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Coordination Analysis of Urban Forest and Urban Development Level: A Case Study of the Yangtze River Delta Urban Agglomeration, China

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Abstract: With the rapid development of the Yangtze River Delta urban agglomeration, sustainability and high-quality development have become the key paths to regional development. The urban forest, referring to the sum of trees, forests, and green space in an urban area, provides a series of ecological benefits and economic values and is essential to the urban ecological system. In the post-urbanization period, the integrated development of urban forests and the city is attached with great importance to long-term development. From the perspective of regional and coordinated development, this research constructed an evaluation index system of urban development and urban forest development. Then, a comprehensive evaluation model and coordination degree model were adopted to systematically study the temporal and spatial characteristics and policy influencing factors on the coordination degree between urban development and urban forest development in the Yangtze River Delta urban agglomeration from 2005 to 2021. The results showed that from 2005 to 2021, urban development displayed continuous growth, while urban forest development exhibited a fluctuating increase and the level of urban forest generally lagged behind that of urban development. From 2005 to 2021, the coordination degree of the Yangtze River Delta urban agglomeration showed a fluctuating trend, of which the maximum value was 0.999 in 2012, the minimum value was 0.730 in 2021, and the coordination degrees were all at the level of good coordination or high-quality coordination except for 2021. In terms of spatial distribution, three provinces and one city all showed a fluctuating increase at first, followed by a downward trend, while Shanghai showed the highest coordination level. From the perspective of policy on urban forests, the Shanghai government showed the best effort, while the Jiangsu government still needs improvement. This research provides a scientific basis for coordinating the relationship between urban development and the environment and for realizing regional sustainable and high-quality development.

Keywords: urban forest; coordination analysis; Yangtze River Delta urban agglomeration

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1. Introduction

A city is a large and highly complex system composed of many subsystems, such as society, economy, ecological environment, and population [1]. The balanced development of each component of a city is related to the sustainability of the city system [2]. As an inevitable process of social and economic development, urbanization presents different characteristics in different stages wherein the speed goes from slow to fast and then gradually falls to stability [3]. After 45 years of tortuous development since the reform and opening up, China's urbanization rate reached 65.22% by the end of 2022, including a period of rapid growth in the past decade. Although China's urbanization level has exceeded the world average, the challenge of balancing urban environmental protection and urban development is becoming increasingly severe. The 14th Five-Year Plan of China, released in 2021, attaches great importance to sustainable urban development and the coordinated development of urban agglomerations, which is the most important strategic document for China's development in the next 5 to 15 years. Therefore, a sustainable, healthy, and coordinated urban development mode is of great importance in the critical transition period of China's urbanization process.

Urban forests, as the main body of the urban ecological environment, provide a series of ecological benefits [4–11], such as improving urban air quality, alleviating the urban heat island effect, purifying urban water quality, and enhancing urban biodiversity, as well as adding social and economic values [12–17], such as providing recreation places, promoting tourism development, reducing energy consumption, and providing employment opportunities. The concept of the urban forest originated in North America in the 1960s, and it can be defined as the sum of the trees and vegetation in the urban geographic area, including forests and green space as the main body, its surrounding environment, and related infrastructure [18–31]. After the concept of urban forests was introduced in China in the 1980s, research institutions on urban forests were gradually established in the following 10 years, and the construction of urban forests became increasingly important in the policy-making process in China. The campaign of "National Forest City" was launched in 2004 by the National Forestry and Grassland Administration of China, becoming a prominent mechanism for the construction of urban forests, and lead to 219 cities being designated as a "National Forest City" by the end of 2022. China's area of urban green space increased from 1321.9 thousand hectares in 2004 to 3479.8 thousand hectares in 2021, and the urban greening coverage rate increased from 31.15% to 42.4%. China has achieved great progress from the perspective of the key indicators of urban forests, but the sustainability and quality of urban forest construction remain a challenge.

The core of urban ecology is to regulate the city and coordinate the contradiction between socioeconomic development and the urban environment from the perspective of the system to promote the sustainable development of the city and the harmony between humans and nature [32–34]. Synergetics points out that in a complex and open system, the regulation and optimization of the system refer to the interaction and cooperation between subsystems to achieve coordination, order, and balance [35]. Many scholars have explored the coupling coordination mechanism between urbanization and the ecological environment [36–38]. The scope of the studies has also expanded from a single city [39–41] to urban agglomerations or larger regions [42–47], and the studies have extended to a more focused field, such as urban resilience, urban ecological security, and urban forests [48–50]. Many empirical analyses have linked urban socioeconomic development with the ecological environment and have explored the coordinated relationship between them, thus proposing an optimized, sustainable, and balanced urban development path for future construction.

China proposed building national forest urban agglomerations in 2016, emphasizing regional urban forest planning and construction by breaking the boundaries of administrative areas instead of focusing on data growth. As the main body of the urban ecosystem, urban forests provide a series of ecological benefits and social and economic values for the city, but the excessive pursuit of urban forest construction also hinders the overall development of the city. It is critical to the sustainability of the city to coordinate and balance the development of urban forests and socioeconomic progress. Under the scale of urban agglomerations, the construction of urban forests can carry out overall and systematic planning according to the characteristics and economic development status of different cities to achieve regional optimization.

The Yangtze River Delta urban agglomeration is one of the most economically developed regions in China, with a much higher degree of urbanization and population density than the average, and it is also one of the earliest areas to initiate the construction of urban forests. This research focuses on urban forests, and the "urban system" hereinafter referred to is the integrated urban system other than the urban forest system; that is, the urban forest system and urban system together constitute the whole integrated urban system. A comprehensive evaluation index system is established for the two systems. The urban system includes three parts: economic development, societal development, and nature and the environment. The urban forest system includes two parts: forest scale and forest management and conservation. Then, the principal component analysis method is applied to calculate the urban development index and the urban forest development index of the Yangtze River Delta urban agglomeration and the four provincial administrative regions included in the urban agglomeration. Finally, the coordination degree model is applied to calculate the change trend of the coordination degree. We then analyze the spatiotemporal characteristics and the policy influencing factors based on the research results and propose policy recommendations to optimize the path of sustainable urban development.

2. Research Area, Data Sources, and Research Methods

2.1. Overview of the Research Area

In accordance with the outline of the integrated regional development of the Yangtze River Delta urban agglomeration released in 2019, the research area of this study covers all areas of three provinces (Jiangsu, Zhejiang, and Anhui) and one city (Shanghai) in the Yangtze River Delta urban agglomeration (Figure 1).

Figure 1. Location map of the Yangtze River Delta urban agglomeration.

The land area of the Yangtze River Delta urban agglomeration is 358,000 km^2, accounting for approximately 3.7% of the total land area, nearly 20% of the GDP, and 17% of the permanent resident population of China. It is one of the most important engines leading China's economic and social development. Here, the urbanization rate has been approximately 10% higher than the national average, and the per capita GDP has been approximately 1.4 times higher than the national level (Figure 2).

