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REVIEW ARTICLE

Advances in forest transition theory research

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ABSTRACT

Forest transition is a trend change process from decreasing to increasing forest area in a country or region. Since the 1990s, ecological and environmental problems such as climate change and loss of biodiversity have received constant attention. The research theory and method of forest transformation has gradually become the frontier and hot topic pursued by international academic circle. With forest transformation as the theme, on the basis of introducing the origin of forest transformation research, along the development vein and internal logic of forest transformation research, this paper reviews the research progress of forest transition theory from the perspectives of Kuznets curve of forest environment and forest transition path, and summarizes the major issues in forest transformation research. The main direction of future research is proposed, including the impact of economic globalization on forest transition, the refinement of research units and the analysis of forest quality transition.

Keywords: Forest Transformation; Forest Area; Deforestation; Forest Restoration

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1. Introduction

The concept of forest transformation was first developed by Finnish geographers and historians A.S. Mather in 1992. Forest transformation, that is, the trend process of forest area of a country or region change from decreasing to increasing. On a global scale, the forest area has tended to decline in the last 20 years mostly in the Latin American, Caribbean region and Africa. Among them, Latin America and the Caribbean suffered the most net forest loss. The trend of deforestation in other areas has been curbed to varying degrees, and the forest area remains stable or growing.

Most of the existing forest transformation studies are carried out at the national level. Scotland was the first place where the forest transition took place. The transformation took place around the 1750s. At the time of transition, forest cover was 3%. France's forest area continued to decline until the 1830s. Until the forest cover drops to about 15% and stabilizes. From then, forest area began to grow continuously. The Irish forest transformation took place in 1920s. The forest coverage rate at the transition point was about 2%. The Danish's forest coverage rate was 4% at the time of forest transition. Forest transformation in the United States took place at the beginning of the 20th century' where forest coverage was around 27% at the time of the transition. Further research has plotted the timing of the transition in each state. The transformation of the eastern region is earlier, and the transformation of

the western region is later. The time span is from 1907 to 2002. Korea's forest transition point has a high forest coverage rate of about 55%. Its forest transformation took place in the 1960s and 1970s. Forest transformation in Costa Rica took place in the end of the 20th century where the forest coverage at the transition point is 30%. In addition, China, India, Vietnam and other developing countries have gradually realized forest transformation after the 1980s[2-6].

The forest coverage rate at the time of forest transition in each country varies greatly: Developed countries precede developing countries. The forest area has been transformed from decreasing to rising, and the rich countries in transition generally have much lower forest cover than developing countries. The previous point suggests a link between forest transformation and economic growth. The developed economies that are the first to achieve economic development and also the first to achieve the trend of deforestation has been reversed. The latter point may indicate that the political, social and economic changes in modern times make developing countries face a different environment from the historical period of forest transition in developed countries in the past, and the driving factors behind forest transition may be different.

Mather[1] discussed the realization of forest transformation on the basis of summarizing the historical trend of forest area change in some European and American developed countries has opened the exploration process of forest transformation research. Later, the mechanism of forest transition and the trend of forest area change dynamic factors, theories and methods of forest transformation are developing rapid. The driving forces of forest transformation may vary in different countries and regions, and at different stages of economic development in a country or region, the same factor may play a different role. Existing research literature[7-10] believes that the factors that explain forest transition include: agricultural concentration, the price of wood and other forest products, policy intervention and system development, urban and rural labor transfer, and the change in the value concept of forest resources.

According to the basic context and logical relationship of forest transition literature development, this paper combs the theoretical changes and internal logic of forest transition research, and summarizes the mechanism of forest transition and the main problems in forest transition research. In view of the lack of research on forest transition in China, this paper aims to promote the development of research on forest transition in China, especially to enhance domestic and international academic discussion based on the empirical rules of forest transition in China.

