Strategic Framework and Optimization of China's Ecological Regions During the 15th Five-Year Plan Period: Postprint

Authors: Zhou Kan, Fan Jie, Zhou Daojing, Qian Zhedong, Yu Hu, Liu Hanchu, Zhang Jian

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Abstract

Since the implementation of the Major Function Oriented Zoning Plan, ecological spaces in key ecological functional zones have continued to expand, vegetation coverage has increased significantly, and population has exhibited a dual trend of overall decline alongside urban population growth. Socioeconomic development has achieved remarkable results, the function of ecological security barriers has steadily improved, and the tense state of human-land relationships has been generally alleviated. During the 15th Five-Year Plan period, adhering to a functional orientation focused on providing ecological services or ecological products, the scale of ecosystem provisioning, regulating, supporting, and cultural services will be stabilized; simultaneously, greater emphasis will be placed on improving service quality to form a more diverse, stable, and sustainable ecological foundation, while accommodating the development and utilization functions of green and low-carbon ecological products, thereby forming an inclusive conservation approach that advances the modernization of harmonious coexistence between humanity and nature. During the 15th Five-Year Plan period, ecological regions will not only constitute an important component of the new national territorial security pattern but will also serve as key support for the new national territorial development pattern. Optimization recommendations: From a strategic pattern perspective, strengthen spatial linkages and supply-demand interactions between ecological security barriers and the national territorial development pattern, fortify national ecological security barriers, optimize the layout of key ecological functional zones, integrate the protected areas system, and strictly adhere to ecological protection red lines; with focus on categorically improving the quality of ecosystem service functions, deeply implementing integrated protection and restoration of mountains, rivers, forests, farmlands, lakes, grasslands, and deserts, actively fostering new drivers of green development, accelerating the establishment of a refined zonal management and control system,

and collaboratively advancing institutional and mechanism reform and innovation, high-level protection will support high-quality development in ecological regions.

Full Text

Preamble

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Strategic Pattern and Optimization of China' s Eco-Regions During the 15th Five-Year Plan Period

ZHOU Kan[12], *FAN Jie*[123], *ZHOU Daojing*[3], QIAN Zhedong[4], YU Hu[123], LIU Hanchu[3], ZHANG Jian[12]

Abstract

Since the implementation of the major function oriented zoning, the ecological space of key ecological functional areas has continuously expanded, with a significant increase in vegetation coverage. Concurrently, there has been a dual change in population dynamics, characterized by a decrease in total population and an increase in the urban population. Furthermore, significant achievements have been made in economic and social development, and there has been a steady improvement in the functions of ecological security barriers, contributing to an alleviation of tension in human-environment relationships. During the 15th Five-Year Plan period, it is imperative to adhere to the functional orientation primarily focused on providing ecological services or products. While consolidating provisioning, regulating, supporting, and cultural ecosystem services, there is an increased emphasis on enhancing the quality of these services, thereby constructing a more diversified, stable, and sustainable ecological foundation. Furthermore, exploring compatible functions of eco-product development and utilization promote greening and decarbonization, aiming to establish an inclusive conservation approach that advances modernization characterized by harmony between humanity and nature. In the 15th Five-Year Plan period, ecological regions will not only be crucial components of the new territorial security pattern but also pillars of the new territorial development pattern. Optimization recommendations are as follows. From the perspective of strategic

patterns, it is necessary to enhance the spatial connection and supply-demand interaction between ecological security barriers and the territorial development pattern. In detail, continued efforts are needed to consolidate the national ecological security barriers, optimize the pattern of key ecological functional areas, integrate the system of natural protected areas, and strictly adhere to ecological conservation red lines. Moreover, a greater focus should be on upgrading quality of ecosystem service functions through classification, fully implementing the holistic approach to protecting and restoring mountains, rivers, forests, farmlands, lakes, grasslands, and sand, actively fostering new growth drivers for green development, accelerating the establishment of a refined zoning control system, and synergistically advancing reforms and innovations of institutions and mechanisms. These measures aim to support high-quality development in ecological regions through high-standard protection.

