Research Paper

Response to "Dual-Carbon" Objective in Comprehensive Territorial Spatial Planning of Resource-Based Cities: A Case Study of Fujin city

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Abstract

The "Dual-Carbon" objectives in China mark a historic shift in carbon emission reduction and pose new requirements for comprehensive territorial spatial planning. Comprehensive territorial spatial planning is the fundamental basis of a spatial blueprint for sustainable development and various development, protection, and construction activities. It views space as a product, asset, and factor, enabling rational planning and layout. Its core purpose is highly consistent with the "Dual-Carbon" objective and provides a realistic pathway for the realization of the "Dual-Carbon" objective. Global resource-based cities account for 75% of carbon emissions, and such cities in China need to shift from resource dependence to high-quality development. This paper focuses on the connotation of the "dual-carbon" objective and the uniqueness of resource-based cities, and establishes a linkage mechanism between the "dual-carbon" objective and comprehensive territorial spatial planning of resource-based cities. Aiming at the dilemmas faced by comprehensive territorial spatial planning of resource-based cities, the response pathways of comprehensive territorial spatial planning of resource-based cities under the "dual-carbon" objective is explored and verified with the example of comprehensive territorial spatial planning of Fujin City. It guides traditional resource-based cities towards low-carbon transformation and sustainable development from a multidisciplinary perspective, thereby achieving a win-win for both the economy and environmental protection.

Keywords

"Dual-carbon" objective, Resource-based cities, Comprehensive territorial spatial planning, Carbon emission reduction, Increasing carbon sink

1. Introduction

The excessive emission of greenhouse gases, specifically carbon dioxide, is contributing to the gradual rise in global temperatures, resulting in important alterations to the climate system, such as rising sea levels, which threaten global ecosystems [1]. During the General Debate of the 75th Session of the United Nations General Assembly, President Xi Jinping announced China's commitment to peak carbon dioxide emissions before 2030 and achieve carbon neutrality by 2060 [2]. To realize the 'dual-carbon' objective, China has introduced a comprehensive set of policies aimed at promoting a green transformation in both economic and social development. The country calls for the integration of carbon peaking and neutrality targets into the medium and long-term planning frameworks for economic and social development, ensuring strong support from national development planning, territorial spatial planning, sectoral planning, regional planning and local planning at all levels.

Comprehensive territorial spatial planning, an important component of the territorial planning system, offers a systematic and scientific pathway to achieving the 'dual-carbon' objective through a multidisciplinary and integrated approach. It focuses on using spatial design to unify critical sectors such as industry, livelihoods, ecology, transportation, and land use. Techniques such as 'dual evaluation' and the delineation of the three lines effectively enhance constraints on resource and environmental thresholds, promoting low-carbon transformation and promoting green, high-quality development within resource-based cities [3].

Resource-based cities play an important role in the transformation and development of urban areas in China. Historically, these cities have depended on abundant natural resources to drive economic growth; however, with the nation's shift towards high-quality development, the previous extensive urban development model is no longer viable. The heavy reliance of these cities on resource industries has led to an increase in carbon emissions, obstructing industrial innovation and transformation while increasing carbon intensity. Worldwide, resource-based cities are responsible for 75% of carbon emissions [4], with a notably higher contribution from Chinese cities. Consequently, the formulation of comprehensive territorial spatial planning for resource-based cities, considering the imperatives of carbon reduction and increasing carbon sinks, is critical for achieving the 'dual-carbon' goals.

2. The correlation mechanism between the "dual-carbon" objective and comprehensive territorial spatial planning of resource-based cities

2.1. The connotation of "dual-carbon" objective

The "dual-carbon" objective encompasses two primary milestones: reaching a peak in carbon dioxide emissions prior to 2030, followed by achieving carbon neutrality before 2060. Carbon peaking refers to the critical point at which total carbon emissions reach a maximum and then begin to decline. Carbon neutrality signifies a state in which human-generated carbon emissions are balanced by carbon absorption and the environment reaches net-zero emissions. Reaching the carbon peaking is the key to achieving carbon neutrality, and the timing and extent of the peak will influence the achieving of this goal [5].

In order to achieve the 'dual-carbon' goal, China has mainly adopted two strategies: emission reduction and carbon sinks enhancement. China advocates the green and low-carbon principle and encourages green technology innovation to promote emissions reduction. The key is promoting industrial transformation and developing low-carbon industries, including clean energy and efficient transportation system. In the enhancing carbon sinks, the collaboration between human and nature has been strengthened through the restoration of forests, wetlands and other ecosystems to increase carbon absorption and storage capacities. Achieving the 'dual-carbon' objective is important for economic development and ecological protection, helping to mitigate the adverse impact of global climate change.

2.2. The specificity of resource-based cities

Resource-based cities refer to urban areas primarily focused on the exploitation, processing and export of natural resources such as oil, coal and agriculture. These cities are important energy supply and security bases in China [6][7]. Resource-based cities exhibit the following characteristics: (1) They are sensitive to changes in external market demand, so fluctuations in resource prices can have an important impact on the local economy. (2) Due to their reliance on natural resource extraction and processing, resource-based cities often possess a single-industry structure and lack high-tech industries, leading to difficulties in economic structural transformation. (3) The unique industrial structure of resource-based cities contributes to severe environmental pollution and ecological degradation. It negatively impacts the quality of living environments and ecosystems. (4) Resource-rich areas experience relative prosperity, while surrounding regions face resource and infrastructure deficiencies, leading to imbalanced urban development.