2. Forest transition based on environmental Kuznets curve

Developed countries realize forest transition earlier than developing countries, suggesting that there may be a certain correlation between economic growth and forest transition. Forest transition describes the trend change process of forest area decreasing first and then rising over time, while the environmental Kuznets curve shows the trend change process of environmental conditions deteriorating first and then improving with economic growth[11]. Considering the environmental attribute of the forest, and the synchronization of economic growing with time of in most countries and regions in the world, is there a forest environmental Kuznets' curve (hereinafter referred to as the forest Kuznets curve), that is, with economic growth, forest area first decline and then rise, economic growth will eventually lead to an increase in forest area?

In the early stage of forest transition research, a large number of documents discussed the relationship between forest area change and economic growth, but no consensus was reached. Most of these studies use multiple country data across time (the main source of forest area change data is form the World Food and Agriculture Organization (FAO), taking the rate of forest area reduction as the dependent variable and the primary and quadratic terms of GDP per capita as the core independent variables. If the primary term coefficient of GDP per capita is positive and the quadratic term coefficient is negative, the forest Kuznets curve is considered to exist. However, with the differences in research period and model setting, researchers have drawn different research conclusions in different

regions[12]. Some studies have shown that the inverted U–shaped forest Kuznets curve exists in Latin America and Africa, but does not exist in Asia[13-15]. Some studies also believe that there is an inverted U–shaped forest Kuznets curve in Asia and Latin America, but not in Africa[16]. Mather *et al.*[7] and Bhattarai *et al.*[13] further discussed forest area loss association between low rate and GDP per capita cubic term, that is to verify whether there is an S–shaped curve relationship between forest area and economic growth. In the early stage, the measurement methods used by Forest Kuznets curve Research Institute were mainly ordinary least square method[17-19], then panel data model[20,21], and feasible generalized least square method[13].

As the research data used by researchers are mostly multinational panel data, the definition of relevant concepts and statistical caliber of data will greatly affect the robustness and consistency of research conclusions. For example, as FAO, the international agency is responsible for compiling data on each country's forest area. In order to overcome the shortcomings of incomplete forest data for some countries and regions, the 1990 Global Forest Resources Assessment was prepared on the basis of population growth projections[22,23]. This means that the FAO data for at least some years are not suitable for analyzing forest transitions between countries using demographic factors as explanatory variables. The quality of data may be an important reason for the contradiction of research conclusions, which needs to be paid attention to in the future research.

Some scholars have discussed the forest Kuznets curve in China. Zhang *et al.*[24] used official statistics of China from 1990 to 2001. The relationship between economic growth and forest area change was studied at the national, regional and provincial levels respectively. Economic growth was the most important factor affecting the change of forest area in China, and China as a whole was in the later stage of inverted U–shaped forest Kuznets curve. However, Zhang *et al.* only considered the linear empirical relationship between the primary term of GDP per capita and economic growth, without considering the influence of the secondary term of GDP per capita. Wang *et al.*[25] made further expansion on the basis of Zhang *et al.* took 1984–2003 as the research interval, introduced the quadratic term of GDP per capita, and found that there was a non–linear relationship between economic growth and GDP per capita, but the research did not support the existence of inverted U–shaped forest Kuznets curve. Liu *et al.*[26] constructed a panel data set of China's forest area and socio–economic variables, and proved the existence of the forest Kuznets curve in China on the basis of controlling the influence of China's forestry system. In addition, Xu[27] compared and verified the relationship between forest area, forest stock and economic growth and they came to the conclusion that there is no forest Kuznets curve in China. Wang[28] added poverty reduction into the study and revised the analysis of forest Kuznets curve based on forest environmental attributes on the basis of considering the contribution of forests to development.

In conclusion, the forest Kuznets curve is not an empirical law, even if the study on the same site, the conclusion will be affected by the study period and research methods. On the one hand, the change of forest area is the result of political, social, economic and cultural factors and economic growth is probably one of the most important factors, but not the only one; on the other hand, forests have not only environmental attributes, but also development attributes. Forests not only provide environmental services, but also play an important role in livelihood, industrial development, and national economic development strategies. The analysis of forest Kuznets curve mainly considers the environmental properties of forest.

