

Green and Low-Carbon Rural Development in China

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Green and low-carbon rural development (GLRD) is becoming an important way to explore sustainable development in rural areas of China. It is significant for the sustainable development of the rural economy and of society to build a rural carbon sink system, advocate low-carbon emissions in rural areas, and promote the development of rural green industries and rural transformation.

Keywords: green and low-carbon ; rural area ; content systems ; China

1. Introduction

Research on GLRD has experienced low-carbon, green, and green–low-carbon integrated development research stages. Thus, three research content systems were formed (**Figure 1**). There is no obvious chronological order between low-carbon and green development research. These two research types both have green development and low-carbon development of agriculture as their main foci, with certain intersections in independent systems. However, with the introduction of various green and low-carbon policies in rural areas, the integration trend of the two major studies is significant.

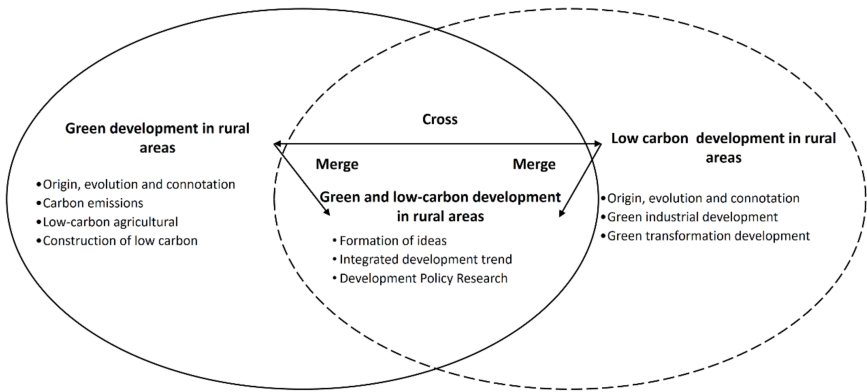


Figure 1. Research content systems of green and low-carbon rural development.

2. Research on Rural Low-Carbon Development

2.1. Origin, Evolution, and Connotation of Rural Low-Carbon Development

The development of the “low-carbon” concept spawned from the 2003 UK Energy White Paper “the future of our energy—creating a low carbon economy”. It became popular worldwide after being used by the World Bank in 2006. A low-carbon economy with low energy consumption, low material consumption, low emissions, and low pollution is the new option for economic development in the 21st century [1]. It has led to the development of low-carbon cities, industries, buildings, and other fields. Rural low-carbon development includes low-carbon agricultural development, low-carbon rural living environment, low-carbon tourism development, and other content systems. Among them, low-carbon agricultural development is the most important component, which has the core goal of using agroecosystems to mitigate and adapt to climate change [2]. The specific pathways of rural low-carbon development includes reducing energy consumption, pollution, and emissions as well as increasing carbon sinks [3].

2.2. Research on Rural Carbon Emissions

The research objects of rural carbon emissions mainly include agricultural and rural living environment carbon emission research. Main rural carbon emission sources include agricultural and residential living systems. The former mainly

includes the energy consumption of agricultural machinery and the use of chemical fertilizers and pesticides, whereas the latter involves project construction processes, construction operation and management of its energy consumption, and transportation and its energy consumption ^[4]. Rural heating energy consumption is also significant ^[5]. Currently, the accounting method for agricultural carbon emissions mainly adopts the inventory preparation method, carbon emission coefficients, the LMDI method, and the Environmental Kuznets Curve (EKC) ^[6]. In addition, carbon emission measurement includes not only large-scale regional carbon emission research from national to interprovincial levels and from provincial to municipal levels, but also small-scale carbon emission research within specific spaces, such as residential communities and rural settlements. Due to the huge differences in production conditions and resource endowment, agricultural economic development levels, agricultural structures, and agricultural production modes vary greatly among cities ^[7]. This leads to significant differences in the spatial and temporal distribution of agricultural carbon emissions. Reducing rural carbon emissions mainly includes strengthening rural ecosystem carbon sinks and reducing agricultural carbon emissions. Studies of carbon sinks in ecosystems (such as forests, wetlands, and farmland) have been the focus of research in recent years, e.g., forest ecosystem carbon revenue and expenditure as well as the regional distribution and reserve changes of soil-organic carbon ^{[8][9]}. The emission reduction ideas and specific suggestions to drive green agricultural transformation with low carbon include increasing carbon constraint indicators in combination with agricultural and rural development planning, accelerating the construction of agricultural carbon emission accounting methodology, actively developing agricultural carbon markets, and using financial measures to promote low-carbon agricultural technologies ^[10].

