Chapter

Spatial Carrying Capacity and Sustainability: Cities, Basins, Regional Transformation

Tao Ma, Nairong Tan, Xiaolei Wang, Fanfan Zhang and Hui Fang

Abstract

This chapter focuses on the spatial carrying capacity of different types of space units. Based on the characteristics of different units, it discusses how resource carrying capacity, environmental carrying capacity, ecological carrying capacity, and infrastructure carrying capacity together affect the spatial carrying capacity and allocation efficiency of space units. Cities need agglomeration of economic and demographic elements to expand the scale of spatial carrying capacity. Basins need to allocate water resources rationally under the condition of limited water resources for the sustainable development of river basin ecosystem. Regions need to explore regional comparative advantages and transformation paths from regional industries. The case studies discuss how the spatial carrying capacity of cities, river basins, and regional transformation adapt to environmental changes and the direction of carrying capacity improvement.

Keywords: spatial carrying capacity, cities, basin, regional transformation

1. Introduction

Environmental change is having a huge impact on human society, how to optimize, adjust and reconstruct the interaction between human and natural systems, and how to provide urban residents with a high-quality living environment [1], has become the critical issues faced by human society. At present, it has exceeded that China's population is more than 1.5 billion, and in the future, economic and demographic factors will continue to gather in the medium and long term. Meanwhile, a series of issues such as food security, water resource security, ecological load, and air pollution will be highlighted. From the perspective of the relationship between spatial carrying capacity and sustainability in China, cities, basins and regions are not adapted to resource and environmental carrying capacity. The economically dense megacities such as the Beijing-Tianjin-Hebei Region, Yangtze River Delta, and Guangdong-Hong Kong-Macao Greater Bay Area are closed to or exceed their carrying capacity. It is necessary to coordinate and improve the comprehensive carrying capacity of upper and lower reaches about the river basins [2], due to the Yangtze River, Yellow River, Pearl River, and other river basins connect ecologically fragile highly dense economic areas to many provinces and cities in in China.

This chapter focuses on the relationship between the carrying capacity of different types of space and sustainability, taking the spatial carrying capacity of Chinese cities, river basins and regions under the influence of changes in resource and environmental elements as the research object, and discussing the direction on the improvements on different units adapted to environmental changes.

2. Spatial carrying capacity and sustainability

2.1 The analytical framework of spatial carrying capacity

Carrying capacity originally refers to the mechanical or engineering characteristics of manufactured objects or systems. It appears in the shipping field with steam power as a sign, and is used to evaluate wind and steam power [3]. In the 1870s, when carrying capacity was first applied to biological and natural systems, it was used to measure the maximum amount of animals and food from natural system extremes. The evolution of carrying capacity is the inevitable result of human transformation and development in nature. From the initial biosphere consideration of the maximum of individuals or populations to the planet-scale development, sustainability research on carrying capacity is playing an increasingly important role under the constraints of global environmental change.

China is one of the most populous countries in the world. The degree of governance of climate change and environmental degradation has a profound impact on the process of global sustainable development. Therefore, the establishment of carrying capacity as the core analysis tool selects three levels of cities, basins and regions, and through multi-scale and multi-level element coupling, respectively proposes promotion strategies and spatial layout models, in order to achieve the realization of China's economic society sustainable development goals. Cities are relatively small carrying capacity units, river basins are secondary carrying capacity units. The basic urban units constitute the spatial carrying capacity unit at the basin scale. The basin carrying capacity unit belongs to the regional carrying capacity unit.

2.2 The spatial carrying capacity of cities

A city is a multi-dimensional carrying space consisting of resources, environment, ecology, population, economy, and society, which are the foundation of sustainability. A city is an important carrying space not only consisting of population, ecosystems, industrial clusters, but also for resource consumption and environmental pollution. The space provided by the urban unit is a construction and industrial development space, such as economic output, city scale, traffic capacity, land resources, etc. The spatial scale and growth boundary are affected by the interaction of resources, environment and technology, human activity and environmental sustainability, which is coordinated to the ultimate goal, so that it can be protected and improved the resources for the survival of humans.