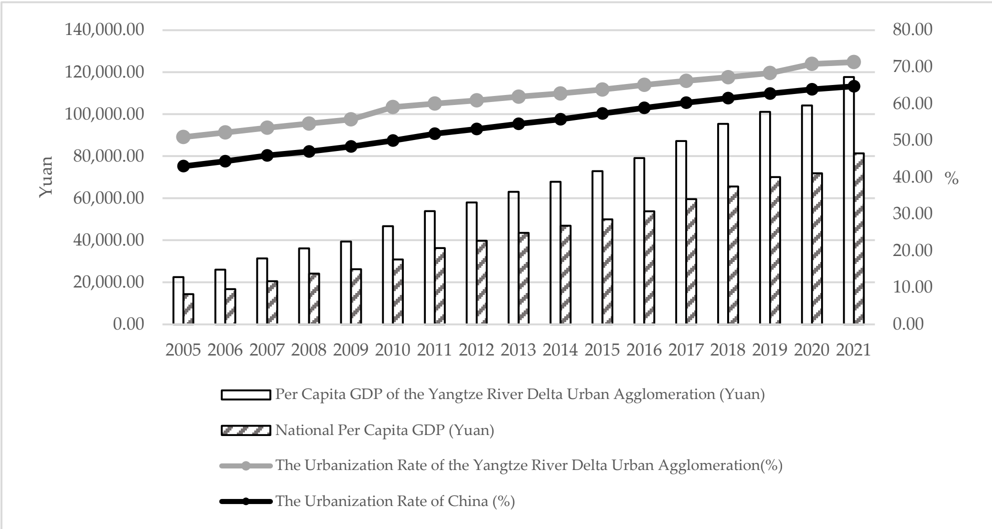

Figure 2. Per capita GDP and urbanization rate of China and the Yangtze River Delta urban agglomeration from 2005 to 2021.

The Yangtze River Delta urban agglomeration is the earliest demonstration and leading region in China to promote regional integration and urban agglomeration development, which took shape as early as the 1980s, as well as the planning and construction of urban forests. By 2022, 39 cities in the Yangtze River Delta urban agglomeration will be entitled a "National Forest City", accounting for nearly 20% of the total amount in China. As a leading area of economic and social development and urban forest construction, it is of great significance to explore the spatiotemporal evolution characteristics and influencing factors of the coordinated relationship between urban development and urban forest development of the Yangtze River Delta urban agglomeration.

2.2. Data Sources

This research includes the dates of urban development and urban forest development of three provinces and one city in the Yangtze River Delta urban agglomeration from 2005 to 2021. The statistical data of China before 2005 have not been collected, and the data indicators of urban forests in 2022 are still not public, so the time range of this research is from 2005 to 2021. All data and indicators were derived from the China Statistical Yearbook of Cities, the China Statistical Yearbook of Forestry and Grassland, the Ecological Environment Bulletin, and the statistical yearbooks and statistical bulletins of provinces and cities in the Yangtze River Delta urban agglomeration. Individual outliers and missing data were represented by using a regression fitting function according to the type of data missing.

2.3. Research Methods

In this research, a comprehensive evaluation index system was established for urban systems and urban forest systems. Then, the principal component analysis method was applied to calculate the urban development index and the urban forest development index of the Yangtze River Delta urban agglomeration and four provincial administrative regions included in the urban agglomeration. Finally, the coordination degree model was applied to calculate the coordination degree between the two systems, and the uniform distribution function method was used to determine the classification standard of the coordination degree.

2.3.1. Construction of the Evaluation Index System

Referring to the existing research [51–55] and integrating the main indicators of economic and social development in the period from China's 11th Five-Year Plan to China's

14th Five-Year Plan, which are the most critical policy guidance documents in China, the urban development indicators are divided into three aspects: economic development, social development, and nature and environment. Seventeen indicators are selected, with the principles of science, objectivity, and accessibility, to represent the urban development of the Yangtze River Delta urban agglomeration. The economic development part includes six indicators to reflect the level of urban economic development: per capita GDP, proportion of value added of tertiary industry, urban registered unemployment rate, annual per capita disposable income of urban residents, total retail sales of consumer goods, and total labor productivity. The social development part includes six indicators to reflect the basic construction, science and technology, education, and health of the city: urban population density, per capita urban road area, gas coverage, research and development expenditure, ratio of government spending on education to GDP, and number of medical and health institutions (excluding village clinics). In the nature and environment part, a typical indicator is selected from the five aspects of exhaust gas emission, air quality, urban sewage, urban solid waste, and energy consumption to reflect the quality of the urban environment, the treatment capacity, and the energy utilization efficiency of the city.

The selection of urban forest development indicators mainly refers to the main indicators in China's five-year forestry development planning as well as the evaluation index system issued by the National Forestry and Grassland Administration of China for the assessment of a "National Forest City". A total of six indicators are selected from two aspects: forest scale and forest management and conservation. The forest coverage rate, urban greening coverage rate, area of urban green space, and per capita park green area reflect the number of urban forest resources and the state of construction; the regional forestry and grassland investment and area of artificial afforestation reflect the level of government input in the field of urban forest. The specific indicators are shown in Table 1.

Table 1. Evaluation index system of urban development and urban forest development.

Target Layer	Criterion Layer	Index Level	Unit	Data Resource
Urban System Evaluation Index	Economic Development	Per Capita GDP	Yuan	China Statistical Yearbook of Cities
		Proportion of Value Added of Tertiary Industry	%	
		Urban Registered Unemployment Rate	%	
		Annual Per Capita Disposable Income of Urban Residents	Yuan	
		Total Retail Sales of Consumer Goods	Billion Yuan	
		Total Labor Productivity	10 thousand Yuan/Person	
	Society Development	Urban Population Density	Person/km^2	
		Per Capita Urban Road Area	m^2	
		Gas Coverage	%	
		Research and Development Expenditure	100 million Yuan	
		Ratio of Government Spending on Education to GDP	%	
		Number of Medical and Health Institutions (Excluding Village Clinics)	pcs	
	Nature and Environment	Sulfur Dioxide Emissions Per Unit of Gross Industrial Output Value	t/100 million Yuan	China Ecological Environment Bulletin
		Average Annual Concentration of PM10	μg/m^3	
		Daily Treatment Capacity of Urban Sewage	10 thousand m^2	
		Annual Harmless Treatment Capacity of Urban Domestic Waste	10 thousand t	
		Energy Consumption Per 10,000-yuan GDP	Ton Standard Coal	

Table 1. *Cont.*

Target Layer	Criterion Layer	Index Level	Unit	Data Resource
Urban Forest System Evaluation Index	Forest Scale	Forest Coverage Rate	%	China Statistical Yearbook of Forestry and Grassland
		Urban Greening Coverage Rate	%	
		Area of Urban Green Space	10 thousand hm^2	
		Per Capita Green Park Area	m^2	
	Forest Management and Conservation	Regional Forestry and Grassland Investment	10 thousand Yuan	
		Area of Artificial Afforestation	Thousand hm^2	

2.3.2. Comprehensive Evaluation Model

In this paper, a comprehensive evaluation model is used to calculate the level of urban development and urban forest development in the Yangtze River Delta urban agglomeration. First, all indicators are standardized, considering the different dimensions and sizes of the selected indicators. The specific formula is as follows:

$$z_{ij} = \frac{x_{ij} - x_j}{S_j} \tag{1}$$

where x_{ij} is the value of the j indicator in year i, z_{ij} is the value after standardization of x_{ij}, x_j represents the average of the j indicator in a total of i years, and S_j is the standard deviation of the j indicator.

