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Article

Rural Ecological Governance Pathways from an Eco-Marxist Perspective

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Abstract: Based on the current realities of imbalanced resource utilization structures, insufficient coordination among governance actors, and weak institutional enforcement constraints in rural ecological governance, this study examines pathways for rural ecological governance from an eco-Marxist perspective.This paper elucidates the logic of ecological Marxism's applicability to rural governance, introducing concepts such as the identification of discrepancies between ecological resource supply and demand, the construction of multi-stakeholder coordination mechanisms, the embedding of the principle of ecological priority, and dynamic assessment, feedback, and regulatory mechanisms. By integrating these concepts with the operational chain of rural governance, the study analyzes the restructuring of grassroots governance systems, the enhancement of ecological governance capabilities, and the ecological transformation of production and lifestyle patterns. The results indicate that rural ecological governance must be developed in a manner that integrates resource allocation, institutional transmission, and process regulation.

Keywords: Eco-Marxism; rural ecological governance; collaborative governance; dynamic assessment; institutional restructuring

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1. Introduction

Rural ecological governance has shifted from piecemeal environmental remediation to a systemic restructuring where resource utilization, institutional operation, and social coordination are mutually embedded. Traditional governance approaches exhibit significant disconnects in the transmission of resource constraints, the coordination of stakeholders, and the closed-loop enforcement of institutions, making it difficult to address the structural accumulation of rural ecological issues. Eco-Marxism provides a suitable framework for analyzing the coupling of human-nature relations, modes of production organization, and governance mechanisms. Focusing on the actual structure and operational logic of rural ecological governance, this paper conducts an analysis across four dimensions---theoretical interpretation, problem identification, pathway construction, and mechanism optimization---with the aim of establishing a governance research framework characterized by internal coherence.

2. Ecological Marxist Interpretation of Rural Ecological Governance

2.1. Core Perspectives of Eco-Marxism

The application of Eco-Marxism in rural contexts is first manifested in the reconstruction of the logic of resource allocation. Capital-accumulation-oriented agricultural production drives the intensive concentration of land, energy, and water resources, creating a structural tension between production expansion and ecological carrying capacity [1]. Against this backdrop, rural ecological governance must incorporate resource metabolism processes into its regulatory framework. By constraining high-energy-consumption inputs, adjusting crop structures, and optimizing spatial layouts, it can mitigate the crimp effect of single-minded economic objectives on ecosystems, ensuring that production activities remain dynamically aligned with nature's regenerative capacity. Extending further to the level of social relations, eco-Marxism emphasizes the role of production relations in shaping ecological problems. Rural areas exhibit an asymmetry of rights and responsibilities among stakeholders in industrial division of labor and interest distribution. The absence of coordination mechanisms among grassroots organizations, farmers, and external capital leads to fragmented ecological governance practices. By reshaping the multi-stakeholder participation structure and linking the allocation of resource usage rights, governance responsibilities, and benefit distribution, it is possible to reduce the scope for disorderly development at the institutional level, thereby shifting ecological governance from isolated interventions to systematic, coordinated operations.

2.2. The Value Orientation of Rural Ecological Governance

The realization of the value orientation of rural ecological governance relies on the collaborative construction of an indicator system and a computational model [2]. First, the system is structurally divided into three submodules: ecological environment, resource utilization, and social output, which are respectively connected to water quality sensors, land use databases, and farmer income collection ports. Subsequently, through data preprocessing, standardization and outlier removal are performed, and the data is uniformly converted into dimensionless indicators within the 0--1 range. The comprehensive evaluation of governance value is constructed by integrating ecological environment quality, social output level, and resource utilization efficiency through weighted aggregation, forming a unified measurement framework.

where the comprehensive governance value index reflects the overall performance of rural ecological governance; the ecological environment quality index is derived from water quality compliance rate and vegetation coverage; the social output index is determined by farm household income growth rate and employment stability; and resource utilization efficiency is represented by indicators such as water-to-land output ratio and recycling rate. The weighting coefficients are dynamically calculated using the entropy weighting method. During model operation, data is updated on a daily rolling basis, and the weighting matrix is adjusted accordingly to shift priorities across different management phases. Furthermore, threshold control rules are introduced at the scheduling level: when the comprehensive value falls below 0.6, a resource reduction strategy is triggered, automatically lowering the proportion of high-water-consumption crops and restricting the intensity of external inputs. A three-dimensional "resource--output--ecology" coupling quantification method is incorporated into the indicator construction, transforming the value orientation from empirical judgment to model-driven decision-making and establishing a computable system for expressing governance objectives.

