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Research on the Realization of Rural Ecological Product Value Empowered by Digital Technology

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Abstract: The realization of rural ecological product value is a crucial measure for implementing the concept that "lucid waters and lush mountains are invaluable assets" and for promoting rural revitalization. Digital technology provides essential support for overcoming the challenges in this value realization process. This paper first defines the core concepts of rural ecological products and their value realization, along with the theoretical foundations, and analyzes the current status of realizing the value of rural ecological products. While progress has been made in areas such as ecological product supply, market-oriented trading systems, financial product innovation, and policy support, significant challenges remain, encapsulated as the "four difficulties": difficulty in measurement, difficulty in using as collateral, difficulty in trading, and difficulty in monetization. The research argues that digital technologies such as the Internet of Things, big data, blockchain, and artificial intelligence fundamentally reshape the entire process of ecological products—from monitoring and accounting to rights confirmation, trading, and management. This is achieved by establishing four core empowerment mechanisms: precise value assessment and quantification, digital rights confirmation, credible and efficient linkage, and value safeguarding. Furthermore, the paper proposes specific empowerment pathways, including strengthening digital infrastructure, constructing a digital value assessment system, promoting digital transformation in production processes, building digital circulation and marketing systems, advancing digital extension of the industrial chain, improving digital supervision and benefit distribution mechanisms, and enhancing the digital literacy of rural stakeholders. This study aims to enrich the theoretical framework for ecological product value realization and provide practical references for local governments in formulating relevant policies and promoting the transformation and upgrading of the rural ecological industry.

Keywords: Digital Technology; Rural Ecological Products; Value Realization; Empowerment Mechanism; Empowerment Pathway.

1. Introduction

With the deepening advancement of Digital China initiatives and ecological civilization construction, the integration of digital technologies with the realization of rural ecological product values has emerged as a pivotal national strategic direction. The Report of the 20th National Congress of the Communist Party of China emphasized the establishment of mechanisms for ecological product value realization, while the Third Plenary Session of the 20th Central Committee further proposed accelerating the refinement of institutional frameworks to operationalize the principle that "lucid waters and lush mountains are invaluable assets." As core carriers of ecological civilization, rural ecological products represent a critical pathway for advancing rural revitalization and common prosperity through value realization. However, contemporary challenges persist, including resource sedimentation, insufficient industrial value addition, underdeveloped market mechanisms, and imbalanced sharing systems. Digital technologies, as a transformative driver of the new era, offer unique advantages in resource integration, transaction cost reduction, and optimized resource allocation. The rapid advancement of big data, Internet of Things (IoT), blockchain, and artificial intelligence (AI) provides novel opportunities to address the "four difficulties" (measurement, mortgage, transaction, and monetization) inherent in rural ecological products. Pilot practices in Fujian, Guizhou, and Zhejiang provinces demonstrate that digital applications—such as ecological cloud platforms, GEP (Gross Ecosystem Product) accounting systems, and ecological credit frameworks—effectively enhance ecological conservation, value quantification, and market transactions. This study investigates the mechanisms and pathways through which digital technologies empower rural ecological product value realization, aiming to activate dormant ecological resources, convert ecological advantages into economic benefits, and inject sustainable momentum into rural revitalization. Through case analysis and pathway design, the research seeks to optimize ecological product supply, transaction, and distribution mechanisms, offering practical guidelines for governments at all levels to strengthen value realization frameworks.

2. Literature Review

International research centers on the theoretical framework of "Ecosystem Services," emphasizing value quantification and market-oriented pathways for natural capital. Foundational theoretical work began with Costanza et al.'s (1997) quantitative study on global ecosystem service values, followed by the United Nations Millennium Ecosystem Assessment (2005), which classified ecosystem services into provisioning, regulating, cultural, and supporting services, thereby establishing a framework for value assessment [1]. At the practical level, international approaches prioritize market-oriented instruments such as Payments for Ecosystem Services (PES) (Wunder, 2005), which employ economic incentives to promote ecological conservation [2]. Additional mechanisms include ecological labeling, carbon trading, and

biodiversity offset systems (TEEB, 2010). Robert L. Deal et al. (2012) advocated for establishing ecological service markets to enhance forest resource utilization through market mechanisms [3], while José R. Soto (2016) demonstrated the effectiveness of forest carbon sinks in realizing ecological values through market mechanisms [4]. SCB (2018) and SELVAGV (2020) examined policy-level issues concerning the realization of ecological value in forest resource assets [5-6]. Existing international research primarily focuses on developed country contexts, lacking targeted analyses of rural scenarios and smallholder economies in developing countries, while paying limited attention to equity and accessibility issues in digital empowerment.

