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Spatio-Temporal Evolution of Forestry Development in China

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Abstract: Since 1949, China's forestry development has made remarkable achievements. To summarize "China's experience," this paper built a logical analysis framework aided by the literature review and adopted the qualitative analysis and quantitative analysis methods to systematically study the evolution of the spatial and temporal pattern of China's forestry development in the past 70 years (1949–2020) and the next 30 years (2021–2050). The results show that the evolution of forestry development can be divided into three stages consisting of nine substages from 1949 to 2050. The first stage is focusing on timber production during 1949–1998, the second stage is focusing on ecological conservation during 1998–2018, and the third stage is focusing on high-quality development during 2018–2050. The faced situations, main signs, evolution process, basic characteristics, and target effects vary by stage. The four drivers of the spatio-temporal evolution of forestry development in China are the administrative system, laws and policies, investment, and science and technology. The "China's experience" is of great significance for the forestry development of other developing countries in the world.

Keywords: green transition, spatio-temporal evolution, wood production, ecological construction, driving mechanism, China

1. Introduction

Since 1949, China's forestry development has made remarkable achievements. From 1949 to 2018, China's forest coverage rate increased from 12.50% to 22.96%, and the forest coverage rate is expected to increase from 22.96% to 28% from 2018 to 2050 [1]. Satellite data show that China ranked first in the world in terms of net growth and net growth rate of the green area during 2000–2017. The net growth of the green area of China accounted for 25% of those in the world, which was equivalent to the sum of Russia, the United States, and Australia, of which afforestation accounted for 42% [2]. According to an article published in Nature, the carbon absorption effect of afforestation in China was actually underestimated [3]. Forestry development is characterized by stages, so with a better understanding of the historical stage of forestry development, future forestry policies and measures would be better formulated [4].

In terms of the literature about the history of China's forestry development, its theme and content are mainly embodied in the following five aspects. First, its theme and content are about the history of forestry thought and literature selection since 1949 [5–8, 9]. Second, they are about the changes in timber production since 1949 [10]. Third, they are about the analysis of the changes in the collective forest tenure system since 1949 [11]. Fourth, they are about the changes in forestry policy since 1949 [12, 13]. Fifth, they are about changes in China's forestry management system and social organizations since 1949 [14, 15]. The research has laid a solid literature foundation for our study, but there were still three obvious shortcomings among them: first, they were retrospective studies of the historical period since the founding of PRC (the People's Republic of China) but lacked a forward-looking analysis of the future development trend; second, they focused on the time dimension but ignored spatial dimension; third, they attached importance to empirical analysis but paid insufficient attention to the construction of the logical analysis framework and ignored theoretical analysis.

Based on the three shortcomings, this paper made targeted improvements. Specifically, based on both time and spatial dimensions, this paper built a logical analysis framework aided by the literature review and adopted the qualitative analysis and quantitative analysis methods to systematically study the evolution of the spatial and temporal development pattern of China's forestry in the past 70 years (1949–2020) and the next 30 years (2021–2050). The summary of "China's experience" will be of great significance to the forestry development of other developing countries over the world. The main purpose of this study is to summarize the experience of China's forestry development.

2. Logical Analysis Framework

2.1. Theoretical basis

It includes institutional economics, ecological economics, restoration ecology, sustainable development theory, and

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modernization theory. According to the speed of institutional change, institutional economics divides social analysis into four levels: social basis, institutional environment, governance structure, and resource allocation [16]; eco-economics pays attention to the multidimensional relationship between the ecosystem and the economic system, attaches importance to the adoption of technical pessimism to carefully examine the practical problems and policy design, and takes a more prudent approach to the constraints of resources and environment, so as to reduce uncertainty as much as possible [17]; restoration ecology is applied ecology, which mainly studies the causes of ecosystem degradation and the technologies and methods of restoration and reconstruction of degraded ecosystems, and their ecological processes and mechanisms [18]. Institutional economics, ecological economics, and restoration ecology mainly reveal the operation rules of economic, social, and ecological systems and attach importance to the treatment of the relationship between humans and nature, which provides a theoretical basis for promoting forestry construction and realizing the maximization of ecological, economic, and social benefits from the perspective of "social-ecological" system. Sustainable development requires that it not only meets the needs of contemporary people but also does not weaken the ability of future people to meet their needs [19]; the modernization theory mainly discusses the theories, models, strategic guidelines, and policy measures of social and economic modernization in developing countries. Scientific and technological innovation has effectively supported the upgrading of China's modernization level. Green development has indirectly promoted China's modernization development through technological innovation, foreign investment introduction, and talent introduction [20, 21]. The sustainable development theory and modernization theory reveal the unity of opposites between development and protection and provide a theoretical basis for systematically explaining the paradigm shift of the evolution of human civilization, the green transformation of modernization construction, the practical transformation of high-quality development, and the transformation of the new and old kinetic energy of the governance system and clarifying the main battlefield position of forestry in the ecological civilization construction. The above-mentioned theories of different disciplines complement each other and together constitute the theoretical basis for the systematic analysis of the evolution of the spatial and temporal pattern of forestry development.

2.2. Driving mechanism

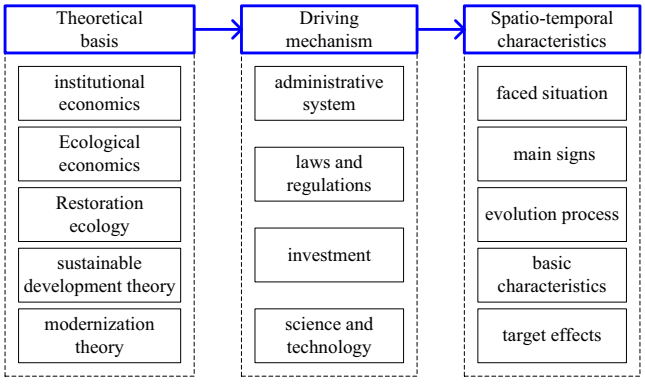
It includes the administrative system, laws and regulations, investment, science and technology. In the process of material, energy, and information flow, the driving force of system operation can be reasonably adjusted and optimized to achieve the coordination and matching of factor endowment and system structure and promote the common realization of multiple functions of the system. As an important aspect of the forestry modernization governance system, the administrative system, laws and regulations, investment, science and technology are the driving mechanisms of forestry development, which promotes the sustainable operation of the forestry eco-economic system. The driving mechanism for the evolution of the spatio-temporal pattern of forestry development is mainly manifested in one way, which means that could give full play to the advantages of the socialist system and concentrate on major events, optimize the strategies, policies, and models of forestry modernization, adjust the investment mode of high-quality forestry development, and strengthen the scientific research and technology application related to forestry, in order to improve the coordination among the driving factors of forestry construction and the coupling between the driving factors and the system structure and promote the function of the forestry eco-economic system.