3. Forest transformation pathway analysis

In different countries or regions and different periods, the factors that affect the change of forest area are often different. Even the same factors have different effects in different countries or regions, and in different historical periods in the same country or region. In the case that forest Kuznets curve could not provide a scientific explanation for forest transition. Researchers began to analyze the driving factors behind forest transition from a broader perspective, analyze the mechanism of each driving

force on forest transition, and develop the theory of forest transition path. Among them, Rudel *et al.*[5] and Lambin *et al.*[29] made the most outstanding contribution to the formation of this theory.

3.1 Forest scarcity path

In some countries, the scarcity of forest products or ecological services provided by forests will prompt the government or forestry departments to implement effective afforestation plans, that is, in response to the negative impact of forest area reduction. It will lead to policy and economic changes in the forestry sector and promote the growth of forest resources[5]. For example, in the 19th century in Europe, especially in the Alps, frequent floods caused by forest destruction in important watersheds forced the recovery and growth of forest resources in the region[30]. In India, the continuous decrease of forest area increases the price of forest products, which in turn promotes the investment in forestry and the growth of forest area[8]. A series of afforestation and ecological restoration projects implemented by the Chinese government to improve the ecological environment are an important driving force for the growth of China's forest area[9,31].

3.2 National forest policy path

The adjustment of forest policies in some countries has played an important role in the transformation of their forests. In addition to the implementation of forest restoration policy caused by forest scarcity, the national forest policy path also includes the adjustment of national land use policy caused by some factors other than the forestry sector, which objectively promotes the restoration and protection of forest resources in the country. Such as policies to modernize the country's economy and land use, and to unite minorities in remote areas of ethnic groups, policies to promote tourism and attract foreign investment through enhancing national image[29] and so on. Bhutan's forest transition occurred during a period of high forest coverage, which increased from 60% in 1990 to 68% in 2005[10]. Bhutan pursues the development model of ecological-centered rather than economic-centered. And environmental protection and sustainable utilization is one of the key goals of Bhutan's development[29]. *The Forest and Nature Protection Act* issued in 1995 established the principles of sustainable forest management, biodiversity conservation and social forestry in Bhutan in legal form[32]. The Bhutanese culture of harmony with nature is reflected in policy implementation, which has contributed to sustainable forest management and forest area growth in Bhutan.

3.3 Economic development path

Economic growth can create non–agricultural employment opportunities and transfer labor force from the primary industry to the second and third industries, and from the countryside to the city. It can reduce the labor force attached to the land, and the pressure on forest resources and promote the recovery of forests[5]. Increased investment in the manufacturing sector has boosted urban wages and reduced the rural workforce. Therefore, in the path of economic development, it is the scarcity of labor rather than the scarcity of forest products or forest services that leads to the recovery of forest resources[29]. In addition, technological progress triggered by economic development may also have a positive impact on forest transformation. For example, the application of agricultural technologies with higher productivity can obtain higher agricultural output with less land, reduce the demand for cultivated land, facilitate the withdrawal of cultivated land with low productivity, and provide conditions for the recovery of forest resources[9]. Conversion from traditional energy sources (fuelwood) to modern energy technologies (electricity, liquefied gas, etc.) will also have a positive impact on forest transformation[29]. Nagendra[33] discussed the positive impact of the application of new technologies on reducing the pressure on forest resources on the change of forest area in Nepal.

3.4 The path of globalization

Compared with the European and North American countries that achieved forest transition in history, the management and change of forest resources in developing countries are deeply influenced by globalization. The increasingly integrated goods, labor and capital markets are the most important international economic environments facing

all countries today. Studies on the impact of globalization on forest transformation mainly focus on agricultural and forestry product trade[34], foreign remittance[35], immigration[36], foreign direct investment in primary industry[37,38], neoliberal economic reform and global diffusion of environmental protection concepts[39]. Under the influence of globalization, the destination of population mobility has expanded from the domestic cities to the economically developed foreign countries, and the labor force pursuing high income can remit money from abroad to its backward rural hometown, thus reducing the pressure of livelihood on local land and resources. The development of global tourism also contributes to the spread of ecological protection concepts[34]. Spillover effect is one of the focuses of research, that is, a country or region can transfer its pressure on forest resource development to other countries or regions through immigration or trade of agricultural and forestry products, so as to realize the protection and recovery of its own forest resources[40-42]. For example, during 1987–2006, 39% of Vietnam's forest area recovery was achieved through imports of agricultural and forestry products[43]. The existence of spillover benefits makes it necessary to evaluate the ecological effects of forest transformation in a country with a more cautious attitude.

