

Balance and Comprehensive Evaluation of Supply and Demand Relationship in Urban Green Space Ecology and Health

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Keywords: Urban green space, Ecological supply, Health needs, Supply and demand balance, Comprehensive evaluation

Abstract: With the acceleration of urbanization, the urban ecological environment is facing severe challenges. Urban green Spaces, as an important component of the urban ecosystem, play a key role in regulating the climate, purifying the air, alleviating the heat island effect, and promoting the physical and mental health of residents. This paper takes the ecological and health supply and demand relationship of urban green Spaces as the research core. Firstly, it defines the connotation and constituent elements of ecological supply and health demand of urban green Spaces. Then, it constructs a comprehensive evaluation index system including three dimensions: ecological supply, health demand, and supply-demand matching degree, and presents the core evaluation dimensions and index logic through a table. Finally, strategies are proposed from four aspects: layout optimization, functional improvement, policy guarantee, and technological strengthening, providing theoretical support for the construction of healthy cities.

1. Introduction

In recent years, China's urbanization rate has risen from 49.68% in 2010 to 66.15% in 2024. The rapid urbanization has brought about "urban diseases" such as dense population, traffic congestion and environmental pollution, which threaten the physical and mental health of residents. Research by the World Health Organization shows that the exposure of urban green Spaces is positively correlated with the mental health level of residents. For every 10% increase in green space area, the incidence of depressive symptoms among residents can be reduced by 5.8%. However, the contradiction between the ecological supply capacity of urban green Spaces and the growing health demands of residents has gradually emerged. How to scientifically quantify the two and assess the balance situation has become a key issue that urgently needs to be solved in the fields of urban ecological planning and public health. This article takes this as the entry point for research. It aims to enrich the relevant theoretical framework and provide references for practice.

2. The core connotation of the ecological and healthy supply and demand relationship of urban green Spaces

2.1 The Connotation and constituent Elements of Urban Green Space Ecological Supply

(1) The connotation of ecological supply

Urban green space ecological supply refers to the total sum of various ecological products and services provided by the urban green space system under natural ecological processes and human intervention to maintain the stability of the urban ecosystem and ensure the production, living and health needs of residents [1]. Its essence lies in the value transformation of the ecological functions of urban green Spaces, featuring publicness, non-exclusivity and sustainability. Moreover, the supply capacity is influenced by factors such as the type of green space (park green space, protective green space, affiliated green space, etc.), vegetation structure (tree, shrub and herb configuration), and management level, showing significant spatio-temporal differences. For instance, the cultural function supply capacity of park green Spaces is relatively strong, while the regulatory function supply capacity of protective green Spaces is more prominent. The cooling and humidification supply capacity of green Spaces in summer is significantly higher than that in winter, and the ecological supply capacity of green Spaces with a high tree coverage rate is generally better than that of pure lawn green Spaces.

(2) Core constituent elements of ecological supply

According to the Costanza Ecosystem Services Classification Framework and in combination with China's "Technical Guidelines for Ecosystem Services Assessment", urban green space ecological supply is divided into four categories. The specific contents and mechanisms of action are shown in Table 1.

Table 1 Core Constituent Elements of Ecological Supply

Supply type	Core function	Mechanism of action and quantitative data
Regulation function	Climate regulation, environmental purification, and hydrological regulation	The transpiration of trees reduces the temperature by 3 to 5 degrees Celsius, and each hectare of trees absorbs 20 to 60 kilograms of SO ₂ annually. The reduction rate of green space runoff is 30% to 70%, which is 50% less than that of hardened ground
Support function	Biodiversity maintenance and soil protection	The number of species in the compound green space of trees, shrubs and grasses is 2 to 3 times more than that in pure lawns. The organic matter content of green space soil is 10-20g/kg higher than that of bare land, and the erosion modulus is 80% lower
Cultural function	Leisure and recreation, cultural education, and aesthetic experience	68% of the residents spend their weekends relaxing in the green Spaces, with an average stay of 2.3 hours. Viewing the green landscape can reduce cortisol levels by 12% to 18%
Supply function	Material products, energy supply	The fruit yield per mu in the community orchard is 500 kilograms. Each hectare of fast-growing willow forest provides 10 to 15 tons of biomass energy annually, reducing carbon emissions by 20 to 30 tons

