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Ecological Space Planning and Management in High-Density Construction Areas: A Case Study of Jinjiang City

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Abstract In the context of rapid urbanization, high-density construction areas face significant challenges, including the reduction of ecological spaces and the deterioration of their functions. Planning and managing ecological spaces have emerged as essential strategies to address the conflict between urban development and ecological conservation. Using Jinjiang City, Fujian Province as the case study, this paper systematically examines the significance and primary challenges of ecological space planning in high-density construction areas. It also identifies prevailing issues within the current research domain, including "an overemphasis on top-level design at the expense of implementation, a focus on isolated aspects rather than systemic integration, and prioritization of control over coordination". This study proposes the key aspects of ecological space planning and management in high-density construction areas, focusing on three fundamental dimensions: human-centered demand orientation, the integration of top-down and bottom-up linkage mechanisms, and a differentiated control system. Drawing on the full-element assessment of the ecosystem, ecological network construction, and full-process control system implemented in Jinjiang City, an integrated approach to ecological space governance, encompassing assessment, planning, and control, has been developed. This approach offers both theoretical insights and practical guidance for optimizing ecological spaces in comparable urban contexts.

Keywords High-density construction areas, Ecological space planning, Ecological management and control, Jinjiang City, Ecological network
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Ecological space, as the central carrier of urban ecosystems, performs multiple ecological functions, including climate regulation, environmental purification, biodiversity conservation, and the provision of recreational services. It constitutes the essential foundation for ensuring urban ecological security, improving residents' quality of life, and promoting sustainable urban development. With China's urbanization rate surpassing 65%, urban development has progressed to a phase focused on "optimizing the existing infrastructure". High-density construction areas have emerged as central regions characterized by a significant concentration of population, industries, and resources. However, intensive development and construction have resulted in significant compression and fragmentation of ecological spaces, a persistent decline in ecosystem service functions, and increasingly severe issues such as the urban heat island effect, urban flooding, and disruption of ecological corridors. These challenges substantially hinder the high-quality development of cities. In this context, scientific ecological space planning emerges as a crucial strategy for restoring urban ecosystems and an essential approach to achieving "carbon peaking and carbon neutrality" goals.

Compared to ordinary areas, ecological space planning in high-density construction areas encounters more complex challenges, which can be primarily categorized into three aspects. The first challenge pertains to achieving functional synergy. High-density construction areas concurrently support production, residential, and ecological functions. Consequently, ecological spaces must be thoroughly integrated with industrial, residential, and transportation zones. The central dilemma in planning lies in balancing ecological protection with economic and social development, while avoiding "an excessive emphasis on development at the expense of ecological considerations". The second challenge pertains to stringent spatial constraints. The construction area is characterized by intricate land ownership arrangements, a substantial proportion of land that has already been developed, and limited opportunities for the expansion of ecological spaces. Consequently, maximizing ecological potential within "existing land" and promoting "greening wherever feasible" has become a central difficulty. The third challenge involves inadequate systematic management. Ecological space planning encompasses multiple departments, including natural resources, housing and urban-rural development, environmental protection, and forestry, with management discrepancies across various administrative levels such as cities, counties, and towns (sub-districts). Overcoming the management obstacles arising from "fragmented administrative divisions" and attaining comprehensive coordination throughout the entire process of planning formulation, implementation, and oversight constitutes a critical bottleneck to ensuring the effective execution of plans.

1 Research status

In recent years, domestic scholars have undertaken extensive research on ecological space planning, achieving considerable advancements in technical methodologies, including ecological element identification[1], ecological sensitivity assessment[2], and ecological corridor construction[3]. Nevertheless, a degree of incompatibility persists when compared to the ecological space planning practices of highly developed regions[4]. Numerous studies have concentrated primarily on the top-level design of ecological spaces or on singular ecological objectives, thereby neglecting more detailed planning approaches necessary for the effective management and guidance of ecological space protection and restoration.

