

Ecological Security Pattern of Island Cities: A Case Study of Pingtan Island (Postprint)

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Abstract

Against the backdrop of an era where threats to urban ecological security posed by rapid urbanization seriously endanger sustainable urban development, constructing urban ecological security patterns constitutes a fundamental guarantee and important pathway for achieving regional and urban ecological security. Integrating the overall planning of the Pingtan Comprehensive Experimental Zone, and from the perspective of urban ecological security, this study selects six key ecological factors closely related to Pingtan Island's urban ecological security for in-depth analysis based on investigations of the baseline conditions of Pingtan Island's ecological environment. Through the Analytic Hierarchy Process and GIS spatial overlay method, a multi-factor ecological sensitivity analysis of Pingtan Island is conducted, ultimately proposing a targeted urban ecological security pattern for Pingtan Island oriented toward a new round of large-scale urban development. The research findings can provide decision-making support for urban development and construction on Pingtan Island, hold important theoretical and practical significance for maintaining Pingtan Island's urban ecological security and promoting its sustainable development, and also offer certain reference value for ecological security pattern research in other island-type cities.

Full Text

Preamble

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Study on Urban Ecosecurity Pattern of Island City: A Case Study of Pingtan Island

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Abstract

The world is undergoing the largest wave of urban growth in history. More than half of the world's population now lives in towns and cities, and the proportion of the global population in urban areas has increased conspicuously from 30% in 1950 to 54% in 2014. Urbanization is projected to increase even further to 60% in 2030. Though the process of urbanization provides comfortable and convenient living conditions for human beings, it also makes our country face a series of serious urban ecological security issues (such as environmental pollution and diminishing resources) because of the high-intensity of human activities and unreasonable land use. Nowadays, urban ecological security brought by rapid urbanization is posing a serious threat to urban sustainable development. Against this background, constructing the urban ecological security pattern is the basic guarantee and important way to realize regional and urban ecological security.

Based on the eco-environmental background conditions of Pingtan Island and considering the overall plan of Pingtan Comprehensive Pilot Zone, this study first investigated six key ecological sensitive factors that were closely related to the urban ecological security of Pingtan Island from the perspective of urban ecological security. These six key ecological sensitive factors were drinking water resources, coastal shelterbelt, scenic spots and forest parks, natural mountain, cultivated land, and coastline resources. Thereafter, a comprehensive evaluation model was established by means of the Analytical Hierarchy Process (AHP) and Geographic Information System (GIS) spatial overlay method to comprehensively evaluate the ecological sensitivity of Pingtan Island. The specific analysis process was as follows: First, an evaluation index system of Pingtan Island's ecological sensitivity was established through data collection, field investigation, remote sensing image interpretation and analysis, and expert reviews. These indices were classified according to their sensitivity. Second, the judgment matrix was constructed and consistency checks were performed in accordance with the AHP method, then the weight of each index was calculated according to the square root method. Finally, considering that scenic spots covered with natural mountain forest have the highest ecological sensitivity, and that other areas may not be ecologically sensitive or may be insensitive, Pingtan Island was divided into five grades (extreme sensitivity, high sensitivity, moderate sensitivity, low sensitivity, and insensitive grades) according to their respective ecological

sensitivity indices.

We propose an ecological security pattern for Pingtan Island in order to adapt to the new round of large-scale urban development boom, and this pattern is mainly composed of ecological security barrier ring, ecological water system, ecological conservation area, ecological coastal zone, urban construction area, and the ecological promotion area. These components play different roles in maintaining ecological safety on Pingtan Island, and they must be rationally developed and utilized on the basis of their respective functions. Generally, the results of this study would help to provide decision support for urban planning, and could be of great theoretical and practical significance to maintain Pingtan Island's ecological security and promote the sustainable development of Pingtan Island. Moreover, these results may also be useful for ecosecurity pattern research on other island cities.