Second, in the index system of urban and urban forests, there may be correlations among various indicators. Since the traditional subjective valuation method assigns weights to each indicator based on the subjective judgment of the rater, thus causing certain instability and interference factors, SPSS 25 software is used to adopt the principal component analysis method on standardized data, and the effective information of the original variables is then extracted. Through orthogonal transformation, based on the dimensionality reduction in data, a group of possibly correlated variables is transformed into a group of new, unrelated comprehensive variables, the original information is retained and reflected as much as possible, and the corresponding weights are obtained to obtain the comprehensive development index of cities and urban forests.

If the eigenvalue corresponding to the principal component >1, the cumulative variance contribution rate $\sum_{k=1}^{r} p_r \geq 80\%$, indicating that the first k components have been able to basically reflect the main information related to the original variables. Therefore, the score value F_{ir} of the first k principal components and their corresponding weight $p_r = (1, 2, \ldots, k)$ can be used. According to the following equation, the indices of urban development and urban forest development in each year are obtained:

$$F_i = \sum\nolimits_{r=1}^{k} p_r \times F_{ir}, F_i' = \sum\nolimits_{r=1}^{k'} p_r' \times F_{ir}' \tag{2}$$

where F_i is the urban development index $(i = 1, 2, \ldots, n)$ of year i and $F_i{}'$ is the urban forest development index $(i = 1, 2, \ldots, n)$ for year i.

2.3.3. Coordination Degree Model

In this research, the concept of the "membership function" in fuzzy mathematics was introduced, and the coordination degree of indices between urban development and urban forest development was calculated with reference to the relevant studies [53]. First, a regression fitting analysis of the urban and urban forest development index was carried out. Y and X were used to represent the urban development index and urban forest development index, respectively. With X as the independent variable and Y as the dependent variable, the development index Y' of the urban forest development level relative to the urban development level can be obtained by regression fitting; with Y as the independent variable and X as the dependent variable, the development index X' of the urban forest development level relative to the urban forest development level can be obtained by regression fitting. Through the calculation of the coordination degree between the urban development level and the urban forest development level, the development coordination state between the two systems is reflected. The equation for calculating the coordination degree is as follows:

$$U_{\left(\frac{i}{j}\right)} = exp\left\{-\frac{(X-X')^2}{{S_1}^2}\right\}, {}^{\circ}U_{\left(\frac{j}{i}\right)} = exp\left\{-\frac{(Y-Y')^2}{{S_2}^2}\right\},$$
$${}^{\circ}C = \frac{min\left\{U_{(i/j)}, U_{(j/i)}\right\}}{max\left\{U_{(i/j)}, U_{(j/i)}\right\}}. \quad (3)$$

where $U_{(i/j)}$ is the state coordination degree between the urban forest development level and the urban development level, X is the urban forest development index, X' is the development index of the urban development level relative to the urban forest development level, and ${S_1}^2$ is the variance of the urban forest development index. $U_{(j/i)}$ states the coordination degree between the urban development level and the urban forest development level, Y is the urban development index, Y' is the development index of the urban forest development level relative to the urban development level, and ${S_2}^2$ is the variance of the urban development index. Based on the state coordination degree and referring to the existing research [56,57], the formula for calculating the coordination degree C between the urban system and urban forest system is then determined.

2.3.4. Coordination Level Classification

In this research, the uniform distribution function method was used to determine the classification standard of the coordination degree. With reference to existing research [58,59], the classification standard of the coordination degree between the urban development level and the urban forest development level was determined, as shown in Table 2.

Table 2. Development level coordination degree criterion.

Coordination Degree	Grade
0–0.09	Extreme Disorder
0.1–0.19	Severe Disorder
0.2–0.29	Moderate Disorder
0.3–0.39	Mild Disorder
0.4–0.49	Borderline Disorder
0.5–0.59	Bare Coordination
0.6–0.69	Primary Coordination
0.7–0.79	Intermediate Coordination
0.8–0.89	Good Coordination
0.9–1	High-Quality Coordination

3. Results

3.1. Spatio-Temporal Characteristics of the Urban Development Level and Urban Forest Development Level

According to the evaluation index system in Table 1, the principal component analysis method is first used to calculate the index weight. Then, the urban development level and the urban forest development level of the Yangtze River Delta urban agglomeration from 2005 to 2021 are calculated with the comprehensive evaluation model (Table 3 and Figure 3). By using the principal component analysis by the SPSS software, the average value of the development indices for each data group is 0, and the difference between the development index and the average value reflects the development level. For example, the urban development index of the Yangtze River Delta urban agglomeration was −1.017 in 2007, and the urban development level in 2007 was lower than the average level from 2005 to 2021.

Table 3. Urban development and urban forest development index of Yangtze River Delta urban agglomeration from 2005 to 2021.

Year	Urban Development Index	Urban Forest Development Index
2005	−1.690	−1.467
2006	−1.494	−1.608
2007	−1.017	−1.135
2008	−0.858	−0.968
2009	−0.701	−0.291
2010	−0.483	−0.403
2011	−0.236	−0.119
2012	−0.002	0.024
2013	0.104	0.764
2014	0.213	0.882
2015	0.433	0.808
2016	0.568	0.553
2017	0.728	0.497
2018	0.887	0.471
2019	1.055	0.591
2020	1.139	0.863
2021	1.355	0.538

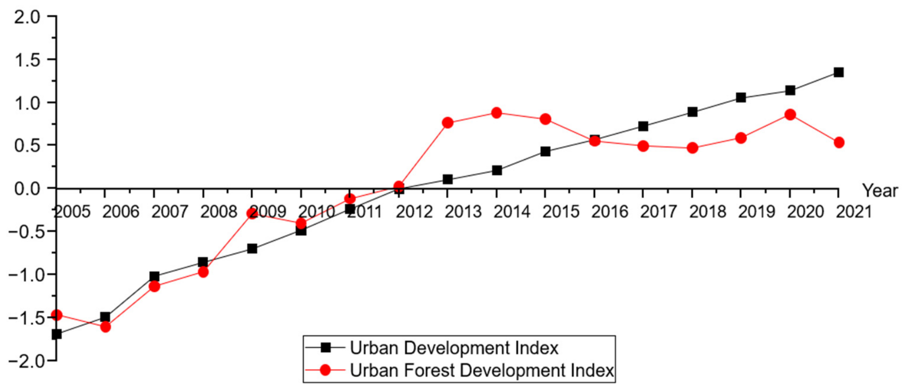

Figure 3. Urban development and urban forest development index of the Yangtze River Delta urban agglomeration from 2005 to 2021.

From the temporal perspective, the urban development index of the Yangtze River Delta urban agglomeration increased year by year from 2005 to 2021, from −1.690 to 1.355. The urban forest development index showed a fluctuating upward trend: it first decreased from 2005 to 2006, with a minimum of −1.608 in 2006, then increased from 2006 to 2009, followed by a fluctuating upward trend from 2009 to 2013, and finally fluctuated at a relatively high level after 2013, with a maximum of 0.882 in 2014.

