ISSN 2616-5783 Vol.6, Issue 16: 61-68, DOI: 10.25236/AJHSS.2023.061609

Research on Coupled and Coordinated Development of New Urbanization and Ecological Environment

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Abstract: *With the acceleration of new urbanization construction, the contradiction between urbanization construction and ecological environment protection has become increasingly prominent, which directly affects regional coordinated development. The coupling system between urbanization and ecological environment is an important part of the regional system of human land relations. In the face of global scale remote connections, spatiotemporal compression, and socio-economic reconstruction in the new era, traditional research frameworks urgently need to be transformed and upgraded. Drawing on theories such as the regional system of human land relations, remote coupling, and planetary urbanization, starting from the perspective of complexity science, this paper first analyzes the connotation of the coupling system between urbanization and ecological environment. Then, from four dimensions of space, time, representation, and organization, an analytical framework is proposed to explain the coupling mechanism between urbanization and ecological environment - the "Coupling Cube (CHNC)", which discusses its concept, connotation Evolutionary law and analytical framework: the system and system, system and elements, and elements and elements in the Rubik's Cube are interconnected and interact through various "coupling lines" to form an organic whole nested, interconnected, and Unity of opposites; The rotation of the Rubik's Cube represents the spatiotemporal nonlinear coupling effect between urbanization and ecological environment in different regions.*

Keywords: *new urbanization; ecological environment; coupling and coordination*

1. Introduction

In 2012, the 18th National Congress of the Communist Party of China (CPC) held a proposal to take the path of new urbanization, abandoning the blind nature of population transfer in the past, and instead promoting comprehensive urbanization, fundamentally elevating the height of the urbanization process. As of the end of 2021, according to data from the National Bureau of Statistics, the number of permanent urban residents in China reached 914.25 million, an increase of 1.33% compared to last year, and the urbanization rate increased by 0.83% compared to the previous year. [1]With the rapid improvement of China's new urbanization level, the problems of air pollution, noise pollution, solid waste and other pollutants brought to the ecological environment are increasingly prominent, and the ecological Carrying capacity is further reduced. In this context, the construction of ecological civilization is particularly important, and the coordinated development of new urbanization and ecological environment has become an urgent problem to be solved. The coordinated and symbiotic development of the two has important practical significance for the high-quality development of the economy and society.

2. Literature Review

The interactive coupling of urbanization and ecological environment is an open and complex giant system involving society, economy and nature, which contains a complex interactive coupling mechanism and the law of Unity of opposites. Scholars from different disciplines such as geography, environmental science, ecology, economics, and management have proposed many research theories and frameworks to address this issue. Due to the mature and stable stage of urbanization in developed Western countries, in recent years, Western scholars have mainly focused on the mechanism exploration and case analysis of the coupling relationship between human activities and the natural environment with cities as the core. The research framework mainly includes the coupling system between humans and

ISSN 2616-5783 Vol.6, Issue 16: 61-68, DOI: 10.25236/AJHSS.2023.061609

nature[2], social ecological systems (SES), ecosystem services, environmental footprints , planetary boundaries Telecoupling, Water Energy Food Network, DPSIR Framework , STIRPAT Framework, Energy Analysis Framework, Sustainable Livelihood Framework, Population Development Environment Research Framework (PDE), etc.. Since the 21st century, Gunderson et al. have proposed the famous cross scale system adaptive nested model; Dietz et al. elaborated on the characteristics of cross boundary coupling between humans and nature; Folke discussed elastic methods for studying social ecosystems; Liu further proposes the Metacoupling framework based on remote coupling, which integrates the interaction coupling relationships between the inside and outside of the system and the distance within one framework.