China's research on ecological product value realization, though initially delayed, has rapidly developed into a comprehensive theoretical and practical system. Theoretical contributions include synthesis models by Gao Xiaolong et al. (2020) and Wang Xiaahui et al. (2020) [7-8]. Recent advancements encompass GEP accounting system construction and local practices (Liu Jiaqi, 2024), as well as explorations of ecological product property rights definition and assetization pathways (Huang Xiaoyong et al., 2025) [9-10]. Mechanism studies focus on government-market synergies through policy instruments like ecological compensation, green finance, and property rights trading (Li Fei, 2025) [11]. Case studies include Fujian's "Ecological Cloud" platform for intelligent environmental monitoring and pollution source control (Hu Changsheng & An Xiaoxing, 2024), Guizhou's exploration of "Ecological Bank" models through big data-driven transactions (Huang Xiaoyong et al., 2025) [12-13], and digital applications in ecological regulation (Wang Xiaoli et al., 2024), blockchain-based traceability (Chen Jun & Chen Ziyi, 2025), and AI-based ecological forecasting [14-15]. Current research lacks systematic revelations of deep integration mechanisms between digital technologies and ecological product value realization, remaining largely descriptive of technical applications while insufficiently addressing rural-specific contexts. Building upon existing achievements, this study investigates empowerment mechanisms of digital technologies in value realization, analyzes implementation pathways for rural ecological products, and proposes targeted policy recommendations to support rural revitalization strategies.

3. Related Concepts and Theoretical Foundations

3.1. Rural Ecological Products

Rural ecological products refer to a series of green, environmentally friendly, healthy, and sustainable products and services provided through the development and utilization of rural ecological resources, based on the full protection of the rural ecological environment and respect for the laws of rural development. Their value composition encompasses multiple attributes, including ecological value, economic value, social value, and cultural value. Rural ecological products can be further classified into forest ecological products, agricultural ecological products, aquatic ecological products, wetland ecological products, etc.

3.2. Realization of the Value of Ecological Products

The realization of the value of ecological products is the process by which their use value is transformed into exchange value. The realization of ecological product value can be categorized into three types based on the differences in participating entities: First, avenues where the government directly purchases ecological products, such as forest ecological compensation and wetland ecological compensation; Second, approaches that achieve the value of ecological products through market allocation and transactions, such as transactions of ecological agricultural products, ecotourism, and carbon emission rights trading; Third, hybrid value transformation pathways led by the government that encourage enterprise and social participation, such as forest carbon sink trading.

3.3. Digital Technology

Digital technology refers to the aggregate of technologies that utilize digital means to convert information into digital signals for processing, storage, transmission, and application. It mainly includes technologies such as big data, cloud computing, the Internet of Things, artificial intelligence, and blockchain. These technologies are characterized by high efficiency, precision, and intelligence, enabling the collection, analysis, and mining of massive amounts of data, thereby providing robust support for the production, management, and marketing of rural ecological products.