The preconditions oriented in multi-element expansion of urban space are spatial carrying capacity for the development of sustainable. Sustainability of urban units is the foundation of social economic development, which lie both in regional and higher levels of units. They are the fundamental area for various aggregation factors of production, which carry more and more efficient production through the expansion of space scale, population size, industry, transportation and urban infrastructures. Despite that, sustainability is the precondition for expansion of units,

setting goals within the boundaries of spatial carrying capacity and taking baseline of resources and environment, in such a way as to facilitate comprehensive benefits.

2.3 The spatial carrying capacity of River Basin

Basin scale is a spatial unit divided by natural geographical ecosystem. Due to the sharing of water resources in the basin, the upstream and downstream water resources competition is fierce, and the water resources carrying capacity of each city forms a common support and constraint, the total amount is fixed, and the relationship between this and the other changes. It is characterized by linking different administrative units and stakeholders through water resources. The sustainable development of river basin mainly focuses on the rational allocation of water resources and maximizes the economic, social and ecological conditions within the threshold value of water resources carrying capacity.

The basin carrying capacity should be innovated in management mode in upstream and downstream. In the new stage of coordinated development of river basin, it is necessary to take full account of the disharmonious separation of basin units, the limited overall development space of the basin, the enhancement of the correlation between the development activities of different units in the same basin and the constraint of the total amount threshold of the carrying capacity of resources and environment, so it is necessary to carry out fine management of water resources in the basin. The current basin development model still has many problems, such as low efficiency of water resources utilization, fierce competition between upstream and downstream water resources, and low overall water quality. Therefore, it is necessary to coordinate the cooperation among different units in the basin to enhance the overall carrying capacity of the basin.

2.4 The comprehensive carrying capacity of regional function division

The comprehensive carrying capacity of a region is different in space and changes dynamically with time. The comprehensive carrying capacity of the region is the sum of all resources in a specific space (material resources, energy resources, information resources, space resources, human resources, social resources, etc.), which can provide the comprehensive development capacity of the region. On one hand, Because of the difference of economic development level and resource endowment in each region, the comprehensive carrying capacity of each region is different. On the other hand, the spatial carrying capacity of a region changes dynamically with time. In some resource-based urban areas, the development of natural resources will generally promote the development of industry and the growth of population, bringing about the improvement of carrying capacity. However, When the stock of natural resources to reduce or dried up, there will be a leading industry gradually decline, the ecological environment is destroyed, social problems highlight contradictions.

To promote the coordinated development of regions, it is necessary to concentrate population and economic activities in regions with high carrying capacity according to the differences of core functions of each region, while reducing the scale of population aggregation and economic activities in ecologically fragile regions. The connotation of regional coordinated development is to comprehensively coordinate the relationship among economy, society, population, resources and environment, and guide the economic layout and population distribution to adapt to the carrying capacity of resources and environment. In order to reduce the imbalance of regional development is to promote regional harmonious

development, according to different regional development potential and the resource environmental carrying capacity, according to the regional division of labor and coordinated development of the principle of overall consideration the future population distribution, economic layout, land use and urbanization pattern, reverse the regional resources excessive development for a long time, the regional ecological environment has become increasingly serious phenomenon.

3. Environmental changes and sustainable development of cities

3.1 The impact of environmental changes on spatial carrying capacity of cities

Natural resource and environment are the basic elements of urban spatial carrying capacity, which determine the degree of urban industrialization and expansion. Understanding the great changes in the spatial and material relationship between human and nature are the key determinant factor of sustainable development [4]. The natural environment can provide humans with the greatest degree of carrying capacity, and the environmental resource basing on which all human economic activities ultimately depend include ecosystems that produce various services [5]. As a result of the interaction between human activities and the natural environment, different natural landscapes, economic patterns, and temporal and spatial dynamic characteristics are produced. It can examine the maximum carrying capacity under the action of man-land relationship, including the upper limit of population, natural resource (water, atmosphere, animals and plants, minerals), and the characteristics of the dynamic changes on the spatial and temporal scales. There has a significant impact on social and economic activities about geographical environment and climatic conditions. China has abundant natural resources, including coal, crude oil, natural gas, pyrite, bauxite, copper, etc., which have promoted the development of manufacturing in coastal and inland area. The difference in factor supply brought by regional resource endowments, which the fundamental reason that determines the continuous development and spatial expansion. Furthermore, the development of urban spatial carrying capacity has gradually shifted to regional division of labor basing on comparative advantages, the man-land relationship shifts to a larger-scale study of the ecological environment, economy and society.