Keywords: Pingtan Comprehensive Pilot Zone; urban ecosecurity pattern; island; urbanization; strong wind environment

Introduction

The world is undergoing the largest wave of urban growth in history, with the global urban population proportion conspicuously increasing from 30% in 1950 to 54% in 2014, and projected to reach 60% by 2030. China possesses the highest urbanization rate and largest population total. While urbanization provides abundant materials and comfortable living conditions, high-intensity human activities and unreasonable land use patterns have caused serious urban ecological security problems, mainly manifested as environmental pollution, resource supply shortages, and threats from natural disasters. In this context, constructing urban ecological security patterns is considered a basic guarantee and important approach to achieving regional and urban ecological security. Different scholars have conducted related research on the theoretical basis, research scope, and scale of ecological security patterns, with the construction of ecological security patterns in rapidly urbanizing areas becoming a hot topic in ecology, geography, and urban planning.

Pingtang Island, the main island of Pingtan Comprehensive Pilot Zone, was established in 2009 as a comprehensive experimental zone for exploring new models of cross-strait exchange and cooperation. As the island city closest to Taiwan, Pingtan has experienced a new round of large-scale urban construction boom. However, Pingtan Island also faces increasingly prominent ecological security issues during rapid urbanization, such as species singularity, scarcity of freshwater resources, soil salinization, and wind-sand erosion. Coordinating the relationship between economic development and ecological environment protection to address current urban ecological security challenges has become an urgent and practical issue for Pingtan Island. Therefore, it is necessary to explore the ecological security pattern of this region to reveal urban development directions

under ecological security guarantees, provide decision support for urban planning, and maintain urban ecological security, which has important theoretical and practical significance for achieving sustainable urban development.

1. Study Area Overview

Pingtang Island is located in the eastern sea area of Fujian Province, facing the Taiwan Strait to the east and separated from the Haitan Strait to the west. It is the largest island in Fujian Province and the fifth largest island in China. The island has a subtropical marine monsoon climate with an average annual temperature of 19.5°C and annual precipitation of 1196.2 mm. The area is frequently affected by typhoons from July to September, with strong winds occurring on 125 days per year. The topography is dominated by marine plains, with winding coastlines. Since its establishment as a comprehensive pilot zone, urban development has been booming. As a typical island city, Pingtang shares common characteristics of island ecology, and its ecological vulnerability has become increasingly severe during this large-scale urbanization process, mainly manifested in scarce freshwater resources, damaged shelterbelts, and soil salinization. The area is at a critical stage of rapid urbanization, and practice has shown that the loss degree and speed of island ecological environment from development are astonishing. Without strengthening ecological protection, it is easy to cause immeasurable losses. Therefore, this study explores and constructs an ecological security pattern for Pingtang Island to minimize the stress of urban construction on the ecological environment and avoid future development limitations due to prominent ecological problems, aiming to achieve sustainable development in this region.

2. Research Methods and Steps

2.1 Analysis of Ecological Sensitivity Factors in Pingtang Island

As China's first comprehensive experimental zone for exploring new models of cross-strait exchange and cooperation, Pingtang's development and construction must be based on ecological civilization, coordinate economic development and resource environmental protection, and build an ecological island city suitable for living and working. When considering the overall ecological function of Pingtang Island, combined with the Pingtang Comprehensive Pilot Zone Master Plan (2011-2030) and fully respecting the existing ecological and geomorphological conditions of Pingtang Island, this study selected six ecological factors closely related to Pingtang Island's urban ecological security for in-depth analysis and research through expert consultation and field investigation: drinking water source areas, coastal shelterbelts, scenic spots and forest parks, natural mountains, cultivated land, and coastline resources.