The first is prioritizing individual elements over systematic integration. Certain studies concentrate on the planning and design of singular ecological elements, exemplified by specialized investigations into the reclamation of abandoned mining sites, including coal mines[5], and the ecological restoration of river systems. While these studies address localized ecological issues, they often lack a "comprehensive" consideration

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of the entire ecosystem[6–7]. Ecosystems in high-density construction areas represent complex systems comprising multiple elements such as “mountains, rivers, forests, farmlands, lakes, and grasslands”. Consequently, optimizing a single element alone is insufficient to achieve a systematic enhancement of ecological functions.

The second is emphasizing the top-level spatial layout while overlooking the use control. Most studies concentrate on constructing ecological security patterns at the regional scale[8–9]. For example, the prevailing research paradigm—comprising “source identification, resistance surface, and ecological corridor construction”—has largely been developed by adapting the classical “patch-corridor-matrix” model from landscape ecology[10–11], thereby establishing a macro-level ecological space framework[9,12]. However, such research frequently remains confined to “pattern description” and does not translate these macro-level patterns into micro-level land use control guidelines. Consequently, this hinders the effective coordination of plans in practical management and fails to provide actionable guidance for the use control of territorial space.

The third is emphasizing unified control over scale adaptation. Current ecological space control systems predominantly employ a “uniform standard” control model, applying identical control indicators across ecological spaces of varying regions and scales[13]. However, in high-density construction areas, ecological space demands differ across scales such as “municipal, district, and plot” levels. At the municipal scale, it is essential to maintain the integrity of the ecological security pattern; at the district scale, enhancing the synergy of ecological functions is necessary; and at the plot scale, attention must be given to the detailed aspects of ecological design. A uniform control system is inadequate for addressing the distinct characteristics of ecological spaces at different scales, resulting in management imbalances and diminishing the efficiency and effectiveness of control measures.

2 Key points of ecological space planning and management in high-density construction areas

2.1 Systematic improvement of ecological services under human-centered demand orientation

The primary objective of ecological space planning in high-density construction areas is to “fulfill the ecological needs of the population”. This requires a systematic enhancement of ecological services through three key dimensions: physical optimization, functional coordination, and management assurance. At the physical level, in response to contemporary challenges such as the isolation of urban water systems, difficulties in maintaining ecological corridors, and the fragmentation of natural mountainous areas, it is imperative to leverage opportunities presented by systematic construction and governance. By adopting an approach that “connects discrete points into lines and weaves these lines into networks”, the interaction among production, living environments, and ecosystems can be enhanced. This strategy aims to establish an interconnected ecological physical network, thereby improving the continuity and integrity of ecological spaces. At the functional level, it is essential to closely integrate regional characteristics and the varying population demands across high-density construction areas, coordinating the three primary functions of ecological regulation, ecological support, and ecological culture to achieve functional synergy between ecological protection and public recreation. At the management level, it is imperative to establish a multi-tiered and precise management system that not only ensures the integrity of ecological spaces but also facilitates the transformation of ecological value.

2.2 Implementation planning for the entire region under the top-down and bottom-up linkage mechanism

Ecological space planning in high-density construction areas must overcome the challenge of disconnection between planning and implementation by establishing an integrated linkage mechanism that connects “compilation, management, and utilization” in a top-down and bottom-up manner. Vertically, it is essential to clearly define the content and transmission processes of planning across the municipal, county, and town (or sub-district) levels. At the municipal level, efforts should concentrate on the comprehensive management of the ecological security pattern, with explicit and stringent control requirements established for ecological core areas and ecological corridors. At the county level, ecological zoning control regulations should be further refined, translating municipal planning directives into specific ecological indicators. At the town or sub-district level, ecological design requirements should be applied at the plot scale, with detailed planning clearly specifying measures such as the development of green spaces and parks. This approach ensures that planning directives are systematically cascaded and seamlessly integrated across all administrative levels. In terms of horizontal coordination, it is essential to establish a “collaborative working mechanism involving multiple departments”. The Department of Natural Resources should be responsible for the overall planning and compilation of ecological space. The Department of Housing and Urban-Rural Development should oversee the approval and management of construction projects within the ecological space. The Department of Environmental Protection should monitor the quality of the ecological environment, while the Forestry Department should implement ecological restoration projects. This framework would create a horizontal coordination system characterized by “a clear division of labor, unified authority and responsibilities”, avoiding management barriers arising from “independent actions”.