In China, important theories and research frameworks for the interaction and coupling between urbanization and ecological environment are mainly based on the paradigm of systems theory and have been well applied. In 1979, Wu Chuanjun proposed the regional system of human land relations, which is a complex and open dynamic system based on a certain area of the Earth's surface. It is formed by the mutual connection and interaction between the geographical environment and human activities in specific regions; In 1984, Ma Shijun and Wang Rusong proposed a social economic natural composite ecosystem. The theoretical core is ecological integration. Through structural and functional integration, the relationship between the three subsystems and their internal components is coordinated, so that the system has the highest comprehensive benefits, the smallest risks, and the largest survival opportunities, and the coupling relationship between the three subsystems is harmonious and orderly; In 1999, Fang Chuanglin proposed the theory of human land coupling circle, which nested the urbanization demand circle with the ecological environment constraint circle, and then judged the type of human land system coupling and future evolution trend; In 2015, Fan Jie innovated the early warning system for resource and environmental carrying capacity based on human land relations, proposing to carry out overload warning from key thresholds such as the upper limit of resource and environmental constraints or the reasonable size of population and economy. The research framework and technical process for process warning from changes in natural basic conditions or changes in resource utilization and environmental impacts.

On the basis of previous theoretical research, this article first analyzes the scientific connotation of the coupling system between urbanization and ecological environment, and then draws on theories such as human land relationship regional system, remote coupling, and planetary urbanization. Based on the complexity science research paradigm , from the four dimensions of space, time, representation, and organization, the concepts of long-term coupling, implicit coupling, and inter group coupling are proposed, We have innovatively constructed a research framework called "Coupled Human and Natural Cube" (CHNC) to explain the coupling mechanism between urbanization and ecological environment, in order to promote the development and improvement of human land system theory in the new era, provide theoretical support for multi-dimensional analysis of urbanization and ecological environment evolution and coupling mechanism, and enhance the sustainability of regional policy formulation.

3. Scientific Cognition of the Coupling System between Urbanization and Ecological Environment

Urbanization is an important driving force of the Anthropocene and one of the most important manifestations of the development and evolution of human society, including a series of complex evolution and transformation processes such as large-scale population migration, urban land expansion, industrial structure adjustment, capital agglomeration, cultural and consumption habits change, etc; The ecological environment is the natural background conditions and supporting system for human survival and reproduction, which covers many natural elements such as water, soil, gas, biology, energy, minerals, etc. It is the sum of various ecological factors and ecological relationships on which living organisms rely for survival, development, reproduction and evolution. "Coupling" was originally a physical concept, which refers to the phenomenon that two or more systems or two forms of motion affect each other through various interactions and thus combine together.[3] Geographers borrowed and developed the term to explain the complex interdependence, interaction, mutual influence The phenomenon or process of mutual adaptation and tending towards coordination and unity has profound connotations. Therefore, the coupling between urbanization and ecological environment also includes two aspects: urbanization exerts coercive or promoting effects on the ecological environment through population growth, economic development, energy consumption, technological progress, urban management, and expansion of construction land. The ecological environment also exerts constraints or carrying effects on urban development through resource carrying capacity, environmental capacity, ecosystem services, environmental equity, and policy intervention. The two systems are mutually inclusive the competition

ISSN 2616-5783 Vol.6, Issue 16: 61-68, DOI: 10.25236/AJHSS.2023.061609

and cooperation of Unity of opposites.

To vividly understand the coupling system between urbanization and ecological environment, we use the conceptual diagram in Figure 1 for explanation. Urbanization and ecological environment are two complex open giant systems. Urbanization system includes population, economy, society, information, infrastructure and other subsystems. Ecological environment system includes water resources, land, atmosphere, biology, energy, minerals and other subsystems. Each subsystem contains many elements, some of which are main control elements (called order parameters in synergetics), and some are general elements. The main control elements in the diagram are large dots, while the general elements are small dots. In Figure 1, the elements within each subsystem interact with each other through horizontal connections, while subsystems interact and connect through vertical connections. There are more interconnections between urbanization and the ecological environment. This article collectively refers to these complex and complex connections as "coupling lines", representing the positive and negative feedback effects between systems, systems and elements, and elements and elements. These include promotion and constraints, opposition and unity, and the coupling mechanisms behind each coupling line are different, with varying coupling strengths. These complex interaction and cooperation forces have an impact on the whole coupling system of urbanization and ecological environment all the time in the spatiotemporal dynamic dimension. The self-organization of the underlying elements and the emergence of the whole system occur at the same time, thus generating the fluctuations of the whole system, Co-determination determining the evolution direction of the whole coupling system.

