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Development Strategy for Urban Agglomerations in Yangtze River Economic Belt Considering Environmental Carrying Capacity

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Abstract: The Yangtze River Economic Belt is a vital ecological security barrier and the focus of China's economic development. Promoting the construction of urban agglomerations in the Yangtze River Basin is crucial for accelerating the development of the Yangtze River Economic Belt. The five urban agglomerations in the Yangtze River Economic Belt were used as the research objects; their environmental carrying capacities and the coupling relationship between these capacities and urban agglomeration development were explored. Based on the results, we categorized these urban agglomerations into three types: (1) mature–environmental overload type constituting the urban agglomeration in the Yangtze River Delta, (2) high-speed development–environmental overload type, comprising the urban agglomerations in Chengdu–Chongqing and the middle reaches of the Yangtze River, and (3) cultivation–environmental non-overload type that comprised the urban agglomerations in central Guizhou and central Yunnan. Herein, we propose strategic suggestions for the development of urban agglomerations in the Yangtze River Economic Belt considering the aspects of ecological space control, optimization of spatial land patterns, green development of urban agglomerations, and improvement of the human settlement environment. These aim to strengthen the guiding role of environmental carrying capacity in developing urban agglomerations and provide basic support for promoting high-quality development of the Yangtze River Economic Belt.
Keywords: Environment carrying capacity; urban agglomeration development; coupling coordination; the Yangtze River Economic Belt

1 Introduction

Under the new normal of the Chinese economy, regional economies with an updated vision are rising as an important breakthrough point for China's rapid economic development [1]. The Yangtze River Economic Belt is an integral part of the strategic patterns of regional economies. It has been given a major opportunity to promote coordinated and sustainable regional and land resource development while overcoming the severe challenge of balancing environmental protection and efficient territorial spatial development [2]. Since the 21st century,

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industrialization and urbanization have been accelerating in the Yangtze River Economic Belt. This has resulted in the occupation and destruction of large amounts of ecological space and high-quality agricultural space, as well as pollutant discharge that is beyond the environmental carrying capacity. Environmental risks are intensifying and seriously threatening the coordination and sustainability of regional development [3]. Therefore, it is necessary to appropriately handle the relationship between environmental protection and economic development, and to explore new ways to promote green growth in harmony with ecological priorities. Urban agglomerations are required to play a major role in driving coordinated environmental and economic development in the Yangtze River Economic Belt. The scientific assessment of resource and environmental carrying capacity has become fundamental for central and local governments to formulate regional strategies and policies, as well as for development and layout planning [4]. In pursuing ecological civilization, studying development strategies for urban agglomerations in the Yangtze River Economic Belt based on environmental carrying capacity is vital for optimizing territorial spatial development patterns, improving the environmental governance system, and promoting regional sustainable development.

In China, research on territorial spatial planning systems based on resource and environmental carrying capacity is at an early stage. Some have gradually explored the reasonable guidance of resource and environmental carrying capacity in urban populations and industrial layouts [5–9] and proposed urban spatial management and access measures that consider regional spatial heterogeneity of carrying capacity. However, research in this area remains limited. Most studies focused on carrying capacity evaluation of single factors, such as atmosphere, water, ecology, water resources, and land resources, and did not fully explore the coupling relationship between carrying capacity and urban development. With respect to the integration of resource and environmental carrying capacity into urban management, the exploration of pathways to transforming theoretical methods into practical applications is still underway. Therefore, the evaluation results for resource and environmental carrying capacity are unlikely to impose rigid constraints on economic and social development.

This study was conducted with the aim of harmonizing environmental protection and socio-environmental development for promoting well-coordinated environmental protection and avoiding excessive development under the Yangtze River Economic Belt strategy. The spatial layout and environmental carrying capacity of five urban agglomerations (Yangtze River Delta, middle Yangtze, Chengdu–Chongqing, central Yunnan, and central Guizhou) were examined, and a four-quadrant approach was used to analyze the coupling relationship between urban agglomeration development and environmental carrying capacity. Strategic suggestions that reflect the environmental carrying capacity and ecological spatial management are proposed, providing basic support for accelerating strategy implementation and promoting high-quality development of the Yangtze River Economic Belt.