2.3. Spatio-temporal characteristics

The process of forestry development in China can be divided into three stages which include timber production, ecological construction, and high-quality development. The situation, facing signs, evolution process, basic characteristics, and target effects are different at different stages. With the two-way flow of material, energy, and information, the elements, structure, and function of the system show different characteristics, and they form a specific system form. The evolution of forestry spatial and temporal patterns also corresponds to different system forms. Specifically, in the stage of timber production, facing the situation of scarcity of natural resources, the operation of the forestry ecosystem is characterized by meeting the demand for timber resources, and the economic function of the forestry ecosystem is emphasized; at the stage of ecological construction, to cope with the crisis of climate change, water and soil loss, desertification, and other crises, the government carries out large-scale afforestation, conversion of farmland to forest, and other forestry ecological engineering construction, emphasizing the ecological function of the forestry ecosystem; at the stage of high-quality development, the integrated restoration of mountains, forests, fields, lakes, and grass should be coordinated, and the ecological, economic, and social functions of the forestry system should be given full play.

Therefore, a logical analysis framework is constructed as shown in Figure 1. Five classic theories such as institutional economics provide the theoretical basis for driving mechanism analysis. The driving mechanism drives the evolution of the spatio-temporal development pattern of forestry, which is mainly characterized by five aspects including faced situation, main signs, evolution process, basic characteristics, and target effects.

Figure 1
Logic analysis framework



3. Methodology

1) Qualitative analysis methods. Literature analysis was used to build the theoretical framework, historical analysis was used to describe main characteristics of spatio-temporal evolution of forestry development and its driving mechanism, and comparison analysis was used to reveal similarities and differences among the different stages.
2) Quantitative analysis methods. Descriptive statistics analysis was widely used to analyze specific indicators reflecting main characteristics of spatio-temporal evolution of forestry development and its driving mechanism.

The basic data used in this paper were mainly from China Forestry Yearbook 1949–1986 [22], Forestry Development in China 1949–1999 [23], China Forestry Statistical Yearbook 2013 [24], China Forest Resources Report 2014–2018 [25], China Forestry and Grassland Statistical Yearbook 2020 [26], China Forestry and Grassland Yearbook 2021 [27], Main Data Bulletin of the Third National Land Survey [28], and National Report on Comprehensive Benefit Monitoring of the Grain for Green Project 2020 [29]. Because of data limitations of Hong Kong, Taiwan, and Macao, the three regions in China were not included in this study.

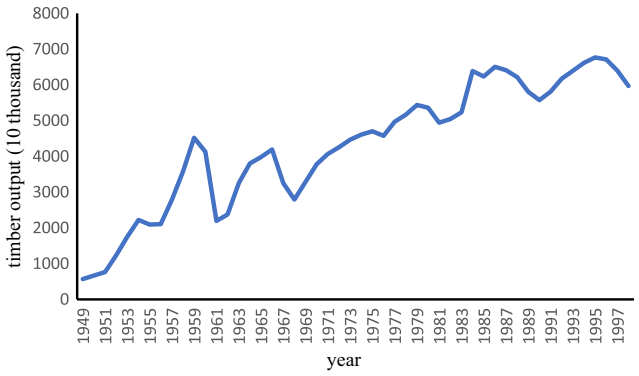
4. Results

4.1. Spatio-temporal evolution of forestry development in China

4.1.1. The stage dominated by timber production (1949–1998)

1) Faced situation. China was a country with a high forest coverage rate in ancient times, but after a long period of war, excessive deforestation, and other destruction, the forest resources were gradually reduced, and it became a country with a low forest coverage rate. By 1949, the forestry foundation had been very weak, and the forest coverage rate of China was only 12.50%. In the early period of the founding of the PRC, the industrial foundation was quite weak, and developing the economy became the country's top priority. Timber was one of the four major raw materials to support the country's construction, and it undertook the important task of supporting the industrialization construction. In the early period of the founding of the PRC, timber was urgently needed for national economic recovery and construction.
2) Main signs. In October 1949, at the beginning of the founding of the PRC, the *Ministry of Forest Reclamation* was specially set up to take charge of the national forestry and reclamation work. In 1956, the *Ministry of Forest Industry* was also specially set up to take charge of the timber production. Later, the *Ministry of Forestry* has always taken timber production as its core function. The government had successively developed and constructed state-owned forest areas, such as the Xing'an Mountains and Changbai Mountains in the northeast, the Jinsha River, the Dadu River, and the Yalong River in the southwest, the Qinling Mountains, the Tianshan Mountains, and the Altai Mountains in the northwest, had successively established 135 state-owned forestry enterprises, and and designated 158 counties for producing timber in the southern collective forest areas. Both the state-owned forest areas and collective forest areas provided a large number of timbers and forest products, made forestry become a pillar industry in the national economy, and made historic contributions to the recovery and development of the national economy.
3) Evolution process. The stage dominated by timber production was shown in Figure 2. The stage was subdivided into three substages. During the timber production subphase (1949–1956), the main task of China's forestry was to vigorously develop timber production and provide raw materials for national economic recovery and reconstruction. In order to meet the needs of national construction for lots of timber, the Ministry of Forest Industry (1956–1958) was specially established. During the phase, China's forest industry developed rapidly. The national timber output increased from 5.67 million m^3 in 1950 to more than 21 million m^3 in 1956; the mechanization level of timber mining and transportation had reached 42%; the forest industry ranked the top in the branches of the country for the profit paid by the country.

Figure 2
The change in timber output in China during 1949–1998



During the timber and afforestation substage (1956–1978), the national annual timber production increased from 21 million m^3 in 1956 to 51 million m^3 in 1978. In March 1956, the national leader Mao Zedong issued a great call for "greening the motherland," which marked that China started the continuous and unremitting journey of greening the country for 70 years. The forestry construction policy in the subphase was "based on forest management and combined with harvesting and cultivation."