Overall, the coupling system between urbanization and ecological environment is a very important part of the human land relationship regional system. The two internal subsystems not only have their own evolutionary laws and constraints, but also form a complex coupling giant system that is interconnected, supported, and constrained through continuous material circulation, energy flow, and information transmission. [4]The evolution process is a self-organizing fluctuation process that gradually transforms from a disordered chaotic state to an ordered structure through interactions with the external environment and subsystems in a certain time and space dimension. This evolution pattern and process exhibit multi-level nature, with interconnected levels and multiple coupling and feedback mechanisms between processes, and different scales of action for different processes. According to the theory of complex systems, the coupling system between urbanization and ecological environment has characteristics such as openness, self-organization, nonlinearity, fragility, robustness, dominance, fluctuation and phase change, multiple feedback, scale nesting, etc.

4. The Theoretical Basis and Conceptual Connotation of the "Coupling Rubik's Cube" between Urbanization and Ecological Environment

4.1 Theoretical basis of the "coupling magic cube" between urbanization and ecological environment

The "Coupling Rubik's Cube" analysis framework to be elaborated in this article is a development and innovation of existing relevant theories, mainly drawing on theories such as human land relationship regional systems, remote coupling, and planetary urbanization.

4.1.1 Regional System of Human Land Relations

Wu Chuanjun believes that the regional system of human land relations is an unstable, nonlinear, and dissipative structure far from equilibrium. It is pointed out that studying the relationship between humans and the environment must pay attention to the relationship between time and spatial changes, taking into account the size, location, and other attributes of spatial regions, as well as the past, current situation, and future prospects of time. The research goal is to explore the interaction of various elements within the system and the overall behavior of the system, and to understand and seek the mechanisms of holistic optimization, comprehensive balance, and effective regulation of human land relationship systems at different scales from the perspectives of spatial structure, time process, organizational order change, overall effects, and synergistic complementarity. In addition, the interaction between humans and the resource environment relies on intermediate products, and the most basic intermediary is food; Input-output is the most fundamental bidirectional process in the human land system. Lu Dadao emphasized the need for a comprehensive and systematic concept, as well as a regional and hierarchical concept, in the study of the human earth system. The research topic is the interaction mechanism and evolutionary trend of system elements.[5] On this basis, other scholars have made certain developments in the structure of the human land system, the coupling theory of human land relations, the evolution of the human land system, and the regional system of human sea relations .

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4.1.2 Remote coupling

Liu et al. published an article in Science in 2007, explaining the nonlinear dynamic mechanisms underlying the coupling system between humans and nature. They pointed out that the evolution of the system is accompanied by thresholds, mutual feedback loops, time lag, resilience, heterogeneity, and mutations, and initially proposed the scientific problem of long-distance coupling between systems; Afterwards, the concept of remote coupling was discussed in detail, and the International Human Nature Coupling System Research Network (CHANS) was created and led. [6]It believed that population migration, tourism, trade, species diffusion, technology transfer, investment, etc. were important remote coupling processes. Taking soybean trade, giant panda habitat protection, etc. as examples, a multi-scale coupling model was constructed to integrate sending, receiving, and overflow systems, Propose a general analysis path for remote coupling based on system, flow, agent, cause, and impact. In recent years, using this theoretical framework, scholars have carried out extensive discussions on land use change , water resource management and virtual water , ecosystem services, energy , fishery management , the Belt and Road connection and other fields.

4.1.3 Planet Urbanization

Planetary urbanization was proposed by Brenner et al. in 2011 and has attracted widespread attention from scholars worldwide. This theory criticizes the discussion of the urban era, pointing out that the city is not a unit, but a process of change. The traditional urban-rural boundary tends to blur. Urbanization is a global and multi-scale historical process, which extends to every corner of the earth. Therefore, the research paradigm should turn to "planetary urbanization". In terms of methodology, we should go beyond "urban centrism", change the binary classification of cities/non cities, and develop the "Urban theory without an outside". It is believed that the Built environment of Global city will directly cause major changes in the global atmosphere, biological habitats, land use and marine conditions, and will have a long-term impact on future human beings and other life forms. Urbanization encompasses two dialectical relationships: concentration and expansion. Many places have developed into "extended regional urbanization", affecting areas traditionally considered non-urban, such as agricultural areas, industrial parks, cross-border transportation, energy pipelines and communication facilities, underground resource extraction, and even the entire biosphere.

