Value added of secondary and tertiary industries in GDP (%)	+	0.041
		Gross industrial output value above scale (yuan)	+	0.071
		Per capita fixed asset investment (yuan)	+	0.046
		Share of employment in secondary and tertiary industries (%)	+	0.025
	Social urbanization	Number of health technicians per 1,000 people (persons)	+	0.059
		The average wage of urban unit on-the-job workers (yuan)	+	0.049
		Disposable income (yuan)	+	0.025
		Number of books in public libraries per 100 people (volumes, pieces)	+	0.062
		Number of public vehicles per 10,000 people (units)	+	0.083
		Urban registered unemployment rate (%)	+	0.030
		Retail sales of social consumer goods per capita (yuan)	+	0.050
	Spatial Urbanization	Construction land area per capita (km2)	+	0.072
		Population density of construction land (people/km2)	+	0.065
		Urban road area per capita (m2)	+	0.062
RECC	Economic perspective	Cultivated land area per capita (hm2/person)	+	0.077
		Per capita water resources (t)	+	0.081
		Per capita public financial expenditure (yuan)	+	0.078
		Forest coverage (%)	+	0.030
	Social Perspective	Elementary school student-teacher ratio	-	0.047
		Secondary school student-teacher ratio	-	0.042
		Number of beds per 1,000 people (sheets)	+	0.055
		Per capita education expenditure (yuan)	+	0.053
		Sewage treatment rate (%)	+	0.037
	Environmental perspective	Industrial wastewater discharge per capita (person/ton)	-	0.023
		Per capita industrial soot emission (t)	-	0.028
		Per capita so2 emissions (t)	-	0.023
		pm2.5 (mg/m3)	-	0.052
		Green space rate of built-up area (%)	+	0.038
		Park green space per capita (m2)	+	0.058
		Harmless treatment rate of domestic garbage (%)	+	0.033
		Energy consumption of 10,000 yuan GDP (t)	-	0.029
		Share of urban construction land in urban areas (%)	+	0.164
		Urban per capita housing floor area (m2)	+	0.051

ISSN 2522-3488 Vol. 7, Issue 7: 40-46, DOI: 10.25236/IJNDES.2023.070706

3.2.2. Research methods

a)Index standardization

Standardization of positive indicators

$$y_{ij} = (x_{ij} - \min\{x_{ij}\})/(\max\{x_{ij}\} - \min\{x_{ij}\})$$

Standardization of negative indicators

$$y_{ij} = (\min\{x_{ij}\} - x_{ij})/(\max\{x_{ij}\} - \min\{x_{ij}\})$$

where x_{ij} denotes the measured data value for indicator j in the city i.$\max\{x_{ij}\}$ and $\min\{x_{ij}\}$ represent the maximum and minimum values, respectively, of the j indicator for the city i.y_{ij} Indicates the standardized value of indicator j for the city i.

b)Entropy method weighting

First of all, calculate the proportion of the index j of the city j

$$p_{ij} = y_{ij} / \sum_{i=1}^{n} y_{ij}$$

Secondly, the entropy of the index j is calculated.

$$e_j = -\frac{1}{\ln n} \sum_{i=1}^{n} p_{ij} \ln p_{ij} \; (0 \leq e_j \leq 1)$$

The weight of each index is

$$w_i = \frac{1 - e_i}{n - \sum e_i}$$

Finally, the comprehensive index of urbanization and resource and environmental carrying capacity of the city j is calculated.

$$UB = \sum_{i=1}^{m} w_i y_{ij}$$

$$RE = \sum_{l=1}^{n} w_i \, y_{ij}$$

c)Coupling coordination degree model

Coupling is a physical concept, and at this stage, coupled coordination degree models are widely used to measure the level of coordination between two or more systems. In this paper, the formula is as follows.

$$C = \sqrt{(UB \times RE)/((UB + RE)/2)^2}$$

$$T = \alpha UB + \beta RE$$

$$D = \sqrt{C \times T} \qquad (0 < CD \leq 1)$$

4. Results and analysis

4.1. Spatio-temporal characteristics of urbanization index and resource and environmental carrying capacity index of Guangxi

The transformations in the urbanization level and the alterations in the resource and environmental carrying capacity of Guangxi during the period spanning from 2008 to 2020 have been comprehensively presented in Table 2 and Table 3. These tables provide empirical evidence indicating a notable overall ascension in the urbanization level. Specifically, the composite index of urbanization escalated from 0.312 in 2008 to 0.360 in 2020, showcasing an average annual growth rate of approximately 0.4%. In terms of the average value of the comprehensive urbanization index, there were nine cities below the regional average level of urbanization in 2008, and the number of cities below the regional average level

ISSN 2522-3488 Vol. 7, Issue 7: 40-46, DOI: 10.25236/IJNDES.2023.070706

of urbanization will drop to 8 by 2020. However, the overall level of urbanization development in Guangxi is still in the middle to lower level.