2.2 The Connotation and Composition of Health Demands for Urban Green Spaces

(1) The connotation of health needs

Based on the WHO's definition of "health" (health is a good state of physical, mental and social adaptation, rather than merely the absence of disease) and Maslow's hierarchy of needs theory, the definition of the health needs of urban green Spaces is that residents maintain normal physical functions, stable psychological states and good social adaptation. The sum total of all kinds of demands put forward for urban green Spaces in terms of ecological environment, activity space, service facilities, etc. [2] Its essence is the manifestation of residents' health rights and interests in urban green space resources, featuring hierarchy, diversity and dynamics. For instance, the elderly are more concerned about the recreational facilities and medical care functions of green Spaces, teenagers are more concerned about sports fields and entertainment facilities, while office workers are more concerned about the stress-relieving function of green Spaces.

(2) Core components of health needs

The health demands of urban green Spaces are classified into three categories. The manifestations, influencing factors and residents' demands of each category are shown in Table 2 below.

Table 2 Core Components of Health Needs

Demand type	Core demand	Influencing factors
Physiological health needs	Exercise and fitness, air purification, and contact with nature	Age, health condition, exercise habits
Mental health needs	Stress relief, mood improvement, and attention restoration	Occupational pressure and the pace of life
Social health needs	Social interaction, community participation, and social integration	Community atmosphere and group characteristics

2.3 The Interaction Mechanism between ecological and health Supply and Demand

The interactive mechanism between ecological supply and health demand of urban green Spaces presents the core characteristics of "two-way empowerment and dynamic adaptation". On the one hand, as the material basis and functional carrier of health demands, the quality and structure of ecological supply directly determine the degree of satisfaction of health demands. For instance, green Spaces with a vegetation coverage rate of over 70% and equipped with complete recreational facilities can increase the satisfaction of residents' physical health demands by 35% and their mental health demands by 42% by purifying the air and creating a quiet environment. However, insufficient ecological supply will lead to the inability to release health demands, causing a contradiction where "the willingness to use green Spaces is low but the health demands are strong" [3]. On the other hand, as a guiding signal for the optimization of ecological supply, the upgrading of health demands and structural changes will drive the functional iteration of green Spaces. With the annual growth rate of residents' demand for sports and fitness reaching 18%, 80% of newly built green Spaces have added fitness trails and ball courts. The growing demand for health and wellness functions among the elderly has also led to 35% of community green Spaces being equipped with health and wellness seats and first aid facilities. However, when health demands differentiate regionally, if ecological supply does not respond promptly, an imbalance of "insufficient supply in the central area and relatively excessive supply in the suburbs" will occur. Only when the two are dynamically adapted in terms of quantity, quality and space, Only in this way can a virtuous cycle of ecological and healthy supply and demand be achieved [4].

3. Construction of a comprehensive evaluation system for supply and demand of urban green space ecology and health

3.1 Principles for Constructing the Evaluation System

(1) The principle of scientificity

Scientificity is the core prerequisite of the evaluation system and must simultaneously meet the two major requirements of "sufficient theoretical basis" and "reliable data sources". At the theoretical basis level, the selection of indicators should be closely integrated with the ecosystem service theory and the demand hierarchy theory to ensure that each indicator corresponds to a certain core dimension of the supply and demand relationship, avoiding "redundant indicators" without theoretical support [5]. At the data source level, it is required that the indicator data be obtained through standardized methods, such as remote sensing monitoring, laboratory testing, structured questionnaire surveys, etc., and the data must undergo reliability and validity tests to ensure the accuracy and representativeness of the data.

(2) Systematic principle

The principle of systematicness requires that the evaluation system should fully cover the three first-level dimensions of "ecological supply - health demand - supply-demand matching degree", and the secondary and third-level indicators under each first-level dimension should form a logical closed loop to avoid one-sided evaluation due to the absence of dimensions. From the inherent logic of the supply and demand relationship, "ecological supply" is the "cause", "health demand" is the "effect", and "supply and demand matching degree" is the "benefit". The three together form a complete evaluation chain of "capacity - demand - coordination" [6]. In the setting of secondary indicators, "ecological supply" should be matched with "regulatory function, supporting function and cultural function", "health demand" with "physiological demand, psychological demand and social demand", and "supply and demand matching degree" with "quantity matching and spatial matching", to ensure that each dimension is supported by corresponding detailed indicators. Form a hierarchical structure of "first-level indicators leading - second-level indicators breaking down - third-level indicators implementing" [7].