2.3. The relationship between comprehensive territorial spatial planning of resource-based cities and the "dual-carbon" objective

The comprehensive territorial spatial planning of resource-based cities plays an important role in achieving the 'dual-carbon' objective [8]. Under the framework of the "dual-carbon" goal, comprehensive territorial spatial planning takes into account multiple factors such as economy, society, environment and culture. It places special emphasis on the control of carbon emissions, optimising energy utilization and protection of ecological environment [9] while optimising the factors layout and configuration. The comprehensive territorial spatial planning promotes the low-carbon development and efficient resource use, which provides a realistic path for the achievement of the 'dual-carbon' goal.

2.3.1. Comprehensive territorial spatial planning of resource-based cities provides pathways for carbon emission reduction

The main industries of resource-based cities are concentrated in the energy, minerals and agriculture sectors, characterised by high energy consumption and high carbon emissions. In order to reduce carbon emissions, the comprehensive territorial spatial planning generally includes the following measures:(1) rational allocation of industrial, ecological and construction land within resource-based cities to achieve optimal layout and allocation of the resources;(2) effective land allocation through controlling multiple factors such as the scale of construction land and the spatial mix of the city to ensure the efficient resources use and the environmental protection;(3) rational planning of industrial areas, residential areas , facility zones and green areas, and supplementing high energy consumption and high carbon emission industries with low carbon industries to achieve optimal allocation of resources. Scientific planning of transport networks and optimisation of public transport routes are also important considerations [10].

2.3.2. Comprehensive territorial spatial planning of resource-based cities provides pathways for increasing carbon sink

Resource-based cities have rich natural resources and space resources, which can effectively solve the problem of increasing carbon sink through land consolidation and ecological layout. Specific measures include:(1) Rectification of illegally occupied land and reclamation of abandoned mines to restore the ecological function of the land. This not only improves land utilization efficiency but also increases carbon sink. (2) Delineating ecological protection redlines and establishing a comprehensive green space system to increase vegetation coverage and enhance carbon absorption and fixation capabilities. (3) Controlling the utilities of different types of land to minimize unnecessary land development and construction. It improves the utilization efficiency of land resource to provide more space for increasing carbon sinks.

3. Response of comprehensive territorial spatial planning of resource-based cities under the "dual-carbon" objective

3.1. Dilemmas facing comprehensive territorial spatial planning of resource-based cities

Although comprehensive territorial spatial planning of resource-based cities has shifted from single-factor control to comprehensive control encompassing all areas, all elements, and the entire process, it still faces numerous challenges in achieving the "dual-carbon" objective. Resource-based cities rely on high-energy-consuming resource development, lack of industrial diversification, and have a singular development path, which hinders low-carbon transition. Planning in the past is disconnected from the "dual-carbon" concept, focusing on resource development while neglecting environmental factors. The "dual-carbon" concept is often only stated at the conceptual level, lacking specific implementation details. There is a lack of carbon emission monitoring and assessment. As a result, planning decisions lack data support and carbon emissions cannot be effectively controlled.

3.2. Response of comprehensive territorial spatial planning of resource-based cities

The "dual-carbon" objective of comprehensive territorial spatial planning of resource-based cities need to be achieved through strengthened support and guarantees from systems such as comprehensive territorial spatial planning and special planning. It is necessary to establish a planning, construction, and management mechanism that is guided by green and low-carbon principles. Based on the characteristics of resource-based cities, such as abundant natural resources and a relatively single industrial structure, comprehensive territorial spatial planning should be used as an effective tool [11] to coordinate the planning of various elements, including land, industry, and ecology. This will promote low-carbon planning and green governance in urban, agricultural and ecological spaces, aiming to create compact and low-carbon urban spaces, promote the building of increasing carbon sink in agricultural and ecological spaces, implement the plan of the "dual-carbon" objective, and form a sustainable territorial spatial pattern.

3.2.1. Efficient site structure

3.2.1.1 Optimization of comprehensive territorial spatial pattern

By constructing a multi-centred, clustered, and intensive comprehensive territorial spatial pattern [12], adjusting the spatial layout and growth mode of urban areas, and promoting the transition of traditional lifestyles towards green and low-carbon directions. It is necessary to build a multi-level urban spatial system that encompasses the entire region, urban-rural areas, and central urban areas. This will promote the two-way flow of resource elements and scientifically plans the layout of eco-agricultural development. It should Strengthen ecological protection and bottom-line constraints, and emphasise ecological features and values to guide sustainable agricultural development.

3.2.1.2 Integration of "three lines" delineation and control

The planning should scientifically draw redlines for protecting the ecosystems, designate permanent basic cropland and delineate boundaries for urban development, and establish a policy system for pollution reduction and carbon mitigation in urban, agricultural, and ecological spaces [13]. The key is to strengthen the control and management of ecological environments zoning. It should keep consistent with the requirements of use control and territorial planning zoning. The requirements of carbon peaking and carbon neutrality should be incorporated into the zoning and control system of the "three lines one permit" to guide industrial structure adjustments and optimize spatial layouts.

3.2.1.3 Optimization of land structure for construction

The planning aims to break the traditional single-centre urban system pattern of resource-based cities, and achieve the intensive utilization of land resources through measures such as land scale control and structural optimization. It is important to abandon the drawbacks of single-function development in cities, where work, residence, and daily life are segregated. Emphasis should be placed on the multifunctional and compound development of urban land, and the rationality of land use planning, leading to a spatial layout of land resource utilization that is multi-centred and intensive [14]. Optimizing land conversion is a important step towards achieving sustainable development. When agricultural land is converted into urban land, priority should be given to protecting high-quality agricultural land to ensure the sustainability of food production and reserves. A portion of agricultural land should be preserved as urban green space or converted to ecological agricultural purposes to increase carbon sink and ecological sustainability in cities.