During the timber and ecological construction substage (1978–1998), the government implemented the policy of reform and opening up, and China's forestry development entered a new stage. During this period, the national annual timber production increased from 51 million m^3 to about 60 million m^3 in 1998. In 1978, the government launched the first national large-scale ecological project which was called the construction project of the three-north shelterbelt system. At the beginning of the reform and opening up, the national leader Deng Xiaoping advocated carrying out the national compulsory tree-planting campaign, calling for "afforestation, greening the motherland, and benefiting future generations." In the 1980s, China successively carried out the

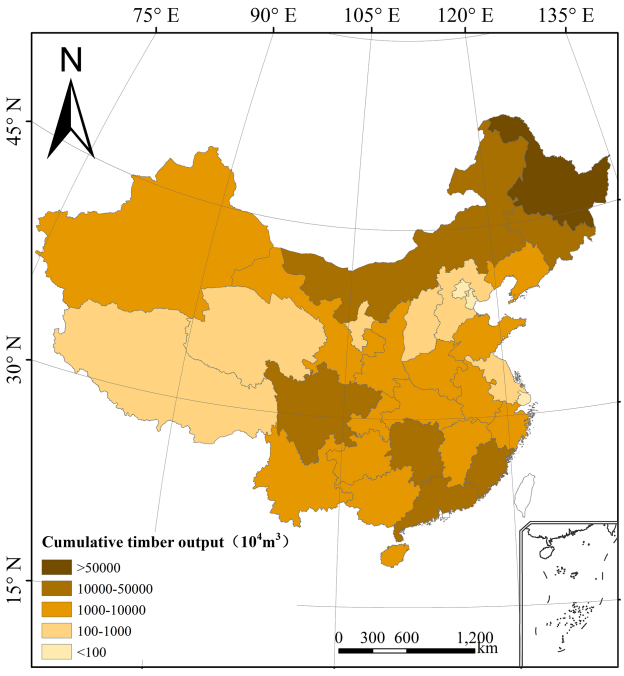
Table 1
Comparison of main characteristics among the three stages

Stage	The stage dominated by timber production (1949–1998)	The stage dominated by ecological construction (1998–2018)	The stage of high-quality development (2018–2050)
Faced situation	The industrial base was very weak, and developing the economy became the country's top priority. Timber undertook the important task of supporting the industrialization construction.	It shifted from focusing on timber production to focusing on ecological construction.	The stage of large-scale expansion of forestry has ended and will inevitably turn to the high-quality development stage of quality priority and moderate scale.
Main signs	It has always taken timber production as its core function.	China launched six key national ecological restoration projects in order to protect its environment and restore degraded ecosystems.	In 2018, the *National Forestry and Grassland Administration* was established. And it promoted the high-quality development of the forestry and grassland industry.
Evolution process	It included the timber production phase (1949–1956), the timber and afforestation substage (1956–1978), and the timber and ecological construction substage (1978–1998)	It included the phase in which ecological construction was officially recognized as the main task (2003–2012) and the phase which promoted the stage of ecological civilization construction (2013–2018).	It includes the top-level design transformation phase (2018–2020), the phase of basically realizing modernization (2021–2035) and fully realizing the modernization stage (2035–2050).
Basic characteristics	It mainly focus on timber production.	Policy shifted toward ecological construction.	It has changed from independent governance to systematic governance, unified governance, and high-quality governance.
Target effect	Lots of timbers and forest by-products were provided, which provided the country with making significant contributions to the socialist construction and reform and opening up of China.	Forest cover and forest stock have achieved rapid growth.	By 2035, the modernization of forestry will be realized. By 2050, the modernization of forestry will fully be realized.

construction of key ecological projects such as plain greening, coastal protection forest, and Taihang Mountain greening. In the 1990s, China vigorously promoted large-scale "afforestation and famine eradication" action, which covered a large area of barren mountains and wasteland in the country. In 1997, the national leader Jiang Zemin called for "rebuilding a beautiful northwest region." During this substage, China had successively put forward some forestry construction ideas such as "division of labor in forestry," "green up, live up, get rich," and "establish two systems"[6].

From the view of provincial spatial distribution (Figure 3), during 1949–1998, the highest cumulative timber output was in Heilongjiang province of the northeast forest region; next was Jilin and Inner Mongolia in the northeast forest region, Fujian, Hunan, and Guangdong in the southeast collective forest region, and Sichuan in the southwest forest region; third, Liaoning, Zhejiang, Anhui, and other 15 provinces; fourth, there were six "Shaolin" provinces, including Hebei, Shanxi, Jiangsu, Tibet, Qinghai, and Ningxia; the provinces with the lowest cumulative timber output were Beijing, Tianjin, and Shanghai. One important reason for this phenomenon was that limited by human and material resources, the central government implemented the vertical management of forestry production in the early days of the founding of PRC, and the Ministry of Forestry was mainly concentrated in the state-owned forest areas in the northeast of China [10].

Figure 3
Spatial distribution of cumulative timber output in China during 1949–1998

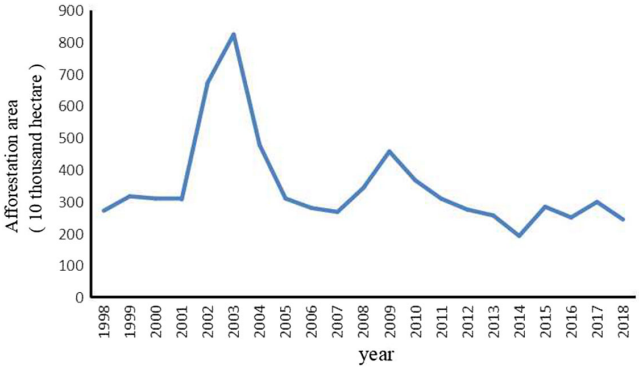


4) Basic characteristics. During the stage, from the Ministry of Forest Reclamation to the Ministry of Forestry and Forest Industry, then to the Ministry of Agriculture and Forestry, and finally to the Ministry of Forestry, no matter how the name was changed, it had always been a part of the central government at the ministerial level which forestry was regarded as one national industrial department. The formulation of various forestry policies and the deployment of key business work mainly focused on timber production.
5) Target effect. According to statistics, it had been 50 years since the founding of the PRC in 1998. The annual timber output had increased from more than 5 million m^3 in 1949 to 60 million m^3. 2.2 billion m^3 of timber, 7.3 billion pieces of bamboo, and a large number of forest by-products were provided over the past 50 years, which provided the country with making significant contributions to the socialist construction and reform and opening up of China [23]. However, due to the overharvesting of forests, the forest resources had declined significantly, leading to the depletion of forest resources and the economic crisis in the forest region and other prominent problems.