Drinking Water Source Areas: Urban drinking water sources are critical support systems for urban residents' lifelines, requiring higher standards for environmental protection and human activity intensity. As an island city with scarce freshwater resources, Pingtan's only medium-sized reservoir, the Thirty-Six Feet Lake, is the most important water source and currently the main source of urban water supply. The Liuqiao Reservoir, Yujing Reservoir, and Sanqiao Reservoir are also important drinking water sources for Aodong Town, Aoqian Town, and Su'ao Town respectively. According to the Technical Specification for Division of Drinking Water Source Protection Areas and the Pingtan Comprehensive Pilot Zone Master Plan, these water sources are divided into primary and secondary protection zones.

Coastal Shelterbelt: Due to its geographic location, Pingtan is inevitably affected by strong wind environments. Influenced by the subtropical high-pressure system and two major weather systems, the dominant wind direction is north-northeast in winter and south-southwest in summer. The terrain is higher in the north and south, with the rest being undulating hills and low mountains. This topographic feature basically aligns with the dominant wind direction of the main island, forming five obvious wind gaps: Changjiang'ao, Xifengkou, Yanxiapu, Yuanzhongpu, and Yuanzhongyang, which pose significant threats to Pingtan's ecological security. The plan emphasizes strengthening shelterbelt construction and protection, prohibiting development and activities that damage shelterbelts within the base shelterbelt. Specifically, the Changjiang'ao wind gap area should have a shelterbelt wider than 3000 m, Xifengkou wider than 2000 m, Yanxiapu wider than 2000 m, Yuanzhongyang wider than 2000 m, and Yuanzhongpu wider than 1000 m.

Scenic Spots and Forest Parks: Vegetation is one of the most important ecological factors affecting ecological sensitivity. Scenic spots and forest parks contain rich vegetation resources and play a vital role in urban ecological security. As rare ecologically affluent areas, forest parks have self-evident ecological barrier functions. Once destroyed, they will directly threaten the environment of themselves and surrounding areas. According to relevant laws and regulations, reasonable development and utilization should be carried out on the basis of strict protection, and construction activities unrelated to protection are prohibited. Based on data provided by the Pingtan Planning Bureau, this study extracted scenic spots and forest parks as sensitivity research areas.

Natural Mountains: Natural mountain forest land on Pingtan Island, including Qingfeng Mountain and Niuzhai Mountain, serves as an important ecological component with multiple ecological functions such as water storage, soil conservation, and biodiversity protection. It must be maximally preserved and strengthened. Extensive urban development and construction that destroys forests and mountains is strictly prohibited. According to the topographic characteristics of Pingtan and relevant technical requirements, areas suitable for ecological forest land are mainly natural mountains with slopes greater than 30 m extracted from SPOT DEM data.

Cultivated Land: As a land resource strictly protected by the state, cultivated land is a fertile agricultural basic resource and important ecological resource that is not easily restored once lost. The arrival of Pingtan's large-scale development era will inevitably impact cultivated land, so it is necessary to rationally plan construction land and strengthen the protection of existing cultivated land to exert its comprehensive functions of production, landscape, and isolation. With the assistance of relevant data, this study interpreted and analyzed 2013 remote sensing images with spatial resolution to extract the cultivated land range.

Coastline Resources: The coastline has unique geographic significance and is an important indicator of sea-land boundaries. Due to natural erosion and human activity interference, there are varying degrees of coastal erosion problems in Pingtan, with some coastlines retreating at a speed of 1-5 m/a, causing huge environmental and socio-economic impacts. Strengthening the protection of coastline resources helps prevent or mitigate coastline erosion, protect coastal ecological functions and landscapes, and ensure coastal zone ecological security. Based on the coastline utilization plan of Pingtan Comprehensive Pilot Zone, this study extracted coastline resources using setback lines as boundaries, including types such as natural ecology, tourism and leisure, and reserved development.