3.2.2. Systematic ecological protection and restoration

3.2.2.1 Strengthening the protection and utilization of resource elements

The planning adheres to the system governance of mountains, rivers, forests, farmlands, lakes, and grasslands, and constructs a large-scale and large-region ecological network structure system [15]. This approach aims to protect natural spaces and achieve network connectivity, stimulating the increasing carbon sink function of agricultural and ecological spaces, and forming an ecological foundation of urban ecological purification. In terms of ecology, the development of natural protected area systems such as national parks are being advanced, integrating protected areas to build an ecological network structure system. This connects protected areas and ecological nodes, forming ecological corridors and ecological linkages, thereby enhancing the stability of ecosystems. In agriculture, there is a focus on strengthening farmland management, improving soil carbon storage capacity, promoting circular agriculture, constructing agroforestry systems, and implementing farmland ecological projects to enhance carbon sequestration capabilities.

3.2.2.2 Ecological restoration and comprehensive land consolidation

We need to strengthen the protection and restoration, and reduce carbon emissions and enhance carbon sinks to promote continuous ecological improvement and low-carbon development [16]. It is necessary to implement a negative list for natural ecological protection and restoration activities, standardize restoration practices, strengthen law enforcement and supervision, reduce non-construction land use, and prevent over-exploitation of land resources and increased carbon emissions. A comprehensive framework for land space remediation and restoration should be established to repair damaged ecosystems and remediate illegal land occupation and reclaim abandoned mines in order to improve the sustainable use of land and soil carbon sequestration capacity. Priority should be given to ecological protection and restoration within ecological protection red lines and key ecological functional areas, focusing mainly on natural recovery supplemented by artificial restoration. Ecosystem protection of the water environment, wetlands, soil and other ecosystems will be strengthened to improve ecosystem stability and carbon sequestration capacity.

3.2.3. Low-carbon layout patterns

3.2.3.1 Industrial spatial layout adjustment

The planning aims to steer resource-based cities towards a high-end, intelligent, green, and service-oriented industrial model through policy guidance and technological innovation [17]. In the primary industry, it promotes green and ecological farming, enhancing production efficiency and resource use while reducing chemical inputs and agricultural greenhouse gas emissions. In the secondary industry, it encourages green manufacturing and renewable energy, adopting clean production methods to decrease non-renewable resource consumption and waste emissions. In the tertiary industry, it promotes the development of green industries like electronic information, builds blockchain and industry chains, and uses "Internet of Things +" technology for smart city construction, enhancing urban management and services, and reducing carbon emissions from transportation and industries.

3.2.3.2 Optimization of the layout of the central urban area

Resource-based cities, with primary and secondary industries as their main focus, face important transportation challenges. To address this issue, the following measures can be implemented: advocating for the "public transportation priority" and Transit-Oriented Development (TOD) concept, an integrated public transportation system should be established with rail transit as the backbone and conventional buses as the main component. This system should provide multi-level public transportation connections, linking various service centres in the city and offering convenient public transportation services to reduce transportation energy consumption and carbon emissions. Establishing a "narrow roads, dense road network" transportation network can expand the coverage of the public transportation system and optimize traffic flow [18], reducing unnecessary transportation-related carbon emissions. Using big data and smart city platforms, a "blockchain + internet" intelligent transportation management system and smart parking facilities should be developed to enhance the operational efficiency of the transportation system [19]. It will help ease traffic congestion and reduce high carbon emissions by providing intelligent support.

Promoting the concept of "low-carbon living" can contribute to carbon emission reduction in various ways, such as resource utilisation, community green commuting and green buildings [20]. Through implementing measures including waste separation and recycling, organic waste composting and water recycling, establishing a community resource recycling system can reduce the demand for natural resources to contribute to reduce greenhouse gas emissions from landfills and incineration. The key is encouraging green commuting within the community to reduce vehicle gas emissions, such as building infrastructure, providing a convenient public transport system and promoting clean energy transport options. Incorporating greening and landscaping into community planning can help mitigate the urban heat island effect and improve air quality, including increasing green space and vegetation cover into community.

Through adopting green building material, optimising spatial layout and implementing low carbon and energy efficient technologies, it will reduce carbon emissions from constructions to improve the sustainability [21]. Utilising renewable green building materials can help reduce carbon footprint and environmental impact, and promote the development of the green building material industries. Using natural lighting and ventilation through thoughtful spatial layout can reduce the reliance on artificial lighting and energy to reduce carbon emissions at source. The adoption of low-carbon and energy-saving designs and technologies will allow for detailed control of building space, which sets carbon emission limits and assesses the science of spatial planning.

4. Implementation and application of comprehensive territorial spatial planning for resource-based cities under the "dual-carbon" objective: a case study of fujin city

4.1. Overview of the situation in fujin

Fujin City, a county-level city under the jurisdiction of Heilongjiang Province, is located in the northeastern part of the province and is primarily agricultural. It has abundant ecological resources. Nowadays, it faces some challenges: a monocentric spatial structure that restricts urban development, an imbalanced land use structure in the old urban area with mixed industrial and residential zones affecting the living environment. The economy is relatively underdeveloped with a singular industry, and the level of urbanization is low. Infrastructure such as water supply, sanitation, and transportation systems are inadequate. The economy development has led to a decline of ecological quality and scarcity of water resource. The distribution of green spaces is uneven, and the green space system is incomplete. The outflow of young people leads to sustainable development problem.