3.5 Intensification of peasant household land use

In areas dominated by smallholder farmers, the increase in forest coverage may be associated with the expansion of orchards, patches of woodland, agroforestry systems, gardens, hedgerows, and secondary forests on abandoned land[35]. This staggered land use pattern has existed for thousands of years, often formed and maintained at the edges of forests. The ecosystem is multi–functional, connecting the natural forest and the plantation ecosystem[44]. Farmers' motivation may be to reduce their vulnerability to economic and ecological shocks and to maintain their livelihoods by diversifying their ecological and economic sources. This land use intensive approach requires a high level of labor input and traditional environmental management knowledge, which is of great value in protecting native tree species and maintaining biodiversity, but the formed ecosystem value is easy to be ignored in forest resource statistics[34]. Mather *et al.*[4], based on the experience of European national forest transformation, proposed a theoretical explanation for forest transition from the perspective of long–term land use adjustment. It meant that agricultural production will constantly adjust to land quality, farmers and will gradually concentrate their agricultural production on better quality plot through a learning process, even in the absence of technological progress, it is possible to produce equal or even greater yields from less land area, and more poor land can be slowly removed from agricultural production, which can be used for natural regeneration of forests or afforestation.

4. Conclusion and prospect

The concept of forest transformation has only been put forward for more than 20 years, and its theory is still under development. The forest transition theory is mostly based on the experience of developed countries. However, nowadays, developing countries are facing different social, economic and political backgrounds from developed countries in realizing the transition in history. Therefore, more studies on developing countries are needed to supplement the forest transition theory. It is found in this paper that forest transition studies based on environmental Kuznets curve are mostly based on transnational panel data, and the quality and consistency of data need to be paid attention to. In addition, there is still a lack of theoretical innovation on the dual attributes of forest environment and development in this field. In the study of forest transition path, researchers have concluded different forest transition path theories based on the practical development experience of various countries, but the logic and scientific interpretation of the theories need to be improved through further research. Following the development trajectory of forest transformation theory, this paper proposes the following three research directions.

One is the impact of globalization on forest transformation. Existing studies mainly study the impact of globalization on forest transition from the perspective of trade in agricultural and forestry

products. However, trade in agricultural and forestry products is only the tip of the iceberg in the process of globalization, and the existing studies have not clearly and profoundly demonstrated the mechanism of globalization on forest transition. Therefore, future studies can try to combine globalization with economic and social changes such as economic restructuring and labor mobility in developing countries, and explore the internal correlation and mechanism between globalization and forest transformation.

Second, in terms of research units, previous studies mostly took the country as the research unit, and research at sub–national levels such as province, county and village need to be further strengthened. National studies mostly use macro social economic statistics and use statistical and econometric methods to explore the important variables affecting the forest transformation process. However, it is difficult to reveal the internal correlation between variables in macro social economic data. The study on forest transition at the meso and micro-levels can make up for this deficiency, and help to reveal the action mode and micro mechanism of various factors on forest transition, so as to have a deeper understanding of the relationship between variables.

The third is the extension of forest transition research to forest quality analysis. Forest transition studies used to focus on the process of forest area change, and it will be of great significance if forest quality analysis can be included in future studies. Forest quality determines the performance of forest ecological functions. The transformation of forest quality and forest quantity into a unified analysis framework for comparative study can reveal the similarities and differences of driving factors of forest area and forest quality change, and better grasp the law of forest resources change.

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Conflict of interest

The authors declare that they have no conflict of interest.

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