Impact of Green Finance on Agricultural Green Development in Henan Province

Lefeng LIN, Yi SHEN, Cheng MA, Sihai ZHANG *

Liangshan College (Lishui) China, Lishui University, Lishui 323000, China

Abstract Against the backdrop of China's accelerated green development and its pursuit of the "dual carbon" goals, green finance, as a crucial instrument for the rational allocation of resources, plays a significant role in promoting agricultural green transformation. Taking Henan Province as a case study, this research employs panel data from 18 prefecture-level cities spanning 2014 to 2023, utilizing dynamic panel models and mediating effect models for empirical analysis. The findings reveal that green finance indirectly fosters agricultural green development by driving agricultural technological progress. This promoting effect is significant, with the mediating effect accounting for 3.67%. Based on these results, policy recommendations are proposed: expanding the coverage of green finance and constructing a diversified product system; comprehensively promoting agricultural technological innovation and mechanization development; and coordinating and integrating green financial resources to facilitate agricultural green transformation tailored to local conditions.

Key words Green finance, Agricultural green development, Mediating effect

0 Introduction

Green finance serves as a vital instrument for guiding resource allocation and supporting the development of environmentally friendly industries, playing a crucial role in advancing agricultural green transformation. Internationally, green finance is recognized as an institutional innovation for addressing climate change and fostering sustainable development[1]; domestically, a policy system encompassing diverse products such as green credit, bonds, and insurance has been established, characterized by a "policy incentive + market response" dual-engine model[2]. In terms of measurement, an indicator system is often constructed across five dimensions: green credit, investment, insurance, securities, and carbon finance[3]. Research on agricultural green development has evolved from the concept of "clean agriculture" to a comprehensive objective system encompassing resource conservation, environmental friendliness, and high output efficiency[4], with its core focus on achieving a win-win outcome of increased production and environmental protection through resource-efficient technologies[5]. Regarding the linkage between the two, studies indicate that green finance can promote agricultural green transformation by optimizing credit structure[6] and incentivizing technology adoption[7], among other mechanisms.

However, existing research still exhibits shortcomings: studies on green finance and agricultural green development remain relatively independent, lacking sufficient integration; the research perspective is often singular, frequently using a single variable like green credit to represent the entirety, failing to reflect the synergistic mechanisms of multiple systems[8]; and the exploration of the underlying mechanisms is insufficient, particularly lacking systematic examination of the mediating role of green technological progress[9]. Therefore, this paper takes Henan Province as an example, positions green technological progress as the mediator, and verifies the transmission path of "green finance → green technological progress → agricultural green development", aiming to enrich theoretical understanding and provide policy insights for regional agricultural green transformation.

1 Theoretical mechanism and research hypotheses

1.1 Direct promoting effects of green finance on agricultural green development Green finance directly promotes agricultural green development through differentiated financial services. At the micro level, the differentiated pricing of green credit makes it easier for entities adopting green technologies to obtain financing, while green insurance mitigates transition risks. At the meso level, by channeling industrial capital (such as green investment funds) towards projects with high environmental benefits, it optimizes the agricultural industrial structure. At the macro level, through mechanisms like green fiscal subsidies and procurement policies, it releases policy signals, fostering an institutional environment conducive to green development. Thus, green finance directly drives agricultural green development through mechanisms operating at the micro, meso, and macro levels.

1.2 The mediating role of green technological progress Green technological progress plays a mediating role between green finance and agricultural green development. On the supply side, green finance provides funding for green agricultural technology innovation through specialized credit and R&D funds, addressing the financing bottleneck characterized by long R&D cycles and high risks, thereby accelerating technology transfer. On the demand side, market incentives such as differentiated pricing and green insurance enhance the willingness of agricultural producers to adopt green technologies, while price signals drive the continuous improvement of these technologies. In terms of the transmission

Received: November 19, 2025 Accepted: January 7, 2026

Supported by Zhejiang Provincial Philosophy and Social Sciences Planning Project (23FNSQ58YB).

* Corresponding author. Sihai ZHANG, associate professor, doctoral degree, research fields: soil improvement and remediation.

path, it optimizes the innovation pathway through information screening and resource integration. Consequently, by leveraging supply-side support, demand-side incentives, and pathway integration, green finance drives agricultural technological progress, thereby indirectly fostering agricultural green development.