To better analyze the spatial pattern and dynamic evolution of the urban development index and urban forest development index, this research used ArcGIS 10.6 software and visualized the levels of urban development and urban forest development in 2005, 2009, 2013, 2017, and 2021 (Figures 4 and 5).

From the temporal perspective, the urban development of the three provinces and one city in the Yangtze River Delta urban agglomeration showed a simultaneous upward trend. The indices of the five equidistant years of the three provinces and one city were all in the same range, which indicates a balanced and similar growth speed in the Yangtze River Delta urban agglomeration in terms of urban development. The urban forest development of the Yangtze River Delta urban agglomeration showed variations in terms of growth speed. With all three provinces and one city showing an upward trend, Shanghai and Anhui showed a more solid foundation. Shanghai showed steadier growth, while the growth speeds of Jiangsu and Anhui were relatively higher, and Zhejiang showed a fluctuating upward trend.

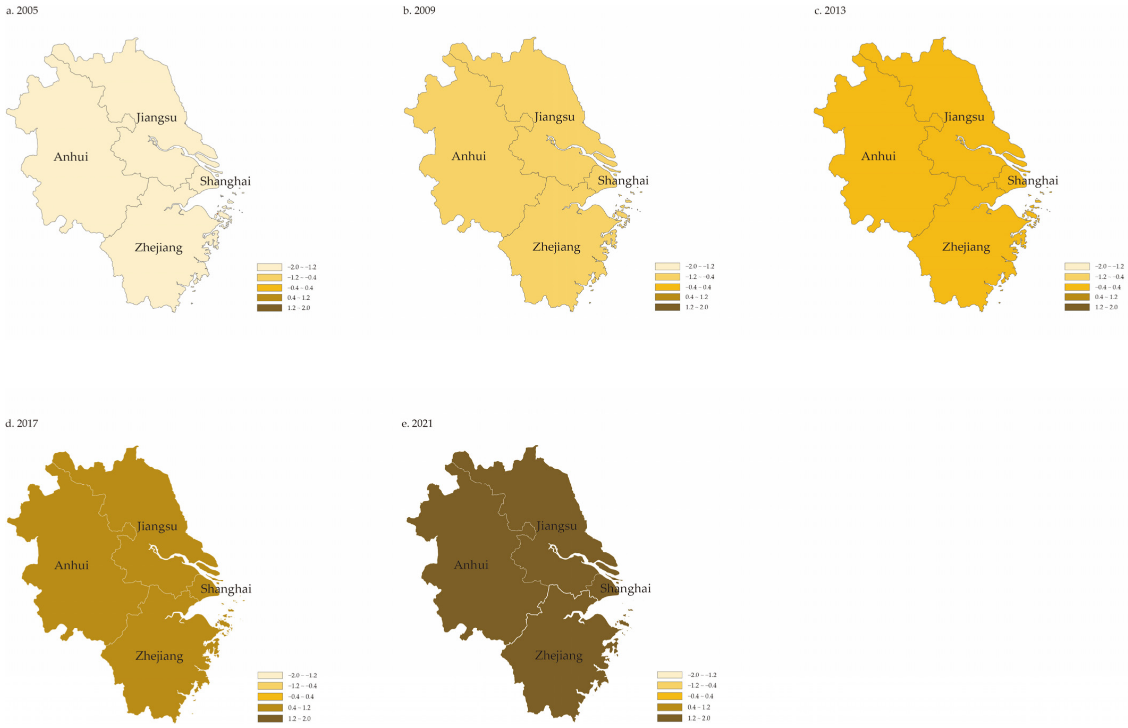

Figure 4. (**a**). First panel shows the spatial patterns of urban development in the Yangtze River Delta urban agglomeration in 2005; (**b**). Second panel shows the spatial patterns of urban development in the Yangtze River Delta urban agglomeration in 2009; (**c**). Third panel shows the spatial patterns of urban development in the Yangtze River Delta urban agglomeration in 2013; (**d**). Fourth panel shows the spatial patterns of urban development in the Yangtze River Delta urban agglomeration in 2017; (**e**). Fifth panel shows the spatial patterns of urban development in the Yangtze River Delta urban agglomeration in 2021.

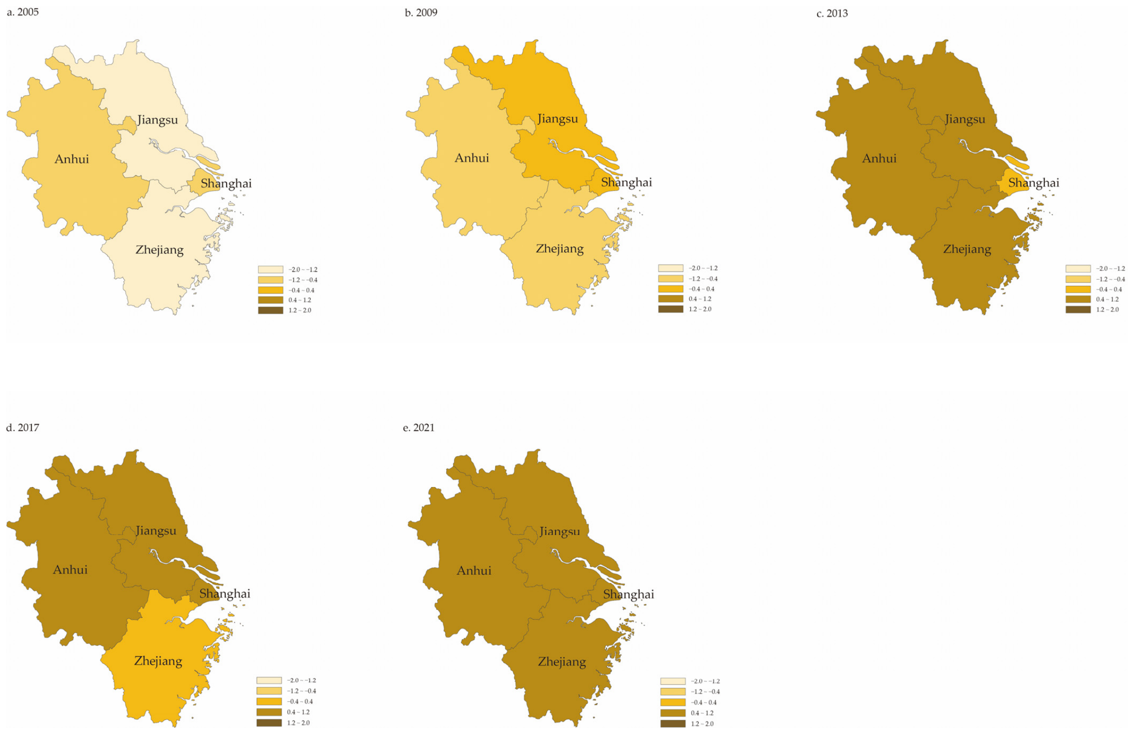

Figure 5. Spatial patterns of urban forest development in the Yangtze River Delta urban agglomeration in (**a**). 2005, (**b**). 2009, (**c**). 2013, (**d**). 2017, and (**e**). 2021.