2 Overview of urban agglomerations in the Yangtze River Economic Belt

2.1 Economic development

The Yangtze River Economic Belt is a core area of population and economic concentration in China. It occupies nearly 20% of the country’s land area and accounts for over 40% of China’s population and economic aggregates. Under the 19+2 city cluster pattern outlined in the 13th Five-Year Plan, five urban agglomerations are distributed in the Yangtze River Economic Belt; these are: Yangtze River Delta, middle Yangtze, Chengdu–Chongqing, central Yunnan, and central Guizhou. Together, they account for 40.8% of the gross domestic product (GDP) and 38.4% of the resident population of national urban agglomerations. These city clusters represent 51% of the land area, 84% of the GDP, and 73% of the resident population of the Yangtze River Economic Belt. Over 80% of the prefecture-level cities in the Yangtze River Economic Belt have a resident population of more than 2 million. In particular, resident populations are large in the Yangtze River Delta, middle Yangtze, and Chengdu–Chongqing urban agglomerations, compared to those in the central Guizhou and central Yunnan urban agglomerations. The Yangtze River Delta urban agglomeration is far more economically advanced, followed by the middle Yangtze and Chengdu-Chongqing urban agglomerations. There is still considerable scope for improvement in the economic development of central Yunnan and central Guizhou urban agglomerations. Economic and population data come from the 2018 Statistical Yearbook of provinces in the Yangtze River Economic Belt.

2.2 Integrated development

The level of integration within urban agglomerations is evaluated by internal connectivity in the population, economic, and transportation dimensions. Specifically, population connectivity can be observed from the population migration intensity, economic connectivity is embodied in total mutual capital investment of enterprises in the whole

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industry, and transportation connectivity is reflected in the number of passenger trains between cities. The data sources include Tencent migration big data, Long Credit big data of industrial and commercial enterprises, and Trip.com railway frequency data.

The level of integration varies widely among the urban agglomerations in the Yangtze River Economic Belt. Cities in eastern clusters have close ties with frequent exchanges of production elements, whereas cities in western clusters are less connected because of evident barriers and obstacles to regional coordination. Population flows are frequent within the Yangtze River Delta and Chengdu–Chongqing urban agglomerations, resulting in the highest population connectivity, followed by the middle Yangtze urban agglomeration. Central Yunnan and central Guizhou urban agglomerations have the lowest levels of internal population flow. Economic connectivity is strongest in terms of scale and intensity in the Yangtze River Delta urban agglomeration and weakest in the central Guizhou urban agglomeration; the other three agglomerations lie in-between. Regarding transportation connectivity, the Yangtze River Delta and middle Yangtze urban agglomerations have fostered a grid-like spatial pattern that dwarfs the connectivity of the other three agglomerations.

2.3 Territorial spatial development pattern

Data on impervious surface change from 1978 to 2017 and GlobalLand30 integrated data on surface cover in 2010, 2015, and 2017 were used to analyze the changes in urban space and ecological space in the Yangtze River Economic Belt.