2.2 Comprehensive Evaluation Method for Ecological Sensitivity in Pingtan Island

This study establishes a comprehensive evaluation model for ecological sensitivity through the spatial overlay analysis method of Analytical Hierarchy Process (AHP) and Geographic Information System (GIS). The specific calculation formula is:

$$ESI = \sum(W_i \times F_i)$$

Where ESI is the ecological sensitivity comprehensive index, W_i is the weight value of factor i 's ecological sensitivity, and F_i is the ecological sensitivity grade value of factor i .

2.3 Establishment of Comprehensive Evaluation Index System

Through government data collection, remote sensing image interpretation and analysis, and expert evaluation, this study conducted in-depth analysis of each ecological sensitive factor to establish the Pingtan Island ecological sensitivity evaluation index system and classify each index.

2.4 Determination of Index Weights

Since Pingtan Island's ecological security is affected by multiple factors with different roles and contributions, it is necessary to determine the weights of evaluation indices. Based on the constructed hierarchical structure, factors at each level were compared pairwise. The AHP scale rule was used to construct

the judgment matrix . The square root method was employed to calculate index weights , with consistency checks performed ($\lambda_{\max} = 6.1922$, $CI = 0.0384$, $RI = 1.24$, $CR = 0.0310 < 0.1$, indicating satisfactory consistency).

2.5 Classification of Comprehensive Evaluation Results

When classifying ecological sensitivity, areas covered by natural mountain forest in scenic spots were ensured to have the highest ecological sensitivity, while areas without selected ecological sensitive factors were considered insensitive. The high sensitivity threshold was set at 2.61, and the low sensitivity threshold at 0.36, with other grades divided equally between them .

3. Results and Analysis

3.1 Analysis of Ecological Sensitivity Characteristics in Pingtan Island

Based on the Pingtan Comprehensive Pilot Zone Master Plan (2011-2030), respecting the existing ecology and geomorphology of Pingtan Island, and selecting ecological factors closely related to Pingtan' s urban ecological security, this study conducted a comprehensive analysis of Pingtan Island' s ecological sensitivity. The results yielded a comprehensive ecological sensitivity zoning map for urban construction and area proportions of each zone [Figure 2: see original paper].

The high ecological sensitivity areas in Pingtan Island mainly include urban drinking water source protection areas, national forest parks, Changjiang' ao wind gap shelterbelt, Yuanzhongyang wind gap shelterbelt, Longfengtou coastal shoreline resources, and Junshan scenic area mountain forest land, covering 26.84 km² (9.46%). These high-sensitivity areas are crucial components for maintaining Pingtan Island' s urban ecological security and should be prioritized as key protection objects during large-scale development.

The relatively high sensitivity areas are mainly distributed in the Liushui Peninsula windbreak zone, Yanxiapu windbreak zone, important scenic areas (such as core protection zones or coastal areas of Wangye Mountain, General Mountain, and Shipaiyang scenic spots), and coastal shoreline resources, covering 19.47 km² (6.86%). These areas serve as important supplements to Pingtan Island' s urban ecological security and play vital ecological functions in maintaining wind safety, conserving water sources, and purifying air, requiring protection during urban development to promote ecosystem service enhancement.

The moderate sensitivity areas are mainly located in scenic protection zones, coastal resort areas, natural ecological shoreline resources, and natural mountains such as Longtou Mountain and Niuzhai Mountain, covering 34.13 km² (12.03%). The low sensitivity areas, covering 82.30 km² (29.01%), are mainly distributed with large amounts of agricultural land. As fertile agricultural basic

resources that are not easily restored once lost, these areas are important bases for human food production and must follow national policies for strict cultivated land protection during urban development.

3.2 Analysis of Pingtan Island Ecological Security Pattern

According to the development plan of Pingtan Experimental Zone and based on the comprehensive analysis results of ecological sensitivity, this study constructed an urban ecological security pattern for Pingtan Island driven by rapid urbanization from the perspective of urban ecological security. This pattern is mainly composed of ecological security barrier ring, ecological water system, ecological conservation area, ecological coastal zone, urban construction area, and ecological promotion area [Figure 3: see original paper].