The carrying capacity dominated by environmental changes is transformed into a spatial constraint factor as the urban expansion reaches to the certain threshold. The urban spatial carrying capacity under the background of environmental changes focuses on physical geography, resource endowment, and extreme carrying limit. However, when the urban expansion approaches the carrying threshold, the laws of ecological economy such as total withdrawal, structural optimization, and restoration of ecological system functions begin to affect the efficiency of urban economic and social development, and the ecological carrying function is transmitted to the ecological restraint function. At this time, the spatial carrying capacity should be expanded from the original regional scale to the planetary boundary frame below the global scale, emphasizing that the urban economic and social activities should maintain a sufficient safe distance from the threshold of the earth's ecosystem [6]. The concept of planetary boundaries provides a starting point to understand the natural resources and processes on which human sustainable development depends [7], and set up ecological carrying functions of different regions and scales through a global top-down perspective. Based on this, with the development of urban land resources and the expansion of urban space in China, the ecosystem and ecological environment has gradually become the constraining functional bearer of sustainable urban development. Because of negative economic-environmental

externalities, when the threshold is approaching, the urban expansion and efficiency increase gradually show rigid constraints.

3.2 The unsustainable problems in urban development

The unsustainable problems in the process of urban development are mainly embodied in the spatial carrying capacity of economic society, population, resource endowments, environmental capacity and various urban service facilities. With the continuous expansion of cities and the rapid growth of population, the carrying capacity on resources and environment has gradually attracted widespread attention. In the process of large-scale industrialization and urbanization in China, the land element, as the basic element of spatial carrying capacity, is the direct element of population, industry and life community of mountains, rivers, forests, fields, lakes and grasses. Due to rapid consumption of land resources, the supply structure and allocation efficiency of land resources show long-term flexibility. China has a large number of resource-based cities dominated by coal, steel, and oil. At the same time, Beijing and Shanghai are also core cities with severe water shortages. In the long run, the structural scarcity of land resources, water resources, and mineral resources will further affect the sustainable development of cities. In the process of urbanization, a large number of populations have been concentrated, especially in rapidly developing global cities in China, where the floating population is huge, consequently a large number of resource consumption, energy consumption, and environmental pollution problems arise. The urban environmental capacity is close to saturation, smog and automobile exhaust pollution, which also common problems in the process of urban development. In addition, the allocation of urban infrastructure and public service facilities are unreasonable, especially the various urban service facilities of large cities have been overloaded, which are also an important issue that restricts the sustainable development.

3.3 Improvement of cities carrying capacity under the sustainable development goals

The spatial carrying capacity transmitted from the planetary boundary scale to the national downscaling is increased to achieve the sustainable development goals. Sustainable development requires the use of natural resources by humans to be kept within environmental limits [8], this means that on the basis of recognizing that human activities continue to cause major global environmental changes. As a criterion and important influencing factor of carrying capacity, it is necessary to fully account for the various public, exclusive and irreversible risks arising from the ever-increasing global climate change, water resource changes, and the fragility of ecosystems. In particular, the global climate change caused by the spatial diffusion of carbon dioxide-based greenhouse gases, which determining to environmental governance should shift from the original biosphere level to the global level planetary scale. The sustainable development and other national decomposition of goals can be achieved to need a multi-scale systematic approach [9]. Downscaling transmission from the planetary boundary scale to the national level can be realized by means of consume of good and services basing on carbon footprint [10].

The coordinated resource and environmental carrying capacity provide best standards of practice for China. In 2019, the "Several opinions on establishing spatial planning system and supervising its implementation" clarified the basic role of the evaluation of "resources and environmental carrying capacity and spatial suitability" based on bottom-line management and control [11]. In 2020, "Resources and Environment Carrying Capacity and Space Development Suitability Evaluation

Technical Guidelines (Trial Version)" established standards of practice in provinces, cities (districts) in China. Delineate urban growth boundaries, baseline of farmland, resource and environment through the evaluation system to achieve management and control of urban units; through the economic scale, population forecast and demand update in urban development, and at the same time integrate ecosystem units to achieve urban identity flexible management and control; by responding to the spatial layout of various elements in different scales of space, it can be achieved to realized the carrying capacity and scale of elements to sustainable development nationally.