4.1.2. The stage dominated by ecological construction (1998–2018)

1) Faced situation. In 1998, China's Yangtze River and Songhua River basins experienced a rare catastrophic flood disaster in history, which caused people's profound reflection and painful experience. China made a strategic decision to stop the logging of natural forests and carry out the conversion of farmland to forest and grassland, which meant that China had achieved a historic transformation of the relationship between humans and nature.
2) Main signs. Since the end of the 20th century, China had launched six key national ecological restoration projects in order to protect its environment and restore degraded ecosystems. The projects included *the Natural Forest Protection Project*, *the Grain for Green Project*, *the Returning Grazing Land to Grassland Project*, *the Desertification Combating Program around Beijing and Tianjin*, *the Key Shelterbelt Development Programs in Regions such as the Three North and the Middle and Lower Reaches of the Yangtze River*, and *the Wildlife Conservation and Nature Reserve Development Program*. The projects covered more than 97% of the country's counties. The scope, scale, and impact of the projects were the largest in the world's ecological engineering construction and became the symbol of the stage.
3) Evolution process. The stage dominated by ecological construction was shown in Figure 4. During the subphase (1998–2002), a catastrophic flood broke out in the Yangtze River flood, which caused social reflection and post-disaster reconstruction thinking; the important document "*Several opinions on Post-disaster Reconstruction, River and lake Regulation, and Water Conservancy Construction*" requested that put "closing mountains and planting trees, returning farmland to forests" as the first priority and implemented the Natural Forest Protection Project and the Grain for Green Project [30]. During this subphase, China had successively put forward new ideas of forestry construction such as "leapfrog development" and "historic transformation." And the average annual afforestation area was 3.76 million ha which had been completed by the key forestry ecological projects.

Figure 4
Change of afforestation area of key ecological projects in China during 1998–2018

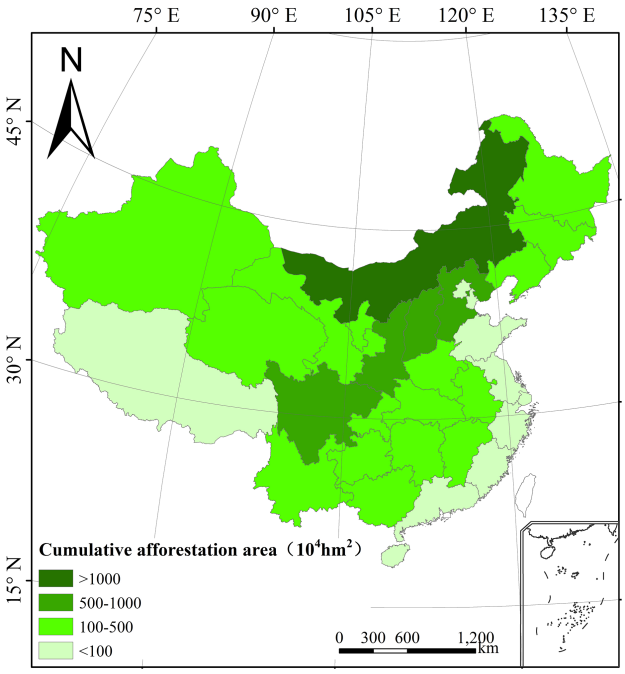


During the subphase, ecological construction was officially recognized as the main task (2003–2012). In the 21st century, China has paid more attention to sustainable development and emphasized the harmonious development of humans and nature. A research project team in China carried out the "*strategic research on China's sustainable development of forestry*" and put forward the "three ecological" strategic ideas of "ecological construction, ecological security, and ecological civilization" [31]. In June 2003, the Central Committee of the CPC (*the Communist Party of China*) and the *State Council* issued one important policy document "*the Decision on Accelerating Forestry Development*" which established the forestry development strategy focusing on ecological construction and made a comprehensive deployment for forestry development in the new era. In 2004, the national leader Hu Jintao requested that "China should adhere to the civilized development path of production development, rich life, and good ecology, and ensure the sustainable development of generation after generation" and "the concept of harmony between man and nature should be firmly established." During this subphase, China had successively put forward the idea of forestry development such as fighting the "stalemate stage" and promoting the protection of "three ecosystems and one biological diversity." The average annual afforestation of key forestry ecological projects in this period was 3.91 million ha. Due to the large-scale promotion of *the Grain for Green Project*, the peak of the construction of China's key forestry ecological projects was formed. In 2003, the afforestation area by the project completed was more than 8 million ha.

During the subphase which promoted the stage of ecological civilization construction (2013–2018), China had successively put forward some forestry development ideas including "ecological forestry and people's livelihood forestry" and "comprehensive construction of modern forestry" and vigorously promoted the construction of ecological civilization and made China become beautiful. The annual afforestation area of the projects was 2.55 million ha.

During 1998–2018, from the views of spatial distribution (see Figure 5), the province with the largest cumulative afforestation area completed by the projects was Inner Mongolia in North China, followed by Hebei and Shanxi in North China and Shaanxi and Sichuan in Western region, followed by most of the central and western provinces and the southeast coastal provinces and Tibet with the least cumulative afforestation area.

Figure 5
Spatial distribution of cumulative afforestation area of key ecological projects in China during 1998–2018



Notes: 1 10^4 hm^2 is equal to 10 thousand hm^2

4) Basic characteristics. The *State Forestry Administration* as a sub-ministerial institution directly under *the State Council* had been in existence for 20 years but had not been restored to a ministerial institution. However, its main responsibility had been changed to focus on ecological construction. From the perspective of its secondary units, *the Forest Industry Department* has been abolished, and *the Wetland Office*, *the Desertification Control Office*, *the Natural Forest Protection Office,* and *the Farmland Restoration Office* had been added. In the past 20 years, the design of laws, regulations, policies, and investment guarantee were mainly carried out around ecological construction.
5) Target effect. According to the results of the Ninth National Forest Resources Inventory (2014–2018) [24], China's forest area was 220 million ha, accounting for 5.5% of the world's forest area, ranking fifth after Russia, Brazil, Canada, and the United States; the forest stock is 17.56 billion m^3, accounting for 3.34% of the world's forest stock; the total biomass of forest vegetation was 18.80 billion tons, and the total carbon storage was 9.186 billion tons; the forest coverage rate was 22.96%. There was only 3% between the forest coverage rate and the long-term goal of forest coverage rate in 2050, and the stage of large-scale quantitative expansion was over. With the implementation of the key national ecological restoration projects, the ecological network could serve as a bridge to better connect human activities and biodiversity in order to support sustainable ecological restoration and planning [32]. The book "*General Introduction to China's Sustainable Development Forestry Strategy Research*" and the document "*the Decision on Accelerating Forestry Development*" were issued at the beginning of the 21st century, of which the strategic objectives of the first and second steps of China's forestry development had been achieved [31, 33].