4.2 The Basic Connotation of the "Coupling Magic Cube" between Urbanization and Ecological Environment

This paper draws on the core ideas of the above three theories, and further expands from the four dimensions of space, time, appearance and organization on the basis of the cognition of the Systems science of urbanization and ecological environment coupling. It systematically deconstructs the spatial distance, time span, apparent and implicit causality, and internal and external links of the organization based on the coupling of urbanization and ecological environment. The four dimensions constitute a panoramic and dynamic analytical framework for explaining the coupling mechanism between urbanization and ecological environment, and are nested, interconnected, and dialectically unified as a whole. To facilitate understanding and memory, this analytical framework is expressed in the form of a Rubik's Cube and is referred to as the 'Coupled Rubik's Cube' (CHNC).[7]

The coupling system between urbanization and ecological environment in any region can be seen as a small cube (CHNC-c) in the Rubik's Cube. Each small cube is magnified (CHNC-c '), which contains numerous natural and cultural elements. In the figure, small balls of different sizes (1,2,3,..., i) are used to represent it. The larger the volume, the stronger the influence on the system (i.e. order parameter), while the smaller the volume, the weaker the influence on the system, Positive and negative feedback occurs between each ball through a "coupling line". At the same time, the system is open, with arrows on the input and output small cubes indicating the inflow and outflow of people, materials, energy, and information. Each small cube represents a coupling system of urbanization and ecological environment in a specific region.

Each small cube has four interconnected and nested dimensions: time, space, organization, and representation. The X-axis represents the time dimension. The axis within the small cube belongs to the recent coupling effect between urbanization and ecological environment, while the axis outside belongs to the long-term coupling effect between urbanization and ecological environment; The Y-axis represents the spatial dimension. The axis inside the small cube belongs to the short-range coupling effect of urbanization and ecological environment, while the axis outside belongs to the long-range coupling effect; The Z-axis represents the organizational dimension. The axis within the small cube

ISSN 2616-5783 Vol.6, Issue 16: 61-68, DOI: 10.25236/AJHSS.2023.061609

belongs to the intra group coupling effect of urbanization and ecological environment, while the axis outside belongs to the inter group coupling effect. [8]In addition, from the perspective of representation, there is not only explicit interactive coupling between urbanization and the ecological environment, but also implicit interaction that is not visible on the surface or needs to be mediated indirectly. This kind of coupling effect is called implicit coupling. Therefore, there are short-term, short-term, intra group, and explicit coupling effects between urbanization and ecological environment within the cube. When extended to the outside of the cube, there are likely to be four mechanisms: remote coupling, long-term coupling, inter group coupling, and implicit coupling.

4.3 The Evolution Law of the "Coupling Magic Cube" between Urbanization and Ecological Environment

There are many colorful small cubes in the Great Rubik's Cube CHNC, each representing a relatively complete regional system of human land relations. They are interconnected and interact with each other through the complex axis chains inside the Rubik's Cube, which are referred to as "coupling lines" above. According to the theory of remote coupling and planetary urbanization, there are countless small cubes with different sizes and attributes on Earth that have either tight or sparse relationships. The global scale urbanization and ecological environment coupling system is a super large Rubik's Cube, while the national and regional scale coupling system is a relatively small Rubik's Cube, and there is a certain degree of scale nesting relationship between them. The evolution regularity of urbanization and ecological environment "coupling magic cube", if the color on each surface of the small cube represents the urbanization or ecological environment subsystems such as water, soil, gas, economy, population, energy, etc., the magic cube drives its own arbitrary rotation through the chain axis, this process involves the collision of different small cubes and different color planes. Among them, the chain axis represents the transmission of people, materials, and information between different regions, while the rotation of the Rubik's Cube represents the nonlinear coupling effect between urbanization and ecological environment systems in different regions, with the entire process constantly experiencing system fluctuations. We vividly believe that when the color of each side of the Big Rubik's Cube is consistent, it represents the coordinated development of all subsystems across different regions (but not the same level of development). This process requires the work of external forces, that is, the system continuously absorbs negative entropy, and when a certain threshold is reached, a critical phase transition occurs, resulting in the emergence of the system as a whole. Urbanization at a certain regional scale and the ecological environment system achieve coordination and order, and at this point, the "Rubik's Cube game" is successful. When internal or external disturbances occur in the human earth system, one is sudden natural disasters, financial crises, etc., and the other is a warm water frog like chronic sedimentation effect. According to the fragility and elasticity of the system, energy is continuously input. Once the threshold is exceeded, the system will collapse (phase transition), and the order will be broken again, entering a new round of evolution.