2 Research design

2.1 Model selection and design

2.1.1 Baseline regression model. To examine the direct impact of green finance on agricultural green development, the following dynamic panel model is constructed:

$$AGDI_{it} = \alpha_0 + \alpha_1 AGD_{i,t-1} + \beta GIF_{it} + \sum \gamma_k Control_{kit} + \mu_i + \nu_t + \in_{it} \quad (1)$$

where $AGDI_{it}$ represents the level of agricultural green development in city i at year t, $AGDI_{i,t-1}$ is its one-period lagged value to account for dynamics; GIF_{it} is the core explanatory variable; $Control_{kit}$ denotes the control variables; μ_i and ν_t represent individual and time fixed effects, respectively; and $\in_{it}$ is the random error term.

The system Generalized Method of Moments (system GMM) estimator is employed to address potential endogeneity issues.

2.1.2 Mediating effect model. To test the mediating role of green technological progress, a three-step mediation model is constructed:

$$AGDI_{it} = \alpha_0 + \beta GIF_{it} + \sum \gamma_k Control_{kit} + \mu_i + \nu_t + \in_{it} \quad (2)$$

$$GTI_{it} = \delta_0 + \theta GIF_{it} + \sum \Phi_k Control_{kit} + \mu_i + \nu_t + \eta_{it} \quad (3)$$

$$AGDI_{it} = \lambda_0 + \rho GIF_{it} + \tau GTI_{it} + \sum \psi_k Control_{kit} + \mu_i + \nu_t + \zeta_{it} \quad (4)$$

The mediating effect value is $\theta \times \tau$. The significance of this effect is tested using the Bootstrap method (with 1 000 replications) to ensure the robustness of the results.

2.2 Variable measurement

2.2.1 Dependent variable. The level of agricultural green development is measured using an index system constructed by drawing on methodologies from Zhao Huijie & Yu Fawen[10] and Ma Lu[11]. This index comprises 11 indicators across four dimensions: resource conservation, environmental friendliness, output efficiency, and livelihood security. The weights for indicators at all levels are determined using the entropy method (Table 1).

Table 1 Agricultural green development index system

Primary indicator	Secondary indicator	Indicator definition
Resource conservation	Multiple cropping index	Sown area of crops/Cultivated land area
	Total agricultural machinery power per unit sown area	Total agricultural machinery power/Sown area of crops
	Share of water-saving irrigated area	Water-saving irrigated area/Actual irrigated cultivated land area
	Agricultural labor productivity	Gross output value of agriculture, forestry, animal husbandry, and fishery/Number of persons engaged in agriculture, forestry, animal husbandry, and fishery
Environmental friendliness	Pesticide application intensity	Total pesticide usage/Sown area
	Chemical fertilizer application intensity	Total chemical fertilizer usage/Sown area
	Agricultural plastic film use intensity	Total agricultural plastic film usage/Sown area
Output efficiency	Grain yield per unit area	Total grain output/Grain sown area
	Gross agricultural output value per unit sown area	Agricultural output value/Sown area
Livelihood security	Per capita net income of rural residents	Per capita disposable income of rural residents/Per capita consumption expenditure of rural residents
	Engel coefficient	Per capita food expenditure of rural residents/Per capita consumption expenditure of rural residents

2.2.2 Core explanatory variable. The level of green finance development is measured using an index system constructed by drawing on methodologies from Yan Xu & Wu Xinke[12] and Gao Jinjie & Zhang Weiwei[13-16]. This index comprises 10 indicators across five dimensions: green credit, green investment, green insurance, green securities, and carbon finance. The entropy method is also applied to calculate the weights (Table 2).

Table 2 Green finance development level index system

Primary indicator	Secondary indicator	Indicator definition
Green credit	Share of green credit	Total credit for environmental protection projects/Total credit
Green investment	Share of environmental pollution control investment	Total investment in environmental pollution control/GDP
Green insurance	Share of green insurance premium income	Premium income from environmental pollution liability insurance/Total premium income
Green securities	Share of green bonds	Total issuance of green bonds/Total issuance of all bonds
Carbon finance	Carbon intensity	Carbon dioxide emissions/GDP

2.2.3 Mediating variable. The mediating variable is green technology innovation. To measure green technology innovation, this study employs the natural logarithm of the total number of green agriculture patents, denoted as *GTI*.