Keywords: ecological regions, key ecological function areas, Fifteenth Five-Year Plan period, strategic patterns, ecological civilization
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*Corresponding authors

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Since the 18th CPC National Congress, China has accelerated the construction of ecological civilization, implementing key ecological projects and carrying out integrated protection and restoration of mountains, rivers, forests, farmlands, lakes, grasslands, and sand across various ecological regions including key ecological functional areas, ecological conservation red lines, and natural protected areas. This has not only essentially curbed the trend of ecological degradation but also led to continuous improvement in natural ecosystems, significantly enhancing the supply scale of ecological service functions and ecological products. China has now basically established a stable and secure framework for its national ecological security barrier [1,2]. As China' s economic and social development enters a stage of high-quality development with accelerated greening and low-carbon transition, ecological regions need to better balance ecological environmental protection with economic and social development while safeguarding ecological conservation red lines and improving the ecological security system. It is essential to consolidate the scale of ecosystem provisioning, regulating, supporting, and cultural services while placing greater emphasis on service quality. During the 15th Five-Year Plan period, addressing new demands for high-quality economic and social development and new public expectations for ecological environment improvement, and following the new

orientation of supporting high-quality development with high-quality ecological environments, ecological regions must further adjust their functional positioning, optimize strategic patterns, improve the ecological environment zoning control system, form a more diverse, stable, and sustainable ecological foundation, leverage ecological advantages, inject new momentum and shape new advantages for high-quality development, and accelerate the formation of modernization featuring harmonious coexistence between humans and nature across all types of ecological regions.

1.1 Continuous Expansion of Ecological Space and Significant Increase in Vegetation Coverage in Key Ecological Functional Areas, with Steady Improvement in Ecological Security Barrier Functions

Key ecological functional areas are primary regions for ensuring national and regional ecological security and providing ecological products [3], where ecological land such as forests, grasslands, and tidal flats typically accounts for over 70% of total land area. Land use survey results show that from 2010 to 2020, various types of ecological land within national key ecological functional areas increased significantly. Forest area increased by 15.115 million hectares, representing a growth rate of 10.37% (Table 1), with the most substantial increases observed in the Qinghai-Tibet Plateau ecological barrier zone (52.08%) and the northern sand prevention belt (46.13%). Comparative analysis of growing season NDVI also reveals that the NDVI of key ecological functional areas rose from 0.44 in 2010 to 0.48 in 2020, a 7.81% increase over the decade—significantly higher than the increases in urbanization areas (4.54%) and major agricultural production areas (5.84%). Additionally, the vegetation coverage and change status in national key ecological functional areas were superior to those in provincial-level key ecological functional areas, with 2020 NDVI values of 0.49 and 0.38, respectively, and decadal NDVI change rates of 8.08% and 5.26%.

As shown in Figure 1 [Figure 1: see original paper], the vegetation coverage status of key ecological functional areas generally exhibits a decreasing pattern from east to west. Functional areas dominated by forest ecosystems in the east have NDVI values generally above 0.8, which gradually transition to grassland and desert-dominated landscapes toward the northwest, with NDVI declining significantly accordingly. Regions with notable vegetation coverage growth include the Loess Plateau, Hulunbuir grassland meadow, and Horqin grassland, all showing NDVI increases exceeding 12% from 2010 to 2020. Abundant evidence demonstrates that the series of ecological restoration projects implemented in these areas not only effectively restored local damaged native vegetation but also significantly improved land degradation problems [4,5]. Meanwhile, functional areas in East China, South China, and Southwest China also experienced rapid vegetation coverage growth. Among them, the Nanling, Sichuan-Yunnan, Guangxi-Guizhou-Yunnan, and southeastern Tibet functional areas showed NDVI growth exceeding 7% from 2010 to 2020. Additionally, grassland and desert-type ecological functional areas in the arid and semi-arid regions of

Northwest China exhibited relatively stable vegetation changes, although declining NDVI trends in the Altun grassland, Tarim River, and Altai Mountains functional areas warrant attention [6,7].

1.2 Dual Population Change Pattern in Key Ecological Functional Areas: Total Population Decrease and Urban Population Increase, with Overall Alleviation of Human-Land Relationship Tension

Comparison of the sixth and seventh national census results reveals that the permanent population in key ecological functional areas decreased from 203 million in 2010 to 191 million in 2020, a reduction of 6.02%, with the proportion of national population declining by 1.62%. Spatially (Figure 2a [Figure 2: see original paper]), 65.90% of functional areas experienced permanent population loss, mainly distributed in Northeast China, Inner Mongolia, and remote central-western regions. Population loss was most severe in northeastern border areas, with county-level population reductions exceeding 30%. Meanwhile, 34.10% of functional areas with permanent population growth were primarily distributed in western regions, particularly forming contiguous distributions in southern Xinjiang, the Qinghai-Tibet Plateau, and areas adjacent to urban agglomerations and metropolitan circles.