However, in reality, it is impossible for the subsystems of urbanization and ecological environment to achieve complete coordination, and the development of each region will not be absolutely coordinated. That is, the evolution of the Rubik's Cube is difficult to achieve color consistency on all sides. The actual situation is that the system constantly undergoes dynamic fluctuations, always in an intermediate state between order and disorder, and between stable and non-stationary states. This is also the general law of the evolution of most complex systems in nature. In addition, in order to make the system as orderly as possible, it is necessary to first select the order parameter that has the greatest impact on the overall evolution of the system for regulation. For example, in the northwest arid region, water resources should be selected as the order parameter, reflected in the Rubik's Cube, and priority should be given to regulating the green surface to make it consistent in color.

5. A Four Dimensional Analysis Framework for the "Coupling Rubik's Cube" of Urbanization and Ecological Environment

5.1 Spatial dimension: short range coupling and remote coupling between urbanization and ecological environment

From the perspective of regional spatial dimension, the coupling effect between urbanization and ecological environment can be divided into two categories: process and remote. Most of the current research by scholars focuses on the short-range coupling between urbanization and ecological environment. The short-range coupling mainly focuses on the coupling mechanisms between

ISSN 2616-5783 Vol.6, Issue 16: 61-68, DOI: 10.25236/AJHSS.2023.061609

urbanization and various subsystems of the ecological environment within the regional system, as well as the coupling mechanisms between various elements within the subsystems, including linear and nonlinear coupling mechanisms of one-to-one, one-to-many, and many-to-many. There are many studies in this category, and I will not elaborate on them here.

Remote coupling refers to the interaction between urbanization and the ecological environment within a regional system, as well as other regional systems or elements beyond a long distance, as well as systems at different spatial scales. Compared with short-range coupling research, the research on the remote coupling mechanism between urbanization and ecological environment is relatively insufficient, and the research difficulty is also relatively greater. International research has received increasing attention in the past decade, while domestic research has just begun to pay attention in recent years. According to Liu's definition, remote coupling is different from the remote connection (Teleconnection) of a simple Systema Naturae, such as the Teleconnection relationship between the onset of the Indian summer monsoon and the plum rain in the Yangtze River basin of China; [9]It is also different from the purely globalized connections of the socio-economic system, such as the impact of the rise in labor costs in China on investment by American multinational corporations. The remote coupling of urbanization and ecological environment studied in this paper emphasizes the remote two-way feedback of Systema Naturae and socio-economic system, which can include the impact of local ecological environment on urbanization in other places, as well as the impact of urbanization process in other places on local ecological environment. Unlike Liu's definition, this article further divides remote coupling into two categories: cross regional telecoupling (MRTC) and cross scale telecoupling (MSTC).

5.2 Long distance coupling across regions

Cross regional remote coupling refers to the interaction, coercion, or promotion of urbanization and ecological environment systems between different regions through various human, material, energy, and information flows. For example, the essential foods such as fruits, vegetables, meat, milk and eggs for the daily lives of citizens in large cities come from other small and medium-sized cities and even other countries, which has a remote impact on the land use, water security, carbon emissions, ecosystems, and even the environment of the input areas; The urbanization and heavy industry energy consumption in Hebei Province have a significant impact on air quality in Beijing, even South Korea, and Japan; The South–North Water Transfer Project in China has made the economic, social and ecological system of the water source area interact with the agricultural development, urbanization and groundwater of the water receiving area in a long distance; In the second half of the 20th century, the acceleration of urbanization in the middle and upper reaches of Shiyang River, an inland river in northwest China, led to the intensification of Desertification in Minqin downstream and the serious deterioration of the ecological environment; Since the the Belt and Road Initiative was put forward, trade between China and countries along the Belt and Road has become more frequent, and interdependence has increased. China's rapid urbanization process needs to import more energy and minerals, which will inevitably affect the ecological security of exporting countries.