4.1.3. The stage of high-quality development (2018–2050)

1) Faced situation. In 2017, the report of the 19th CPC National Congress pointed out that "socialism with Chinese characteristics has entered a new era" and "China's economy has shifted from a stage of rapid growth to a stage of high-quality development." In 2018, one important document "*put forward the Opinions on Promoting High-quality Development*" pointed out that promoting high-quality development will be the fundamental request for determining development ideas, formulating economic policies, and implementing macro-control in the coming period; and government should accelerate the creation and improvement of the institutional environment and coordinate the establishment of indicators, policy systems, standard systems, statistical systems, performance evaluation, and performance evaluation methods for high-quality development. It has made a top-level design for the high-quality development of China's economy and society. For the development of China's forestry and grassland, there are three strategic opportunities which include the inclusion of ecological civilization in the overall layout of national development, the entry of China into the second century of the new development stage, and the integration of forestry, grassland, and national park. The stage of large-scale expansion of forestry has ended, and it will inevitably turn to the high-quality development stage of quality priority and moderate scale.
2) Main signs. The construction of a beautiful China has been written into the Constitution. In 2018, according to the institutional reform plan of *the State Council*, the *National Forestry and Grassland Administration has been* established as a secondary bureau managed by *the Ministry of Natural Resources*, which is responsible for supervising and managing the protection and utilization of forest, grassland, wetland, desert, and terrestrial wildlife resources, organizing ecological protection and restoration, carrying out afforestation and greening work, and managing various nature reserves such as national parks. In 2019, the *National Forestry and Grass Administration* issued one document "*The Guiding Opinions on Promoting the High-quality Development of the Forestry and Grassland Industry and the Supporting Rules for the High-quality Development of the Forestry and Grassland*" which put forward the basic ideas for the high-quality development of the forestry and grassland, promoting the quality change, efficiency change, and dynamic change of the development of the forestry and grassland and striving to achieve the higher-quality, more efficient, and more sustainable development. And the document defined that the modernization of the forestry and grassland would be initially realized by 2035.
3) Evolution process. During the top-level design transformation phase (2018–2020), through deeply implementing the concept of "T*wo Mountains*" and coordinating "four ecosystems and one biodiversity," China has been promoting the coordinated development of forestry, grassland, and national parks, striving to build a natural reserve system with the national park as the main body and completing the phased tasks of six key ecological projects which has produced significant ecological, economic, and social benefits [27, 34].

The second subphase is basically realizing modernization (2021–2035). Forestry modernization includes the modernization of the forestry governance system and forestry governance capacity, which reflects the main characteristics of modern society, the development level of

modern productivity, maximizing the development of forestry functions, and meeting the diversified needs of society. Forestry modernization is also the modernization of the forestry governance system with the "five-in-one" high-quality development of the four ecosystems of forest, grassland, wetland, and desert as the main content. Forestry modernization must use modern science and technology to promote forestry, use modern information means to lead forestry, use modern material conditions to equip forestry, use the modern institutional system to manage forestry, and use modern international cooperation to promote forestry for realizing the modernization of governance system and forestry governance capacity. By implementing "*the Overall Plan for National Major Projects for the Protection and Restoration of Important Ecosystems (2021–2035)*," the forestry ecological project has entered the era of "life community" for the unified management of mountains, forests, fields, lakes, grassland, and sand systems. By 2035, China will realize forestry modernization [27, 35].

The third subphase is fully realizing the modernization stage (2035–2050). By 2050, the forest coverage rate will reach more than 26%, and the forest and grass vegetation coverage rate will reach more than 50%, which means that forestry modernization will fully realize [35]. By comprehensively realizing the modernization of the forest and grassland management system and the modernization of the forest and grassland management capacity, the modernization of the forest and grassland will become a reality.

4) Basic characteristics. In 2018, the *State Forestry Administration* was reorganized into the *National Forestry and Grassland Administration* (National Park Administration), thus realizing the unified supervision of the four natural ecosystems and various natural reserves. This is a major institutional breakthrough in China's development history and has also set a benchmark in the setting of government institutions around the world, which reflects a major change in China's ruling philosophy. It has changed from independent governance in the past to systematic governance, unified governance, and high-quality governance.
5) Target effect. In 2020, China's forestland area was 284 million ha, grassland area was 265 million ha, wetland area was 23 million ha (Office of the Third National Land Survey Leading Group of the State Council et al., 2021). By 2035, the modernization of forestry will be realized, the quality of the four major ecosystems of forest, grassland, wetland, and desert will be significantly improved, the forest coverage rate will reach about 25%, the forest and grass vegetation coverage rate will be close to 50%, the protection level of wildlife and biodiversity will be significantly improved, the natural reserve system with national parks as the main body will be completed, the forest and grass ecological products will basically meet the needs of national modernization development, and the ecological situation will be fundamentally improved. By 2050, the modernization of forestry will be fully realized. The four natural ecosystems will have a reasonable structure, optimized functions, and scientific distribution. The forest coverage rate will reach more than 26%, the forest and grass vegetation coverage rate will reach more than 50%, the wild animals and plants will be fully protected, the natural reserve system will be fully established, and the ecological, economic, and social benefits of forest and grassland will be fully developed to meet the needs of building a socialist modern country in an all-round way. Ecological conditions have achieved a virtuous cycle, and ecological civilization and beautiful China have been fully built.

4.2. Driving mechanisms of forestry development in China

4.2.1. Administrative system

The evolution of forestry development in the PRC is closely related to the national forestry administrative system. The design of the management system and its responsibilities is the organizational guarantee of forestry development and the "headquarters" of industry development, which plays the role of "central nerve." From the perspective of the national forestry administrative department, the evolution of forestry development can be roughly divided into three periods which include the stage of the *Ministry of Forestry* during 1949–1998, the stage of the *State Forestry Administration* during 1998–2018, and the stage of the *National Forestry and Grassland Administration* since 2018. This classification is consistent with the above classification which includes the stage dominated by timber production (1949–1998), the stage dominated by ecological construction (1998–2018), and the stage of high-quality development (2018–2050).