3.2. Spatial-Temporal Characteristics of the Coordination Degree between Urban Development and Urban Forest Development

Temporal Evolution of the Coordination Degree

The coordination degree model was used to determine the coordination between urban development and urban forest development in the Yangtze River Delta urban agglomeration from 2005 to 2021 (Figure 6). According to the coordination degree grade standard of Table 2, except for the level of intermediate coordination in 2021, the coordination degrees are all at the level of good coordination and high-quality coordination. The maximum coordination degree is 0.999 in 2012, and the minimum coordination degree is 0.730 in 2021. From a temporal perspective, the coordination degree showed a significant periodic fluctuation in the 16 years: it showed upward trends from 2006 to 2012, from 2014 to 2016, and from 2019 to 2020, and downward trends in the rest of the years. The downward trend appeared when the difference between the maximum and minimum coordination degree values among the three provinces and one city was relatively larger.

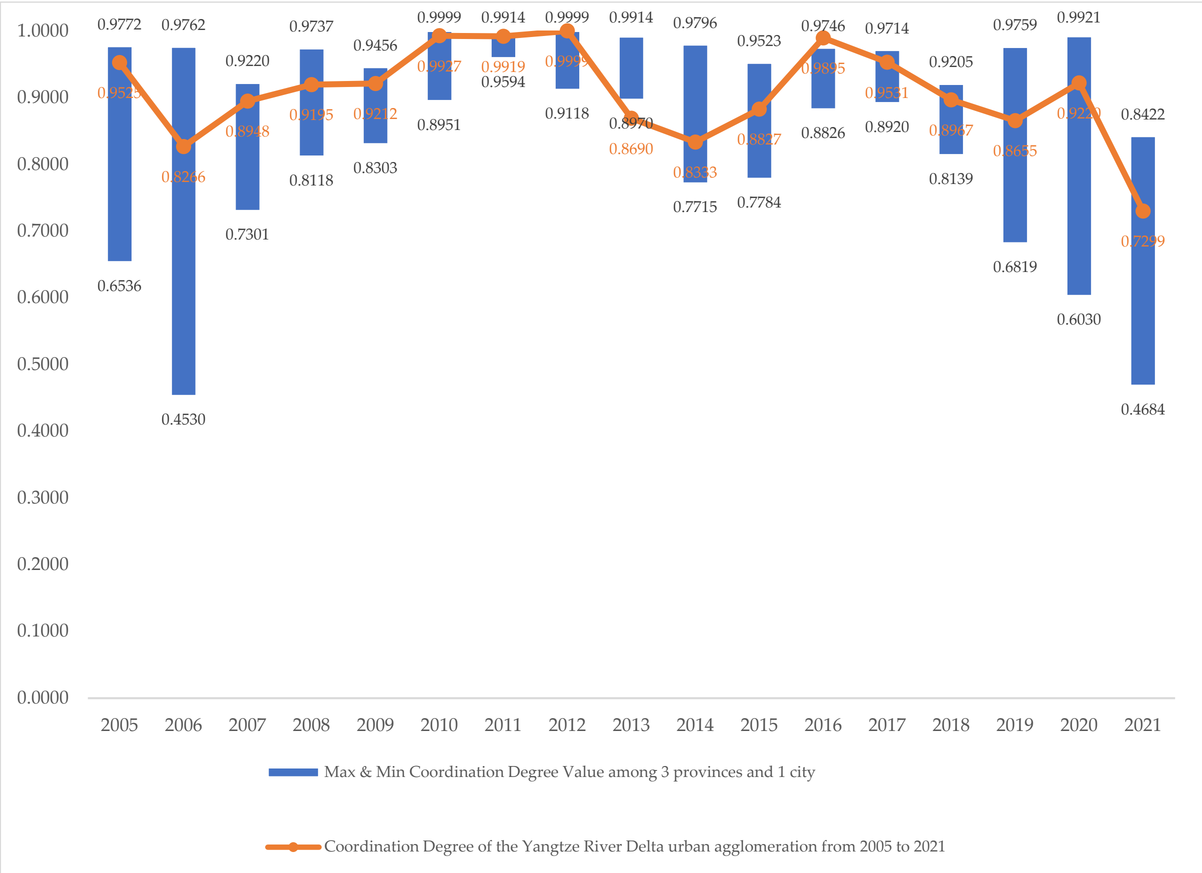

Figure 6. Temporal evolution of the coordination degree between the urban development and urban forest development of the Yangtze River Delta urban agglomeration from 2005 to 2021.

To better explore the spatiotemporal evolution and characteristics of the coordination degree from 2005 to 2021, the coordination degree of three provinces and one city is shown in Table 4. This research selected nine years from 2005 to 2021 at a two-year interval to visualize the spatial distribution of the coordination degree through ArcGIS10.6 software (Figure 7).

Table 4. Coordination degree between the urban development and urban forest development of three provinces and one city of the Yangtze River Delta urban agglomeration from 2005 to 2021. (The highest coordination degree among the three provinces and one city of each year is marked in green, and the lowest is marked in orange).

Year	Shanghai	Grade	Jiangsu	Grade	Zhejiang	Grade	Anhui	Grade
2005	0.977	High-Quality Coordination	0.654	Primary Coordination	0.977	High-Quality Coordination	0.963	High-Quality Coordination
2006	0.976	High-Quality Coordination	0.453	Borderline Disorder	0.956	High-Quality Coordination	0.665	Primary Coordination
2007	0.922	High-Quality Coordination	0.808	Good Coordination	0.730	Intermediate Coordination	0.815	Good Coordination
2008	0.946	High-Quality Coordination	0.974	High-Quality Coordination	0.812	Good Coordination	0.838	Good Coordination
2009	0.946	High-Quality Coordination	0.830	Good Coordination	0.941	High-Quality Coordination	0.941	High-Quality Coordination
2010	0.999	High-Quality Coordination	0.895	Good Coordination	0.982	High-Quality Coordination	0.984	High-Quality Coordination
2011	0.991	High-Quality Coordination	0.959	High-Quality Coordination	0.989	High-Quality Coordination	0.976	High-Quality Coordination
2012	0.989	High-Quality Coordination	0.999	High-Quality Coordination	0.912	High-Quality Coordination	0.998	High-Quality Coordination
2013	0.991	High-Quality Coordination	0.905	High-Quality Coordination	0.909	High-Quality Coordination	0.897	Good Coordination
2014	0.980	High-Quality Coordination	0.808	Good Coordination	0.896	Good Coordination	0.771	Intermediate Coordination
2015	0.952	High-Quality Coordination	0.875	Good Coordination	0.952	High-Quality Coordination	0.778	Intermediate Coordination
2016	0.915	High-Quality Coordination	0.966	High-Quality Coordination	0.975	High-Quality Coordination	0.883	Good Coordination
2017	0.946	High-Quality Coordination	0.892	Good Coordination	0.909	High-Quality Coordination	0.971	High-Quality Coordination
2018	0.916	High-Quality Coordination	0.814	Good Coordination	0.844	Good Coordination	0.920	High-Quality Coordination
2019	0.976	High-Quality Coordination	0.682	Primary Coordination	0.825	Good Coordination	0.781	Intermediate Coordination
2020	0.992	High-Quality Coordination	0.693	Primary Coordination	0.888	Good Coordination	0.603	Primary Coordination
2021	0.842	Good Coordination	0.468	Borderline Disorder	0.669	Primary Coordination	0.536	Bare Coordination