2.2.4 Control variable. Based on an analysis of factors influencing agricultural green development, five control variables are selected: urbanization rate (UR), industrial structure adjustment (ISA), government support for agriculture ($INFRA_{gov}$), transportation infrastructure level ($INFRA_{tran}$), and education level (EDU). Specifically, the urbanization rate (UR) is measured as the ratio of urban population to rural population within a region. Industrial structure adjustment (ISA) is measured using an agricultural structural diversification index. This index is constructed based on four indicators: the proportion of planting industry, forestry, animal husbandry, and fishery. The structural diversification index is calculated using the entropy method. Government support for agriculture ($INFRA_{gov}$) is measured by the total expenditure on "Agriculture, Forestry, and Water Affairs" in local government fiscal expenditures. The transportation infrastructure level ($INFRA_{tran}$) is represented by the natural logarithm of the region's annual total freight volume. The education level (EDU) is measured by the number of high school students enrolled per 100 000 population.

2.3 Descriptive statistical analysis This study analyzes panel data from 18 prefecture-level cities in Henan Province spanning 2014 to 2023. (Data were sourced from the *Henan Statistical Yearbook*, *Henan Survey Yearbook*, and statistical yearbooks of various cities in Henan. Missing values were addressed using mean imputation or trend extrapolation to ensure data integrity and coherence.) Descriptive statistical analysis of the variables was first conducted. As shown in Table 3, regarding the dependent variable, the Agricultural Green Development Index ($AGDI$) has a mean of 0.356, a standard deviation of 0.124, a minimum value of 0.112, and a maximum value of 0.678. The range spans over sixfold. Regarding the core explanatory variable, the mean value of Green Finance Index (GFI) is 0.278, with a standard deviation of 0.098. This indicates a moderate level of development and substantial regional disparities. The maximum value (0.512) is 5.75 times the minimum value (0.089), signifying that some localities have developed significant scale in financial instruments such as green credit and green insurance, while in others, the green finance service system remains underdeveloped, with insufficient financing support. This reveals a relatively pronounced "tiered development gap".

Table 3 Descriptive statistics of variables

Variable	*Obs.*	*Mean*	*Std. Dev.*	*Min*	*Max*
AGDI	180	0.356	0.124	0.112	0.678
GIF	180	0.278	0.098	0.089	0.512
GTI	180	4.852	1.118	2.485	8.442
UR	180	1.456	0.789	0.567	4.000
ISA	180	0.412	0.156	0.197	0.732
GOV	180	45.672	28.345	7.130	108.600
INFRA	180	9.124	0.765	7.858	10.515
EDU	180	3 842.500	912.340	1 859.900	5 265.500

3 Empirical analysis

3.1 Benchmark regression results This study employs the system GMM approach to estimate the dynamic panel model; the results are presented in Table 4. Building upon this, we test the impact of green finance on agricultural green development. The coefficient for the one-period lagged agricultural green development level ($L.AGDI$) is found to be 0.712, significant at the 1% level, indicating significant path dependence in agricultural green development. The green development level of the previous period can generate a cumulative effect, laying a solid foundation for green development in the current period. This demonstrates that the green transformation of agriculture is a gradual and progressive dynamic process. Furthermore, the coefficient for Green Finance Index (GFI) is 0.458 ($p<0.01$), signifying a distinct positive promoting effect of green finance on agricultural green development. This validates research hypothesis H1, namely, green finance exerts a significant influence on agricultural green development.

Table 4 Benchmark regression results

Variable	Coefficient	*Std. Err.*	*z*-value	*p*-value
L. AGDI	0.712***	0.045	15.82	0.000
GIF	0.458***	0.078	5.87	0.000
UR	0.124**	0.056	2.21	0.027
ISA	0.189***	0.062	3.05	0.002
GOV	0.236***	0.071	3.32	0.001
INFRA	0.145**	0.058	2.50	0.012
EDU	0.167***	0.049	3.41	0.001
AR(1)	–	–	−2.34	0.019
AR(2)	–	–	0.87	0.384
Sargan	–	–	28.45	0.156

3.2 Robustness tests To ensure the scientific validity and generalizability of the research findings, this paper conducts extensive robustness tests. These tests encompass multiple dimensions including variable measurement, estimation methods, data quality, model specification, and causal identification, providing a comprehensive verification of the intrinsic relationship between GFI and AGDI (Table 5). Across these six tests, the results exhibit high consistency; regardless of the test method employed, the positive promoting effect of GFI on AGDI remains stable. The coefficients and overall effects consistently show the same directional trend. The coefficients all fall within the narrow range of 0.43 to 0.47, and their mean value is statistically significant at the 1% level.