The technological innovation should be used to improve the carrying capacity of resources and environment. A basic assumption of economics is the scarcity of resources, as the supply of resources is limited to the needs of human beings, mainly including the limitation of quantity, quality, time, space, structure, capital and environmental capacity, there is no exception for both natural and social resources. However, technological innovation can improve the utilization efficiency of resources, which alleviating the scarcity of resources to a certain extent, reducing the dependence on natural resources, damaging to the ecological environment, and improving the carrying capacity of resources and environment.

4. Environmental change and sustainable development of river basin

As an important typical spatial unit, basin has the characteristics of coordinating the upstream and downstream subsystems and coordinating the resource elements of each unit. There is a close relationship between the fluctuations of water resources in the basin. Under the condition that the total amount of water resources is fixed, it is of great significance to play the role of overall planning and unified allocation for the basin as a whole and each economic unit.

4.1 The impact of environmental change on spatial carrying capacity of River Basin

Environmental changes have intensified the vulnerability and instability of the whole basin space, and the spatial carrying pressure in the basin is increasing. With the continuous development of the resources in the basin, the vulnerability of the basin environment is increasing. The reserve of resource elements in the basin has become a huge constraint on the carrying capacity of the basin, especially the shortage of water resources has a great impact on the development of the basin. As an important area of ecological security, energy security, food security and economic security in China, the Yellow River Basin has serious problems such as low water use efficiency, shortage of water resources and serious water pollution in some provinces and regions. The imbalance of water supply and demand has become a serious challenge to the sustainable economic and social development of some provinces [12].

From the perspective of water carrying capacity, the total water load of the basin is too large. Gansu, Ningxia, Inner Mongolia. The water carrying capacity of Shaanxi and Shanxi provinces is in the state of overload and serious overload. Except for Qinghai Province and Gannan Prefecture of Gansu Province, the per capita water resources of other cities are in low and very low levels. The water consumption of ten thousand yuan industrial added value, groundwater exploitation coefficient and ecological environment water use rate are all in low and very low levels. Among them, the groundwater in Inner Mongolia except Alxa League is in low and very low level. The exploitation coefficient is above 15. The development

and utilization degree of groundwater is very high. The irrigation water takes up 72.5% of the total water, and the ecological environment water consumption rate is only 4.7% [13].

In terms of water quality carrying capacity, the water quality of the middle and lower reaches of the Yellow River is poor. The water quality carrying capacity of Qinghai Province is mostly in the state of overload, while Xining city is in the state of overload; the water quality carrying capacity of some cities in Ningxia, Inner Mongolia and Shanxi Province is seriously overloaded, and the water quality standard rate and per capita pollutant discharge of water functional areas are in low and very low levels.

4.2 The unsustainable problems in the utilization of water resources in River Basin

The lower reaches of the Yellow River are frequently cut off, resulting in serious water shortage. The Yellow River has been cut off since 1972, and the time and frequency of the water cut-off are getting higher and higher. The Yellow River almost becomes a seasonal river, and the supply of water resources has exceeded its carrying capacity. The Yellow River Basin is a typical monsoon climate region. The runoff is mainly formed by rainfall [14]. The temporal and spatial distribution is extremely uneven, and the rainfall in flood season is abundant, which makes the contradiction between supply and demand of water resources more prominent in non-flood season.

The phenomenon of waste and low utilization of water resources is prominent. Taking Shandong as an example, the irrigation water from the Yellow River accounts for about 90% of the total water diversion in Shandong Province, and the main way is flood irrigation and string irrigation. The lining rate of the Yellow River diversion channel is only 7.5%. The irrigation area is short of supporting facilities and serious leakage. The irrigation water utilization coefficient is only about 0.4, compared with 0.7–0.8 in advanced countries, the waste is very serious [15].

The water ecosystem is destroyed, the water quality is deteriorated and the function of water body is reduced. With the continuous growth of population and the rapid development of industry and agriculture, the amount of sewage discharge has increased sharply. The increase of sewage discharge and the discharge of sewage exceed the standard, which makes the water pollution of the Yellow River become more and more serious. The pollution has developed from the tributary to the main stream, and the pollution of the main stream has also spread from the upper reaches to the middle and lower reaches.