Research shows that since China's reform and opening up in 1978, construction land growth in the Yangtze River Economic Belt has been driven mainly by downstream urban agglomerations. Such growth is most evident in the Yangtze River Delta urban agglomeration, followed by that in the middle Yangtze urban agglomeration, and is relatively small in Chengdu–Chongqing, central Yunnan, and central Guizhou urban agglomerations. Specifically, the construction land area has rapidly expanded in the Yangtze Delta urban agglomeration. Newly added construction land is widely distributed and has spread from the periphery of the metropolis to the interlocking region, mainly concentrated in the connection channels between the cities. The urban dense areas around Shanghai have been basically converted into construction land. In the middle Yangtze urban agglomeration, the area of construction land has grown rapidly since 2009, and has fluctuated significantly since 2012. The addition of construction land is concentrated around three central cities in the region: Wuhan, Changsha, and Nanchang. As for the Chengdu–Chongqing urban agglomeration, construction land has been added mainly in Chengdu and Chongqing, which are core cities and are still developing their respective metropolitan areas. In the central Guizhou urban agglomeration, the expansion of construction land was slow but increased during 2009–2011, and has fluctuated at a high level since then. Land for construction is relatively scattered, with small concentrated and contiguous patches that are typically narrow and long. In the central Yunnan urban agglomeration, construction land has been added to Kunming, the area around Dianchi Lake, and extends to Yuxi and Qujing along the transportation corridor.

3 Evaluation of environmental carrying capacity

Environmental carrying capacity characterizes the capability of the regional environmental system to carry various pollutants generated by social and economic activities and become self-purified. The pollutant excess index measures it as the gap between monitored annual average concentrations and limits as specified in the national standards for major air and water pollutants [10]. The extreme value method is employed to classify the environmental carrying capacity into non-overload, critical overload, or overload state. In our study, the 2016 air and water quality monitoring data from the environmental monitoring centers of the provinces (cities) in the Yangtze River Economic Belt were used to assess the environmental carrying capacity.

3.1 Atmospheric environmental carrying capacity

Atmospheric environmental carrying capacity was measured using the excess index of six air pollutants: fine particulate matter ($PM_{2.5}$), inhalable particulate matter (PM_{10}), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2), carbon monoxide (CO), and ozone (O_3). The formulae for calculating the excess index of various air pollutants in different regions are as follows:

$$R_{\text{气}ij} = C_{ij}/S_i - 1 \tag{1}$$

$$R_{\text{气}j} = \max_i(R_{\text{气}ij}) \tag{2}$$

Here, C_{ij} is the monitored annual average concentration of air pollutant i in area j, and S_i is the secondary limit for this pollutant. $R_{气ij}$ is the excess index of air pollutant i in area j; i=1, 2, …, 6, correspond to the six air pollutants, respectively. $R_{气j}$ is the air pollutant excess index of area j, taken as the maximum value of the excess index of each pollutant. $R_{气j} > 0$, $-0.2 < R_{气j} \leq 0$, and $R_{气j} \leq -0.2$ suggests that the atmospheric environment is in overload, critical overload, and non-overload states, respectively.

The results showed that the atmospheric environment was overloaded in 761 of the 1069 districts and counties in the Yangtze River Economic Belt, critically overloaded in 136 districts and counties, and non-overloaded in 172 districts and counties, representing 71.2%, 12.7%, and 16.1% of the total, respectively. Overload was most evident in Xinyi City (Xuzhou City, Jiangsu Province), Ziliujing District, Gongjing District, Daan District, Yantan District, Rongxian County, and Fushun County (Zigong City, Sichuan Province), and Qianjiang City and Tianmen City (Hubei Province), where the air pollutant excess index was larger than 1. Serious overload was also found in the districts and counties of Jiangsu Province, eastern Sichuan Province, and Hubei Province. The atmospheric environment was found to be good in Shangri-La City, Deqin County, and Weixi Lisu Autonomous County in Diqing Tibetan Autonomous Prefecture, Yunnan Province, with an air pollutant excess index of approximately −0.5. Atmospheric environmental carrying capacity was not exceeded in the mountainous areas of Yunnan Province, Sichuan Province, and Guizhou Province, and most of the districts and counties in Huangshan City, Anhui Province.