In the first stage during 1949–1998, the name of the national forestry administrative department had been changed several times. From the *Ministry of Forest Reclamation* to the *Ministry of Forestry*, the *Ministry of Forestry* and the *Ministry of Forest Industry* have been merged into the *Ministry of Forestry*, and then into the *Ministry of Agriculture and Forestry*. After the reform and opening up, the *Ministry of Forestry* had been restored. The national forestry administrative department had always been an integral part of the State Council and was the "*Ministry of Forestry*" (1951–1970 and 1979–1998, about 40 years) most of the time in the stage. During this period, the forestry department had gradually changed from the planned economic system to the socialist market economic system, and its main responsibility had shifted from timber production to ecological construction of forestry.

In the second stage during 1998–2018, the main responsibility of the *State Forestry Administration* was to protect and repair the three major ecosystems of forest, wetland, and desert, and the biodiversity protection based on wild animals and plants, which fully embodies the principle of focusing on ecological construction.

In the third stage since 2018, the *National Forestry and Grassland Administration* has realized the unified management of all four natural ecosystems and the unified supervision of nature reserves which means that it has completely ended the situation of "Jiulong Water Control" for decades and given a solid foundation for promoting high-quality development [15].

4.2.2. Laws and regulations

Laws and regulations are the institutional guarantees for forestry development. Since the founding of the PRC, China has formulated and implemented a series of forestry policies and regulations, which had an obvious impact on the evolution of forestry development. The property rights system is the basic forestry management system. Due to externalities and free-rider problems, the production efficiency of public or state-owned forests managed by the government was low [36]. The research results of a study showed that the reform of China's collective forest tenure system would distribute the use right of forest land

to individual farmers, but if the cutting quota system was not relaxed synchronously, the incentive effect of forest tenure reform would be limited [37]. In addition, the compensation standard of collective ecological public welfare forest was low, which affected the enthusiasm of forest farmers [38]. Regarding cultural factors, some studies had found that customary norms were of great significance in ensuring the security of rural forest tenures [39].

In the stage dominated by timber production (1949–1998), timber production was taken as the center of forestry work. In the early days of the PRC, China learned from the Soviet Union in an all-round way and gradually formed a set of economic management systems with centralized power of the Soviet Union. The forestry plan was basically issued from top to bottom in the form of instructions. During this period, a series of policies and regulations on timber production and afforestation, and forest protection had been issued successively. In 1950, the Government Council issued the policy document "*The Instruction on National Forestry Work*" which established the forestry construction policy that meant "universal forest protection, key afforestation, rational cutting and rational utilization." In 1953, the Government Council issued the policy document "*The Instruction on Mobilizing the Masses to Carry out Afforestation, Forest Cultivation and Forest Protection Work*." In 1961, the Central Committee of the CPC formulated the policy document "*Several Policies and Regulations on Determining Forest Tenures, Protecting Mountain Forests and Developing Forestry (Trial Draft)*." In 1978, the first large-scale forestry ecological project "the *Three North Shelterbelt System*" was launched in China. In 1979, the *National People's Congress* (NPC) passed the first major forestry law of PRC "*the Forest Law (for Trial Implementation)*" and decided that March 12 of each year would be the *National Tree-planting Festival*. In 1981, the *CPC Central Committee* and the *State Council* issued a policy document "*Decision on Several Issues Concerning the Protection of Forests and the Development of Forestry*" which focused on stabilizing forest use rights, delineating self-retained mountainous land for villagers, and formalizing both family forest management and the household responsibility system within the collectives. In 1990, the *State Council* formulated "*the Outline of the National Afforestation and Greening Plan*" and vigorously promoted the afforestation and elimination of barren mountains. In 1998, the *State Council* issued "t*he Notice on Protecting Forest Resources and Stopping Deforestation, Reclamation and Misappropriation of Forestland.*"

In the stage dominated by ecological construction (1998–2018), in 1998, the *CPC Central Committee* and the *State Council* formulated some policies for post-disaster reconstruction and put "closing mountains and planting trees and the grain for the green" in the first place and successively piloted the implementation of key forestry projects. In 2001, the national forestry key ecological projects were integrated into six key forestry projects [40]. In 2003, the CPC Central Committee and the State Council issued "the Decision on Accelerating Forestry Development," and it was clearly proposed that "in implementing the sustainable development strategy, forestry should be given an important position; in ecological construction, forestry should be given a primary position; in the development of the western region, forestry should be given a basic position" and "establish a sustainable development path of forestry based on ecological construction, establish a land ecological security system with forest vegetation as the main body and forest and grassland as the combination, and build a beautiful ecological civilization society." This was the first time that the construction of an ecological civilization had been proposed in the Central Committee of CPC document. In 2007, the *State Forestry Administration* put forward the development idea of "modern forestry," the core of which was to build a perfect forestry ecosystem, a developed forestry industrial system, and a prosperous ecological and cultural system [7]. In 2008, the *CPC Central Committee* and the *State Council* issued "*The Opinions on Comprehensively Promoting the Reform of the Collective Forest Tenure System.*" The second round of forest reforms has motivated the enthusiasm of farmers and enterprises and attracted private investment in forestry, which has partly promoted the growth of forest area and inventory. In 2015, the *Central Committee of CPC* and the *State Council* issued "*The Opinions on Accelerating the Construction of Ecological Civilization*," "*the Overall Plan for the Reform of the Ecological Civilization System*," "*the Guiding Opinions on the Reform of State-owned Forest Areas*," and "*the Reform Plan of State-owned Forest Farm*" which made the top-level design for the construction of ecological civilization.

