

Practical Pathways for Agricultural Green-Low-Carbon Transition Toward Common Prosperity of Farmers in Qinling's North Piedmont Region

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Abstract: Under the dual imperatives of China's 'Dual Carbon' goals and Rural Revitalization Strategy, the northern foot of Qinling Mountains, as an important ecological barrier and agricultural production area in China, faces a dichotomous paradox between ecological protection, agricultural efficiency improvement, and farmers' income increase. This study comprehensively adopts literature research, case comparison, and field survey methods to systematically identify three systemic bottlenecks hindering regional agricultural green and low-carbon transition: unbalanced tech cost structure, disconnected institutional transition, and insufficient subject capabilities. Innovatively, a "ecology-economy-society" three-dimensional synergy theoretical model is constructed, and four practical paths are proposed—green finance innovation, supply chain quality improvement, digital transformation, and industrial integration and value-added—aiming to unblock the market-oriented transformation channel of ecological value and strengthen the synergistic efficiency of multiple subjects. The research provides theoretical support and a replicable practical paradigm for ecological fragile areas in China to achieve "carbon reduction without output reduction and income increase without imbalance."

Keywords: Agricultural green and low-carbon transition; Common prosperity; Practical paths; Northern foot of Qinling Mountains

1. Introduction

The in-depth integration of the global consensus on "carbon peaking and carbon neutrality" and China's rural revitalization strategy has made agricultural green and low-carbon transition a core issue to break the shackles of traditional development models and achieve a win-win situation between ecological protection and farmers' income increase. China's new nationally determined contribution (NDC) submitted in November 2025 for the first time incorporates agriculture into the absolute emission reduction system covering the entire economy, marking the upgrade of agricultural emission reduction from a voluntary action to a mandatory requirement. This transition process

needs to simultaneously align with consumption upgrading (eating well and healthily), ecological system resilience building, and the orientation of ecological value-driven income increase, forming a development pattern of multi-dimensional goal coordination.

The northern foot of Qinling Mountains bears multiple attributes as the "Central Water Tower," "core biodiversity hotspot," and an important agricultural production area, shouldering the dual missions of ecological barrier protection and regional economic development. However, the traditional agricultural development model is characterized by significant "high-carbon lock-in": farmers' direct income from ecological protection accounts for <5% of their total income, and the income level of farmers in the grain-to-forest conversion areas is significantly lower than that of traditional farmers. The dichotomous paradox between "protecting the ecology" and "stabilizing income increase" has become a core constraint to regional high-quality development. Although a number of low-carbon demonstration bases for characteristic industries have been built in the region, and the carbon emission intensity per unit output has decreased, deep-seated problems such as high promotion costs associated with green technologies, lagging ecological compensation mechanisms, and insufficient cross-departmental collaborative governance have not been fundamentally resolved.

Based on this, this study focuses on the internal correlation between agricultural green and low-carbon transition and common prosperity, rooted in the tripartite characteristics of ecology, economy, and society in the northern foot of Qinling Mountains. It systematically sorts out the realistic foundation of the transition and the three core obstacles (technology, institution, and subject), constructs a "ecology-economy-society" three-dimensional synergy theoretical model suitable for ecological fragile areas, reveals the mechanism and transmission path of the transition promoting common prosperity, and finally proposes targeted practical paths and institutional guarantees. This study provides a scientific plan for the region to achieve "carbon reduction without output reduction, efficiency improvement without emission increase, and income increase without imbalance," and also offers replicable "Shaanxi experience" for the Yellow River Basin and even similar ecological fragile areas nationwide.

2. Literature Review and Reference to Domestic and Foreign Practical Experience

2.1 Literature Review

International academic research on agricultural green development started early, forming a pattern of parallel qualitative definition and quantitative evaluation. Qualitative research, from the perspectives of organic agriculture and ecological agriculture, clarifies that green development is a key path to achieve the coordination of environmental protection and economic growth through science and technology, which can not only ensure food security but also address climate change [1]. Quantitative research has evolved from a single green index [2] to a multi-dimensional evaluation system covering agricultural resources, environmental quality, and socio-economy [3] confirming that technology-driven agricultural green transition can simultaneously improve production efficiency and ecological benefits [4] providing basic theoretical support for agricultural development in ecologically sensitive areas.