Table 5 Summary of robustness test results

Test method	*GFI* coefficient	*p*-value
Alternative *GFI* measure	0.431***	0.000
Difference *GMM*	0.446***	0.000
Winsorize	0.462***	0.000
Additional controls	0.450***	0.000
Excluding Zhengzhou	0.439***	0.000
Instrumental variables	0.471***	0.000

3.4 Mediating effect analysis Based on the established mediating effect model, this paper analyzes the pathways through which green finance influences agricultural green development (Table 6).

Empirical results from Column (2) of the baseline regression model show that the total effect coefficient of Green Finance Index (*GFI*) on Agricultural Green Development Index (*AGDI*) is 0.458, highly significant at the 1% statistical level. This indicates that green finance, as a policy tool, significantly accelerates the green transformation of agriculture. Furthermore, in the regression of Column (3), the coefficient of green finance on Green Technology Innovation (*GTI*) is 0.312 ($p < 0.01$), signifying that green finance promotes the R&D of green patents and advances in agricultural technology through mechanisms like dedicated funding support and risk sharing. This provides empirical evidence for the existence of a mediating pathway for green finance.

Introducing the full mediating effect model in Column (4), where both green finance and green technology innovation variables are included, reveals that the direct effect coefficient of green finance decreases from 0.458 to 0.441, remaining highly significant at the 1% level; concurrently, the coefficient for green technology innovation is 0.054, also statistically significant at the 1% level. This systematic change indicates that green finance exerts both an intrinsic direct promoting effect and an extrinsic indirect promoting effect on agricultural green development, with both forces working synergistically. Calculating the mediating effect value using the standard approach yields: $0.312 \times 0.054 = 0.0168$, accounting for 3.67% of the total effect. Bootstrap test results show that while the 95% confidence interval [0.008, 0.025] contains zero, all other tested intervals exclude zero, indicating a significant mediating role for green technology innovation, thereby enhancing the reliability of the research findings.

Table 6 Mediating effect regression results

Variable	(1) *AGDI*	(2) *GTI*
GIF	0.458***	0.312***
	(0.078)	(0.065)
GTI	–	–
	–	–
Control	Yes	Yes
Obs.	180	180

4 Conclusions and policy recommendations

4.1 Conclusions First, both green finance and agricultural green development levels in Henan Province show an overall upward trend, yet exhibit significant regional disparities. The ratio of maximum to minimum green finance development levels is 5.75, while the regional disparity in agricultural green development levels reaches sixfold. Spatially, a gradient differentiation pattern emerges: high in Central Henan, medium in Eastern Henan, and low in Southern Henan. Second, green finance exerts a significant positive direct promoting effect on agricultural green development, with a benchmark regression coefficient of 0.458. This conclusion is robust, having survived multiple robustness tests. Simultaneously, agricultural green development exhibits significant path dependence (lagged coefficient of 0.712), indicating that its transformation is a gradual, cumulative dynamic process. Finally, green technology innovation plays a partial mediating role in the process by which green finance influences agricultural green development, accounting for 3.67% of the mediating effect. This demonstrates that green finance not only directly drives agricultural green transformation but also generates indirect positive effects by promoting green technology innovation.

4.2 Policy recommendations

4.2.1 Expanding green finance coverage. A diversified toolkit, primarily composed of green credit, insurance, and investment instruments, should be developed. Capital should be guided towards green projects, such as water-saving irrigation and organic agriculture, through mechanisms like differentiated pricing and fiscal subsidies. Financing for projects with high energy consumption and high emissions should be strictly prohibited. A financial environment characterized by incentive compatibility should be fostered.

4.2.2 Comprehensively innovating agricultural technology. A special fund dedicated to green technology research and development should be established. Credit products and risk-sharing mechanisms should be innovated to support the R&D of technologies like green agricultural machinery and precision fertilization. A collaborative platform integrating industry, academia, research, and finance should be established to accelerate technology commercialization and strengthen its intermediary and conductive role.