2.3 Construction of differentiated ecological space control system

In addressing the characteristics and functional demands of various ecological spaces in high-density construction areas, it is essential to develop a differentiated control system that incorporates hierarchical, classified, and unit-level controls. Regarding hierarchical control, ecological spaces are categorized into three levels according to their significance and the requirements for territorial space control: ecological conservation zones, ecological control zones, and ecological coordination zones. Among these, ecological conservation zones are subject to “the most stringent regulations”, prohibiting any construction activities that do not pertain to ecological protection. The ecological control zone is governed by “restrictive management and control”, permitting only a limited range of environmentally sustainable construction activities. The ecological coordination zone operates under a framework of “guiding control”: while ensuring the preservation of ecological functions, it may accommodate a moderate level of commercial, cultural, and other ancillary facilities. Regarding classified control, the management measures for “elemental guidance”—such as mountains, rivers, forests, farmlands, and grasslands—have been refined. Additionally, the planning and land use controls for ecological projects, including agriculture, forestry, water bodies, and land improvement, have been progressively enhanced. The control requirements for ecological elements such as forests, wetlands, and water bodies are integrated to coordinate protection systems across various elements, thereby facilitating the classification and conservation of diverse ecological elements. Regarding unit control, the function of units as spatial frameworks for hierarchical and classified management should be enhanced. Ecological function units should be delineated by integrating ecological resources with the administrative boundaries of implementing entities, dominant ecological functions, and river basin protection. These units should serve as spatial frameworks to facilitate the transmission of ecological land elements.

3 Empirical exploration: ecological space planning and control in Jinjiang City

3.1 Overview of the region

Jinjiang City is situated on the southeastern coast of Fujian Province and ranks among the top 100 county-level economies in China. In 2023, its permanent resident population reached 2.06 million. The regional development intensity exceeded 50%, with each town and sub-district exhibiting development intensities above 40%, characterizing it as a high-density construction area. As a prominent manufacturing hub, Jinjiang has established leading industries including textiles and garments, footwear, and food processing. Due to a high degree of industrial agglomeration and substantial demand for construction land, ecological, urban, and industrial spaces are closely interwoven. Consequently, the tension between ecological conservation and economic development is particularly pronounced.

3.2 Ecosystem full-element assessment and problem identification

Based on a full-element assessment of remote sensing images and NDVI data, it is evident that dense population and economic activities have significantly disturbed and impacted the ecological environment. These impacts are primarily manifested in the insufficiency of large-scale ecological systems and the poor quality of small-scale ecological areas. For example, an analysis of forest land data in Jinjiang City over the past decade reveals an increase of 29 km^2 in forest land area, accompanied by a continuous rise in total ecological volume. Nevertheless, the fragmentation index of forest land patches has consistently exceeded the average level observed in Quanzhou City, indicating a high degree of ecological resource fragmentation. The ecological service system demonstrates limited functionality, and there is an urgent need to enhance cultural service capacity. Additionally, the per capita park green space area remains lower than that of comparable cities and leading regions. Based on the findings of the 2020 land change survey in Jinjiang City, land types associated with ecological elements were extracted and consolidated into six primary categories: mountains, rivers, forests, farmlands, green spaces, and wetlands. Building upon the identification of these ecological elements, damage to ecological landforms was further assessed, enabling precise localization of existing ecological issues. Through the application of both qualitative and quantitative methodologies, three primary requirements for ecological space planning in Jinjiang City have been identified. First, it is essential to enhance ecosystem connectivity by identifying critical ecological nodes, such as Zimao Mountain Forest Park and Shenhu Bay Wetland, establishing a comprehensive ecological network, and implementing ecological protection zones within designated spatial management areas. Second, improving the quality of the ecological environment is necessary by balancing the spatial demands of ecological conservation and industrial development, while increasing vegetation coverage and strengthening the ecological regulatory functions of these spaces. Third, the capacity for ecological recreational services should be augmented to satisfy citizens' demands for a high-quality living environment, aiming to achieve comprehensive coverage of 15-min ecological recreation zones.