5.3 Cross scale interaction coupling

Cross scale interaction coupling refers to the nested effect of interaction coupling between urbanization and ecological environment systems at different scales, which can occur through two pathways: top-down and bottom-up. Generally speaking, the coupling effect between systems with similar scales is more frequent and strong, such as at the scale of urban agglomerations and urban scales, while the coupling lines between systems with large scale differences are relatively small, such as between the national scale and the block scale. When analyzing the mechanism of cross scale interaction coupling, attention should be paid to the scale effect of coupling. There are significant differences in the manifestations and measurement indicators of urbanization and ecological environment at different scales.[10] In addition, urban agglomerations and cities are the mesoscale of national macro strategy and micro implementation entities, and regional synergy of industries and regional linkage of environmental governance must be completed at this mesoscale. They are nodes of scale transformation and cross scale coupling, and have their own special political and economic scale attributes. Relatively speaking, the cross scale coupling effect from top to bottom is more common, for example, the impact of global climate change on local urban development is a typical global scale effect on local scale; For another example, the policy of joint prevention and control of air pollution in Beijing Tianjin Hebei led to the closure of a chemical plant in Xingtai City, Hebei Province, which further promoted the ecological environment of the nearby villages and towns of the chemical plant to improve significantly. [11]The cross

ISSN 2616-5783 Vol.6, Issue 16: 61-68, DOI: 10.25236/AJHSS.2023.061609

scale coupling effect from bottom to top is also widely present, for example, the disorderly expansion of cities in central Inner Mongolia in China has intensified land desertification, which will affect the ecological security of the entire Northeast Asia scale.

6. Conclusion

(1) The coupling system between urbanization and ecological environment is a very important part of the regional system of human land relationship. The two subsystems not only have their own evolutionary laws and constraints, but also form a complex coupling giant system that is interconnected, supported, and constrained through continuous material circulation, energy flow, and information transmission.[12] The evolution process is a self-organizing fluctuation process that undergoes a transition from an disordered chaotic state to an ordered structure through interactions with the external environment and subsystems in a certain time and space dimension, and is mostly in an intermediate state between order and disorder.

(2) Drawing on theories such as the regional system of human land relations, remote coupling, and planetary urbanization, this article proposes an analytical framework - the "Coupling Cube" (CHNC) - to explain the coupling mechanism between urbanization and ecological environment from four dimensions: space, time, representation, and organization. The system and system, system and elements, and elements and elements in the Rubik's Cube are interconnected and interact with each other through various "coupling lines", forming an organic whole nested, interconnected, and Unity of opposites. The arbitrary rotation transformation of the Rubik's Cube represents the nonlinear coupling effect between urbanization and ecological environment systems in different regions. When each surface color is consistent, it indicates that all subsystems develop synergistically among different regions. When the energy input in the Rubik's Cube reaches a certain threshold, a critical phase transition occurs, resulting in the overall emergence of the system, which may become more orderly or collapse and enter the next cycle.

(3) The 'coupling Rubik's Cube' is interconnected and dialectically unified in four dimensions of time, space, organization, and representation, including eight types of coupling: short range, long range, near term, long term, intra group, inter group, explicit, and implicit. Among them, remote coupling refers to the interaction between urbanization and the ecological environment within the regional system, as well as other regional systems or elements beyond a long distance, as well as systems at different spatial scales; Long term coupling refers to the interaction and feedback between urbanization and ecological environment coupling systems and past or future systems or elements; Implicit coupling refers to the interaction between elements or systems that does not directly affect, but rather indirectly affects through intermediaries or other implicit systems or elements; Inter group coupling refers to the balancing of interests and game strategies between different organizations and stakeholders within different organizations in the process of urbanization for social and economic development and ecological environment protection. Furthermore, corresponding research methods and typical cases of different coupling types were summarized. Finally, based on the "coupling magic cube", a general analytical framework for the coupling matrix of human land relations was formed, proposing an analytical approach of "systematic thinking, prioritizing importance before lightness, and breaking through one by one".

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