4.2. Technological route

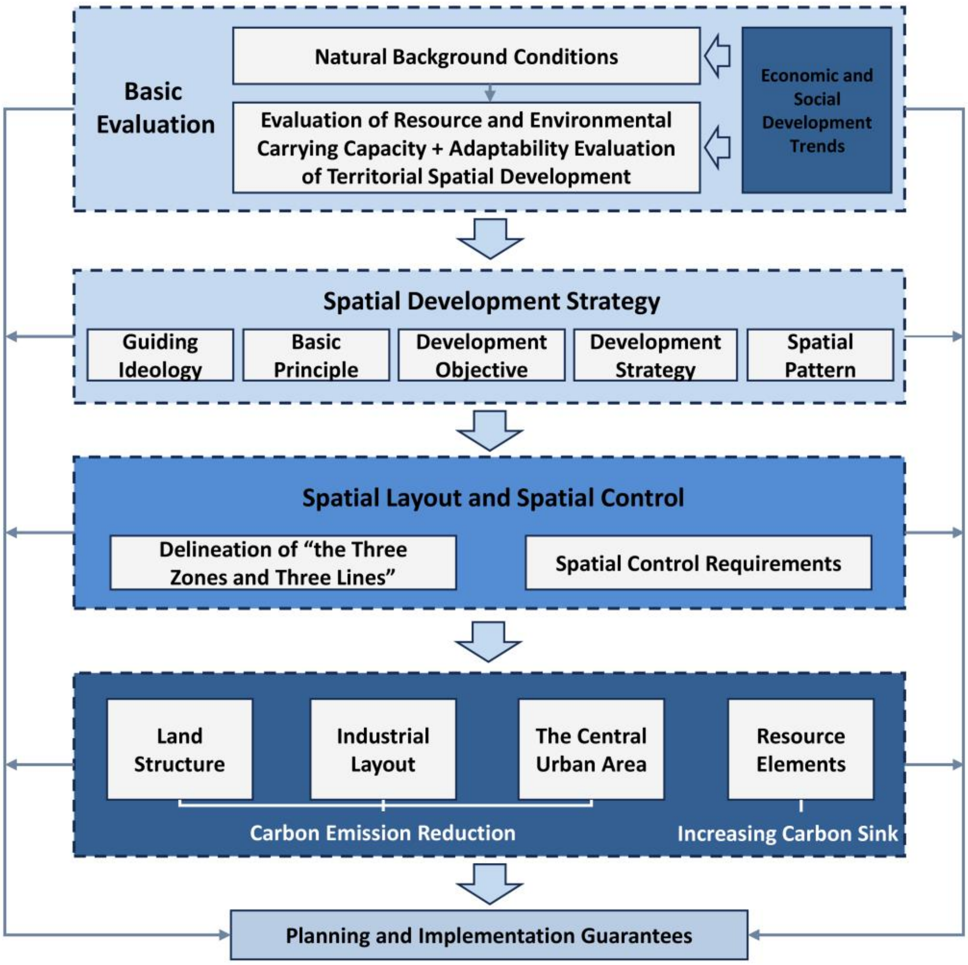

Figure 1. Technical Roadmap for the Comprehensive Territorial Spatial Planning of Fujin City. Source: Self-drawn by the author.

The Comprehensive territorial spatial planning of Fujin City is based on "three investigations" data, combined with natural background conditions such as land and water resources, and ecology. Five individual evaluations are conducted for natural background conditions, water resources, and other indicators. Based on this, an integrated evaluation of resource and environmental carrying capacity is carried out, which comprehensively identifies the strength and weakness levels of carrying capacity. Quantitative analysis is primarily employed, supplemented by qualitative analysis, to conduct individual evaluations of potential for back-up suitable lands and disaster risks, and integrated evaluations of ecological suitability, urban function suitability, agricultural function suitability, and other factors. Based on the adaptability evaluation of territorial spatial development, in combination with higher-level planning and spatial development strategic planning, the spatial pattern and spatial control are determined. In order to coordinate the rational utilization of resources, we need to delineate urban development boundaries, permanent basic farmland redlines and ecological protection redlines, and determinate spatial control requirements for ecological, agricultural, and urban spaces. In response to the "dual- carbon" objective, comprehensive territorial spatial planning of Fujin City provides various implementation paths in terms of land use, industries, resources, and the central urban area. This aims to promote green economic transformation, ecological protection, and utilization, in order to promote carbon emission reduction and increase carbon sink (refer to Figure 1).