As can be seen in Table 3, the average value of the resource and environmental carrying capacity index of Guangxi rose from 0.403 to 0.482 from 2008 to 2020, with an average annual growth rate of about 0.7%, which is similar to the magnitude of changes in the level of urbanization. It is worth proposing that the resource environmental carrying capacity index of Guilin and Beihai City declined during the study period. Guilin, as a typical karst landscape area with an ecologically sensitive and harsh natural environment, inevitably leads to a decline in resource and environmental carrying capacity in the process of economic development. Meanwhile, Beihai, as an essential node city of the Beibu Gulf Urban Agglomeration, has rapid economic development, which puts tremendous pressure on the resources and environment and leads to a decline in its resource and environmental carrying capacity.

Table 2: Urbanization Index for cities in Guangxi, 2008-2020.

City	urbanization index						
	2008	2010	2012	2014	2016	2018	2020
Nanning	0.642	0.675	0.712	0.723	0.731	0.735	0.712
Liuzhou	0.667	0.733	0.733	0.719	0.668	0.752	0.719
Guilin	0.443	0.413	0.421	0.418	0.389	0.402	0.36
Wuzhou	0.274	0.341	0.355	0.349	0.331	0.339	0.322
Beihai	0.488	0.384	0.426	0.445	0.422	0.479	0.426
Fangchenggang	0.385	0.474	0.471	0.477	0.471	0.515	0.496
Qinzhou	0.197	0.27	0.291	0.333	0.346	0.298	0.23
Guigang	0.144	0.216	0.211	0.2	0.211	0.254	0.216
Yulin	0.226	0.302	0.289	0.29	0.266	0.28	0.258
Baise	0.184	0.218	0.23	0.222	0.229	0.245	0.22
Hezhou	0.231	0.292	0.302	0.273	0.319	0.37	0.373
Hechi	0.164	0.231	0.194	0.185	0.227	0.246	0.203
Laibin	0.169	0.269	0.254	0.255	0.269	0.269	0.242
Chongzuo	0.16	0.208	0.196	0.207	0.24	0.283	0.263
Average	0.312	0.359	0.363	0.364	0.366	0.391	0.360

Table 3: Resource and Environmental Carrying Capacity Index for Cities in Guangxi, 2008-2020.

City	Resource Environmental Carrying Capacity Index						
	2008	2010	2012	2014	2016	2018	2020
Nanning	0.452	0.427	0.461	0.419	0.413	0.510	0.496
Liuzhou	0.624	0.663	0.577	0.574	0.605	0.550	0.591
Guilin	0.597	0.548	0.569	0.532	0.474	0.475	0.508
Wuzhou	0.362	0.392	0.456	0.412	0.456	0.404	0.495
Beihai	0.582	0.508	0.538	0.436	0.473	0.523	0.554
Fangchenggang	0.398	0.461	0.443	0.419	0.505	0.569	0.649
Qinzhou	0.326	0.295	0.356	0.367	0.373	0.389	0.409
Guigang	0.302	0.279	0.274	0.254	0.282	0.345	0.377
Yulin	0.340	0.394	0.449	0.347	0.391	0.422	0.391
Baise	0.345	0.405	0.393	0.387	0.404	0.460	0.458
Hezhou	0.266	0.402	0.411	0.327	0.436	0.430	0.509
Hechi	0.446	0.504	0.425	0.374	0.486	0.445	0.538
Laibin	0.214	0.369	0.349	0.357	0.399	0.324	0.337
Chongzuo	0.395	0.397	0.436	0.464	0.480	0.503	0.442
Average	0.403	0.432	0.438	0.405	0.441	0.453	0.482

4.2. Analysis of the coupling coordination between urbanization and resource and environmental carrying capacity in Guangxi

The coupling coordination degree of urbanization and resource and environmental carrying capacity rises slowly. The average value of the coordination degree rises from 0.580 in 2008 to 0.634 in 2020, and the coupling coordination relationship between urbanization and resource and environmental carrying capacity improves from barely coordinated type to primary coordinated type.

