Assessment and Regulatory Enhancement of Resource-Environment Carrying Capacity in Xiong' an New Area: A Postprint

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Abstract

The establishment of Hebei Xiong' an New Area represents a major historic strategic decision made by the Party Central Committee with Comrade Xi Jinping at its core, constituting a millennial plan and a national priority. To support the planning and construction of Xiong' an New Area, the research group "Study on Evaluation and Regulation Enhancement of Resource-Environment Carrying Capacity in Xiong' an New Area" from the Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, conducted an evaluation and regulation enhancement study on the resource-environment carrying capacity of the three counties in the new area (Xiong County, Anxin County, and Rongcheng County), based on satellite and UAV remote sensing, fixed-point observations, and historical literature data, from historical, present, and future perspectives. The results indicate: (1) The new area possesses obvious locational advantages and abundant land resources, but suffers from water resource shortages, relatively serious surface water pollution, and high flood disaster risks; if existing production, living, and ecological patterns are maintained, the resource-environment carrying capacity of the three counties in the new area has already approached its natural limits. (2) Increases in population and industrial scale will significantly intensify resource-environment pressures on the new area; when population reaches 5 million, demands for urban construction and industrial land will be 670 km^2 and 130 km^2 respectively, with annual water consumption of 1.16 billion m^3, and approximately half of the built-up area will face flood disaster risks. (3) To achieve the new area' s construction goals, scientific regulation and enhancement of regional water resources and ecological environment carrying capacity are required, with specific measures including: controlling population size within 5 million; diverting water through multiple channels while appropriately controlling wetland and forest areas; strengthening emission reduction and pollution control efforts to improve ecological environment quality; raising flood control standards and scientifically selecting project sites.

Full Text

Abstract

The establishment of Xiongan New Area represents a major historic strategic decision made by the Central Committee of the Communist Party of China with Comrade Xi Jinping at its core—a millennium-long project of national significance. To support the planning and construction of Xiongan New Area, the research team from the Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, conducted a comprehensive evaluation and proposed regulatory measures for enhancing the resource and environmental carrying capacity of the three counties within the new area (Xiong County, Anxin County, and Rongcheng County). This study integrated satellite and UAV remote sensing data, fixed-point observations, and historical documents to analyze the region from historical, present, and future perspectives. The results indicate: (1) The New Area possesses distinct locational advantages and abundant land resources, yet faces critical challenges including severe water shortages, serious surface water pollution, and high flood disaster risk. Under current production, living, and ecological patterns, the resource and environmental carrying capacity of the three counties has nearly reached its natural limits. (2) Population and industrial growth will significantly intensify pressure on regional resources and environment. At a population scale of 5 million, urban construction land will require 670 km^2 and industrial land 130 km^2, with annual water consumption reaching 1.16 billion m^3, and approximately half of the built-up area will face flood risk. (3) Achieving the New Area' s development objectives necessitates scientifically regulated enhancement of regional water resources and ecological environmental carrying capacity through specific measures: controlling population below 5 million; diversifying water transfer approaches while moderately controlling wetland and forest areas; strengthening pollution reduction and treatment to improve environmental quality; and elevating flood control standards with scientifically selected project sites.

Keywords: Xiongan New Area, resource and environmental carrying capacity, pressure on resources and environment, regulation and promotion countermeasures

Introduction

The establishment of Hebei Xiongan New Area constitutes a major historic strategic choice by the Party Central Committee with Comrade Xi Jinping at its core, representing a millennium-long project of national significance. President Xi Jinping has emphasized that Xiongan New Area must first serve as a concentrated carrier for relieving Beijing of its non-capital functions, adhering to ecological priority and green development. The vision is to build a green, forested, smart, and water-integrated new district that demonstrates orderly flow of factors, effective functional constraints, equal access to basic public services, and resource-environment sustainability, thereby providing support for building a world-class city cluster in the Beijing-Tianjin-Hebei region.

Located at the confluence of the Daqing River system within the Haihe River basin, Xiongan New Area sits on the alluvial plain at the eastern foot of the Taihang Mountains. The Haihe River system originates from the Loess Plateau, cuts through the Taihang Mountains, and flows into the North China Plain. Nine tributaries—including Zhulong River, Xiaoyi River, Tang River, Fu River, Cao River, Ping River, Yangcun River, Bao River, and Baigou Yin River—converge into Baiyangdian Lake, the "Pearl of North China." This unique geography endows the New Area with a mountain-backed, sea-facing orientation and possession of the largest wetland in the North China Plain.