2.3. Research on Rural Low-Carbon Agricultural Development

Low-carbon agriculture is modern agriculture with “low consumption, low emission, and low pollution”. It meets the objective requirements of controlling agricultural greenhouse gas emissions and slowing down global warming ^[11]. The low-carbon agricultural economy is developing into a new mode and concept that affects the “low-carbon” of China’s agricultural industry chain ^[12]. However, it also faces some problems, such as low agricultural modernization level, difficulties in large-scale land production, weak agricultural infrastructure, lack of scientific and technological innovation capabilities, and extensive agricultural production modes ^{[13][14]}. The research content involves research on the transformation pathways of promoting low-carbon agricultural development ^[15], low-carbon agricultural development modes under different rural regional types, and low-carbon innovation of agricultural enterprises. The development pathways of low-carbon agriculture include transforming agricultural development modes, promoting agricultural energy conservation and emission reduction technologies, reducing agricultural non-point source pollution, and improving rural energy utilization efficiency ^[16]. The main factors affecting low-carbon innovation of agricultural enterprises include low-carbon innovation cost, the increase of low-carbon innovation revenue, and governmental regulation ^[17].

2.4. Research on Rural Low-Carbon Construction

Under the wave of low-carbon town construction, research on low-carbon rural development (e.g., low-carbon rural construction, tourism development, rural planning, communities, industry and energy-carbon residential development and design) is gradually emerging. The pathways of low-carbon rural construction mainly include expanding rural carbon sinks and reducing rural carbon sources. Low-carbon rural tourism advocates low-carbon consumption, reduces resource consumption, and pays attention to low-carbon rural landscape construction ^[18]. Low-carbon-friendly town construction methods include advanced road transportation systems, water environment ecosystems, green building energy systems, and resource utilization ^[19]. The research on the rural low-carbon community includes evaluating the degree of low-carbon reformations by constructing the index system for planning and layout ^[20], road and transportation, residential design, and environmental engineering. Low-carbon energy reform leads to the development of rural low-carbon industry ^[21]. Research on rural low-carbon residential technologies in different climatic areas is in-depth, such as research on key technology systems of rural low-carbon construction in cold winters and hot summers ^[22] as well as research on the technology systems and implementation pathways of rural distributed photovoltaics in areas with rich solar energy resources ^[23]. In addition, farmers’ low-carbon production decisions directly affect the carbon emission reduction and sustainable development of agriculture ^[24]. Research shows that farmers’ willingness to participate in low-carbon agriculture is often affected by income levels and the technical difficulties of agricultural production ^[25].

3. Research on Rural Green Development

3.1. Origin, Evolution, and Connotation of Rural Green Development

In August 2005, Comrade Xi Jinping first proposed the “two-mountain theory” during his visit to Yucun in Anji County, Zhejiang Province, advocating the green transformation of traditional economic development modes. The 2018 Central

Rural Work Conference introduced the road to green development in rural areas. Rural green development has a relatively complete conceptual connotation and theoretical framework. Its scientific connotation lies in achieving sustainable resource use, green agricultural development, urban–rural relationship coordination, rural living environment reconstruction, and local complexes [26]. As an important component of rural green development, sustainable green agricultural development has far-reaching significance [27]. Green agricultural development is a mode relative to the cost of excessive consumption and environmental damage [28]. It takes resource environment carrying capacity, resource utilization efficiency, and ecological conservation as fundamental requirements, environmental friendliness as an intrinsic property, and green product supply as the important goal [29]. Based on the system deconstruction and construction perspective, agricultural green development systems include three subsystems (i.e., agricultural production, agricultural ecology, and social and economic systems), as well as coordination, correlation coupling, ecological threshold, and sustainable development theory support systems [29]. In addition, the theoretical research of rural green development has high permeability and guidance. The organic combination of rural green development and rural poverty governance forms the green poverty reduction theory [30].

3.2. Research on Green Development of Rural Industry

First, research on green agriculture development modes, industrial clusters, innovation and entrepreneurship, agricultural green transformation and development, and agricultural green development measurement have emerged [31][32][33]. Second, agricultural green development research focuses on rural industries' green development, mainly including green development measurement, agricultural green production efficiency, constraint factors, development countermeasures, and realization pathways. The findings of the evaluation of agricultural green development levels in Chinese provinces show that China's agricultural green development levels vary greatly. The growth of agricultural output value in eastern regions is significantly higher than that of central, western, and northeast regions [33]. According to the research conclusion of the comprehensive evaluation of green agricultural development in Zhejiang Province from 2002 to 2016, the comprehensive utilization index of green agricultural resources showed a fluctuating upward trend and regular changes in different development stages [34]. The research on the implementation pathways of green development of rural industries includes large-scale operations, construction of green agricultural industry chains, and improvement of socialized service levels of green agricultural production [35]. Third, from a micro perspective, individual farmers and new business entities are chosen as the research objects to study their green production willingness and behavior-influencing factors. The research shows that general value, cost risk, government incentives, sales prospects, and environmental value are relevant factors affecting farmers' green production [36]. The transformation of green production of new business entities can be guided by cultivating a market environment, reducing endowment constraints based on economic guidance, and adhering to classified policies [37].