4.2.3 Coordinating and integrating green finance resources. Regionally differentiated policies must be implemented. Measures should be precisely tailored according to regional development levels: In regions with a solid foundation, the integration of green finance with digital technologies and cutting-edge agriculture should be promoted. In areas with scaling advantages, the efficiency of green investments should be enhanced. In ecologically fragile zones, support should be provided primarily through green insurance and policy-oriented finance. Differentiated support should be offered for different stages of technological maturity: Dedicated start-up loans should be made available for low-technology stages. For medium-technology stages, scale-up loans linked to emission reduction performance should be provided. For high-technology stages, support through investment-loan linkages and capital market financing should be facilitated. Concurrently, an agricultural carbon accounting system should be established, and one-stop transition services should be offered. Furthermore, loan risk compensation and fiscal interest discount mechanisms should be set up to reduce financing costs.

References

[1] SEGHINI C, DEES S. The green transition and public finances[J]. Macroeconomic Dynamics, 2025, 29: e152.
[2] LI BY, LI TR, SHEN Y. Can green finance promote renewable energy development: A case study of green credit and green venture capital[J]. Ecological Economy, 2024, 40(5): 63–70. (in Chinese).
(To page 24)

ity of *Acanthus ebracteatus* Vahl. aqueous extract: The potential for skin infection treatment[J]. International Journal of Biological Chemistry, 2009, 3(2): 95–98.
[30] NGUYEN PD, HO CL, TEO SS, *et al.* Sequence and transcript analyses of antioxidant genes from *Acanthus ebracteatus* Vahl[J]. Tree Genetics & Genomes, 2008, 4(4): 705–713.
[31] NAKAMURA T, SUZUKI T, RUDIANTO ARIEFTA N, *et al.* Meroterpenoids produced by *Pseudocosmospora* sp. Bm-1-1 isolated from *Acanthus ebracteatus* Vahl[J]. Phytochemistry Letters, 2019(31): 85–91.
[32] WANG M, WANG WQ, LIN GS, *et al.* 2019. The mangrove of Sanya [M]. Beijing: Science Press, 2019. (in Chinese).
[33] ZHANG MW, ZHONG CR, LV XB, *et al.* A review of studies on the relict mangrove plant *Nypa fruiticans* Wurmb in the World[J]. World Forestry Research, 2022, https://kns.cnki.net/kcms/detail/11.2080.s.20220615.20220902.20220001.html. (in Chinese).
[34] MU MR, JIANG QL, WANG WQ. Comparisons of leaf chloride content and leaf traits between true mangrove plants and semi-mangrove plants [J]. Journal of Plant Ecology, 2007, 31(3): 497–504. (in Chinese).
[35] NGUYEN PD, HO CL, HARIKRISHNA JA, *et al.* Generation and analysis of expressed sequence tags from the mangrove plant, *Acanthus ebracteatus* Vahl[J]. Tree Genetics & Genomes, 2006, 2(4): 196–201.
[36] NGUYEN PD, HO CL, HARIKRISHNA JA, *et al.* Functional screening for salinity tolerant genes from *Acanthus ebracteatus* Vahl using *Escherichia coli* as a host[J]. Trees, 2007, 21(5): 515–520.
[37] HO CL, NGUYEN PD, HARIKRISHNA JA, *et al.* Sequence analysis and characterization of vacuolar-type H^+-ATPase proteolipid transcript from *Acanthus ebracteatus* Vahl[J]. DNA Sequence, 2008, 19(1): 73–77.
[38] SULTANA S, KHEW CY, MORSHED MM, *et al.* Overexpression of monodehydroascorbate reductase from a mangrove plant (*AeMDHAR*) confers salt tolerance on rice[J]. Journal of Plant Physiology, 2012, 169(3): 311–318.
[39] SULTANA S, TUREČKOVÁ V, HO CL, *et al.* Molecular cloning of a putative *Acanthus ebracteatus*- 9-*cis*-epoxycarotenoid deoxygenase (*AeNCED*) and its overexpression in rice[J]. Journal of Crop Science and Biotechnology, 2014, 17(4): 239–246.
[40] ZHANG Y, CHEN GC, ZHONG CR, *et al.* Research on endangered mangrove species and recovery status in China[J]. Journal of Applied Oceanography, 2021, 40(1): 142–153. (in Chinese).
[41] XU YB. Fangchenggang procuratorial organ urged the protection of mangrove living environment administrative public interest lawsuit[J]. Prosecutor, 2022, 2022(3): 62–64. (in Chinese).
[42] ZHANG Y, XIN K, LIAO B, *et al.* The characteristics of pods and seeds of liana species *Derris trifoliata* and their relationship with environmental factors in Guangdong, China[J]. Ecological Indicators, 2021, 129: 107930.
[43] ZHANG Y, ZHONG CR, YANG Y, *et al.* Rescue of germplasm resources of endangered mangrove plant *Lumnitzera littorea*[J]. Molecular Plant Breeding, 2018, 16(12): 4112–4118. (in Chinese).
[44] LAI TH, MO NZ, HE BY, *et al.* A technological method of cottage raising and planting of *Acanthus ebracteatus*[P], 2021. (in Chinese).
[45] BAI LX, ZHAGN TX, ZHANG Y, *et al.* A method for hydroponic seedling cultivation using leaves of *Acanthus ebracteatus*[P]. ZL 2022 1 1364107.5, 2024. (in Chinese).
[46] SUDHEER WN, PRAVEEN N, AI-KHAYRI JM, *et al.* Role of plant tissue culture medium components[M]//CR, *et al.* Advances in plant tissue culture. Academic Press: New York, 2022: 51–83.
[47] CHI SP, LIANG GH, JIANG CY, *et al.* Study on callus induction in leaves of *Kandelia candel*[J]. Journal of Green Science and Technology, 2020, 23(38): 96–99. (in Chinese).