Table 1. Key Digital Technologies Enabling the Realization of Rural Ecological Product Values and Their Applications

Technology Category	Core Functionalities	Typical Applications in the Field of Ecological Products
Internet of Things (IoT) & Remote Sensing	Data Collection and Sensing	Real-time monitoring of ecological environment indicators (e.g., soil moisture, vegetation coverage, biodiversity) and tracking the entire production process of products through sensors, drones, and satellite remote sensing.
Big Data & Cloud Computing	Data Storage, Management, and Analysis	Aggregating multi-source heterogeneous data to construct a "unified map" of ecological resources, supporting automated calculation of GEP (Gross Ecosystem Product), carbon sink estimation, and big data analysis for decision-making.
Blockchain	Trust Building and Data Authentication	Providing tamper-proof "digital IDs" for ecological products, enabling full-chain traceability from origin to consumer; facilitating the registration and credible transactions of ecological assets.
Artificial Intelligence (AI)	Intelligent Recognition and Predictive Optimization	Used for automatic species identification, pest and disease early warning, intelligent assessment of ecological values, and intelligent matching of market supply and demand.

3.4. Theoretical Foundations

Tang Lin and Chen Chibo (2025) argue that Trist and Bamforth's socio-technical systems theory can elucidate the co-evolutionary relationship between digital technology and the realization of the value of rural ecological products [16]. Firstly, digital technology, as a new factor of productive forces, reshapes eco-economic relationships through data

collection, algorithmic modeling, and platform connectivity. On the other hand, the complexity of agricultural ecosystems, the path dependency of institutional environments, and the heterogeneity of market structures collectively constitute the constraints and adjustment targets for technological empowerment. Digital technology systematically enables the realization of the value of agricultural ecological products through a three-dimensional interactive mechanism of "technological empowerment - institutional response - value reconstruction." These three elements form a dynamic closed loop that starts with "technological empowerment," undergoes transformation through "institutional response," achieves the goal of "value reconstruction," and ultimately feeds back into the continuous optimization of technology and institutions. Digital technology drives the realization of the value of agricultural ecological products through the interactive relationships among these three elements, while the realization of the value of agricultural ecological products also necessitates the construction of a mechanism for dynamic adaptation among these three elements to avoid system failures caused by technological silos, institutional rigidity, or value disconnection.

4. Analysis of the Current Status of Rural Ecological Product Value Realization

4.1. Key Developments

4.1.1. Enhancement of Ecological Product Supply Capacity

With the intensification of ecological conservation efforts and the advancement of agricultural transformation and upgrading, the quantity and quality of rural ecological products in China, such as green and organic agricultural products and eco-tourism destinations, have been steadily increasing, thereby catering to diverse market demands. For instance, by the end of 2024, the number of nationally certified green food products had exceeded 35,000, and the number of designated eco-tourism demonstration villages surpassed 12,000. Furthermore, numerous localities have initiated county-level Gross Ecosystem Product (GEP) accounting, referencing the national Guidelines for GEP Accounting. This has provided a preliminary basis for the valuation of ecological assets. A case in point is Jiangkou County in Guizhou Province, which has completed consecutive years of GEP accounting.

4.1.2. Progressive Refinement of the Market-Based Trading System

The trading of rights-based assets, such as forestry carbon sinks, water rights, and pollution discharge rights, has been gradually expanding, facilitating the transition of ecological products from being "priceless" to "valuable." For example, Tongren City successfully executed the transaction of Guizhou's first provincial-level forestry carbon credit certificate and has pioneered the digital trading of standing timber. In Sanming, Fujian Province, blockchain technology has been integrated into the forestry carbon sink registration system. Utilizing distributed ledgers to record data throughout the entire timber growth cycle, the city has issued a cumulative total of 800 million RMB in forest asset certificates, leading to an annual income increase of over 50,000 RMB for collective entities in pilot villages.

4.1.3. Innovations in Financial Instruments

Jiangxi Province has launched loan services secured by revenue rights from economic forests, carbon sink forests, under-forest economies, and public welfare forest compensation. It has also developed novel financial products like forestry carbon sink insurance and loan guarantee insurance. As of August 2024, the province had cumulatively acquired 910,000 mu of forest land and facilitated 53.29 million RMB in guaranteed loans backed by forest rights acquisition. Various regions are exploring mechanisms to link ecological value to credit access. For instance, Baisha County in Hainan introduced the "'Two Mountains' Loan," while Tongren in Guizhou launched the "'Ecological Points' Loan," both of which convert individual or community conservation behaviors into financial credit.