The Taihang Mountains' eastern alluvial plain has been prosperous since ancient times, earning the designation "ancient capital corridor" for its succession of capital cities from north to south (Beijing, Yanxiadu, Lingshou Ancient City, Handan, Xingdu, Yecheng, Anyang) [Figure 2: see original paper]. Situated near this corridor and connected by the Rongwu, Daguang, and Jinggang' ao Expressways, as well as the Beijing-Guangzhou and Beijing-Kowloon Railways, the New Area lies just over 100 kilometers from both Beijing and Tianjin, offering clear locational advantages.

Geologically, the New Area occupies a safe zone between the Taihang Mountain fault zone and the Tan-Lu fault zone, with stable conditions and a historical seismic intensity of VII degree, comparable to low-value areas in northwestern Beijing and southern Tianjin. The three counties have a total land area of 1,557 km^2, substantially exceeding the planned initial development zone (100 km^2) and medium-term development zone (200 km^2), though slightly below the long-term control zone (2,000 km^2). The terrain consists primarily of low-altitude plains and depressions, with elevations ranging from 5 to 18 meters (average 8.3 meters). Approximately 1,166 km^2 lies below 10 meters elevation, suitable for agriculture, aquaculture, wetland tourism, and low-pollution modern industries.

Remote sensing surveys reveal that in 2015, land cover in the three counties was dominated by cultivated land, settlements, and wetlands (including water bodies), accounting for 90% of the total area. Urban built-up areas covered only 34.4 km^2 (2.2% of the region), indicating ample development space [Figure 3: see original paper]. In 2016, the registered population was 1.13 million with an urbanization rate of 42% . The current population density of 726 persons/km^2 is substantially lower than Shanghai' s Pudong New Area (4,523 persons/km^2, economic output 653 million yuan/km^2) and Shenzhen Special Economic Zone (5,398 persons/km^2, economic output 966 million yuan/km^2), demonstrating significant potential in land resources carrying capacity.

Water Resources Carrying Capacity

The three counties receive an average annual precipitation of 516 mm, with total water resources of 120 million m^3/year, 91% of which is groundwater . In 2015, total water consumption reached 253 million m^3, with groundwater exploitation accounting for 247 million m^3 (97.6% of total use). Agricultural irrigation consumed 77.3%, residential use 9.9%, and industrial use 8.6%. The current water deficit of 140 million m^3/year indicates that water resources carrying capacity has reached its natural limit.

A critical manifestation of insufficient water carrying capacity is the rapid decline in groundwater levels. From 2006 to 2015, groundwater depth in Rongcheng decreased from 19.2 m to 22.5 m, in Xiong County from 17.8 m to 19.2 m, and in Anxin from 7.8 m to 10.8 m—a 38% decline. Over-exploitation has created a 20-meter-deep funnel in Rongcheng.

Water scarcity in North China represents a rigid, long-term challenge. Since 1960, the region has warmed by 0.1–0.3°C per decade while precipitation decreased by 5–20 mm per decade [Figure 4: see original paper], with evaporation showing an increasing trend. CAS atmospheric physics simulations indicate a weak rainy period before 2026, followed by an extreme drought period from 2026–2046, potentially exacerbating water shortages [Figure 5: see original paper].

Ecological and Environmental Carrying Capacity

Baiyangdian Lake, the largest wetland in the North China Plain, covers 312 km^2 in Anxin County and 18.3 km^2 in Xiong County, comprising 143 lakes and 3,700 channels as a typical shallow freshwater lake system. As a crucial flood retention area in the Haihe River basin, Baiyangdian plays an irreplaceable role in flood control, climate regulation, and groundwater recharge. However, its environmental condition directly reflects and affects the New Area' s ecological carrying capacity.

Historical records show Baiyangdian has dried up multiple times, including a five-year dry period from 1984–1988. To maintain basic wetland functions, water has been diverted to the lake 32 times since 1996. Remote sensing data reveal the lake' s water area shrank from 177 km^2 in 1995 [Figure 6: see original paper] to 53 km^2 in 2005 [Figure 7: see original paper], recovering to 78.5 km^2 after the "Yellow River to Baiyangdian" diversion in 2015 [Figure 8: see original paper].