3.2 Water environmental carrying capacity

The water environmental carrying capacity was measured using the excess index of six water pollutants: chemical oxygen demand (COD_{Cr}), ammonia nitrogen (NH_3-N), total nitrogen (TN), total phosphorus (TP), permanganate index (COD_{Mn}), and five-day biochemical oxygen demand (BOD_5). The formulae for calculating the excess index of various water pollutants in different regions are as follows [11]:

$$R_{水ijk} = C_{ijk} / S_{ik} - 1 \tag{3}$$

$$R_{水ij} = \sum_{k=1}^{N_j} R_{ijk} \Big/ N_j, i = 1, 2, \cdots, 6 \tag{4}$$

Here, C_{ijk} is the monitored annual average concentration of water pollutant i in section k of area j, and S_{ik} is the target value for water quality specific to water pollutant i in section k. $R_{水ijk}$ is the excess index of water pollutant i in section k of area j; $R_{水ij}$ is the excess index of water pollutant i in area j; i=1, 2, …, 6, correspond to the six water pollutants, respectively. k is the controlled section, $k = 1, 2, \ldots, N_j$, where N_j is the number of controlled sections in area j. The formula for calculating the water pollutant excess index of different regions is as follows:

$$R_{水jk} = \max_i \left(R_{水ijk} \right) \tag{5}$$

$$R_{水j} = \sum_{k=1}^{N_j} R_{水jk} \Big/ N_j \tag{6}$$

Here, $R_{水jk}$ is the water pollutant excess index in section k of area j; $R_{水j}$ is the water pollutant excess index of area j. $R_{水j} \leq -0.3$ suggests that the water environment is not overloaded, $-0.3 < R_{水j} \leq 0$ suggests that the water environment is in a critical overload state, and $R_{水j} > 0$ suggests that the water environment is overloaded.

The results show that the water environment of the Yangtze River Economic Belt is, overall, in a state of critical overload. More specifically, the water environment was found to be overloaded in Jiangsu, Zhejiang, and Shanghai, where the water pollutant excess index reached 0.23, 0.06, and 0.10, respectively. The water environments of other provinces and cities were relatively good and in a state of non-overload or critical overload. Of the 126 prefecture-level cities/prefectures, the water environment of 44 (35.0%) was found to be overloaded, that of 41 (32.5%) to be critically overloaded, and that of the remaining 41 (32.5%) to be non-overloaded. Among the 892 districts and counties covered, 210 (23.5%) exceeded their water environmental carrying capacity, 273 (30.6%) approached the water environmental carrying capacity, and 409 (45.9%) did not exceed the water environmental carrying capacity.

3.3 Comprehensive environmental carrying capacity

The comprehensive pollutant excess index was calculated using the maximum value method, as follows:

$$R_j = \max\left(R_{气j}, R_{水j} \right) \tag{7}$$

Here, R_j is the comprehensive pollutant excess index of area j.

When either the atmospheric environment or water environment is overloaded, the comprehensive result is overload; when one of the atmospheric and water environments is critically overloaded, and the other is non-

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overloaded or critically overloaded, the comprehensive result is critical overload; when neither of the atmospheric and water environments is overloaded, the comprehensive result is non-overload.

The results showed that in 2016, the Yangtze River Economic Belt exceeded the overall environmental carrying capacity, with a comprehensive pollutant excess index of approximately 0.28. Of the 1069 districts and counties, 799 (74.7%) were in a state of overload, 153 (14.3%) were in a state of critical overload, and 117 (11.0%) were not overloaded. The most serious overload, with a comprehensive pollutant excess index above 1, was observed for Anhui, Jiangsu, Hubei, Shanghai, and Chongqing. Moderate overload with a comprehensive pollutant excess index between 0.5 and 1 could be observed for some districts and counties of Anhui, Hubei, Sichuan, Jiangsu, and Chongqing. The non-overloaded districts and counties were mainly distributed in Yunnan and Guizhou and a few cities in Hubei, Hunan, Sichuan, and Zhejiang.