The urban population change pattern further demonstrates (Figure 2b) that urban populations in key ecological functional areas increased rapidly—from 67.6906 million in 2010 to 88.4930 million in 2020, representing a 30.73% growth over the decade. Among these, 86.39% of functional areas experienced varying degrees of urban population growth, with the most significant increases occurring in functional areas adjacent to urban agglomerations and metropolitan circles. Conversely, 13.61% of functional areas showed declining urban populations, mainly distributed in northeastern and northern border regions and central-western mountainous and hilly areas. Under the combined effects of overall population growth slowdown, accelerated urbanization, and ecological migration policies, the dual pattern of total population decrease and urban population increase represents a key characteristic of population changes in key ecological functional areas from 2010 to 2020. As population and economy shift toward county seats and key towns, this transition not only reduces human disturbance intensity in ecological spaces but also positively contributes to transforming the fundamental regional conditions characterized by fragile ecological foundations, important ecological status, frequent natural disasters, and prominent human-land conflicts, thereby facilitating the development of a protection pattern where population distribution adapts to resource and environmental carrying capacity in ecological regions.

1.3 Significant Socioeconomic Development Achievements in Key Ecological Functional Areas, Though Economic Development Gaps with Non-Ecological Regions Persist

From 2010 to 2020, per capita general public budget expenditures in key ecological functional areas steadily increased, with the ratio to urbanization areas rising from 67.54% to 99.38%. The major function oriented zoning construction effectively promoted equalization of basic public services, continuously narrowing the welfare gap between residents in ecological and non-ecological regions. At comparable prices, per capita GDP in key ecological functional areas increased from 18,421 yuan/person in 2010 to 34,087 yuan/person in 2020, a growth of 85.05%, reducing the gap with the national average level. However, long constrained by natural endowments, geographical conditions, economic foundations, and industrial division of labor, key ecological functional areas still lag behind non-ecological regions in economic scale and growth rate (Table 2). From 2010 to 2020, GDP growth in key ecological functional areas was 73.90%, lower than that in urbanization areas (91.44%) and major agricultural production areas (78.18%), with its share of national GDP decreasing from 9.06% to 8.41%. Moreover, the GDP growth gap in provincial-level key ecological functional areas was even larger at only 61.37% over the decade, compared to 78.70% in national-level key ecological functional areas.

Economic growth in key ecological functional areas from 2010 to 2020 exhibited a distribution pattern decreasing from southwest to northeast. Both the total GDP and per capita GDP growth rates were relatively high in the Yangtze River Basin and Yellow River Basin, while economic growth was slower in key ecological functional areas of Northeast China, with some border regions even experiencing negative growth (Figure 3 [Figure 3: see original paper]). The 2020 distribution of ratios between per capita GDP in key ecological functional areas and the national average level further indicates (Figure 4 [Figure 4: see original paper]) that areas rich in energy and mineral resources or strongly influenced by central city agglomeration and radiation effects, such as the Yellow River "Ji-Zi-Wan" region and the Yangtze River Delta, have reached or exceeded the national average level. In contrast, 88.29% of the vast key ecological functional areas remain below the national average. This demonstrates that key ecological functional areas urgently need to activate comparative advantages such as high-quality ecological product resources to effectively support high-quality development with high-quality ecological environments.

2 Functional Positioning and Strategic Pattern of China' s Ecological Regions During the 15th Five-Year Plan Period

2.1 Optimization of Functional Positioning

During the 15th Five-Year Plan period, building upon the new starting point of high-quality ecological environments already achieved and following the new requirements of supporting high-quality development with high-quality ecolog-

ical environments, ecological regions will serve not only as crucial components of the new territorial security pattern but also as key pillars of the new territorial development pattern. In key ecological functional areas with important ecological functions or fragile ecosystems, functional positioning must address the relationship between development and protection while strengthening ecological environmental protection, supporting high-quality development through high-standard protection. The optimization should focus on three key directions.