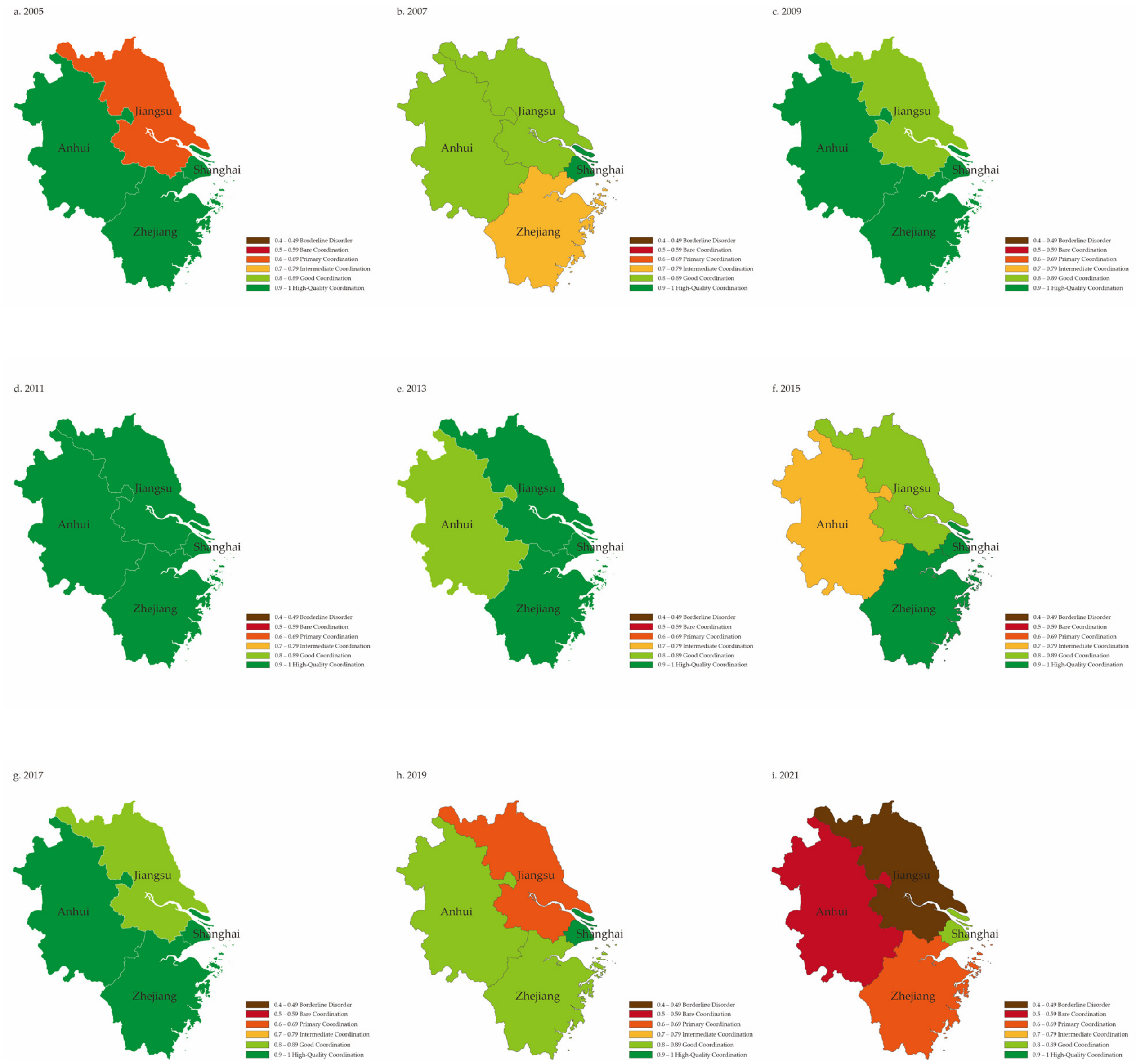

Figure 7. Spatial patterns of the coordination degree between urban development and urban forest development in the Yangtze River Delta urban agglomeration from 2005 to 2021. Key: 0.4–0.49 represents borderline disorder; 0.5–0.59 represents bare coordination; 0.6–0.69 represents primary disorder; 0.7–0.79 represents intermediate coordination; 0.8–0.89 represents good coordination; and 0.9–1.0 represents high-quality coordination.

The coordination degree between the urban development and urban forest development of the Yangtze River Delta urban agglomeration reached good coordination or high-quality coordination in 2009, 2011, 2013, and 2017, and the coordination degree was relatively low in 2021, experiencing a rise followed by a downward trend with fluctuation. Specifically, Shanghai showed the highest coordination level, as its coordination degree reached high-quality coordination in every year except in 2021. The coordination degree of Zhejiang ranked second only to Shanghai, except for intermediate coordination in 2007 and primary coordination in 2021, of which the coordination degrees in all other years were at the level of high-quality coordination or good coordination. Jiangsu showed the lowest coordination degree in 2005, followed by steady growth from 2007 to 2013 and a rapid descent from 2015 to 2021; its coordination degree in 2021 was at the level of borderline disorder. Anhui showed a fluctuating trend from 2005 to 2021 and was at the level of intermediate coordination and bare coordination in 2015 and 2021, respectively.

3.3. Policy Formulation on the Urban Forest of the Yangtze River Delta Urban Agglomeration

In general, from 2005 to 2021, the urban development of the Yangtze River Delta urban agglomeration was in a steady growth period, while urban forest development showed obvious fluctuations and spatial differentiation. Unsynchronized development led to spatiotemporal differences in the coordination degree between urban development and urban forest development. From the campaign of "National Forest City" launched in 2004 to the "Forest-Chief" scheme proposed in 2021, characterized by the chief executive responsibility system, the role of government in the practice of urban forest development in China has been increasingly strengthened in recent decades [60]. To further explore the influencing factors on urban forest construction, this research listed the policies and plans for urban forests in the three provinces and one city of the Yangtze River Delta urban agglomeration.

3.3.1. Policy Formulation for the Urban Forests of Shanghai

Shanghai's municipal government was one of the earliest in China to pay attention to urban ecological and environmental protection. Shanghai's first city master plan in 1986 had already focused on the construction of an urban green system. In the early 21st century, three special plans on urban forests and green space were issued to demarcate the green line and plan the structure and layout of urban forests. Over the next two decades, the Shanghai Municipal government and Shanghai Forestry Bureau issued a series of regulations and plans aimed at different subdivided parts of urban forests, such as forestland protection, ecological networks, boulevards, ecological corridor systems, greenway construction, and ecological ren lines, thus gradually forming the policy system of urban forests. Table 5 shows the main policies, regulations, and management measurements related to urban forests in Shanghai since 2000.

Table 5. Policies, regulations, and management measurements on the urban forests of Shanghai since 2000.