4 Evaluation of the coupling relationship between urban agglomeration development and environmental carrying capacity

The four-quadrant approach was used to analyze the coupling relationship between economic development and the environmental carrying capacity of cities in the Yangtze River Economic Belt. The dimension of economic development was measured by the per capita GDP of prefecture-level cities in 2016. A per capita GDP higher (lower) than the average of the Yangtze River Economic Belt indicates high (low) economic quality. The dimensions of environmental carrying capacity were examined using the comprehensive pollutant excess index. A negative index indicates overload, whereas a positive index indicates no overload. Four quadrants were formed in two dimensions; as such, the cities in the Yangtze River Economic Belt were divided into four types: low economic quality–environmental non-overload, high economic quality–environmental overload, high economic quality–environmental non-overload, and low economic quality–environmental overload. If key ecological functional zones are considered, there are five types.

The characteristics and distribution of various cities by type are described as follows: (1) Cities with high economic quality and environmental overload were found to be mainly distributed in the lower reaches of the Yangtze River and the core of urban agglomerations in the middle and upper reaches; examples include Shanghai, Hangzhou, Wuhan, Changsha, Chongqing, and Chengdu. The rapid economic development of these cities has caused serious damage to the ecological environment owing to high resource consumption and severe environmental pollution. (2) Cities with low economic quality and environmental overload were mainly found in the middle reaches of the Yangtze River and in the periphery of the metropolitan areas; examples include Huanggang, Jiujiang, Yiyang and Zunyi. Most of these cities have strong momentum and potential for urbanization. However, the extensive model of development has led to serious occupation of ecological spaces and rural areas, making environmental protection extremely challenging. (3) Cities with low economic quality and environmental non-overload were mainly distributed in the upper reaches of the Yangtze River, represented by Bijie, Chuxiong, and Lijiang. Such cities enjoy a favorable ecological environment, with little damage from social and economic development. (4) Cities with high economic quality and environmental non-overload, such as Yuxi and Panzhihua, were found to be located in the upper reaches of the Yangtze River. For these resource-based cities, development depends highly on resources and deteriorates the environment to some degree; however, environmental overload has not yet occurred owing to superior natural endowments. (5) Cities with key ecological functional areas were mainly distributed in the upper reaches of the Yangtze River; examples include Zhangjiajie City, Qiannan Prefecture, and Liangshan Prefecture, as well as districts and counties in the cities of Chongqing, Lijiang, and Dali.

Through a coupling analysis, the five urban agglomerations in the Yangtze River Economic Belt were categorized. First, the economic development, environmental quality, and internal connectivity were evaluated. Indicators included GDP, resident population, density, per capita green space, population connectivity, and 2-hour transportation accessibility in central cities. Urban agglomerations can thus be categorized into three types: mature (Yangtze River Delta urban agglomerations), fast-growing (middle Yangtze and Chengdu–Chongqing urban agglomerations), and incubating (central Yunnan and central Guizhou urban agglomerations). Second, the environmental carrying capacity was evaluated. An urban agglomeration is believed to experience environmental overload if the environmental carrying capacity of more than half the cities is exceeded; by contrast, if more than half of the cities do not exceed their environmental carrying capacity, the agglomeration does not experience environmental overload. By coupling the results of the above two aspects, urban agglomerations can be further categorized into three categories: incubating–environmental non-overloaded, fast-growing–environmental overloaded, and mature–environmental overloaded.

4.1 Incubating–environmental non-overloaded urban agglomeration

The central Guizhou and Yunnan urban agglomerations fall into the incubating–environmental non-overloaded category. They face relatively low environmental pressure, with environmental overload being observed only in central cities and development corridors.

Such urban agglomerations should place emphasis on environmental protection by firmly restricting large-scale urbanization in ecologically vulnerable areas and allowing appropriate environmentally friendly development on the premise of ensuring geological and ecological safety in relatively flat areas with strong environmental carrying capacity. Developing ecologically livable urban agglomerations to create a new growth pole with a certain driving force for development in Western China is a strategic move to ensure sustainability between environment and development. Future work will focus on developing central cities and cultivating metropolitan areas, with these central cities as the core. As such, central cities are expected to better drive the development of surrounding cities through the interconnection of transportation facilities and industrial division of labor.