Domestic research focuses on multiple fields closely linked to the "dual carbon" goals and the rural revitalization strategy. In the field of green finance, scholars have confirmed that diversified tools such as credit and bonds can provide capital and risk guarantees for agricultural green transition, requiring multi-subject collaborative operation [5,6]. Research on agricultural product supply chain supervision includes game theory analysis and the construction of blockchain and IoT

traceability systems, emphasizing dual constraints of technology and institutions [7,8]. Research on agricultural digitalization has verified that it can alleviate information asymmetry, reduce transaction costs, and promote the formation of agricultural economies of scale [9]. Research on green and low-carbon agriculture clarifies that its core is all-dimensional green development, and its goal is to assist rural revitalization through industrial optimization and green supply [10].

Despite the rich existing research, there are significant gaps: first, insufficient regional pertinence—lack of special research targeting the ecological-economic dual characteristics of the northern foot of Qinling Mountains, and the boosting effect of green finance has not been systematically explored; second, limited research perspective—research on agricultural product supply chain supervision mostly focuses on a single technology or subject, lacking a full-chain collaborative perspective; third, disconnection between theory and practice—research on agricultural digitalization emphasizes strategy discussion, lacking theoretical models and schemes suitable for mountainous characteristics; fourth, insufficient model innovation—existing research focuses on development level measurement and influencing factor analysis, with insufficient localized exploration of "agriculture +" integration models. Based on this, this study, rooted in the realistic characteristics of the northern foot of Qinling Mountains, focuses on the synergy mechanism between transition and common prosperity, filling the regional and perspective gaps in existing research.

2.2 Reference to Domestic and Foreign Practical Experience

Internationally, the tea industry in Shizuoka, Japan, takes "sixth industry" as the core, constructing a full-chain value system of "planting-processing-cultural tourism-derivatives." Through 521 planting standards and HACCP certification, it establishes a strict quality control system, enabling the premium rate of high-end products to reach 300% and cultural tourism income to account for 35% of the total output value. The core enlightenment lies in the in-depth value mining of industrial integration. The northern foot of Qinling Mountains can learn from this logic to promote the extension of deep processing chains for leading industries such as kiwifruit, develop high-value-added products, and integrate orchards, ecological popular science bases, and intangible cultural heritage resources to design "picking + research + experience" themed scenarios, improving the comprehensive industrial benefits. The Bordeaux wine industry in France relies on a blockchain traceability platform to realize the on-chain of 137 production data throughout the chain. Combined with real-time IoT monitoring and carbon footprint visualization labels, it reduces counterfeit wine cases by 72% and achieves a 25% premium for high-end products, providing a technical model for supply chain upgrading. The northern foot of Qinling Mountains can adopt the domestic FISCO BCOS framework to build a blockchain platform for characteristic agricultural products, focusing on the on-chain of 25 key production and ecological data, and integrating carbon footprint and ecological contribution information through "one product, one code" to strengthen market trust and premium space.

Domestically, Huzhou, Zhejiang, has innovated the "green finance + ecological agriculture" model, constructing an agricultural carbon account and Gross Ecosystem Product (GEP) accounting system. It has issued more than 500 billion yuan in green credit, driving an average annual increase of 15% in farmers' income. The core experience lies in the market-oriented transformation of ecological value. The northern foot of Qinling Mountains can pilot the "orchard carbon account" system, converting the average 0.5 tons of carbon sequestration per mu into tradable assets, developing carbon sink pledge loans with supporting financial interest subsidies, and realizing direct

compensation funds to farmers through "ecological red envelopes." JD Farm has built a digital supply chain system of "blockchain traceability + intelligent sorting + cold chain direct supply," reducing the agricultural product loss rate from 18% to 6% and achieving a 40% premium for high-end fruits, providing an adaptive solution to solve the dilemma of scattered small-scale farmers. It is feasible to promote the low-cost intelligent equipment rental model, build a two-level cold chain network of "hub warehouses + node warehouses," and optimize product grading standards based on consumer-side big data to improve supply chain efficiency and added value.

In comparison, international cases have significant advantages in full industrial chain integration and in-depth digital application, but face implementation obstacles such as scattered small-scale farmers and ecological red line constraints in the northern foot of Qinling Mountains. The "government guidance + market coordination" governance model of domestic cases is more in line with the local context, and the experiences of green finance and digital supply chains have direct reference value, but need to adapt to the reality of weak infrastructure in mountainous areas. In summary, the northern foot of Qinling Mountains should base itself on its own ecological endowments and industrial foundation, selectively absorb the standardized quality control system and scenario innovation thinking of international cases, focus on learning from the policy tool design logic and lightweight technology application paths of domestic cases, and construct an innovative and feasible transformation plan.

Table 1: Comparative Analysis of Typical Domestic and Foreign Cases.