4.3. Implementation pathway

4.3.1. Efficient site structure

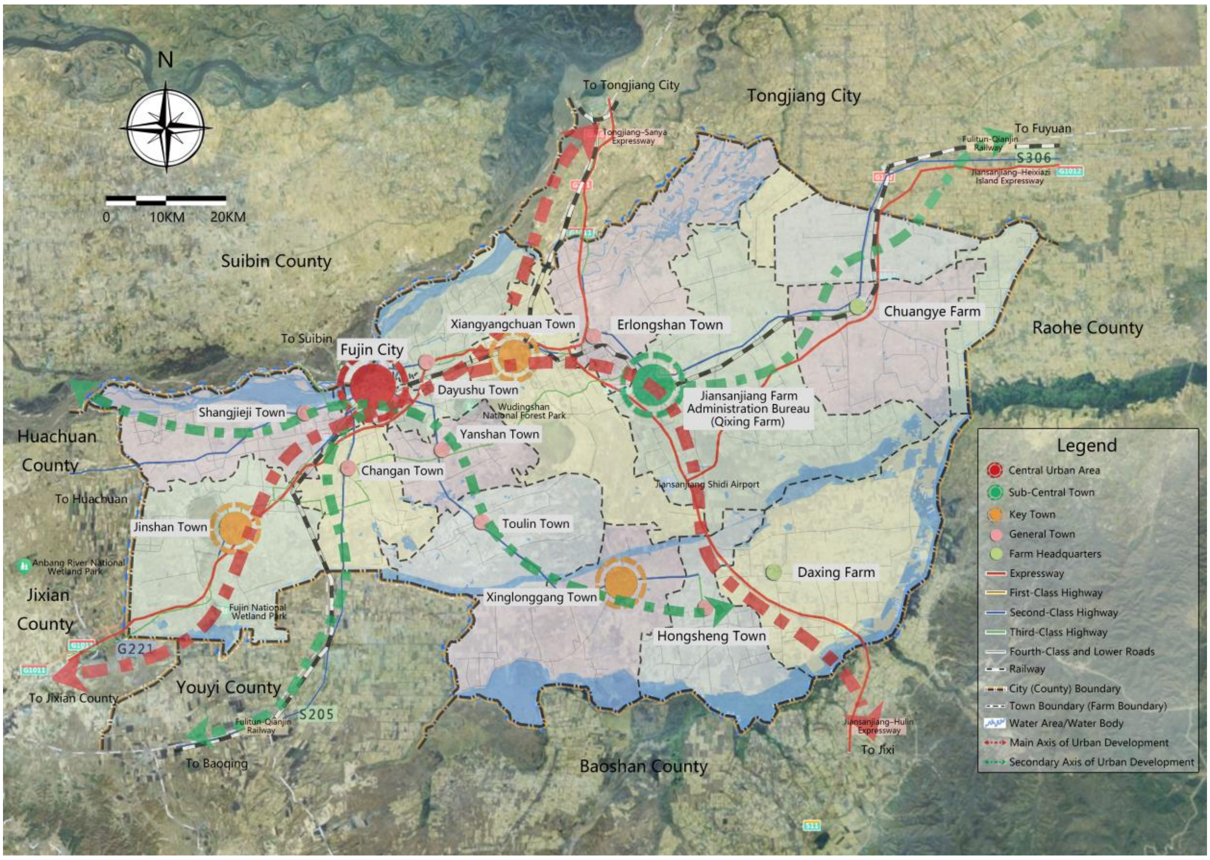

Figure 2. Spatial Structure Plan of Fujin City. Source: The Comprehensive Territorial Spatial Planning of Fujin City.

In spatial structure planning, to strengthen the connection between industries and urban zones, promote the linkage of various transportation modes, and promote the development of eco-agricultural towns, Fujin City's spatial development pattern has shifted from the previous single-centre development model to a "dual-core driving, dual-axis traction" development pattern (refer to Figure 2). The "dual-core driving" approach refers to using the central urban area of Fujin and the sub-centre as engines to drive the overall economic and social development of the city. These two central urban areas primarily focus on the development of secondary and tertiary industries, promoting the concentration of production factors and population in the two core zones within the city. The "dual-axis traction" relies on the road system to form the main and secondary axes for urban development. These two axes unify various townships into a cohesive whole and play a role of spatial traction to realize the transformation of the overall spatial pattern. It effectively alleviates the problems of traffic congestion and carbon emissions brought about by the single-centre city development pattern. Through the shortening of commuting distance and time and providing diversified travelling options, it promotes the development of public transport and non-motorised transport to reduces transport energy consumption and carbon emissions.