(From page 17)
[3] FANG S, LIU J, ZHANG NM, *et al.* Environmentally friendly fertilizers and agricultural green development[J]. Fertilizer & Health, 2022, 49(5): 1–5. (in Chinese).
[4] TILMAN D, CASSMAN KG, MATSON PA, *et al.* Agricultural sustainability and intensive production practices [J]. Nature, 2002, 418(6898): 671–677.
[5] RIGBY D, WOODHOUSE P, YOUNG T, *et al.* Constructing a farm level indicator of sustainable agricultural practice[J]. Ecological Economics, 2001, 39(3): 463–478.
[6] AN GJ, LIU K. The role of green finance in rural revitalization[J]. China Finance, 2018(10): 63–65. (in Chinese).
[7] ZHANG JW, FEI JX, XU YC. Incentive effects of financial support on green agricultural development[J]. Journal of Zhongnan University of Economics and Law, 2020(6): 91–98. (in Chinese).
[8] LIN SH. Research on green finance driving green transformation of rural agriculture[J]. Value Engineering, 2025, 44(23): 94–97. (in Chinese).
[9] WU S. Coupling coordination study of green finance on high-quality economic development in Henan Province[J]. Time-Honored Brand Marketing, 2023(6): 75–77. (in Chinese).
[10] ZHAO HJ, YU FW. Evaluation of agricultural green development level in major grain-producing areas based on entropy method[J]. Reform, 2019(11): 136–146. (in Chinese).
[11] MA L. Evaluation and influencing factors of agricultural green development level in Henan Province[D]. Luoyang Henan University of Science and Technology, 2022. (in Chinese).
[12] YAN X, WU XK. Research on green finance promoting agricultural green development path in Henan[J]. Agricultural Economy, 2023(9): 120–121. (in Chinese).
[13] GAO JJ, ZHANG WW. Impact of green finance on ecologicalization of China's industrial structure: Empirical test based on system GMM model [J]. Economic Review, 2021(2): 105–115. (in Chinese).
[14] FAN SY, LI YL, MA XJ, *et al.* Empirical study on the impact of digitalization level on agricultural green development: Based on panel data of 30 provinces in China[J]. World Agriculture, 2021(12): 4–16. (in Chinese).
[15] PAN FH, ZHANG C, CUI NB. Impact effects and mechanism of green finance on agricultural green development[J]. Agricultural Economics and Management, 2024(1): 42–55. (in Chinese).
[16] YAO P, LI HZ. Can agricultural water rights trading promote agricultural green development[J]. Chinese Rural Economy, 2023(2): 17–40. (in Chinese).