3.3. Research on Rural Green Transformation and Development

The research types include different regional modes (such as water towns and mountainous areas) and different location modes [38] (such as economically developed areas and suburban integration areas). The ecological mulberry-based fish pond mode in water towns is one way to promote green transformation [39]. The green development in mountainous areas has formed specific countermeasures to four systems: green livability, green industry, green support systems, and green governance [40]. The research content includes overall rural transformation, green transformation of rural micro and small enterprises and industries, and rural green infrastructure. The evaluation research of rural green development is mainly based on quantitative research, showing the increasing efficiency of rural green development in China. However, there are certain interprovincial differences: green development efficiency in economically underdeveloped areas is higher than in economically developed areas; the efficiency in coastal areas is higher than inland areas [41]. In terms of the evaluation system of rural green development, some studies have constructed the index system of rural green development in China from three dimensions: rural ecological environment quality, intensive and efficient rural production, and a healthy and livable rural living environment. The conclusion shows regional differences and spatial agglomeration characteristics in China's rural green development level [42].

4. Research on Green and Low-Carbon Integrated Rural Development

4.1. Formation of the Concept of Green and Low-Carbon Rural Development

The broad concept of green development focuses on ecology and low-carbon fields. It forms the overall concept and practice system of GLRD. In 2021, the Guiding Opinions of The State Council on Accelerating the Establishment and Improvement of the Economic System for Green, Low-Carbon, and Circular Development proposed to establish and improve an economic system for green, low-carbon, and circular development. The Law of the Promotion of the People's

Republic of China in 2021 proposed to promote the reduction of agricultural inputs, cleaner production, and industrial ecological modes to guide rural society to form green and low-carbon modes of production, life, and consumption. The introduction of various important policies, measures and construction standards, such as the Evaluation Index for Green and Low-Carbon Key Small Towns (Trial) (2011), Guidelines for Low-Carbon Community Pilot Construction (2015), and Opinions on Strengthening Green and Low-Carbon Construction in Counties (2021), marks the gradual formation of the concept of GLRD.

4.2. Research on Green–Low-Carbon Integrated Development in Rural Areas

First, “green” and “low carbon” are more integrated in terms of technical systems. Taking the study on green agriculture and green agricultural development as an example, low-carbon production conditions are important indicators of the comprehensive evaluation of green agriculture. The specific indicators include carbon emissions from agricultural production activities and material utilization, N₂O emissions caused in the crop planting process, and CH₄ emissions produced in rice fields [43]. The agricultural green development technology system includes promoting biopesticide and degradable film production technology and constructing a low-carbon circular ecological agricultural production system. Second, driving rural and agricultural green transformation using low carbon has become a possible way of reducing carbon emissions [10]. Green and low-carbon coordinated development is transforming into new urbanization [44]. Third, GLRD also has interactions. For example, excessive agricultural carbon emissions are mainly responsible for the low efficiency of agricultural ecology. Strengthening agricultural carbon emission control is an important way to improve agricultural ecological efficiency [45].

4.3. Policy Research on Green and Low-Carbon Rural Development

Foreign experience and research mainly include three directions. The first direction involves the experiences of other developed Asian countries, such as Japan's agricultural development policy of building a value chain through agricultural cooperatives and regulating greenhouse gas emissions through differentiated regional budget distribution policies [46][47]. The second is focused on the GLRD transformation experience and policies of developed agricultural countries or regions in Europe, such as the Netherlands, Germany, and Israel. Their experience includes: (1) a sustainable development mode, strict agricultural resources, and environment supervision systems (water management) and government support systems in the Netherlands [48][49]; (2) focusing on the improvement of a protection mechanism for farmers' interests in the EU Common Agricultural Policy [50]; (3) efficient use of water and soil resources embodied in the management policies, utilization efficiency priorities, efficient use of innovative resources, and public participation and publicity in Israel [51]. The third direction involves advanced management GLRD policies in the United States, such as the carbon pricing policy [52] and low-energy building verification policy [53]. Meanwhile, the United States has also formed a low-carbon agricultural policy system, including specific topics such as soil conservation and tillage, agricultural carbon energy, and agricultural carbon trading. China's rural green development policies are constantly evolving and improving [54], and they have limitations of unbalanced policy tool structures and a low coordination of policy subjects [55]. There are more policy recommendations on green and inclusive finance [56], whereas relatively few studies were conducted on land use and space control policies that address actual GLRD needs.

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