Year	Name of Policy	Department
2001	Shanghai City Master Plan (1999–2020)	Shanghai Municipal People's Government
2001	Shanghai City Center Public Green Space Planning	Shanghai Landscaping and City Appearance Administrative Bureau and Shanghai Forestry Bureau
2002	Shanghai Urban Green Space System Planning (2002–2020)	Shanghai Landscaping and City Appearance Administrative Bureau and Shanghai Forestry Bureau
2003	Shanghai Urban Forest Planning	Shanghai Landscaping and City Appearance Administrative Bureau and Shanghai Forestry Bureau
2008	Regulations on Park Management of Shanghai	Shanghai Landscaping and City Appearance Administrative Bureau and Shanghai Forestry Bureau
2008	Regulations on Greening of Shanghai	Shanghai Municipal People's Government
2009	Regulations on Forest Management of Shanghai	Shanghai Municipal People's Government
2011	Shanghai Forest Land Protection and Utilization Planning (2010–2020)	Shanghai Landscaping and City Appearance Administrative Bureau and Shanghai Forestry Bureau
2012	Shanghai Basic Ecological Network Planning	Shanghai Landscaping and City Appearance Administrative Bureau and Shanghai Forestry Bureau
2014	Management Measures on Boulevard of Shanghai	Shanghai Landscaping and City Appearance Administrative Bureau and Shanghai Forestry Bureau
2016	Shanghai City Master Plan (2016–2040)	Shanghai Municipal People's Government
2017	Shanghai City Master Plan (2017–2035)	Shanghai Municipal People's Government
2017	Shanghai Ecological Corridor System Planning (2017–2035)	Shanghai Landscaping and City Appearance Administrative Bureau and Shanghai Forestry Bureau
2018	Management Measures on Greenway Construction Projects of Shanghai	Shanghai Landscaping and City Appearance Administrative Bureau and Shanghai Forestry Bureau
2021	Shanghai Ecological Space Special Planning (2021–2035)	Shanghai Municipal People's Government

Table 5. *Cont.*

Year	Name of Policy	Department
2021	Technical Guidelines for Construction of Pocket Park of Shanghai	Shanghai Landscaping and City Appearance Administrative Bureau and Shanghai Forestry Bureau
2021	Guidelines on Promoting the Construction of Park City of Shanghai	Shanghai Landscaping and City Appearance Administrative Bureau and Shanghai Forestry Bureau

3.3.2. Policy Formulation for the Urban Forests of Jiangsu

Jiangsu promoted the construction of "Grenn Jiangsu" and 10 major forestry projects in 2004 and started the construction of the "National Forest City" in 2008. The Five-Year Forestry Development Planning of Jiangsu has been formulated since 2006, mentioning the significance of urban forest construction. Until now, Jiangsu has not issued specific policies or plans for urban forests or their components. Table 6 shows the main policies, regulations, and management measurements related to urban forests in Jiangsu since 2000.

Table 6. Policies, regulations, and management measurements for the urban forests of Jiangsu since 2000.

Year	Name of Policy	Department
2003	Notice on Issues related to Forest Land Management	Jiangsu Forestry Bureau
2006	Opinions on Strengthening the Management of Forest Resources	Jiangsu Forestry Bureau
2006	The 11th Five-Year Forestry Development Planning of Jiangsu	Jiangsu Forestry Bureau
2010	Jiangsu Forest Land Protection and Utilization Planning	Jiangsu Forestry Bureau
2012	The 12th Five-Year Forestry Development Planning of Jiangsu	Jiangsu Forestry Bureau
2013	Management Measures on Forest Parks of Jiangsu	Jiangsu Forestry Bureau
2013	Jiangsu Ecological Civilization Construction Planning (2013–2022)	Jiangsu Provincial People's Government
2014	Jiangsu Ecological Protection and Construction Planning (2014–2020)	Jiangsu Provincial People's Government
2016	The 13th Five-Year Forestry Development Planning of Jiangsu	Jiangsu Forestry Bureau
2021	The 14th Five-Year Forestry Development Planning of Jiangsu	Jiangsu Forestry Bureau

3.3.3. Policy Formulation for the Urban Forest of Zhejiang

As early as 1995, the Zhejiang Provincial government issued Management Measures on Urban Greening, proposing the systematic construction of urban forest systems. In the first decade since 2000, Regulations on Forest Management and Forest Land Protection and Utilization Planning were issued, building the foundation of urban forest construction in Zhejiang. During the process of constructing the "National Forest City", Zhejiang also actively promoted the construction of a forest city agglomeration, emphasizing the systematic layout and regional construction of urban forests. The development of forest resources was an important indicator in the assessment of the Zhejiang government at all levels. Table 7 shows the main policies, regulations, and management measurements related to urban forests in Zhejiang since 2000.

Table 7. Policies, regulations, and management measurements for the urban forests of Zhejiang since 2000.

Year	Name of Policy	Department
2003	Regulations on Returning Farmland to Forests	Zhejiang Provincial People's Government
2004	Regulations on Forest Management of Zhejiang	Zhejiang Provincial People's Government
2007	The 11th Five-Year Forestry Technology Planning of Zhejiang	Zhejiang Forestry Bureau
2010	Zhejiang Forest Land Protection and Utilization Planning (2010–2020)	Zhejiang Forestry Bureau
2011	Urban System Planning of Zhejiang Province (2011–2020)	Zhejiang Provincial People's Government
2012	The 12th Five-Year Forestry Development Planning of Zhejiang	Zhejiang Provincial People's Government
2014	Opinions on Accelerating Forestry Reform and Development and Greening and Forest Construction of Zhejiang	Zhejiang Provincial People's Government

Table 7. *Cont.*

Year	Name of Policy	Department
2016	The 13th Five-Year Forestry Development Planning of Zhejiang	Zhejiang Forestry Bureau
2017	Regulations on Public Welfare Forests and Forest Parks of Zhejiang	Zhejiang Provincial People's Government
2021	Zhejiang Medium and Long-term Development Planning on Forestry Technology Promotion (2021–2035)	Zhejiang Forestry Bureau
2021	The 14th Five-Year Forestry Development Planning of Zhejiang	Zhejiang Forestry Bureau
2021	Implementation Plan for Comprehensive Forestry Reform in Zhejiang (2021–2025)	Zhejiang Forestry Bureau

3.3.4. Policy Formulation for the Urban Forests of Anhui

In the early 21st century, Anhui still focused on the economic benefits of forestry. Until approximately 2010, the planning on forestry in Anhui had shifted the emphasis on forestry to ecological construction and the integrated pattern of urban and rural greening; the Five-Year Forestry Development Planning was first proposed in 2012. In 2017, Anhui took the lead in piloting the "Forest-Chief" scheme, further strengthening the role of the government in terms of urban forest construction. Table 8 shows the main policies, regulations, and management measurements related to urban forests in Anhui since 2000.

Table 8. Policies, regulations, and management measurements for the urban forests of Anhui since 2000.