4.1.4. Continuous Improvement of the Policy Support Framework

The central government has successively issued a series of policy documents, including the Opinions on Establishing and Improving the Mechanism for Realizing the Value of Ecological Products and the Outline of the Digital Rural Development Strategy. These policies provide comprehensive support for the value realization of rural ecological products, covering aspects such as ecological conservation, value assessment, and the development of digital infrastructure. Local governments have also actively responded by formulating and implementing detailed implementation measures tailored to their local conditions, ensuring effective policy deployment.

4.2. Existing Difficulties and Challenges

4.2.1. Difficulty in Measurement

Current GEP accounting results often yield static, macro-level aggregate data, which are inadequate for precisely interfacing with micro-level market transactions and individual decision-making. The standardization, dynamism, and granularity of the accounting methodologies remain insufficient.

4.2.2. Difficulty in Collateralization

The property rights of ecological assets are often ambiguously delineated, and there is a lack of authoritative and dynamic valuation methods and registration systems. This undermines the legal and credit foundations for these assets to serve as eligible collateral.

4.2.3. Difficulty in Transaction

There is a scarcity of efficient and transparent cross-regional trading platforms and standardized market-based trading rules. Consequently, the market for ecological products is fragmented, characterized by high costs for supply-demand matching and limited trading activity.

4.2.4. Difficulty in Monetization and Limited Pathways

The realization of value for rural ecological products is overly reliant on government-led ecological compensation and project-based investments. Sustainable, market-driven pathways for commercial development and industrialization are still in their exploratory phases. Consequently, the tangible benefits, or "sense of gain," for farmers as direct custodians of the ecosystem require further enhancement.

Table 2. Entry Points for Digital Technologies to Address Challenges in Realizing Rural Ecological Product Values

Core Challenges	Specific Manifestations	Entry Points for Empowerment through Key Digital Technologies
Difficulty in Measurement	Inconsistent calculation standards, abundant static macro data, scarce micro dynamic data.	IoT monitoring, remote sensing, and big data analysis for precise, dynamic, and automated calculation.
Difficulty in Mortgaging	Unclear property rights, unstable values, lack of credible assessment reports and registration systems.	Blockchain for property rights registration and dynamic value assessment platforms.
Difficulty in Trading	Fragmented markets, information asymmetry, high transaction costs, and lack of liquidity.	Big data platforms for intelligent supply-demand matching, and blockchain for credible transactions and payments.
Difficulty in Monetization	Single pathway, excessive reliance on financial compensation, low level of industrialization	Integration of resources through digital technologies to create new product forms (e.g., carbon credits, data products) and connect with diversified markets.

5. Analysis of the Mechanism by Which Digital Technology Enables the Realization of the Value of Rural Ecological Products

5.1. Precise Value Assessment Mechanism

Digital technology addresses the challenge of quantifying ecological value, often described as the "difficulty of measurement," through all-weather monitoring and automated accounting. Technologies such as IoT sensors and remote sensing enable precise identification and dynamic monitoring of the quantity, quality, and changes in ecosystems . Building on this, big data platforms can integrate multidimensional data and operate automated accounting models. For instance, the establishment of automated Gross Ecosystem Product (GEP) accounting platforms facilitates independent and rapid annual GEP calculations, translating intangible ecological value into reportable and comparable data indicators. This provides a vital value "anchor" for decision-making and market transactions. Furthermore, digital technology promotes the green transformation of ecological product production paradigms. By accurately monitoring environmental system elements and utilizing algorithms for optimization, it enables more effective resource management, as seen in smart ecological tea plantations that significantly reduce chemical pesticide use .

5.2. Digital Rights Confirmation Mechanism

Digital technologies, particularly blockchain, digitize the spatial and matching relationships of natural resource property rights, enhancing the accuracy and precision of rights registration and management . This helps to coordinate the allocation of natural resource rights across different times and spaces, addressing issues of fragmentation and decentralized utilization. By transforming abstract ecological rights into concrete "digital asset certificates," this mechanism provides a prerequisite for ecological assets to enter the capital market. Examples include the use of blockchain technology to register rights for individual standing trees, issuing verifiable digital asset certificates, and upgrading traditional paper vouchers for grassland carbon sinks into electronic operation platforms, enabling the digital confirmation and circulation of ecological contributions .