First, maintain the functional orientation primarily focused on providing ecological services or ecological products. While continuing to enhance water conservation, soil and water retention, windbreak and sand fixation, and biodiversity maintenance functions, efforts should synergistically strengthen ecological regulation and supply services such as coastal protection, flood storage, carbon sequestration, and climate regulation to address major needs including global warming, extreme weather response, and "dual carbon" target achievement [8-10]. This will comprehensively secure the bottom line of the security pattern and build a more resilient new territorial spatial pattern.

Second, use the enhancement of ecosystem cultural service functions as an entry point. This involves improving the possibilities for people to obtain non-material benefits from ecosystems through spiritual experiences, knowledge acquisition, recreation, and aesthetic experiences, thereby resolving the supply-demand contradiction of beautiful ecological environments in improving residents' well-being. Particularly in national parks, large-area protection should be combined with small-scale utilization and moderate concession operations, implementing refined park-use classification and zoning controls, activating and standardizing concession management and operation mechanisms, constructing net-zero-emission green infrastructure, and leveraging the "public welfare value for all" through co-construction, sharing, and win-win approaches to better advance modernization featuring harmonious coexistence between humans and nature.

Third, activate green development momentum based on high-quality ecological environmental foundations. This includes expanding compatible functions such as ecotourism, organic agricultural product supply, deep processing of biological resources, clean energy production, and environmentally sensitive manufacturing that are compatible with ecological protection positioning and highlight ecological comparative advantages. This approach transforms past "one-size-fits-all" or "fortress-style" exclusive protection into more equitable and sustainable inclusive protection. Developing the industrial ecologicalization and ecological industrialization of key ecological functional areas should become an organic component of the new territorial development pattern, focusing particularly on optimizing ecological security barrier zones that provide stable, sufficient, and clean water resources for major urban agglomerations (such as Beijing-Tianjin-Hebei, Yangtze River Delta, Guangdong-Hong Kong-Macao, and Chengdu-Chongqing) and major agricultural production areas (such as Songnen and Sanjiang Plain,

Huang-Huai-Hai Plain, etc.). This will consolidate a more stable natural ecological foundation for high-quality development and provide safer ecological security for urban and rural residents [11,12].

2.2 Strategic Pattern Improvement

To meet the needs of functional positioning adjustment and upgrading during the 15th Five-Year Plan period, ecological regions should adopt a multi-perspective approach focusing on more complete ecosystems, more coordinated conservation and utilization methods, and more adaptive security and development orientations. Building upon the original ecological security strategic pattern, the spatial connection and supply-demand interaction between ecological security barriers and the territorial development pattern should be further enhanced (Figure 5 [Figure 5: see original paper]): expanding key ecological zones such as the Yangtze River, Yellow River, and coastal belts to push the ecological security strategic pattern from remote ecological source areas toward population and economic agglomeration axes; broadening the spatial coverage of the "Three Zones and Four Belts" to ensure that each urban agglomeration, metropolitan area, and major agricultural production area has nearby key ecological functional areas, thereby providing ecological support for major regional strategies.

First, consolidate the national ecological security barrier. In the Qinghai-Tibet Plateau ecological barrier zone, focus on enhancing water conservation and biodiversity maintenance functions, strengthening natural recovery of alpine ecosystems, and stabilizing the "Asian Water Tower." In the Yellow River key ecological zone, prioritize enhancing ecosystem stability in the Yellow River Basin, constructing a watershed green barrier for windbreak, sand fixation, and soil retention. In the Yangtze River key ecological zone, focus on improving water conservation and soil retention functions in the upper reaches, strengthening ecological restoration of Yangtze River shorelines and important lake wetlands, and enhancing basin ecological functions such as flood storage and aquatic species biodiversity maintenance. In the Northeast forest belt, prioritize restoring degraded forests and grasslands, controlling soil erosion, strengthening forest management, and strategic timber reserves. In the northern sand prevention belt, focus on improving windbreak and sand fixation functions in desertified areas, constructing border-locking windbreak and sand fixation systems and shelterbelt forests. In the southern hilly and mountainous belt, prioritize enhancing mountain biodiversity maintenance and water conservation functions, building trans-provincial integrated biodiversity conservation networks. In the coastal belt, focus on restoring typical habitats in bays and coastal wetlands, enhancing estuarine biodiversity and coastal protection functions (Figure 6 [Figure 6: see original paper]).