Comparative Dimensions	Domestic Cases	International Cases	Implementation Difficulties in the Northern Foot of Qinling Mountains
Green Finance	Government-led policy innovation	Market-oriented financial tool design	Lack of authoritative institutions for agricultural carbon asset pricing
Supply Chain Quality	E-commerce platform-driven standardization	Century-old industrial cluster quality control system	Contradiction between scattered small-scale farmers and centralized brands
Digital Transformation	Rapid penetration of consumer-side digitalization	In-depth integration of production-side digitalization	Insufficient coverage of digital infrastructure in mountainous areas
Agriculture-Culture e-Tourism Integration	Rapid monetization of cultural IP	Balance between heritage protection and tourism development	Ecological red lines restrict large-scale development

3. Current Situation and Core Bottlenecks of Agricultural Green and Low-Carbon Transition in the Northern Foot of Qinling Mountains

3.1 Current Situation of Transition Development

The northern foot of Qinling Mountains has significant natural resource advantages with dual

attributes of ecological barrier and agricultural production area: vertical zonality forms 7 climate zones, with an annual average temperature range of 7.6-15.5°C and a precipitation gradient of 550-1100 mm, supporting diversified agricultural formats such as kiwifruit and alpine vegetables. The region is home to 3,829 species of higher plants and 722 species of terrestrial vertebrates, with a prominent proportion of biodiversity in the country, serving as an important ecological security barrier. However, ecological constraints are equally severe: more than 60% of the cultivated land is distributed in ecologically sensitive areas, some of which are located on steep slopes with prominent soil erosion problems; chemical fertilizer application exceeds the safety threshold, and pesticide residues and non-point source pollution pose threats to water source safety. Although projects such as the Grain for Green Program have effectively improved vegetation coverage, the ecological supervision capacity is lagging behind and law enforcement forces are insufficient, forming a contradictory pattern of "remarkable restoration effects but weak continuous management and control."

In terms of industrial structure, regional agriculture is dominated by fruit industry, supplemented by protected agriculture and Chinese medicinal materials planting. A number of low-carbon demonstration bases for characteristic industries have been built, and green formats such as photovoltaic agriculture and carbon sink development have emerged. However, there are obvious shortcomings in industrial upgrading: the proportion of primary products is high, and the processing conversion rate is much lower than the national average; the cost of green transformation of protected agriculture has increased significantly, with a long investment recovery cycle, leading to insufficient willingness of small-scale farmers to adopt technologies; the premium space for ecological products is limited, and most agricultural-related enterprises have not participated in the carbon trading market, resulting in the absence of market incentive mechanisms. Typical cases show that some industries have reduced carbon emission intensity through the application of low-carbon technologies, but problems such as post-harvest cold chain loss and high green certification costs still restrict the transition effect.

In terms of social foundation, the proportion of rural left-behind groups is high, with 73% of the population over 50 years old and low educational levels, resulting in a significant gap between the quality of the labor force and the technical needs of green transformation. The cultivation of new types of business entities shows a trend of "increasing quantity but weak quality": cooperatives have limited coverage, loose interest linkage mechanisms, and insufficient fulfillment rates of contract farming. Capital and digital support are weak: the proportion of investment in agricultural-related projects is low, the coverage rate of green financial products is insufficient, and the digital divide is prominent. Most farmers have difficulty operating agricultural IoT equipment independently, leading to a deviation between ecological protection concepts and actual participation behaviors.

3.2 Core Transition Bottlenecks

The current transition faces three systemic bottlenecks: technology, institution, and subject. Technically, the application of low-carbon technologies faces a dilemma of "high investment and low return": the initial investment of high-end technologies exceeds the affordability of farmers, with a long investment recovery cycle; supporting technologies such as post-harvest emission reduction and green certification have high costs, and insufficient technology integration limits the full-chain emission reduction effect. Institutionally, the market-oriented transformation mechanism of ecological value is fractured: the carbon sink trading price is low, and the ecological compensation

standard is insufficient to cover the protection cost; the green certification system has insufficient incentives, and cross-departmental policy coordination is inadequate. Some agricultural projects lack supporting compensation due to adjustments in ecological protection policies, increasing the uncertainty of the transition. Subjectively, small-scale farmers are trapped in a predicament of "capacity poverty - organizational failure - financing exclusion": weak human capital leads to the idleness of some intelligent equipment; cooperatives and other organizations have insufficient driving capacity; small-scale farmers face high financing costs and narrow channels, and most individual farmers still rely on traditional high-carbon production models, becoming the "last mile" obstacle to green transition.