Table 4 shows the coupling coordination between urbanization level and resource environmental carrying capacity of various cities in Guangxi from 2008 to 2020. In 2008, the urbanization level of the whole region of Guangxi was low, resulting in weak interaction with resource and environmental carrying capacity.As a result, the predominant coupling coordination type was the 'barely coordinated' category,

ISSN 2522-3488 Vol. 7, Issue 7: 40-46, DOI: 10.25236/IJNDES.2023.070706

encompassing a total of 6 prefecture-level cities, representing 43% of the entire region. These cities were primarily situated in the western and southeastern regions of GuangxiFollowing closely was the 'near coordinated' type, including a total of 3 prefecture-level cities, mainly concentrated in the central part of Guangxi. By 2014, the coupling coordination degree of the various prefectures was improved to varying degrees. In 2020, most prefectures had improved to 0.580 by , and a significant portion reaching 0.634. In 2014, the coupling coordination degree of all prefectural-level cities was improved to different degrees, with most of them transitioning into the barely coordinated type, and the largest number of barely coordinated cities at seven, or 50 percent. By 2020, the coupling coordination degree of urbanization and resource and environmental carrying capacity of the whole region entered the coordinated development type, and it is worth putting forward that the coupling coordination degree of Liuzhou has been kept in the first place in the study period.

Table 4: Degree of coordination and ranking of urbanization level coupled with resource and environmental carrying capacity of cities in Guangxi, 2008-2020.

	2008	2010	2012	2014	2016	2018	2020
Nanning	0.734	0.733	0.757	0.742	0.741	0.782	0.771
Liuzhou	0.803	0.835	0.807	0.801	0.797	0.802	0.807
Guilin	0.717	0.690	0.699	0.687	0.655	0.661	0.654
Wuzhou	0.561	0.605	0.634	0.616	0.623	0.608	0.632
Beihai	0.730	0.665	0.692	0.664	0.668	0.707	0.697
Fangchenggang	0.626	0.684	0.676	0.669	0.698	0.736	0.753
Qinzhou	0.504	0.531	0.567	0.591	0.599	0.584	0.554
Guigang	0.457	0.495	0.490	0.475	0.494	0.544	0.534
Yulin	0.527	0.587	0.600	0.563	0.568	0.586	0.564
Baise	0.502	0.545	0.548	0.542	0.551	0.579	0.563
Hezhou	0.498	0.585	0.594	0.547	0.611	0.631	0.660
Hechi	0.520	0.584	0.536	0.513	0.577	0.575	0.575
Laibin	0.436	0.561	0.545	0.549	0.572	0.544	0.534
Chongzuo	0.501	0.536	0.541	0.557	0.583	0.614	0.584
Average	0.580	0.617	0.620	0.608	0.624	0.640	0.634

5. Conclusion

From 2008 to 2020, there was a discernible upward trajectory in the urbanization rate of Guangxi province, as evidenced by the urbanization index ascending from 0.312 to 0.360. Notably, substantial regional disparities were observable in the urbanization index across various cities within the province. Cities exhibiting higher levels of urbanization were predominantly concentrated in the northern and central-southern regions, while a ring of cities with lower urbanization levels encircled Nanning. Additionally, the eastern sector of the GuiDong region predominantly featured cities of intermediate urbanization status. The dynamics of resource and environmental carrying capacity exhibited notable fluctuations during this period, with an increase observed from 0.403 in 2008 to 0.482 in 2020. This evolution manifested spatially in a concave distribution pattern.

Furthermore, the carrying capacity of resources and the environment within prefectural-level cities showcased a roughly decagonal configuration. This characteristic structural layout can be attributed to multifaceted influences, including natural conditions and economic development. Consequently, the decagonal band development pattern aptly typifies the resource and environmental carrying capacity within each prefecture-level city.

From 2008 to 2020, the level of coordination between urbanization and resource and environmental carrying capacity in Guangxi has been rising.The average value of coupling coordination degree has increased from 0.580 to 0.634. Prefectural-level municipalities have experienced a stage of change of "on the verge of dislocation-barely coordinated-primary coordination-intermediate coordination". Furthermore, there is an observable spatial distribution pattern from west to east, which exhibits the following characteristics: 'low-high-low-high.' This spatial distribution pattern aligns closely with the spatial distribution of resource and environmental carrying capacity.

References

[1] Guo, Y., Wang, H., Nijkamp, P., & Xu, J. (2015).Space–time indicators in interdependent urban–environmental systems: A study on the Huai River Basin in China. Habitat International, 45, 135–146.

ISSN 2522-3488 Vol. 7, Issue 7: 40-46, DOI: 10.25236/IJNDES.2023.070706

[2] Wang, J., Shen, L., Ren, Y., Wei, X., Tan, Y., & Shu, T. (2019). An alternative model for evaluating the balance of carrying capacity between functional urban infrastructures. Environmental Impact Assessment Review, 79, 106304.
[3] Ye, W., Xu, X., Wang, H., Yang, H., & Yang, Z. (2016). Quantitative assessment of resources and environmental carrying capacity in the northwest temperate continental climate ecotope of China. Environmental Earth Sciences, 75(10), 868.
[4] Zhu, M., Shen, L., Tam, V. W. Y., Liu, Z., Shu, T., & Luo, W. (2020). A load-carrier perspective examination on the change of ecological environment carrying capacity during urbanization process in China. Science of The Total Environment, 714, 136843.