4.3.2. Adjustment of industrial spatial layout

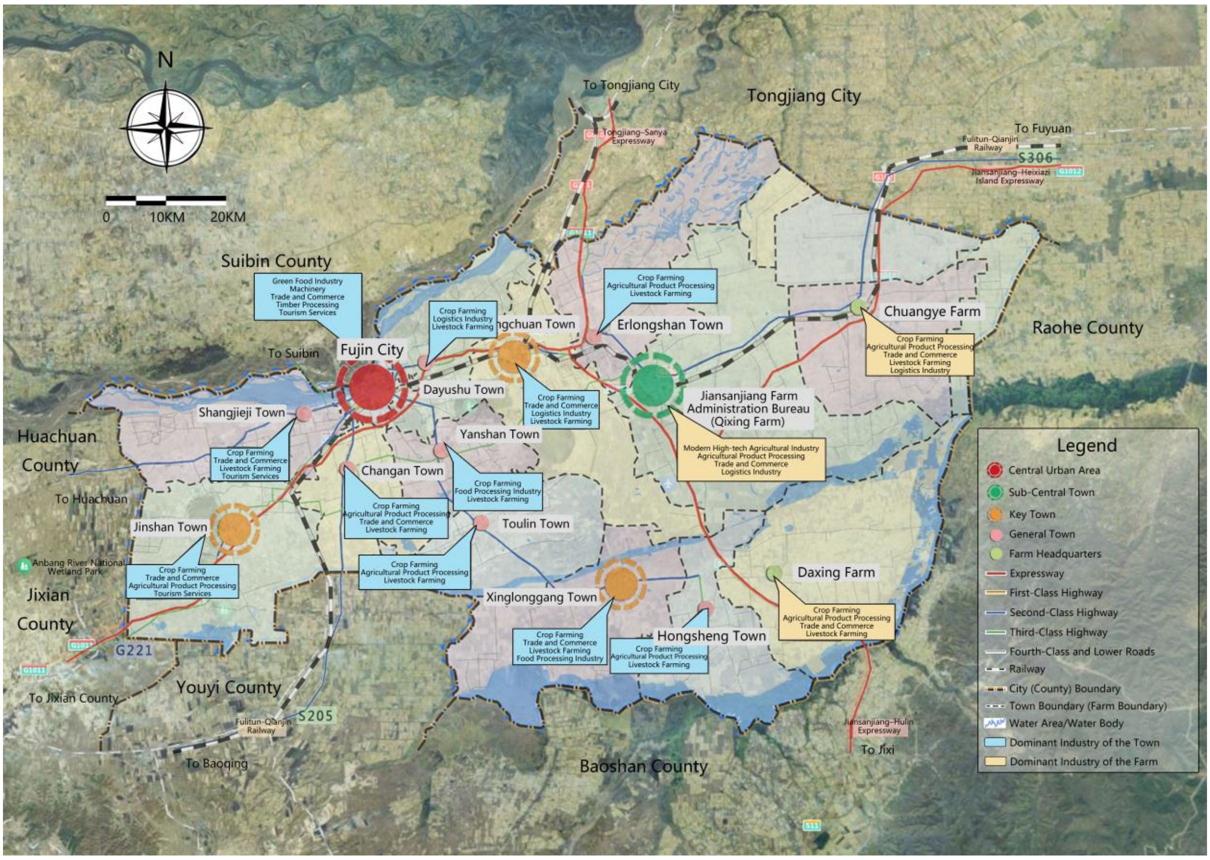

Figure 3. Industrial layout plan of Fujin City. Source: The Comprehensive Territorial Spatial Planning of Fujin City.

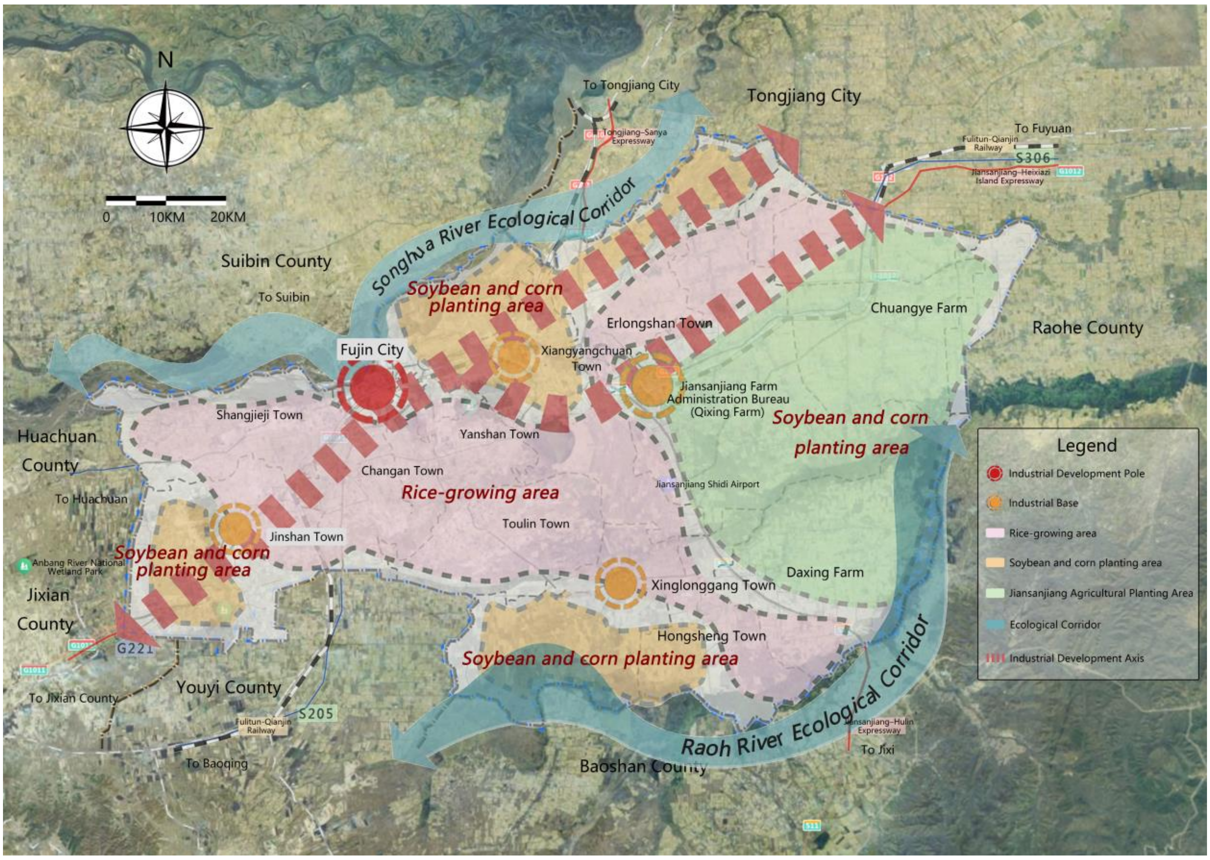

Figure 4. Agricultural layout plan of Fujin City. Source: The Comprehensive Territorial Spatial Planning of Fujin City.