Second, optimize the pattern of key ecological functional areas. Optimize and implement the construction scope of 49 inland and 11 maritime national key ecological functional areas within the "Three Zones and Four Belts," clarifying

functional positioning and the minimum proportion of ecological conservation red line area to ensure that the terrestrial ecological conservation red line area within national key ecological functional areas remains above 73.84% (Table 3). Classify and formulate key ecological functions and compatible composite functions, specifying targets for high-quality ecological product supply. Expand the scope of key ecological functional areas in critical sections for water conservation and supply in the Qinghai-Tibet Plateau ecological barrier zone, soil and water retention and windbreak-sand fixation in the Yellow River key ecological zone, and flood storage and biodiversity maintenance in the Yangtze River key ecological zone. Promote the upgrading of provincial key ecological functional areas in the trans-provincial ecological corridor intersection zones of the Northeast forest belt and the border-locking windbreak and sand fixation zones of the northern sand prevention belt to national-level key ecological functional areas. Strengthen land-sea coordination in important bays and estuaries such as the Yellow River Estuary, Yangtze River Estuary-Hangzhou Bay, western coast of the Taiwan Strait, Pearl River Estuary, and Beibu Gulf, aligning and matching the determination of major functional positioning and expanding the scope of key ecological functional areas for critical species and habitats in coastal belts.

Third, integrate the natural protected area system. Among the 49 candidate national park areas selected in the *National Park Spatial Layout Plan* (including 44 terrestrial, 2 land-sea coordination, and 3 maritime areas) , prioritize the establishment of a batch of terrestrial national parks with important ecological locations, good original natural landscapes, and clear natural resource asset property rights, such as the Qinghai-Tibet Plateau national park cluster. Actively create tropical marine national parks in the South China Sea to fill gaps in maritime national parks, and steadily advance a natural protected area system with national parks as the main body, nature reserves as the foundation, and various natural parks as supplements. Address issues of spatial overlap, embedding, fragmentation, and numerous divisions in protected areas, particularly the major overlapping types between landscape-type protected areas (scenic spots, forest parks, and wetland parks) and nature reserves. Reconstruct the classification system and spatial layout according to ecological value and protection intensity, ensuring comprehensive protection and demarcation of suitable habitats and habitats for rare and endangered flora and fauna, flagship species, and indicator species, as well as their concentrated distribution areas and critical ecological corridors. This will maintain ecosystem integrity and improve protection effectiveness while strengthening deep integration of ecology and culture in recreational spaces, refining control zones according to ecological environment capacity, and orderly expanding comprehensive functions such as scientific research, education, and recreation.

Fourth, strictly adhere to ecological conservation red lines. According to planning targets of no less than 3 million square kilometers for terrestrial ecological conservation red lines and no less than 150,000 square kilometers for marine ecological conservation red lines, areas with extremely important ecological functions and extreme ecological vulnerability should be designated as ecological

conservation red lines. While stabilizing the scale of natural ecological space protection, ecosystem quality and stability should be enhanced. Establish a dynamic optimization mechanism for ecological conservation red line boundaries. In coordination with natural protected area integration and optimization, on one hand, supplementarily demarcate ecological spaces with low human disturbance and potential important ecological value, as well as those located at key ecological positions such as both banks of important river source streams, surrounding important wetlands and reservoirs, serious desertification and soil erosion areas, and basic shelterbelt forest belts in coastal protection forests. On the other hand, address historical legacy issues where large-scale, population-concentrated villages and towns, contiguous cultivated land, infrastructure with low protection value, and commercial forests that do not affect ecological functions were included in red lines due to past "rescue-style" protection [13]. After scientific assessment, these should be gradually adjusted out of red line scope.