3.3 Construction and structural optimization of the ecological network in Jinjiang City

3.3.1 Construction of ecological network. The extraction of ecological source areas is grounded in the evaluation of ecological elements. Initially, this process aligns with higher-level planning frameworks and relevant specialized plans, such as the key ecological source areas delineated in the *Fujian Territorial Space Ecological Restoration Plan (2021–2035)* and the *Quanzhou Territorial Space Master Plan (2021–2035)*. Subsequently, by integrating the activity patterns of various wild fauna and flora, regions characterized by high concentrations of terrestrial wildlife with significant conservation value, as well as marine wildlife habitats, are designated as critical zones for biodiversity preservation. Finally, taking into account landscape connectivity, areas with aggregations of rare species, ecological conservation red lines, and nature reserves are identified as ecological sources. Ecological corridors consist of structural ecological elements, including vegetation belts and water bodies. Their functions encompass habitat maintenance, water source conservation, wind prevention and sand fixation, habitat isolation, and facility assistance. Typically, ecological corridors are identified through the application of minimum resistance factor model, which analyze the resistance encountered during urban land expansion, assess network connectivity, and delineate ecological corridors accordingly.

Table 1 Requirements for ecological space control

Name	Content	Objective
One regional ecological ring	Connecting Zimao Mountain, Lingyuan Mountain, Longhu Lake, Shenhu Bay and other places to form a regional ecological ring that reaches both mountains and the sea	Promoting ecological conservation initiatives, including the establishment of ecological public welfare forests, the protection of water sources, soil and water conservation efforts, and the preservation of biodiversity
Two ecological cores	Two ecological cores of Lingyuan Mountain and Longhu Lake	Enhancing the development of ecological landscapes and recreational facilities to improve ecosystem services, establishing a high-quality ecological park characterized by a healthy environment, attractive scenery, and suitability for both tourism and leisure, and forming a premier urban green space to provide citizens with an optimal destination to connect with nature
Four Bay areas	Four bays of Quanzhou Bay, Weitou Bay, Shenhu Bay and Anhai Bay	Quanzhou Bay strictly regulates the development intensity within the Jindong New District, fosters the creation of a modern coastal landscape, and enhances the protection and restoration of estuarine wetlands. Shenhu Bay has reinforced standardized fishery breeding practices and marine pollution prevention and control measures, moderately utilized shoreline and island resources, and developed ecological tourism landscapes. Weitou Bay and Anhai Bay have coordinated the relationships among fisheries, shipping, industrial development, and marine ecological protection, while actively undertaking wetland restoration efforts
Five ecological corridors	Three river-type ecological corridors (99 River, Hongjiang River Channel, Anhai Bay), one farmland-type ecological corridor (Lingxiu Mountain−Weitou Bay), and one comprehensive ecological corridor (Quanzhou Bay−Lingxiu Mountain−Longhu Lake−Weitou Bay)	Rationally delineating the boundaries of water-related ecological spaces, including rivers, lakes, and flood detention areas, and maximizing the ecological functions of river ecological corridors as critical pathways for waterfowl migration and water source conservation

Considering Jinjiang's ecological context and development objectives, the city has established an ecological security framework characterized by "one ring, two cores, four bays, and five corridors" (Table 1).