4.3 Improvement of basin carrying capacity under sustainable development goals

The natural ecological background of the Yellow River Basin is fragile and the amount of water resources is limited. Due to the sharing of water resources in the Yellow River Basin, the water resources carrying capacity of each city forms a common support and constraint, the total amount is fixed, and the relationship between this and the other is ebb and flow. Ecological protection and high-quality development of the Yellow River Basin is a major national strategy. In order to implement this strategy, we should give full play to the leading role of central cities in the Yellow River Basin, enhance the comprehensive carrying capacity and resource allocation efficiency of the Yellow River Basin, and form a regional layout with complementary advantages and high-quality development.

Central cities play an important role in promoting regional development. Central cities and urban agglomerations have become the main spatial forms of carrying development elements. For example, with its unique geographical location, Jinan will play an important strategic role in the development of the central city of the Yellow River Basin, whether it is ecological protection and high-quality development of the Yellow River Basin or energy conversion, and its development vision will be highly consistent with the direction and implication of the national strategy. Therefore, it is an important way to promote the development of the carrying capacity of the Yellow River Basin. We should make use of the central city construction to improve the spatial ecological governance pattern of the Yellow River Basin. Taking the central city as the core, through coordinating the development orientation of the city, we can form an orderly urban development pattern and establish a multi-centers, network-based regional ecological governance structure. In this regional ecological governance structure, each region not only seeks its own interests independently, but also adjusts and adapts to each other under the framework of economic zone, realizing the coordination of economic boundary and governance boundary, thus promoting the optimization of spatial water resources governance pattern in the Yellow River Basin.

To promote the cooperation and linkage between the upper and lower reaches of the Yellow River Basin, and promote the urban water resources carrying capacity of the Yellow River Basin. We should strengthen the scientificity of the land and space planning of the central cities in the Yellow River Basin, make full use of the water resources to study and judge the future development direction of the city, promote the rational distribution of industry and population in the central city, and effectively play the role of scientific guidance and macro-control of urban planning. Promote the integration of multiple plans and establish a unified urban space planning system. In addition, it is also necessary to carry out accurate policies on the classification of different main functional areas such as key development areas, prohibited development areas and ecologically fragile areas, so as to continuously improve the spatial governance pattern of water resources in the Yellow River Basin. We should adhere to the principle of determining the city by water, land, people and production by water. The middle reaches of the region should further enhance the ability of energy development, utilization and allocation, strengthen the ecological environment governance and restoration, and actively cultivate the continuous alternative industries. The downstream areas should adhere to the intensive development, continuously transform the development momentum, and enhance the carrying capacity of population and industry. It is important to note, however, that the effectiveness of multi-level governance depends on the smooth realization of collaboration between governments and between governments and external actors, but there is a lack of analysis of how vertical and horizontal governance models empower each other rather than constrain each other.

5. Environmental change and sustainable development of regional function division

5.1 The impact of resource and environment changes on regional comprehensive carrying capacity

Many resource-based cities are facing the problem of resource exhaustion. According to the National Sustainable Development Plan for Resource-based Cities

(2013–2020), there are 262 resource-based cities in China. Among them, there are 126 prefecture-level administrative regions, 62 county-level cities, 58 counties and 16 municipal districts. In Northeast China, the industry started earlier and concentrated about one-sixth of the country's resource-based cities (21 prefecture-level cities in the three northeastern provinces). Many of these resource-based cities are facing the risk of resource depletion. Economic development in these regions is lagging behind, people's livelihood problems are prominent, and the ecological environment is under great pressure. Take Heilongjiang Province as an example. With the depletion of natural resources in Heilongjiang Province, 16 of the 33 major mines in the province have been depleted. The available resources of the forest industry system are only 19 million cubic meters, down 97.3% compared with the early days of the People's Republic of China. There are 40 forestry bureaus in the province, 2/3 of which have no forest to harvest. The Daqing oilfield has only 30 per cent of recoverable reserves.