Water reduction and sewage discharge have further degraded Baiyangdian' s ecological carrying capacity. According to the Haihe River Basin Water Resources Bulletin (2015), approximately one-third of the lake' s water area meets Class V standards, while two-thirds falls below Class V, with contaminated sediments preventing two-thirds of the water bodies from meeting basic functional standards. This degradation directly impacts biodiversity, aquatic production, and tourism. The Baiyangdian Wetland Ecosystem Nature Reserve has experienced frequent fish kills, threatening 47 species of macrophytes and 197 bird species (including 4 first-class and 26 second-class nationally protected species).

Atmospheric haze also profoundly affects environmental carrying capacity. Over the past 30 years, windy days in the three counties have decreased by 2–5 days per decade. In 2015, Baoding' s annual average PM2.5 concentration reached 107 g/m^3, 3.1 times the standard limit, ranking last among 74 major Chinese cities.

Flood Risk Assessment

The Daqing River basin receives 500–600 mm of annual precipitation, with 60% concentrated in July–August, when heavy rains frequently occur. Stormwater rapidly discharges through piedmont fan-shaped river networks into Baiyangdian, creating synchronized inflow and extreme flood vulnerability. Historical records show Xiong County experienced catastrophic floods once every 12 years over the past 700 years. The 1963 flood kept water levels above 11 meters elevation for 13 days, interrupting the Beijing-Guangzhou Railway for 27 days and causing massive losses.

Global warming will intensify storm events. CAS atmospheric physics simulations project a 20% increase in storm intensity with 2°C warming. Analyses of historical drought-flood atlases, archival flood records, and simulations using the VIC land surface model and HiPIMS hydrological-geological disaster modeling system reveal that: a 20-year flood would inundate 34% of the three counties with an average depth of 3.2 meters [Figure 9: see original paper]; a 100-year flood would inundate 61% with depths of approximately 4.5 meters [Figure 10: see original paper]; and a 300-year flood would submerge the entire region with average depths exceeding 7 meters.

Flood risk assessment indicates that approximately 1,100 km^2 (68% of the New Area) faces high flood risk, excluding only small portions of the northwest, northeast, and southwest [Figure 6: see original paper].

Future Development Scenarios and Resource-Environment Pressure Simulation

Based on Xiongan' s positioning and referencing advanced coastal cities, we modeled development scenarios targeting population scales of 3 million and 5 million, incorporating land suitability evaluation and flood disaster simulation.

Key Assumptions: 1. Future population and industry will concentrate in non-agricultural sectors, with mechanical growth from Beijing' s non-capital function relocation and gradual urbanization of existing rural populations. 2. New urban residents will be allocated 100 m^2 of construction land per capita. Infrastructure land will increase 20% annually in the first decade, 10% in the second, and 5% in the third, then stabilize. Industrial land will comprise 20% of urban construction land. 3. Development will prioritize land suitability considering elevation, flood risk, and accessibility. 4. Industry selection will favor low-water-consumption sectors; water-intensive and polluting industries (leather, papermaking, chemicals, non-ferrous metallurgy) will phase out. 5. Future industries will focus on high-end, high-tech, green sectors with output efficiency matching peer regions.

Simulation Results for 3 Million Population: - Core population: 2.5 million - Urban construction land: 485 km^2 (31% of total area), including 100 km^2 industrial land - Water demand: 811 million m^3/year (urban living: 500 million; rural living: 14 million; agricultural: 214 million; industrial/mining: unchanged) - Traditional agricultural ecosystems reduced by 60% - Approximately one-third of built-up area faces flood risk during 100-year floods [Figure 12: see original paper] - Economic output: 40 billion yuan/km^2, totaling over 190 billion yuan annually

Simulation Results for 5 Million Population: - Core population: 4.5 million - Urban construction land: 671 km^2 (43% of total area), including 130 km^2 industrial land - Water demand: 1.16 billion m^3/year (urban living: 900 million; rural living: 10 million; agricultural: 170 million) - Traditional agricultural ecosystems reduced by 90% - Approximately half of built-up area faces flood risk during 100-year floods [Figure 14: see original paper] - Economic output: 80 billion yuan/km^2, totaling over 530 billion yuan annually

Strategies for Regulating and Enhancing Carrying Capacity

Simulation results demonstrate that current resource-environment carrying capacity has reached natural limits, and future construction will further intensify pressure. To achieve development goals, scientifically regulated enhancement is essential. Four strategic recommendations address the primary constraints of water shortage, water pollution, and flood risk.