3.3.2 Delimitation of ecological zones. This study integrates the ecological security pattern with the urban development plan, centering on the ecological protection red line and incorporating various ecological elements such as nature reserves, "dual evaluation", ecological public welfare forests, wetlands, drinking water sources, and blue lines. Consequently, the entire ecological space of Jinjiang City is categorized into three primary zones, each with clearly defined control boundaries and management requirements. The first category comprises ecological conservation zones, including Zimao Mountain Forest Park and Shenhu Bay Wetland Nature Reserve. The second category consists of ecological control zones, encompassing ecological corridors and buffer zones along river shorelines. The third category includes ecological coordination zones, such as urban parks and community green spaces (Table 2).

3.4 Construction of full-process ecological space control system in Jinjiang City

3.4.1 Ecological structure control: clarifying the mechanism of "vertical transmission + horizontal coordination". Regarding vertical transmission, Jinjiang City has established a three-tier transmission system encompassing the municipal (county), district, and plot levels. At the municipal level, the *Jinjiang Territorial Space Master Plan (2021–2035)* explicitly defines the ecological security pattern and ecological zoning control requirements. At the district level, ecological indicators are specified in the *Control Detailed Planning for Key Districts of Jinjiang City*, with important ecological control lines clearly delineated. At the plot level, ecological design requirements are explicitly stipulated in the *Conditions for Construction Land Planning*.

Regarding horizontal collaboration, during the planning phase, the ecological restoration efforts of departments including natural resources, water conservancy, and agriculture and rural affairs are comprehensively integrated. Projects are systematically planned with a focus on maximizing overall benefits. While maintaining strict bottom-line controls, priority support is provided to the execution of major tasks and projects, thereby ensuring the effective implementation of the integrated protection and restoration plan. During the construction and implementation phases, ecological space protection and restoration planning is employed to regulate and coordinate ecological restoration activities across relevant sectors and departments. By centering efforts on specific projects, the responsibilities of all stakeholders are clearly delineated, and the content, scope, and sequence of mandatory controls are explicitly defined to ensure alignment of rights and responsibilities and to facilitate the orderly progression of plan implementation. In the implementation management phase, emphasis is placed on the project business chain, adopting a "comprehensive implementation approach" that considers the entire domain, all elements, the full process, and multiple dimensions. This approach aims to develop an integrated system for implementation that rationalizes administrative rights and responsibilities related to the formulation, approval, and construction management of ecological restoration plans, thereby establishing a closed-loop management workflow encompassing the entire "planning, construction, and management" cycle.

3.4.2 Ecological boundary control: implementing the requirements of "orderly withdrawal + functional access + element guidance". To effectively manage the boundaries of ecological spaces, it is essential to establish appropriate control measures that align with the management requirements of various levels and types of ecological spaces. The first measure involves orderly withdrawal: illegal construction projects located within ecological protection and control zones should be subject to a time-limited removal process, with phased demolition and ecological restoration implemented accordingly. The second measure pertains to functional access: clear guidelines must be established regarding permissible and prohibited construction activities within different ecological zones. For example, in ecological control zones, only projects such as "park support facilities and ecological science museums" should be permitted, whereas industrial plants and high-rise buildings should be strictly prohibited. The third measure concerns element guidance, which entails regulating elements such as building height and vegetation types within ecological spaces to ensure that ecological elements are consistent with their intended ecological functions.