(3) Operability principle

The principle of operability requires that indicators should simultaneously meet the requirements of "quantifiable" and "easily accessible", and avoid choosing indicators that are "theoretically feasible but not practically feasible". In terms of quantifying indicators, abstract concepts need to be transformed into specific numerical values. For instance, "health demand intensity" can be replaced by quantifiable indicators such as "Weekly frequency of green space activities" and "duration of each activity". The "green space service capacity" can be reflected through concrete indicators such as "density of fitness trails" and "number of recreational facilities". In terms of data acquisition costs, it is necessary to avoid choosing indicators that require high costs and long acquisition periods. For instance, although the "green space carbon sink" indicator can reflect ecological supply, it needs to be calculated through complex biomass estimation and carbon cycle models, and the data acquisition period is long. In addition, to further enhance operability, this system has set "simplified calculation methods" for some indicators. For instance, for the "green space accessibility" indicator, the "average time to walk to the nearest green space" (taking the average of 30 sample points from field research) can be used to replace the complex GIS network analysis model, enabling non-professionals to also complete data collection and calculation.

3.2 Framework of Comprehensive Evaluation Index System

Based on the above theories and principles, 27 third-level indicators were finally determined, and

a three-level evaluation system was constructed, as shown in Table 3.

Table 3 Comprehensive Evaluation Indicators

First-level indicator	Secondary indicators	Third-level indicators	Indicator definition
Ecological supply (A)	Regulation function (A1)	Vegetation coverage rate (A11)	Green space vegetation coverage area/total green space area (%)
		Cooling effect (A12)	The temperature difference between green and non-green areas (°C)
		Pollutant removal rate (A13)	Removal efficiency of PM2.5 and SO ₂ (%)
	Support function (A2)	Biodiversity Index (A21)	Comprehensive index of species richness and uniformity
		Soil organic matter content (A22)	Mass fraction of soil organic matter (g/kg)
	Cultural function (A3)	Density of fitness trails (A31)	Total length of the trail/green area (km/km ²)
		The number of science popularization facilities (A32)	Total number of science popularization display boards and interpretation boards (pieces)
Health needs (B)	Physiological needs (B1)	Frequency of exercise demand (B11)	The frequency of residents' green space activities per week (times per week)
		Air quality satisfaction (B12)	Residents' ratings of air quality in green Spaces (1-5 points)
	Psychological needs (B2)	Demand for stress relief (B21)	The number of times to relieve stress through green Spaces per week (times per week)
		The proportion of attention recovery needs (B22)	The proportion of residents with the need for attention recovery (%)
	Social demand (B3)	Frequency of social activities (B31)	Monthly number of green space social events (times per month)
Degree of supply and demand matching (C)	Quantity matching (C1)	Per capita green space supply and demand ratio (C11)	Actual per capita green space/Per capita green space in demand
	Spatial matching (C2)	Green space accessibility (C21)	Average walking time to the green space (in minutes)
		Degree of spatial overlap between supply and demand (C22)	The overlapping ratio of high supply and high demand regions (%)

4. Urban Green Space Ecology - Optimization Strategies for Healthy Supply and Demand Balance

4.1 Optimize the layout of green Spaces to alleviate the imbalance between supply and demand in regions

In response to the spatial feature of "imbalance in the central area and relative balance in the peripheral area", a layout strategy of "greening the core area and improving the quality of the peripheral area" is adopted. In the central urban area, pocket parks and community green Spaces are constructed by making use of idle plots, rooftop Spaces, vertical walls, etc., to enhance the accessibility of green Spaces and shorten the travel distance for residents [8]. In the peripheral areas of cities, efforts should be made to enhance the ecological functions and service facilities of existing green Spaces, and avoid oversupply caused by blind expansion of green space areas. Meanwhile, in combination with the urban rail transit network, green space nodes should be planned and constructed within a 500-meter radius around the stations to form a "point-line-surface combined" green space system, promoting the spatial matching of supply and demand [9].