5.3. Credible and Efficient Connection Mechanism

Digital technology breaks the spatiotemporal constraints of traditional transactions by constructing credible trading platforms, thereby building efficient markets that connect a wide range of supply and demand . Digital platforms integrate data and enable intelligent matching, significantly reducing information search costs and transaction disputes prevalent in traditional ecological product trading . This mechanism expands market reach and activates potential demand. Platforms that integrate various ecological resource elements, such as forest rights, water rights, carbon sinks, and tourism services, create regional markets for ecological resource factors, facilitating the efficient conversion of ecological value into economic benefits .

5.4. Value Guarantee Mechanism

Digital technology ensures the fairness and sustainability of ecological product value realization by establishing digital supervision systems and benefit distribution mechanisms. For supervision, technologies like big data and IoT enable real-time monitoring throughout the entire lifecycle of ecological products—from production to circulation and consumption—allowing for timely identification and resolution of issues, thereby safeguarding consumer interests . Blockchain's features of decentralization and immutability enhance the transparency and credibility of value assessment and transactions . Regarding benefit distribution, digital platforms can establish precise models to allocate profits fairly among producers, distributors, and other stakeholders based on their contributions, which protects the legitimate rights of producers and boosts their participation incentives. Additionally, digital technology optimizes ecological compensation mechanisms, enabling the targeted allocation and efficient use of funds.

6. Pathways for Digital Technology to Empower the Realization of Rural Ecological Product Value

6.1. Strengthening the Construction of Rural Digital Infrastructure to Consolidate the Empowerment Foundation

First, increase investment in rural digital infrastructure to extend the coverage of next-generation information infrastructure such as 5G and fiber optic networks to rural areas. Focus should be placed on addressing insufficient network coverage in remote mountainous regions, enhancing rural network transmission speeds, and reducing internet service costs. Second, improve the supporting infrastructure for rural digital initiatives by constructing facilities such as

rural digital service centers and IoT sensing nodes, thereby providing the necessary hardware support for the application of digital technologies in realizing the value of rural ecological products. Third, promote the deep integration of digital infrastructure with rural ecological industries by developing digitalized industrial carriers like smart agricultural parks and smart tourism scenic areas, thereby enhancing the digitalization level of these industries.

6.2. Constructing a Digital Value Assessment System for Ecological Products to Clarify Value Connotation

First, relying on digital technologies such as big data and artificial intelligence, establish a scientific and reasonable indicator system for assessing the value of rural ecological products, encompassing multiple dimensions including ecological value, economic value, and social value. Second, develop a digital value assessment platform that integrates various data sources such as ecological environment monitoring data, market transaction data, and socio-economic data. Utilizing quantitative models, this platform should enable precise assessment of ecological product value, forming operable and scalable assessment methodologies. Third, strengthen the application of assessment results by linking them to ecological compensation, market transactions, and policy formulation, thereby ensuring the full manifestation of ecological product value.

6.3. Promoting Digital Transformation in the Production Phase to Enhance Product Quality and Efficiency

First, promote the application of digital technologies such as the Internet of Things, big data, and artificial intelligence to establish a smart agricultural production system. This system should enable precise and standardized management of the planting and breeding processes for ecological agricultural products. For instance, promote the use of intelligent irrigation, fertilization, and breeding equipment to enhance production efficiency and product quality. Second, establish a digital service platform for agricultural production to provide producers with precise services such as meteorological warnings, pest and disease control, and technical guidance, thereby improving their digital application capabilities. Third, encourage the development of ecological circular agriculture by utilizing digital technologies to optimize the utilization processes of agricultural waste resources, achieving greening of the production process.