Ecological Security Barrier Ring: To mitigate the impact of perennial strong northeast winds, the urban development center should shift westward while maximizing the retention and strengthening of natural mountain forest land and windbreak base shelterbelts along the eastern coast, forming a north-south ecological security barrier ring for wind protection. The construction and protection of windbreak shelterbelts should be strengthened in the five major wind gap areas along the east coast, with widening and gap-filling of coastal base shelterbelts. Existing forest parks such as Shibacun and Haidao, as well as natural mountain forest lands like Qingfeng and General Mountain, should be protected to form a connected mountain-forest windbreak system, maintaining biodiversity and island ecological security.

Ecological Water System: Protection of centralized drinking water sources such as Thirty-Six Feet Lake and Yujing Reservoir should be strengthened with clear redline control ranges. Greening of peripheral protection zones should be enhanced within water source protection areas, and construction activities unrelated to water supply facilities and source protection should be strictly prohibited. On this basis, existing rivers should be fully retained, and existing surface reservoirs and fish ponds should be utilized to form different regulating lakes, connected by artificial channels to create an integrated island ecological water network system for storage and drainage.

Ecological Conservation Area: Large areas of natural mountain forest land and natural scenic areas distributed around Pingtan Island greatly promote the ecosystem services of the entire city. Therefore, relevant policies must be strictly implemented, building height within a certain range around mountains should be strictly controlled, sight corridors between mountain viewing nodes and mountains should be protected, and ecological functions such as water storage, soil conservation, and biodiversity protection should be strengthened. For some important mountains, afforestation should be increased to further improve urban environmental quality.

Ecological Coastal Zone: The coastal zone is the transition area between land and sea with important ecological and economic benefits. Due to seawater

erosion and human activity interference, China's coastal ecosystems have degraded seriously, and Pingtan Island's coastal resource and environmental issues cannot be ignored. Based on the coastline plan of Pingtan Experimental Zone, key protection should be given to coastal resources such as Shanqi' ao, Jinnan Bay, Jinjing operation area coastline, Niuzhai Mountain coastline, Longfengtou Beach, Junshan northern coastline, General Mountain coastline, Haitan Bay section, and Shanqi' ao section to promote the structure and function of coastal ecosystems to a higher level.

Urban Construction Area: Under the protection of the green ecological barrier ring, urban construction should be oriented toward the Haitan Strait, using the marine alluvial plains and beach lands distributed in central-western Pingtan as carriers to build a city cluster structure open to the Haitan Strait, leading urban construction and industrial development.

Ecological Promotion Area: This area is mainly distributed with large amounts of agricultural land. As a land resource strictly protected by the state, it is a fertile agricultural basic resource and important ecological resource that is not easily restored once lost. With the arrival of Pingtan's large-scale development era, cultivated land will inevitably be impacted. Therefore, it is necessary to rationally plan construction land, strengthen protection of existing cultivated land, and exert the comprehensive functions of production, landscape, and isolation.

4. Conclusion

As an extremely ecologically sensitive island city, Pingtan Island faces the severe challenge of maintaining urban ecological security against the backdrop of large-scale development. How to achieve dynamic balance and coordination among various matrices constitutes the ecological spatial background of Pingtan Island. This study, combined with the Pingtan Comprehensive Pilot Zone Master Plan (2011-2030), fully respecting the existing ecology and geomorphology of Pingtan Island and the requirements of various nature reserves, as well as key ecological environment elements important for maintaining urban ecological security, conducted a comprehensive ecological sensitivity analysis and constructed a corresponding urban ecological security pattern to maintain ecological security and landscape diversity and promote sustainable development of Pingtan Island. The research results can provide decision support for the development and construction of Pingtan Island and have certain theoretical and practical significance for promoting sustainable urban development. However, due to insufficient data, the analysis of ecological sensitivity elements in this study is not yet comprehensive, such as the lack of consideration for social and humanistic elements.

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