4. Systematic Construction of the "Ecology-Economy-Society" Three-Dimensional Synergy Theoretical Model

In response to the dual core contradictions between ecological protection and agricultural development and the multi-dimensional transition bottlenecks in the northern foot of Qinling Mountains, the traditional single-dimensional development model can no longer meet the multi-dimensional collaborative demands of "carbon reduction, income increase, and inclusiveness." Relying on the cross-disciplinary empowerment of resource cycle theory, ecological value theory, and collaborative governance theory, this study innovatively constructs a "ecology-economy-society" three-dimensional synergy theoretical model. The core logic is to break the isolated operation pattern of the three systems, realize the sustainable dynamic balance of "ecological preservation, economic value-added, and social inclusiveness" through cross-border factor restructuring and institutional mechanism innovation, resolve the zero-sum game dilemma between "protecting the ecology and stabilizing income increase," and provide core theoretical support for agricultural green and low-carbon transition to empower common prosperity.

The core connotation of the model is embodied in the organic unity of "threefold synergy and two-way empowerment." First, the ecology-economy synergy constructs a two-way value-added cycle. Ecological resources are transformed into explicit economic benefits through multiple paths such as carbon sink trading, cross-regional ecological compensation, and in-depth integration of agriculture, culture, and tourism, realizing the value leap from "lucid waters and lush mountains" to "gold and silver mountains." The economic value-added benefits are directed back to the field of ecological protection through institutional feedback mechanisms, specifically for forest ecological restoration, R&D and promotion of low-carbon agricultural technologies, forming a virtuous cycle of "protection - value-added - re-protection" and resolving the core dilemma of imbalanced "input - return" in ecological protection. Second, the economy-society synergy lays a foundation for distributive justice. In the primary distribution, the "enterprise + cooperative + farmer" interest-sharing joint-stock model is promoted, supporting farmers to invest in land management rights, labor, technology, and other factors to deeply share the value-added benefits of the industrial chain. In the secondary distribution, policy tools such as financial interest subsidies and green production subsidies are used to reduce the marginal cost of green transition for small-scale farmers, and special compensation is given to farmers who adjust their production structure due to ecological protection. The tertiary distribution guides social capital to participate in ecological public welfare undertakings and establishes village-level ecological mutual assistance funds to alleviate the financing constraints and production and operation risks of small-scale farmers. Third, the ecology-society synergy achieves a symbiotic pattern of inclusive well-being and ecological

co-governance. The effectiveness of ecological governance directly overflows into the increment of people's well-being: the reduction of chemical fertilizers and pesticides ensures the quality and safety of agricultural products, and the improvement of vegetation coverage optimizes the living ecological environment. At the same time, ecological education, "field classrooms," and other immersive training carriers are used to consolidate social consensus on ecological protection. Village-level digital service stations are used to bridge the digital divide and capacity gap, promoting farmers to transform from "passive participants" in ecological protection to "active builders and direct beneficiaries," and building an ecological protection governance pattern of full participation, co-governance, and shared benefits.

5. Design of Practical Paths Based on the Three-Dimensional Synergy Model

Based on the "ecology-economy-society" three-dimensional synergy theoretical model, targeting the three core bottlenecks (technology, institution, and subject) of agricultural green and low-carbon transition in the northern foot of Qinling Mountains, and combining domestic and foreign practical experiences, four practical paths are constructed—green finance innovation, supply chain quality improvement, digital transformation, and industrial integration and value-added—to achieve the synergistic goals of ecological preservation, economic value-added, and social inclusiveness.

5.1 Green Finance Innovation Path: Unblocking the Ecology-Economy Value Transformation Channel

Focusing on the core obstacle of transforming ecological value into economic value, this path aims to solve the practical problems of difficult financing, scattered compensation, and high risks through financial tool innovation and mechanism design. Pilot the "orchard carbon account" system in major kiwifruit production areas such as Zhouzhi and Huyi, quantify agricultural carbon sequestration through digital monitoring means, convert ecological assets into tradable and pledgeable financial assets, build a characteristic carbon sink trading module in conjunction with regional environmental exchanges, and launch carbon sink pledge loan products with supporting financial interest subsidies to reduce the financing cost of small-scale farmers' transition. Promote cross-regional ecological compensation coordination, establish a horizontal compensation mechanism for water source protection and beneficiary area payment, and ensure the reasonable income of ecological protectors such as farmers in the grain-to-forest conversion areas through direct methods such as "ecological red envelopes." Construct a four-dimensional risk prevention and control system of "government + bank + insurance + cooperative," establish a green transition risk compensation fund, develop low-carbon technology application insurance, and promote the interest-sharing joint-stock model. Ensure that small-scale farmers share industrial value-added benefits through carbon sink dividends and secondary rebates, and simultaneously increase subsidies for green agricultural machinery and carbon sequestration performance rewards to reduce the threshold for adopting high-end technologies.