3 Optimization Priorities for China' s Ecological Regions During the 15th Five-Year Plan Period

3.1 Classified Improvement of Ecosystem Service Function Quality

During the 15th Five-Year Plan period, we must not be satisfied merely with the expansion of ecological space and growth of ecological resources achieved in ecological civilization construction. Greater consideration must be given to the sustainability and quality of "green expansion," with classified improvements to the diversity, stability, and sustainability of the ecological foundation. Focus on plateau wetlands, river sources, and important water source areas to reduce excessive human activity impacts, strengthen wetland ecological functions and surrounding vegetation restoration, and consolidate water conservation functions. Target water-wind erosion interlaced zones, concentrated sediment source areas, and contiguous karst rocky desertification areas to restrict steep slope cultivation and overgrazing, strengthen small watershed comprehensive management, and improve soil and water retention functions. Focus on important main and tributary streams, lakes, and reservoirs to implement farmland and polder withdrawal for wetland restoration, improve water system connectivity along lake and river coasts, maintain the integrity of river-lake ecosystems and aquatic biodiversity, and restore flood storage functions. Prioritize forest-grass ecosystems in sand source areas and farming-pastoral ecotones to strengthen livestock and grazing management based on grassland carrying capacity, accelerate construction of border-locking windbreak and sand fixation forest-grass belts, and consolidate windbreak and sand fixation functions. Focus on primitive forest ecosystems and areas rich in rare flora and fauna resources to strengthen endangered species and habitat protection, improve trans-boundary biodiversity conservation networks, and enhance biodiversity maintenance functions. Prioritize estuaries and bays to strengthen restoration of coastal wetland biological resources such as mangroves and coral reefs, rebuild damaged marine ecosystems, and improve marine biodiversity maintenance and coastal protection functions.

3.2 Systematically Enhancing Ecological Support Capacity for High-Quality Development

While implementing integrated mountains-rivers-forests-farmlands-lakes-grasslands-sand protection and restoration projects with "Three Zones and Four Belts" as the overall layout , prioritize watersheds as the main unit to address prominent ecological issues constraining regional high-quality development and green, efficient resource utilization, and prevent and resolve ecological environment risks by zone (Table 4). Advance flood storage capacity enhancement and ecological protection restoration in eastern coastal urban agglomerations and adjacent areas, strengthen green infrastructure network construction, and focus on improving flood diversion and storage functions in flood diversion zones. Layout comprehensive disaster prevention and mitigation projects in high natural disaster risk areas, focusing on enhancing comprehensive natural disaster prevention capabilities and system resilience. Strengthen comprehensive watershed ecological environment management and restoration of ecologically damaged estuarine and coastal zones, coordinate solutions to water resources, aquatic ecology, water environment, and water disaster issues in upstream-downstream, left-right bank, and main-tributary relationships, with emphasis on enhancing ecological support for major regional strategies such as high-quality development of the Yangtze River Economic Belt, Guangdong-Hong Kong-Macao Greater Bay Area construction, and ecological protection and high-quality development of the Yellow River Basin. Enhance water conservation functions in water source areas of major water diversion projects such as the East, Central, and West routes of the South-to-North Water Diversion Project, construct ecological water networks interweaving natural and artificial water systems, and focus on enhancing water security capacity for the national water network main arteries. Implement green development projects for important grain, energy, and mineral resource bases, focusing on enhancing national resource security and sustainable utilization capacity.

3.3 Actively Cultivating New Drivers of Green Development

Under the dominant function of ecological protection and guided by the value realization of high-quality ecological products, fully explore ecological material products, regulating service products, and ecological cultural products. Construct differentiated factor groups from dimensions of resource carrying capacity, location endowment preferences, and environmental constraint conditions, and conduct classified suitability evaluations for ecological product utilization to scientifically determine priorities for ecological product utilization and compatible development functions. Formulate more refined urban and rural living functions and production function layouts and access lists for "ecology + agriculture," "ecology + manufacturing," and "ecology + services" to guide traditional characteristic productivity to supplement and extend industrial chains and transition toward green and low-carbon practices, while encouraging new

quality productivity layouts driven by scientific and technological innovation. Establish a green economic system in ecological regions that integrates the three industries, including organic agricultural product supply, ecotourism industry, deep processing of biological resources, environmentally sensitive industries, and green energy and strategic mineral resources development. Cultivate new green momentum for the conversion of "lucid waters and lush mountains" into "invaluable assets," and create livable, business-friendly, and tourism-friendly beautiful homes in ecological regions where "everyone has work and every family has income."