4.2 Fast-growing–environmental overloaded urban agglomeration

The Chengdu–Chongqing and middle Yangtze urban agglomerations fall into the fast-growing–environmental overloaded category. They, as a whole, experience overloading of the ecological environment. The quality of economic development is relatively high in central cities and metropolitan areas but low in peripheral areas.

Such urban agglomerations should adjust the economic structure by actively developing emerging industries with little disturbance to the environment, stimulating scientific and technological innovation, and strengthening integration within metropolitan areas and the role of peripheral areas.

For the Chengdu–Chongqing urban agglomeration, the central cities are relatively developed, while other areas have low economic quality. Focus should be on building a high-quality growth pole in the west and a strategic highland for an inland opening while considering ecological protection. Chengdu and Chongqing, as dual centers, should improve comprehensive service and radiation capabilities and strengthen collaboration, exchange, and functional complementarity. It is also necessary to cultivate secondary node cities and development axes and promote the integrated development of transportation, ecology, and services within the region. As for the middle Yangtze urban agglomeration, metropolitan areas with closely connected central cities as the core have taken shape, such as the Changsha–Zhuzhou–Xiangtan metropolitan region; however, economic quality outside the metropolitan areas is relatively low. Many lakes in the region perform an important ecological function of flood regulation; hence, environmental protection of lakes (such as Dongting Lake and Poyang Lake) should be a focus area in the future. It is also advisable to build core growth poles and comprehensive transportation hubs that drive the rise of Central China. Central cities, such as Wuhan, Changsha, and Nanchang, should strengthen cooperation, exchange, and functional complementarity to develop metropolitan areas capable of serving as regional centers at higher levels.

4.3 Mature–environmental overloaded urban agglomeration

The Yangtze River Delta urban agglomeration falls into the mature–environmental overload category. It remains at the forefront of the country in terms of comprehensive strength and integrated development. In addition to the geographical advantage of the intersection of the Yangtze and the sea, the vast plain area and high ecological carrying capacity make it suitable for considerable economic development. However, the relatively extensive model of resource and environmental utilization in the rapid urbanization process has caused environmental problems in recent years. Environmental overload is common in this cluster of cities, and economic quality is high, except for some cities in the western regions such as Anqing, Chizhou, and Xuancheng.

Future development in the Yangtze River Delta urban agglomeration should aim to improve the development quality and reduce environmental pressure. The developed areas along the eastern coast should define the bottom line of urban development based on environmental carrying capacity and strengthen the revitalization and utilization of stock construction land while highlighting efficiency. To foster a world-class urban agglomeration with global influence, Shanghai as an international metropolis is expected to play a central role in further strengthening the coordinated and integrated development with surrounding areas and drive the rise of the Yangtze River Economic Belt. Attention should be paid to the economic and intensive use of land and other resources by promoting multifunctional mixed layouts and mixed-use. Cities with low-quality economic development in the west should undertake spillover industries from other cities and develop the economy without undermining the environment.

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5 Development strategy for urban agglomerations in the Yangtze River Economic Belt under the constraint of environmental carrying capacity

Among the five major urban agglomerations in the Yangtze River Economic Belt, the Yangtze River Delta urban agglomeration is the most developed but plagued by environmental overload. The Chengdu–Chongqing and middle Yangtze urban agglomerations are in a stage of rapid development and also experience environmental overload to a certain extent. The central Guizhou and Yunnan urban agglomerations are still in the cultivation stage and perform well in terms of ecological background and protection. In the future, efforts should be directed toward further optimizing the development patterns of urban agglomerations, practicing the philosophy of green ecological development, and improving the living environment.