At the stage of high-quality development (2018–2050), in 2018, "*the National Forestry and Grassland Administration*" (NFGA) was established in accordance with a document of the Central Committee of CPC, and the NFGA is also known as National Park Administration. In 2019, the Office of *the Central Committee of CPC* and the *State Council* issued "*The Natural Forest Protection and Restoration System Plan*" and "*The Guiding Opinions on the Establishment of a Natural Reserve System with National Parks as the Main Body*"; the NPC issued the newly revised "Forest Law" to promote the high-quality development of forest and grassland. In 2021, the Office of the *Central Committee of CPC* and the *State Council* issued "T*he Opinions on the Comprehensive Implementation of the Forest Chief System*" and "*The Opinions on the Establishment and Improvement of the Value Realization Mechanism of Ecological Products*" which was to establish and improve the organizational guarantee policy, the value realization mechanism of ecological products, and the technical policy system for high-quality development of forestry and strive to explore a new way for high-quality development of forestry [39, 9]. In 2022, China's first special law on wetland protection "*the Law of the People's Republic of China on Wetland Protection*" was formally implemented, and the National Park Law (Draft) would be formulated as soon as possible, which would provide a solid foundation for establishing a national park system with Chinese characteristics, maintaining the authenticity and integrity of the natural ecosystem, and building a new pattern of territorial space protection.

4.2.3. Investment

Investment is the material basis of forestry development. Forestry is characterized by natural weakness and is faced with dual pressures of natural risk and market risk. Forestry construction is an industry with a large investment scale, a long recovery cycle, and high uncertainty. It is difficult to maintain the project progress without financial support for any forestry construction project, and it is difficult to continue to promote the project progress without the continuous investment of funds. How to obtain funds, how to use funds, and how to improve the efficiency of the use of funds have become important issues for forestry producers and operators to consider. With the continuous input of large-scale funds, the change in national forest resources showed a fundamental improvement [41].

Since the founding of the PRC, the national forestry investment has increased year by year, from 10 million yuan in 1950 to more than

400 billion yuan in 2020. The total amount completed over the years was about 5 trillion yuan, of which the national investment was 2.4 trillion yuan, accounting for about 1/2 of the total investment [22, 24, 26, 27] (Figures 6 and 7).

Figure 6
Change of forestry investment in China during 1950–2020

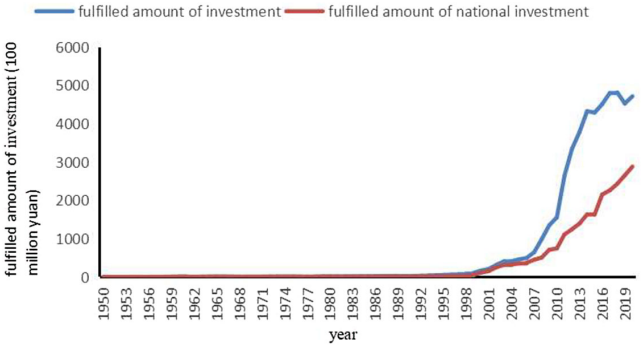
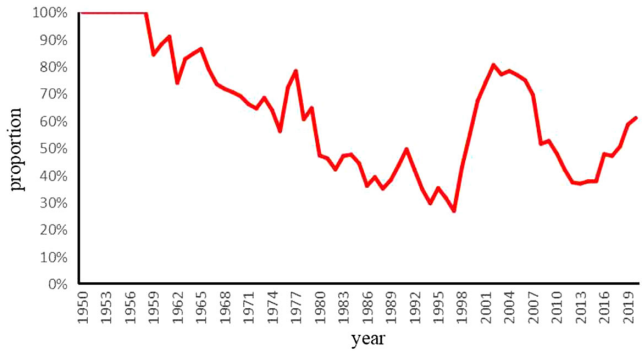
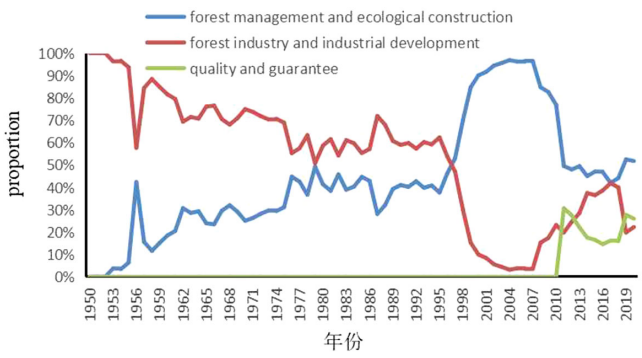


Figure 7
Change in the proportion of national forestry investment in China during 1950–2020



It could be seen from Figure 8 that the evolution of investment structure in China's forestry development over the past 70 years has obvious regularity. The proportion of "investment in the forest industry and industrial development" had gradually decreased from 100% in 1950 to more than 60% in 1996; the proportion of

Figure 8
Change of forestry investment structure in China during 1950–2020



investment in "forest management and ecological construction" increased year by year from 0 in 1950 to less than 40% in 1996. In 1997, two types of investment proportion curves formed an intersection, and their proportions were exchanged and changed sharply. Previously, it supported the strategy of focusing on timber production and then supported the strategy of focusing on ecological construction. In 2011, a new investment in "quality and guarantee" was added, and the proportion of the three was gradually approaching. After several years of adjustment, the investment in "quality and guarantee" increased year by year after 2018. In 2019, the proportion exceeded the investment in "forest industry and industry," effectively supporting the high-quality development of forestry. High demand for timber and environmental services has caused a rapid growth of government spending in forest conservation, afforestation, and reforestation [42].

4.2.4. Science and technology

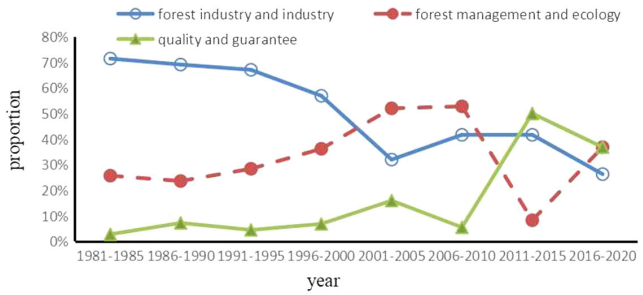
In 1988, the national leader Deng Xiaoping put forward an important assertion "*Science and Technology Constitute A Primary Productive Force*" which has got the recognition of the Chinese people. Since the founding of the PRC, China has continuously strengthened its scientific and technological support for forestry development. The driving effect of science and technology on forestry development was mainly reflected in the following aspects. First, scientific and technological innovation played a fundamental role in promoting forestry development. With the further development of economic globalization, many countries had taken measures such as increasing investment, reforming the system, and organizing major scientific and technological actions to accelerate the progress and innovation of forestry science and technology, especially the breeding technology and forestry machinery had continuously made major breakthroughs and rapidly industrialized, and the application of remote sensing monitoring, big data analysis, artificial intelligence, and other high-tech in forestry had become more and more widespread. Second, science and technology could improve the comprehensive productivity of forestland and the utilization rate of forest resources, reduce the cost of forestry production, and increase the added value of forest products. Science and technology made forestry machinery and equipment more and more intelligent, which could effectively improve labor productivity, improve the utilization of resources, reduce production costs, increase the added value of forest products, and improve the market competitiveness of forest products. Third, the development of science and technology increased farmers' income and helped rural revitalization. Science and technology could effectively improve the productivity of forestland and ensure national wood security and grain and oil security.