Based on the resources and industrial advantages of Fujin City, the industrial development strategy aims to create a strategic pattern of "one core, two bases, one axis, two corridors, multiple districts and multiple nodes" (refer to Figure 3). "One core" refers to the core area of industrial development in the downtown area of Fujin. It integrates the production and related service functions, commercial and residential functions, and modern port logistics functions of the green food industrial park to realize the multi-functional and integrated connection between the port, industry and city. We can promote the coordinated industrial development to improve resource utilisation efficiency and reduce carbon emissions. The "two bases" feature agricultural resources to form a special agricultural industrial base and a cultural tourism industrial base integrating grain planting, production, processing and sales. In terms of agriculture (refer to Figure 4), the focus is on shifting from traditional inefficient agriculture to seven modern, industrialised and ecological agricultural development models, including high-tech facility agriculture, recycled agriculture and leisure and tourism agriculture. Using of agro-ecological resources to promote the development of rural tourism and service industry as part of the tertiary sector aims to achieve mutual promotion and large-scale development of the industries. In the secondary industry, information technology is used to drive industrialisation and industrialisation is used to promote information technology. We can accelerate the emerging industries development and promote the optimisation and upgrading of industrial structure. Through the development of green technology and circular economy, it reduces dependence on traditional fossil fuels to provide more choices and possibilities for carbon emission reduction.

4.3.3. Enhancing the protection and utilization of resource elements

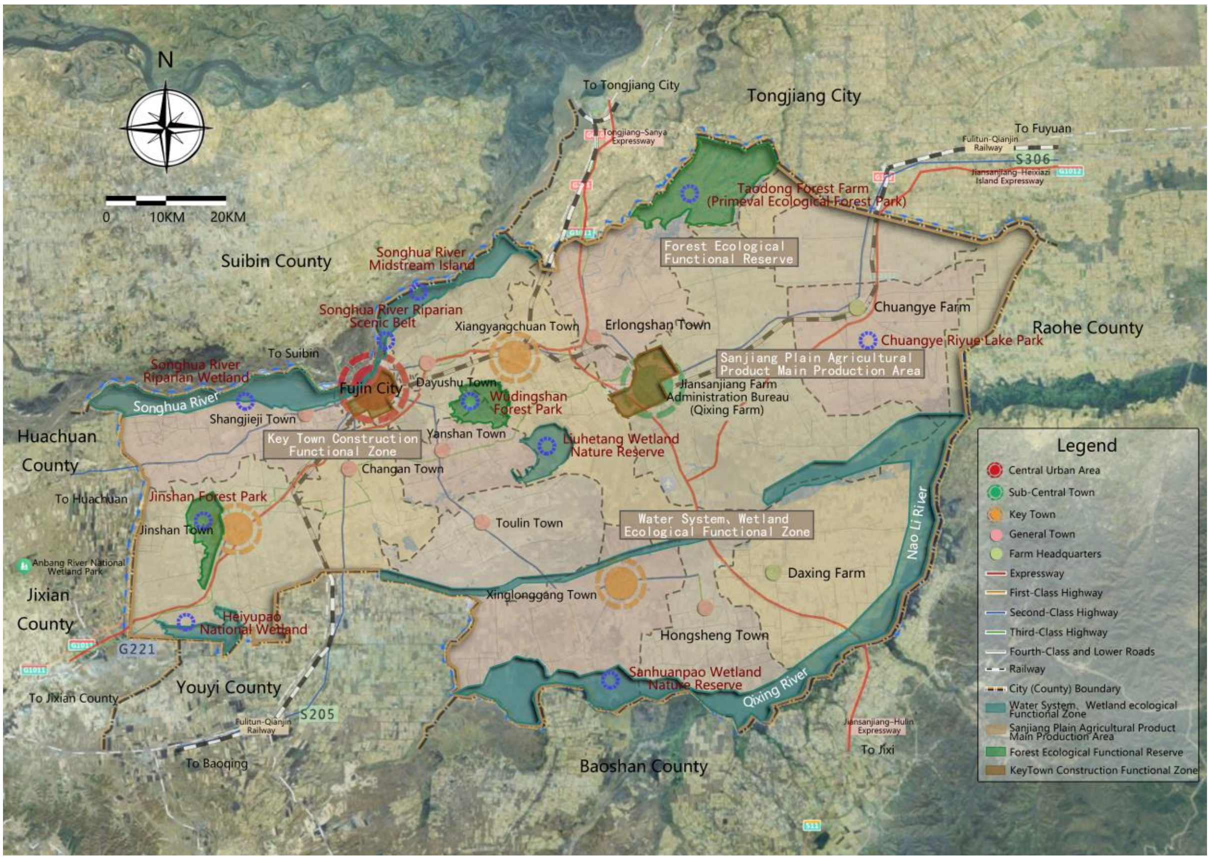

Figure 5. Ecological Resources Layout Plan of Fujin City. Source: The Comprehensive Territorial Spatial Planning of Fujin City.

Based on the land use function and ecological characteristics of Fujin City, the city is divided into four ecological environment function zones: key urban construction function zone, primary agricultural production function zone, water wetland ecological function zone and forest ecological function protection zone (refer to Figure 5). Each zone implements different development and conservation strategies. In the key urban construction function zone, the key is environmental protection, soil and water conversation, and improvement of the living environment to minimize the impact of human activities on the ecological environment. In the primary agricultural production function zone, development and construction activities will be strictly controlled, which creates ecological, green and high-yield agricultural production areas. The water wetland ecological zone focuses on safeguarding the grassland ecosystem and ensuring the stability of the grassland wetland environment. The multi-functionalities of wetlands are used effectively to promote tourism development. In the forest ecological function protection zone, all construction and development activities are strictly prohibited to protect the original forest ecosystem and maintain surface vegetation diversity. Based on the ecological functional zoning, an ecological security pattern of "two mountains, one river, four rivers, and multiple points" is established. Various nature reserves are scientifically established, and different ecological protection mechanisms are put in place. This approach is adaptable to local conditions and maximizes the carbon capture and regulatory capacity of the ecosystem.