5.2 Supply Chain Quality Improvement Path: Strengthening the Economy-Society Synergy Efficiency

With standardized production and full-chain control as the core, this path strengthens the synergy efficiency of economy and society, and improves product premium and market competitiveness. Build a blockchain traceability platform for characteristic agricultural products based on the domestic framework, integrate data from key links such as planting, processing, cold chain, and sales, develop "one product, one code" labels integrating carbon footprint and ecological

contribution, mandate the full-chain on-chain of geographical indication products, and cooperate with financial institutions to launch traceability data pledge loans to enhance market trust. Upgrade the cold chain logistics system, build a two-level cold chain network of "hub warehouses + node warehouses," introduce intelligent pre-cooling and sorting technologies to reduce post-harvest loss and logistics costs, provide purchase subsidies for new energy refrigeration equipment, and promote the low-carbon transition of the cold chain link. Formulate local standards for green planting, unify agricultural material procurement and technology promotion through the "leading enterprise + cooperative + farmer" model, implement contract farming and minimum purchase price mechanisms, carry out green production skill certification training relying on agricultural demonstration areas, cultivate exemplary cooperatives, and improve the coverage rate of standardized production.

5.3 Digital Transformation Path: Bridging the Society-Ecology Synergy Gap

Targeting the shortcomings of weak digital infrastructure and insufficient subject capabilities in mountainous areas, this path bridges the gap between society and ecology synergy. Implement the digital infrastructure improvement project in mountainous areas, prioritize the full coverage of 5G networks in characteristic industrial demonstration bases, build supporting village-level digital service stations, and promote the low-cost IoT equipment rental model to reduce the threshold for small-scale farmers to apply digital technologies. Construct an intelligent agricultural management system, integrate satellite remote sensing, soil moisture monitoring, and UAV inspection technologies to realize intelligent management such as precise water and fertilizer regulation and pest early warning, reducing production energy consumption and costs. Launch the "digital new farmer" training program, improve farmers' digital skills such as intelligent equipment operation and e-commerce operation through "theory + practical operation" field classrooms and mentoring mechanisms, and resolve the digital divide among elderly farmers. Develop the "Qinling Agricultural Cloud" one-stop service platform, integrate functions such as production management, market connection, and financial application, and guide farmers in precise production and graded harvesting based on consumer-side big data to improve product premium space.

5.4 Industrial Integration and Value-Added Path: Achieving the Three-Dimensional Synergy Closed Loop

Through format innovation and resource integration, this path achieves a three-dimensional synergy closed loop and maximizes comprehensive industrial benefits. Learn from the experience of "sixth industry," integrate orchards, ecological popular science bases, and intangible cultural heritage resources, design "picking + research + experience" themed agricultural tourism routes, and support with carbon footprint visualization interactive systems to promote the transformation of ecological landscape resources into cultural tourism income. Implement the "joint village party committee + enterprise + farmer" model, integrate idle farm houses and collective forest land, build agricultural tourism and health complexes, and allow farmers to share asset value-added benefits through land management right investment. Promote the "livestock-biogas-fruit" circular agricultural model, build biogas projects and straw comprehensive utilization centers, convert livestock and poultry manure, straw, and other wastes into organic fertilizers and biomass fuels to replace chemical fertilizers and coal consumption, and reduce carbon emission intensity. Pilot new formats such as "shared agriculture," attract urban capital to remotely adopt orchards, realize customized supply of ecological products and shared carbon sink benefits, and leverage social capital to participate in agricultural

green transition.

6. Conclusions

This study has three limitations: first, insufficient depth of quantitative analysis—failure to empirically test the effect intensity of the three-dimensional synergy model and the implementation effect of each path; second, insufficient attention to regional differences—the sample focuses on core production areas, lacking attention to the transition differences of small-scale farmers in remote mountainous areas, and the regional adaptability analysis needs to be deepened; third, lack of long-term tracking evaluation of digital technology empowerment—insufficient attention to the sustainability and dynamic adjustment of technology application.

Future research can be deepened in three aspects: first, strengthen quantitative empirical research, construct a collaborative development evaluation index system, and use panel data models and other methods to empirically test the effectiveness of the model, providing data support for precise policy formulation; second, expand regional differentiated research, refine path adaptation plans for different functional areas such as ecological protection areas and major agricultural product production areas, and extract general mechanisms of cross-regional collaborative governance; third, focus on long-term mechanisms and emerging formats, explore new applications of digital technologies such as artificial intelligence and metaverse in agricultural green transition, innovate market-oriented green finance tools, and continuously improve the ecological value transformation path.

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