During 1949–1998, the research on forest aerial survey, mechanization of forest cutting and renewal, wood measuring technology, aviation forest protection, forest chemical technology, wood preservative technology, tree classification and physiological and biochemical, forest breeding and forest cultivation, construction of protective forest system and ecological positioning monitoring, forest fire prevention and pest control, forest chemical processing technology, etc., were carried out successively in key forest areas, which provided technical support for forestry development at the stage dominated by timber production. From 1998 to 2018, the research on key technologies of forestry ecological engineering construction, desertification prevention and control, protection and restoration technologies of rare and endangered wild animals and plants, carbon sink afforestation and forest management methodology, land ecosystem positioning observation, breeding,

and cultivation of main afforestation species, forest chemical industry, and other aspects were carried out successively, which provided scientific and technological support for forestry development at the stage dominated by ecological construction. Since 2018, it has mainly carried out research on the breeding of new varieties of high-yield, high-efficiency, and high-resistance forest and grass, key technologies for precise improvement of forest quality, technologies for improving the quality and efficiency of woody grain and oil such as *camellia oleifera*, advanced forestry machinery and equipment manufacturing, refined processing and manufacturing of timber and bamboo, forest lightning fire prevention and control technology, efficient control technology of major exotic pests such as pine wood nematode disease, etc., which provided technical support for high-quality development of forestry.

It could be seen from Figure 9 (according to the statistics of the five-year planning period) that lots of advanced scientific and technological achievements had been produced to meet the needs of forestry development at different stages. Since the establishment of the *National Science and Technology Achievement Award* in the early stage of reform and opening up, the evolution of the number of award-winning achievements in forest industry and industry, forest management and ecology, and quality and security had obvious regularity. During 1982–2000 (mainly in the stage dominated by timber production), the number of award-winning scientific and technological achievements in "forest industry and industry" accounted for more than 55%, the proportion of award-winning achievements in "forest management and ecology" was less than 37%, and the proportion of "quality and guarantee" awards was less than 7%; during 2001–2015 (mainly in the stage dominated by ecological construction), the proportion of "forest management and ecology" awards first rose to the first place, and then there was a significant decline in "forest management and ecology"; during 2016–2020 (mainly in the stage of high-quality development), the proportion of "quality and guarantee " awards rose to the first place, followed by "forest management and ecology," and "forest industry and industry" rapidly dropped to the lowest. It could be seen that science and technology were the sources of vitality for forestry development.

Figure 9
Structural change of award-winning achievements of China national science and technology in forestry



5. Summary and Discussion

5.1. Summary

The key results of this study include two parts as below.

1) The evolution of China's forestry development showed obvious phased characteristics: from 1949 to 2050, the evolution of China's forestry development can be divided into three major stages and nine substages. This specifically refers to: 1) the stage dominated by timber production (1949–1998) also divided into three subphases which included the timer production phase (1949–1956), the timber and afforestation phase (1956–1978), and the timber and ecological construction phase (1978–1998); 2) the stage dominated by ecological construction (1998–2018), which could be divided into three subphases which included the transition phase at the turn of the century (1998–2002), the phase which ecological construction was officially recognized as the main tasks (2003–2012) and the phase which promoted to the stage of ecological civilization construction (2013–2018); 3) the stage of high-quality development (2018–2050) which could be divided into three substages which include the top-level design transformation phase (2018–2020), the second subphase is the phase of basically realizing modernization (2021–2035), and the third subphase is fully realizing the modernization stage (2035–2050).
2) The four driving mechanisms including the administrative system, laws and policies, investment, and science and technology are the main mechanisms driving the spatio-temporal evolution of forestry development in New China for 100 years. Among them, the administrative system is the organizational guarantee for the forestry development; the laws and policies are the institutional guarantees; the investment provides the material basis for the forestry development; science and technology are the sources of vitality for the development of forestry.

5.2. Discussion

The forest area and inventory have increased greatly in the last few decades in China. Zhang [42] regarded the main reasons for the phenomenon included government investment, market and police reform, tax reduction, and government subsidy, increasing productivity, urbanization, and development of forest science and technology. The view was consistent with the above four driving mechanisms.

How to deal with the relationship between timber production and ecological construction is an important issue in the history of forestry development in China. According to the relationship, the development evolution of China's forestry can be divided into three major stages. During both the stages dominated by timber production and the stage dominated by ecological construction in China, the relationship between timber production and ecological construction was not handled well. The stage dominated by timber production paid too much attention to timber production, and the stage dominated by ecological construction paid too much attention to ecological construction. In other words, the relationship between the two was conflict or substitution relationship. During the stage of high-quality development, the relationship of one ebb and flow would be got out, and the coupling relationship would be really formed. In other words, the relationship between the two would present a virtuous circle. During the third stage, forestry not only provides enough ecological and social benefits but also creates lots of economic benefits with timber production.

During the third stage, forestry modernization is the top priority in China. Forestry will provide forest regulation services and create miracles in increasing carbon sinks; it will provide forest products and services and create miracles in the development of forestry industries; it will play the social and cultural functions of forests and create miracles in terms of employment and tourism; it will provide forest public goods and services and create miracles in terms of achieving sustainable

development goals [1]. Fully understand the ecological value of forests and realize the value of forest ecological benefits through the market mechanism. Build the market including a mature regulation mechanism, good supervision mechanism, and active participants, which encourage foresters to pursue economic value and realize the value of ecological products [10].

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Ethical Statement

This study does not contain any studies with human or animal subjects performed by any of the authors.

Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

Data Availability Statement

Data available on request from the corresponding author upon reasonable request.

Author Contribution Statement

Shidong Li: Conceptualization, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Visualization, Project administration. **Youliang Ning:** Conceptualization, Methodology, Software, Data Curation, Writing – original draft, Writing – review & editing, Supervision, Project administration, Funding acquisition.

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