1. Control Population Scale and Industrial Structure to Regulate Regional Pressure Resolutely implement Beijing' s non-capital function relocation while limiting Xiongan' s population to under 5 million to prevent population aggregation while Beijing' s population remains unchanged. Develop water-efficient, non-polluting high-tech industries and modern service systems.

2. Diversify Water Transfer and Moderately Control Wetland/Forest Areas to Enhance Water Carrying Capacity The South-to-North Water Diversion Project can supply 400 million m^3 annually. Implementing a "population relocation + water transfer quota"policy could add 150–230 million m^3/year [Figure 15: see original paper]. Upstream reservoirs and the "Yellow River to Baiyangdian" project provide 260 million m^3 annually. Converting farmland to construction land saves 100 million m^3/year. Combined, these measures could increase water resources by 900–1,000 million m^3 annually. Additionally, promote unconventional water sources and sponge city concepts. With annual evaporation from water surfaces at 1,124 mm (double precipitation), wetland area should be controlled at 400 km^2. Forest coverage should remain below

35% given that forest evapotranspiration (550 mm) equals precipitation, while grassland evapotranspiration is approximately three-quarters of forest levels.

3. Strengthen Pollution Reduction and Treatment to Improve Environmental Quality The primary task is protecting Baiyangdian. The entire lake should be incorporated into the New Area' s jurisdiction as a national wetland park. Pollutant discharge should be limited to 20% of current levels. Construct 1–2 km forest belts around the lake to maintain 350 km^2 of wetland area. Develop ecological corridors along rivers and scientifically plan urban green spaces.

4. Elevate Flood Control Standards and Scientifically Select Project Sites Construct dikes (Qianli, Xin' an North, Simen, Zhangshuiyan, and Diannan New Dikes) to 100-year flood standards [Figure 16: see original paper]. Dredge upstream/downstream channels and reinforce embankments. Implement channel clearance projects within Baiyangdian. Construct urban projects to 200-year flood standards. Establish basin-wide flood monitoring and early warning systems. Prioritize northwestern areas for project siting to mitigate flood risk. If the startup zone location remains unchanged, "raising ground elevation by 3 meters" should be incorporated as a planning condition.

Conclusions

Three key conclusions emerge from this analysis:

1. **Current State**: Xiongan New Area possesses clear locational advantages and abundant land resources, but its resource-environment carrying capacity has reached natural limits under existing production and living patterns. Primary constraints are water shortage, surface water pollution, and flood disaster risk.

2. **Development Pressure**: New Area planning and construction will significantly increase resource-environment pressure. At 3 million population, urban construction and industrial land will require 485 km^2 and 100 km^2 respectively, with 811 million m^3 annual water consumption and 60% reduction in traditional agricultural ecosystems. At 5 million population, these figures become 671 km^2, 130 km^2, and 1.16 billion m^3, with 90% agricultural ecosystem reduction. During 100-year floods, one-third to one-half of built-up areas will face flood risk.

3. **Regulation Requirements**: Achieving development goals requires scientifically regulated enhancement of water resources and ecological environmental carrying capacity through: population control under 5 million; diversified water transfer with controlled wetland/forest areas; intensified pollution reduction; and elevated flood standards with scientifically selected project sites.

Over a century-scale perspective, population size, water supply capacity, and environmental quality will be key determinants. Over a millennium, whether

Xiongan becomes a historic legacy depends on the resilience of North China' s resource-environment system and the New Area' s disaster risk prevention capabilities. To build Xiongan into a green, ecological, livable, innovation-driven, coordinated, and open development demonstration zone, systematic and detailed optimization plans for resource-environment carrying capacity are needed. Immediate priorities include refining six areas: water-land resource evaluation, environmental pollution remediation, flood disaster simulation, urban development forecasting, industrial structure planning, and ecological construction strategies. Through in-depth research and scientific planning, the New Area can fundamentally resolve its water shortage, water pollution, and flood risk challenges by both enhancing carrying capacity and rationally controlling resource-environment pressure.

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Note: Figure translations are in progress. See original paper for figures.