4.2 Enhance the service functions of green Spaces to meet diverse health needs

Based on the differentiated characteristics of residents' health demands, the functions of green Spaces are classified and optimized: In response to physiological health needs, fitness trails, sports fields (such as basketball courts and badminton courts), fitness equipment and other facilities are added to the green Spaces, and night lighting systems are equipped to meet residents' all-weather exercise needs. In response to mental health needs, Spaces such as quiet rest areas and meditation gardens are planned and constructed, combined with native plants to create a natural atmosphere and enhance the psychological adjustment function of green Spaces. In response to the social health demands, community activity squares, parent-child interaction areas, etc. are set up, and green space cultural activities (such as gardening experiences and science popularization lectures) are regularly organized to enhance residents' social interaction and sense of belonging to the community. In addition, it is necessary to enhance the scientific nature of vegetation configuration in green Spaces, select plant varieties with strong dust retention capacity and good noise reduction effects, and improve the ecological regulation function of green Spaces.

4.3 Improve the policy guarantee system and establish a dynamic supervision mechanism

To provide a guarantee for the balance between supply and demand at the institutional level, the first step is to formulate differentiated green space construction standards. The green space area indicators and facility configuration standards should be determined based on the population density and health demand intensity of different regions [10]. For instance, the per capita green space area in the central area should not be less than 10 square meters, and that in the peripheral areas should not be less than 15 square meters. Second, establish a green space ecological - health supply and demand monitoring platform, integrating remote sensing data, environmental monitoring data, and resident demand survey data to monitor changes in supply and demand in real time and promptly warn of risks of supply and demand imbalance. Third, introduce a public participation mechanism. Collect residents' opinions and suggestions on green space construction through online questionnaires, residents' hearings and other means to ensure that the planning and construction of green Spaces meet the actual needs of residents. At the same time, the balance between supply and demand of green Spaces should be incorporated into the urban ecological environment evaluation system as an important indicator for government performance assessment to promote the

implementation of policies.

4.4 Promote cross-disciplinary collaborative cooperation and strengthen technical support

The research on the ecological and health supply and demand balance of urban green Spaces involves multiple disciplines such as ecology, urban planning, and public health, and it is necessary to enhance cross-disciplinary collaborative cooperation. On the one hand, a research team composed of experts from multiple fields should be formed to conduct joint research in areas such as quantifying the ecological functions of green Spaces, assessing health needs, and constructing supply-demand matching models, thereby enhancing the scientificity and practicality of the research results. On the other hand, advanced technological means should be promoted and applied, such as using GIS spatial analysis technology to optimize the layout of green Spaces, applying big data to analyze the characteristics of residents' health demands, and leveraging Internet of Things technology to achieve real-time monitoring of the environmental quality of green Spaces, providing technical support for the optimization of supply and demand balance. In addition, efforts should be made to enhance international exchanges and cooperation, draw on advanced foreign experience, and in light of the actual development of cities in China, explore a green space supply and demand balance model that suits the national conditions.

5. Conclusion

The intensification of urbanization has made urban ecological environment problems more prominent. The contradiction between the ecological supply of urban green Spaces and the health demands of residents is gradually emerging. It is extremely urgent to scientifically quantify the two and assess the balance status. The article defines the connotations and constituent elements of ecological supply and health demand of urban green Spaces, and clarifies the interactive mechanism of "mutual empowerment and dynamic adaptation" between the two. Based on this, following the principles of scientificity, systematicness and operability, a comprehensive evaluation index system covering three dimensions: ecological supply, health demand and supply-demand matching degree is constructed. Finally, optimization strategies are proposed from four aspects: optimizing layout, enhancing functions, improving policies, and promoting cross-disciplinary cooperation.

In the future, as urbanization continues to advance, research on the supply and demand relationship between the ecology and health of urban green Spaces needs to be continuously deepened. The evaluation system should be continuously improved and the accuracy of assessment should be enhanced by integrating new technologies. Strengthen the monitoring of the implementation effect of strategies and dynamically adjust and optimize them based on actual conditions. Strengthen international exchanges, absorb advanced experiences, to achieve a deep balance between the ecological supply of urban green Spaces and the health demands of residents, and contribute to the construction of healthy cities.

Funding

Anhui Provincial Department of Education 2024 Action Plan for the Training of Young and Middle aged Teachers "Domestic Visiting and Training Funding Project for Young Backbone Teachers" (JNFX2024098), 2023 Anhui Provincial Department of Education Quality Engineering "Four New" Research and Reform Practice Project "Construction and Implementation of Applied Teaching System for Environmental Design Professional Courses Based on CDIO Mode" (2023sx169), 2023 Anhui Province Quality Engineering Teaching Innovation Team Construction "Landscape Design Teaching Innovation Team" (2023cxtid127).

Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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