Year	Name of Policy	Department
2000	Regulations on Forest Land Protection and Management of Anhui	Anhui Provincial People's Government
2004	Opinions on Implementing the Decision of Accelerating Forestry Development	Anhui Provincial People's Government
2006	Regulations on Forest Park Management of Anhui	Anhui Provincial People's Government
2007	Opinions on Promoting the Reform of Collective Forest Rights System	Anhui Provincial People's Government
2009	Opinions on Accelerating Forestry Reform and Development	Anhui Provincial People's Government
2011	Anhui Forest Seedling Development Planning (2011–2020)	Anhui Forestry Bureau
2012	Anhui Forestry Economic Development Planning (2012–2016)	Anhui Forestry Bureau
2012	The 12th Five-Year Forestry Development Planning of Anhui	Anhui Forestry Bureau
2012	Master Planning on Forest Growth Project of Anhui	Anhui Forestry Bureau
2016	The 13th Five-Year Forestry Development Planning of Anhui	Anhui Forestry Bureau
2017	Opinions on Establishing the "Forest-Chief" Scheme	Anhui Provincial People's Government
2019	Opinions on Adhering to Ecological Green Development and Strengthening the Management of Nature Reserves	Anhui Provincial People's Government
2020	Implementation Plan on Establishing Protected Natural Areas System with National Parks as the Main Body	Anhui Provincial People's Government
2021	The 14th Five-Year Forestry Development Planning of Anhui	Anhui Forestry Bureau

4. Conclusions and Discussion

4.1. Conclusions

A sustainable, balanced, and healthy urban development mode has become an important issue in modern cities. Therefore, the coordinated development between cities and urban forests, the main body of the urban ecological environment, is of great significance for the construction of green, healthy, and sustainable urban ecological environments. This research constructed a comprehensive evaluation index system to measure the development level of urban systems and urban forest systems in the Yangtze River Delta urban agglomeration from 2005 to 2021 and analyzed their spatiotemporal evolution characteristics. On this basis, the spatiotemporal evolution characteristics of the coordination degree between the two systems were analyzed, and the influencing factors were analyzed from the perspective of government policy. The following conclusions were then drawn:

1. From 2005 to 2021, the development level of the urban system and urban forest system of the Yangtze River Delta urban agglomeration generally showed an upward trend.

The urban development index continued to rise from −1.677 to 1.370 (taking 0 as the average value), and the growth trends of the three provinces and one city were similar. The urban forest development index showed a fluctuating upward trend from −1.467 to 0.538, with a maximum value of 0.882 in 2014. From the spatial perspective, the three provinces and one city all showed a fluctuating upward trend, and Shanghai and Anhui showed the best urban forest development level. In general, the level of urban forest development lagged behind the level of urban development, indicating that the construction of urban forests in the Yangtze River Delta urban agglomeration was still relatively extensive, and it is necessary to further improve the construction of urban forests on the premise of meeting the needs of urban development.

2. From 2005 to 2021, the coordination degrees between the urban development and urban forest development in the Yangtze River Delta urban agglomeration were all at the level of high-quality coordination or good coordination, except in 2021. From the temporal perspective, the coordination degree showed a significant fluctuation trend, with a maximum value of 0.999 in 2012 and a minimum value of 0.730 in 2021. The spatial differentiations were significant, while Shanghai showed the best coordination level among the three provinces and one city, and the coordination degree of Jiangsu was at the level of borderline disorder in 2006 and 2021.
3. The analysis of the policies on urban forest development showed that the urban forest development of the Yangtze River Delta urban agglomeration largely depended on the government's regulation and policy promotion. The systematic planning and refined management of urban forests in Shanghai and Zhejiang greatly facilitated the development of urban forests. Jiangsu lacked specific policies or regulations as well as systematic planning for the construction of urban forests. The Anhui government attached great importance to the development of urban forests, but it was still in the transition period from the forestry economy to forestry ecology.

4.2. Discussion

As a world-class urban agglomeration, the Yangtze River Delta urban agglomeration has a high level of urbanization and economic development. From 2005 to 2021, the urban development level of the Yangtze River Delta urban agglomeration increased year by year, while the urban forest development level showed an upward trend in general, with obvious fluctuations, lagging behind the urban development. This unsynchronized development led to significant fluctuations in the coordination degree between them. To further explore the evolution characteristics, a spatiotemporal analysis was conducted, and policy formulation on the urban forests of the three provinces and one city of the Yangtze River Delta urban agglomeration was reviewed. Among them, Shanghai showed the highest level of coordination, indicating a virtuous cycle and coordinated development between these two systems. With early overall planning for urban forest construction, the policy system was gradually improved by issuing a series of regulations and management measures on the subdivided part of the urban forest. With the limitation of land resources, Shanghai has promoted the construction of three-dimensional greening since the early 21st century, with the carrier from the roof to the exterior wall of buildings and elevation of roads. Additionally, Shanghai proposed the construction of pocket parks in 2016 through the transformation of roadside green space and sharing of public green space and introduced relevant guidelines for construction. Thus, the combination of systematic planning and the refined management of urban forest construction in Shanghai should be taken as a demonstrative example of a sustainable development mode.

The development of urban forests in the other three provinces was facilitated by the construction of the "National Forest City". The urbanization rates of Zhejiang and Jiangsu were less than 50% in the early 21st century and exceeded 70% in 2019. During rapid urbanization, the construction mode of urban forests should adapt to the process of development. On the basis of the issue of policies on urban greening and forest management in the early stages, Zhejiang shifted its emphasis to systematic planning and the regional integrated construction of urban forests, promoting balanced and coordinated development. However, the development pattern of urban forests in Jiangsu basically remained the same, and specific policies or plans for urban forests had not been formulated by the Jiangsu government, which led to significant fluctuations in the coordination degree between urban development and urban forest development. Regarding Anhui, the overall development level lagged behind the others; the urbanization rate was lower than 30% in 2000 and was over 60% for the first time in 2022. In the early 21st century, Anhui still focused on the economic benefits of forestry. Until approximately 2010, the planning on forestry in Anhui had shifted the emphasis on forestry to ecological construction and integrated patterns of urban and rural greening. The exploration of the "Forest-Chief" scheme in Anhui, initiated in 2017, indicated the strengthening of the role of government in urban forest construction.

The coordinated development of cities and urban forests is directly related to the security and sustainable development of urban agglomerations. Based on the research results of this study, the following policy recommendations are put forward: (1) the combination of systematic planning and the refined management of urban forests should be introduced based on the different objective conditions and stages of development; (2) to support the formulation of policies, the academic research and scientific and technological resources in this field should be strengthened; (3) on the basis of policy promotion, it is necessary to strengthen the internal driving force of urban forest construction by cultivating new modes of urban forest development such as "ecology +", "Internet +", and "forest +" and enhance the public's recognition and participation in the construction of urban forests; and (4) for integrated developing areas such as urban agglomerations, mutual complementarity within the region should be strengthened.

The data calculation results and theoretical analysis of the research will help optimize the treatment between cities and the environment in the process of urbanization to achieve the goal of high-quality and sustainable development in the Yangtze River Delta urban agglomeration. The research also provides data-based support for government administrators to adjust policies on sustainable urban development.

Compared with other studies, this research is innovative. This research focuses on urban forests and discusses the relationship between urban forests and urban development. Through the combination of a comprehensive evaluation model and a coordination degree model, the coordination relationship between these two systems and their spatiotemporal characteristics are analyzed, and the factors affecting the development of urban forests are analyzed from the perspective of policy.

Due to the complexity of the urban system and urban forest system and the limitation of data, with the data before 2005 and after 2021 unable to be obtained, this paper only preliminarily discusses the coordination degree between the urban and urban forest development level and its influencing factors in the Yangtze River Delta urban agglomeration from 2005 to 2021. In the future, it is necessary to further optimize the index system, include more perspectives, compare different urban agglomerations, and more systematically explore the internal mechanism and influencing factors of urban and urban forest development.

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