4.3.4. Optimization of the layout of the central urban area

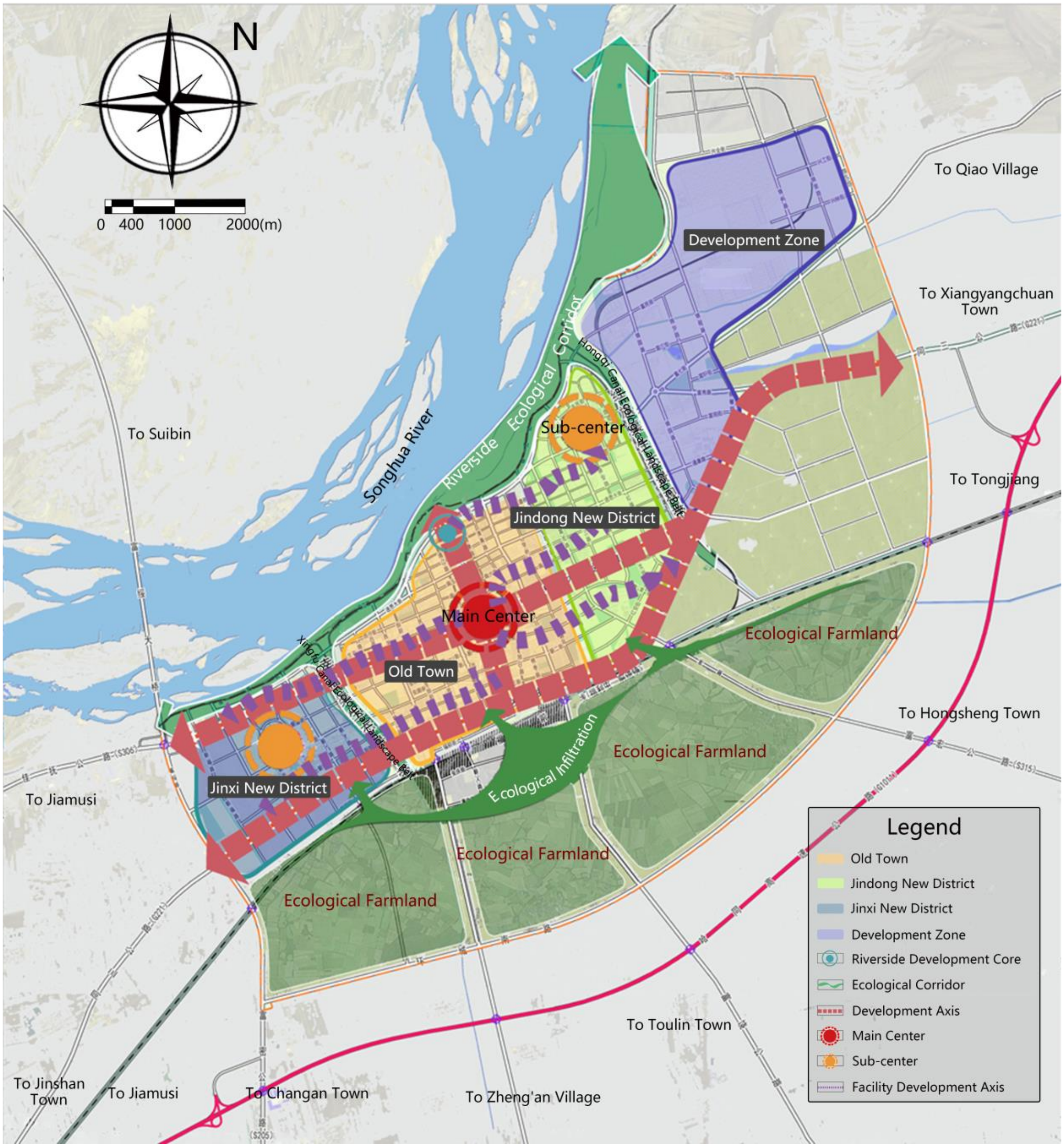

Figure 6. Spatial Structure Plan of Fujin City Centre. Source: The Comprehensive Territorial Spatial Planning of Fujin City.

In the central urban area of Fujin City, the overall urban pattern of "three zones, two cores, one corridor, and two axis belts" is being created (refer to Figure 6), with green spaces and facilities acting as barriers between different functional zones. The city's road system is the foundation for building a segregated urban slow system and a public transportation transfer system. Based on urban slow zones and pedestrian units, a continuous network of slow transportation systems is established, including the development axes for slow community, riverside scenic belt, and slow transportation corridors. By promoting and developing public transportation and slow modes of transportation, the urban transportation network is optimized, and the urban road system is improved. This reduces private car usage and the demand for energy resources such as petroleum, while improving energy utilization efficiency and reducing energy consumption.

5. Conclusion and Prospects

Achieving the "dual-carbon" goal is a necessary way for China's green development and is a systematic project involving various fields and elements. This paper discusses the response of comprehensive territorial spatial planning for resource-based cities to the "dual-carbon" goal. In the future, incorporating the "dual-carbon" goal as an evaluation factor into the evaluation system [22][23] will help guide decision-making, promote the green development and sustainable transformation of resource-based cities, comprehensively evaluate urban development to achieve sustainable development and carbon emission reduction goals.

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