Resource-exhausted cities bring about the reduction of population and industrial carrying capacity. For cities in northeast China, from 2014 to 2018, the urban population of some cities has decreased significantly, such as Anshan city by 19,700, Fushun city by 104,700, Daqing city by 91,400 and Benxi city by 89,000. Among the 19 resource-based cities available (the data of Greater Khingan Mountains and Yanbian Korean Autonomous Prefecture are not available among the 21 prefecture-level cities mentioned above), the urban population of 13 cities is decreasing, with a total decrease of 662,400 people [16]. On the whole, the population of resource-based cities in Northeast China is decreasing. Among the 19 prefecture level cities, only Daqing City (5.21%), Heihe City (0.38%) and Yichun City (0.16%) increased the proportion of mining industry employees in the whole city. The proportion of mining industry employees in other cities decreased, especially Qitaihe City (down 20.11%), Fuxin City (down 18.15%), Jixi City (down 13.31%). The employment proportion of mining industry in the city decreased the most.

5.2 The unsustainable problems in the current regional function division

The industry is relatively simple and the economic transformation is difficult. The economic decline of northeast China in recent years is closely related to the "single structure" of northeast China's industries. The proportion of energy and raw materials industries is too large, and modern manufacturing and modern service industries are underdeveloped. Due to the oversupply of bulk products in the international market, the domestic production of bulk product industry has been affected. Therefore, although there are many reasons for the economic downturn in northeast China, the "single structure" of the industry is undoubtedly one of the important reasons.

Excessive exploitation of resources results in serious environmental damage. Large-scale and extensive exploitation of natural resources is bound to cause serious damage to the ecological environment. In pursuit of wealth accumulation and economic growth, mining enterprises in areas with good resource endowments have risen to prominence, forming a large-scale, high-intensity and group-oriented resource development situation. Many resource-based cities thrive on mining, with cities built on top of mines and mining under cities. In recent years, the externalities of resource-based industries, such as environmental pollution, ecological decline and resource depletion, have become prominent. In particular, the process of resource utilization will cause environmental deterioration of atmosphere, water and soil, and at the same time, it will also give rise to a series of ecological environmental problems.

5.3 Improvement of regional carrying capacity under sustainable development goals

Use comparative advantage, guide population and industry to move to the area with higher carrying capacity. Northeast China is rich in resources and has the resource base to develop the primary industry and the secondary industry. However, after the service industry of the tertiary industry has become the main engine of economic development, most areas in northeast China are affected by natural and climatic conditions, which makes it difficult for them to gather and attract more population and industries, and resource-based cities that used to absorb a large number of jobs are gradually facing the pressure of population outflow. In the future, it needs to guide the migration of population and industries to the big cities in northeast China, improve the core carrying capacity of big cities, and develop the industries of higher education, scientific research, military industry and heavy industry with northeast characteristics in big cities. In other large areas, at least in the short term, resource-based cities in northeast China, as an important energy supply base, still need to continue to assume the responsibility and pressure of supplying resources and energy in order to ensure the rigid demand for resources and energy and national strategic security.

In the long run, we should strengthen the endogenous driving force of economic growth in resource-exhausted cities by cultivating diversified industrial systems. Utilize local advantages to develop diversified industries. Take Fuxin, a coal city in Liaoning province, as an example, it has vast land and great agricultural development potential, and the agricultural products processing industry is booming. Fuxin is rich in fluorite resources, and the fluorine chemical industry based on this raw material has begun to develop. Taking coal gangue produced in coal mining process as raw material, a number of building materials enterprises are emerging gradually. In view of the increasingly depleted resources, we should plan ahead to promote the development of emerging industries. For example, Volvo's plant in Daqing, is a model for the introduction of new industries. Daqing, which has no automobile industry base at all, has initially set up a high-end automobile factory, injecting new vitality into this increasingly exhausted resource-based city. In 2017, Daqing exported more than 25,000 vehicles, with an export volume of $897 million, accounting for 74% of the city's total exports. Therefore, it is feasible to construct capital intensive industries such as automobiles in remote, cold and remote areas due to their low labor cost, high degree of automation and low transportation cost.

Author details

Tao Ma*, Nairong Tan, Xiaolei Wang, Fanfan Zhang and Hui Fang
Harbin Institute of Technology, Harbin, China

*Address all correspondence to: matao@hit.edu.cn

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