3.4 Accelerating the Establishment of a Refined Zoning Control System

Deepen the top-down, level-by-level transmission and precise implementation of functional positioning in key ecological functional areas, improve and perfect the ecological environment zoning control system and differentiated control measures, and guide ecological value conversion through a combination of spatial access and positive/negative lists. In national key ecological functional areas, refine township-level ecological protection and ecological economic zones (key ecological functional areas), green agriculture and rural revitalization zones (major agricultural production areas), key industry and population agglomeration zones (urbanization areas), and other major functions and compatible functions. Achieve precise spatial implementation of composite functions with development potential cultivation value that supports high-quality development after access, using land parcels as basic units. Under the premise of not damaging ecological functions, clarify implementation details for allowable human activities and net-zero-disturbance green infrastructure support within ecological conservation red lines. Furthermore, integrate and construct unified land use approval rules, procedures, and management platforms to break down single-element land use control policy barriers for forests, grasslands, waters, and wetlands within ecological spaces. In summary, by constructing more refined and flexible land use control systems and positive/negative access lists, compatible regional functions can provide more equitable and sustainable development rights to ecological regions, fundamentally resolving the pain point where ecological conservation red line constraints exceed ecological dividend support.

3.5 Synergistically Advancing Institutional Mechanism Reform and Innovation

Institutional mechanism reform constitutes the policy and institutional guarantee for strategic pattern optimization of ecological regions during the 15th Five-Year Plan period. On one hand, explore innovations in the realization mechanism of "lucid waters and lush mountains are invaluable assets" and ecological product valuation mechanisms, establish comprehensive green development assessment and incentive mechanisms, and steadily increase central fiscal transfer payments to ecological regions. Establish a special fund for national key

ecological functional areas, explore market-oriented operation models such as ecological product operation and development, mortgage loans, and rights trading, and effectively resolve the long-standing prominent contradiction between large ecological protection investments and small county-level fiscal capacity in key ecological functional areas [14,15]. On the other hand, address issues and tendencies of parallel various element compensation funds and "sprinkling pepper" or duplicate compensation in various ecological regions by exploring the establishment of an ecological compensation coordination system to integrate different channels of ecological protection compensation funds and improve the integrity and comprehensive benefits of ecological protection compensation. Improve horizontal compensation mechanisms between beneficiary regions and ecological regions, and cultivate advantageous industries, improve equalization of basic public services, and guide orderly outward migration of populations from ecologically important areas through methods such as paired collaboration, industrial transfer, talent training, co-construction of parks, and procurement of ecological products and services.

4 Conclusions and Discussion

Various ecological regions including key ecological functional areas, ecological conservation red lines, and natural protected areas constitute both important components of the new territorial security pattern and key pillars of the new territorial development pattern. In the process of accelerating ecological civilization construction, key ecological functional areas have experienced continuous ecological space expansion, significant vegetation coverage increase, dual population changes of total decrease and urban increase, and remarkable socioeconomic development achievements, though economic development gaps with non-ecological regions persist. This means that on the basis of having well completed the first half of the "protection" article, ecological regions urgently need to explore how to write the second half on "supporting high-quality development with high-quality ecological environments."

During the 15th Five-Year Plan period, building upon the new starting point of high-quality ecological environments, ecological regions need to address the relationship between ecological environmental protection and economic and social development from a higher standpoint and broader perspective, timely upgrade functional positioning, optimize strategic patterns, classify and improve key ecosystem service functions, and systematically enhance the capacity of ecological environments to support high-quality development. Emphasis should be placed on cultivating new drivers of green development, accelerating the establishment of a refined zoning control system, synergistically advancing institutional mechanism reform and innovation, and promoting positive interactions among population, society, economy, and resources-ecological environment [16]. Additionally, ecological regions need to establish scientific monitoring and early warning systems for all ecological environment elements and processes, implement differentiated performance assessment and evaluation mechanisms based

on monitoring and early warning results, with key assessments of ecological conservation red lines, ecological environmental quality, ecological product value realization, negative list constraints and positive list implementation for industrial access, and basic public service improvement. This will drive key ecological functional areas to enter a green, low-carbon, high-quality development stage synchronously with urbanization areas and major agricultural production areas, writing a new chapter of modernization featuring harmonious coexistence between humans and nature in the new era.

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ZHOU Kan is an Associate Professor at the Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences. He has long been engaged in research on resources and environmental carrying capacity and regional development, focusing on comprehensive evaluation methods and applications for regional carrying capacity, carrying capacity constraints and sustainable regulation in ecological regions, and territorial spatial planning and governance. E-mail: zhoukan@igsnrr.ac.cn

ZHOU Daojing is a Ph.D. and Assistant Professor at the Institutes of Science and Development, Chinese Academy of Sciences. Her major research covers resource-ecological-environmental impacts of regional development. E-mail: zhoudaojing@casisd.cn

Responsible Editor: Yue Lingsheng

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