3.4.3 Ecological unit control: achieving precise "diagram management + project management". Regarding diagram management, it is essential to ensure thorough coordination with detailed planning, particularly the redevelopment planning of inefficient land. Ecological spaces should be segmented into distinct "ecological control units", with the *Ecological Control Unit Diagram* prepared for each unit. This diagram should explicitly specify "index constraints, spatial guidance, and construction guidelines". The "index constraint" requirements correspond to the zoning type and the associated control objectives. Essential control index elements are selected from the index system table to regulate the intensity of ecological protection, restoration, and construction activities. "Spatial guidance" focuses on managing existing land use, offering recommendations for the retention and phased elimination of current land status, and delineating spatial layout guidelines for new construction areas and key construction nodes. These guidelines serve

Table 2 Requirements for ecological space control

Category of ecological space	Source	Control requirements
Ecological conservation zone (I)	Ecological protection red line Nature reserve "Dual evaluation" ecologically critical areas Key ecological public welfare forests Important wetlands Primary drinking water source	Developmental and productive construction activities are strictly prohibited. In accordance with applicable laws and regulations, only limited human activities that do not impair ecological functions are permitted, except in the case of major national strategic projects.
Ecological control zone (II)	General wetlands Blue line	In principle, no additional industrial or warehousing/logistics land shall be allocated. Existing general industrial and warehousing/logistics land will be progressively transformed over the long term into ecological green spaces or other land uses that are compatible with ecological functions.
Ecological coordination zone (III)	Ecological corridor	Human activities that are compatible with ecological systems can function as compensatory zones for the first two categories of ecological spaces. Utilization models such as "ecology + agriculture" and "ecology + landscape" design are recommended.

as a critical foundation for the implementation of ecological corridor protection and restoration projects. The "construction guidelines" comprise an access list and construction regulations. By explicitly defining use controls for various types of construction land across different zones, these measures restrict construction activities and facilitate precise ecological zoning control, extending from planning guidance to construction execution.

In terms of project management, Jinjiang City has designed and executed three primary categories of ecological initiatives aimed at establishing a comprehensive ecological network and enhancing its structural configuration. The first initiative, the Green Heart Optimization Project, aims to enhance the ecosystem's self-sustaining capacity through the optimization of vegetation communities and habitat restoration. This initiative integrates the needs of local residents and regional cultural elements to incorporate low-disturbance ecological and cultural functions. The second initiative, the Green Corridor Connection Project, focuses on ecological clearance efforts along the mountain corridor fault section, restoring and maintaining the ecological corridor's width, and facilitating wildlife habitat connectivity. The third initiative, the Bay Restoration Project, entails targeted ecological management in severely degraded areas to restore and enhance the aesthetic and ecological quality of the bays.

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mountains and water.

4 Conclusions

The spatial organization of the Lanzhou Baiyun Taoist Temple exemplifies a profound integration of functionality and artistic expression. By employing a comprehensive approach to architectural layout, spatial sequencing, and garden design techniques, the temple manifests the distinctive features characteristic of plain-style Taoist temples in Lanzhou during the Qing Dynasty.

The overall layout exhibits a distinct pattern comprising three zones: the sacrificial area, the living area, and the garden area. The north-south axis primarily governs the sacrificial sequence, while the living courtyards are positioned on the eastern and western sides. The surrounding area is enclosed by an attached garden. The functional zoning is clearly defined, and the organization of streamline is both coherent and logical. Regarding spatial creation, the sacrificial area employs a multi-courtyard layout that extends throughout the entire site. By varying scale and architectural forms, a spatial atmosphere aligned with religious rituals is established. The garden area structures the tour routes using circular pathways, thereby providing a continuous and engaging viewing experience. In the creation of artistic conception, a range of techniques, including centripetal layout, spatial infiltration, and the borrowing of scenery, are systematically utilized to enhance visual depth. These methods integrate Taoist philosophy and natural concepts, thereby imbuing the garden landscape with rich cultural significance.

Lanzhou Baiyun Taoist Temple, a quintessential example of Taoist architecture in the Lanzhou region during the Qing Dynasty, exemplifies spatial structures and garden designs that not only reflect the typical characteristics of Taoist architecture but also embody distinctive regional cultural features. This temple thus serves as a significant reference for comprehensive studies of temple and Taoist architectural complexes in the Lanzhou area during the Qing Dynasty.

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