5.1 Establishing an ecological security management pattern in the Yangtze River Economic Belt and implementing classified management of ecological spaces such as ecological protection red lines and key ecological functional areas

The strictest ecological protection measures should be applied to areas within the red lines for ecological protection. In principle, industrialization and urbanization activities should be prohibited to maintain the natural background status of environmental quality. Regional integrity of ecosystems in terms of both structure and function should be restored and safeguarded to support environmental quality, biodiversity maintenance, and natural reproduction of rare species, so as to ensure sustainable living and development space in the future. For other key ecological functional areas that are not covered by ecological protection red lines, such as functional areas for water source conservation, soil and water conservation, biodiversity maintenance, and rocky desertification control, requirements for restricted development zones should be observed. With priority given to protection, it is possible to rationally choose development directions, develop characteristic and advantageous industries, and strengthen ecological protection, restoration, and environmental supervision to protect and restore regional ecological functions [12].

5.2 Optimizing the spatial pattern of urban agglomerations through classified guidance and creating an urbanization pattern of two metropolis and three clusters by stages

Setting the sight on world-class city clusters in the Yangtze River Delta and Chengdu–Chongqing region, efforts should be made to develop Shanghai, Chengdu, and Chongqing into world-class cities, improve the comprehensive carrying capacity of secondary central cities such as Hangzhou, Nanjing, and Suzhou, strengthen regional development axes, and facilitate the two-way flow of elements between central cities and the surrounding areas to form a networked development pattern. With a view to building a national-level city cluster in the middle reaches of the Yangtze River, efforts should be focused on the development of the three major metropolitan areas of Wuhan, Changsha, and Nanchang in the near future, and the construction of regional development corridors in the long term, while developing and deploying emerging functional growth poles and smoothing the flow of factors between regions. In the western region, two major metropolitan areas should be built, wherein Kunming and Guiyang, as centers, should improve their driving capabilities and build an intra-city transportation system, with peripheral areas mainly providing ecological services and agricultural products.

5.3 Boosting green development and promoting joint construction, protection and governance of urban agglomerations

It is advisable to jointly create green ecological spaces on a large scale and foster an ecological green network system for urban agglomerations. For example, ecological green centers can be built around the Taihu Lake in the Yangtze River Delta; Dongting Lake, Poyang Lake, and Changsha–Zhuzhou–Xiangtan Green Center in the middle Yangtze urban agglomeration; Dianchi Lake in the central Yunnan urban agglomeration; and Longquan Mountain in the Chengdu–Chongqing urban agglomeration. It is necessary to coordinate water conservation facilities, such as the Three Gorges Dam, Gezhouba Dam, and Ertan Dan, and establish a graded zoning protection system for drinking water sources in the upper, middle, and lower reaches. Further work is needed for the coordinated management of the water environment of the Yangtze mainstream and tributaries, joint prevention and control of air pollution, and coordinated prevention and control of soil pollution. It is also important to explore pathways for ecological value transformation in multiple forms and improve the systems and mechanisms for green development. While encouraging innovative market-oriented business models for trading environmental resource rights, efforts should be made to develop carbon trading and green financial systems, facilitate the application of the results of the environmental credit evaluation system, and improve the cross-regional ecological compensation mechanisms.

5.4 Stepping up green infrastructure construction and improving the living environment

It is important to ensure centralized and decentralized treatment of sewage, coordination of sewer network and treatment facilities, and differentiated effluent standards. Under this integrated model, eco-friendly sludge treatment and disposal model should be developed with the aim of resource recovery and energy utilization. A diversified energy supply model that harmonizes various heating methods should be established, with large-scale centralized heating as the mainstay and distributed heating as a supplement. Development of streamlined ecological parks that combine effective sorting and transportation of waste with comprehensive treatment is also encouraged. It is wise to advance the construction of building information modeling platforms and comprehensive pipeline corridors and promote the intelligent operation and management model for power grids, to contribute toward the optimal configuration of various energy sources.

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