6.4. Building a Digital Circulation and Marketing System to Broaden Value Transformation Channels

First, strengthen the development of rural e-commerce platforms, nurture rural e-commerce entities, and enhance the online sales capabilities of rural ecological products. Encourage the development of emerging digital marketing models such as live-streaming commerce and community group buying, establish live-streaming bases for rural ecological products, and cultivate local influencer hosts. Second, improve the rural logistics and warehousing system by constructing digital warehousing centers and promoting cold-chain logistics technology to reduce product loss rates. Utilize big data technology to optimize logistics distribution routes and enhance logistics efficiency. Third, construct a digital traceability system for ecological products, employing blockchain technology to achieve end-to-end traceability from production to consumption, thereby boosting product credibility and market competitiveness.

6.5. Promoting Digital Extension of the Industrial Chain to Increase Product Added Value

First, encourage enterprises to utilize digital technologies for the deep processing of ecological products, developing high-value-added products. Establish digital deep-processing production lines to optimize production techniques and improve both product quality and production efficiency. Second, build a digital collaboration platform for the industrial chain to integrate resources across various stages including production, processing, circulation, and sales, fostering collaborative development among all entities in the chain. Utilize big data technology to analyze market demand, precisely connect different links of the industrial chain, and enhance the overall competitiveness of the industry. Third, strengthen the digital development of brands for rural ecological products, creating regional public brands and corporate brands. Promote these brands through digital marketing channels to increase their visibility and influence.

6.6. Perfecting Digital Supervision and Benefit Distribution Mechanisms to Ensure the Sustainability of Value Realization

First, construct a digital supervision platform for rural ecological products, integrating regulatory data from departments such as market supervision, agriculture and rural affairs, and ecological environment. Utilize technologies like big data and artificial intelligence to achieve real-time supervision of the entire ecological product chain. Establish product quality traceability and accountability mechanisms to strictly combat counterfeit and substandard products. Second, establish a digital benefit distribution platform, using blockchain technology to ensure transparency and fairness in benefit distribution. Develop reasonable benefit distribution schemes based on the contributions of different stakeholders in the value realization process to protect the legitimate rights and interests of producers. Third, optimize digital mechanisms for ecological compensation by establishing a linkage mechanism between ecological product value assessment and the allocation of compensation funds, ensuring precise distribution and efficient use of compensation funds.

6.7. Enhancing the Digital Literacy of Rural Stakeholders to Strengthen Talent Support

First, conduct digital literacy training programs for rural residents, targeting different groups such as farmers, cooperative members, and rural entrepreneurs. Training should cover areas like digital technology application, e-commerce operations, and brand building to improve their digital application skills. Second, establish incentive mechanisms to encourage digital technology professionals to work in rural areas. Encourage university graduates, scientific and technical workers, and e-commerce talents to contribute to rural areas, providing talent support for realizing the value of rural ecological products. Third, set up a communication platform for rural digital talents to facilitate exchange and

cooperation between digital technology professionals and rural stakeholders, promoting the widespread application of digital technologies in the value realization of rural ecological products.

7. Conclusion

The value realization of rural ecological products constitutes a pivotal pathway for advancing the coordinated development of rural revitalization and ecological protection, while digital technology provides crucial support for addressing the predicaments in this process. Through four core mechanisms—precision value assessment, digital right confirmation, trusted and efficient connection, and value guarantee—digital technology has resolved the long-standing challenges of rural ecological products, namely "difficulty in measurement, mortgage, transaction, and monetization," thereby promoting the realization of their value. To advance the empowerment of digital technology in the value realization of rural ecological products, efforts should be made through multiple pathways: strengthening the construction of rural digital infrastructure, establishing a digital value assessment system for ecological products, promoting the digital transformation of production links, building a digital circulation and marketing system, advancing the digital extension of the industrial chain, improving the digital supervision and benefit distribution mechanism, and enhancing the digital literacy of rural subjects. The empowerment of digital technology in the value realization of rural ecological products serves as an important approach to transforming "lucid waters and lush mountains" into "mountains of gold and silver," and a key means to achieve rural revitalization and common prosperity. In the era of the digital economy, it is imperative to accelerate the construction of a long-term mechanism for digital technology to empower the value realization of rural ecological products, thereby providing strong support for promoting ecological civilization construction and rural revitalization.

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