2.3. Theoretical Adaptability of Eco-Marxism

The process of adapting Eco-Marxism to rural ecological governance must be embedded within specific production organization and resource allocation contexts. The agricultural structure, characterized by predominantly decentralized operations, dictates that the regulation of ecological factors must be implemented through micro-level units. Therefore, institutional design must refine indicators such as arable land utilization intensity, upper limits on input use, and ecological restoration targets down to the household level. Precise constraints are enforced through digital ledgers and plot coding, ensuring that resource metabolism processes are spatially identifiable and traceable, thereby preventing deviations in the implementation of macro-level policies. Building on this foundation, adaptability is further manifested in the manner in which multi-stakeholder relationships are integrated [3]. In the rural governance system, grassroots organizations assume organizational and coordinating functions, while cooperatives and business entities are responsible for resource integration and production execution. By establishing information-sharing interfaces and profit-sharing rules, ecological constraints are embedded into the production decision-making chain, ensuring that governance requirements are simultaneously reflected in input selection, crop structure, and output distribution. This creates an operational structure where institutional constraints drive behavioral adjustments.

3. Analysis of the Actual Structure of Rural Ecological Governance

3.1. Imbalances in the Structure of Ecological Resource Utilization

The identification of imbalances in the ecological resource utilization structure employs a "resource supply--demand matching" analysis process. The system structure consists of a resource monitoring layer, a demand analysis layer, and a deviation calculation module: the monitoring layer collects data on water usage, arable land area, and energy consumption, with a sampling period set at 1 day; the demand layer calculates theoretical demand values based on crop structure and industrial load, and corrects for seasonal fluctuations using a linear regression model; subsequently, the calculation module performs normalization, standardizing the proportion of each resource type to the [0,1] range. The core deviation evaluation is constructed by aggregating the normalized differences between actual resource allocation and corresponding demand across multiple resource types, forming a unified measure of structural imbalance.

where the degree of resource structural imbalance reflects the deviation between actual allocation and corresponding demand of each resource type; the actual allocation of each resource is compared with its theoretical demand, while total supply and total demand serve as reference baselines; and the number of resource types determines the scope of aggregation. The model is updated weekly; when the imbalance degree exceeds 0.25, a structural adjustment strategy is triggered, automatically reducing the allocation proportion of resources with high deviation and reconstructing the crop allocation matrix.By incorporating a mechanism to accumulate the absolute values of the differences in supply-demand ratios into the computational workflow, we achieve quantitative identification and graded regulation of resource misallocation, thereby establishing a structural diagnostic method tailored for practical application. The structural deviation between the supply of rural ecological resources and industrial demand can be intuitively represented through the supply-demand matching process, as shown in Figure 1.

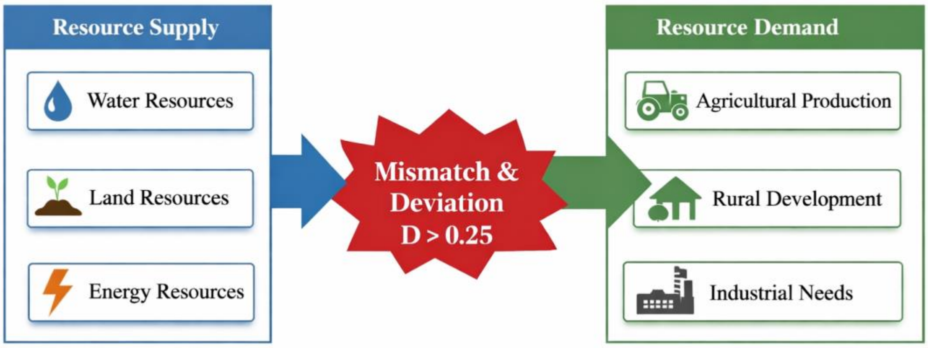

Figure 1. Schematic Diagram of Structural Imbalance in Rural Ecological Resource Supply and Demand

3.2. Weakening of the Coordination Mechanism Among Governance Actors

The weakening of coordination mechanisms among governance actors is primarily manifested in the discontinuity of information flow. Rural ecological governance involves grassroots organizations, agricultural operators, and external service providers. However, multi-source data lacks a unified interface during collection, transmission, and utilization, and a stable mapping relationship has not been established between monitoring data and production decisions. This makes it difficult to synchronously integrate resource regulation and environmental constraints into the production process [4]. Differences among stakeholders in data acquisition frequency, indicator definitions, and update cycles cause delays and distortions in the transmission of governance information, making it difficult to establish collaborative decision-making based on a consistent data foundation. At the operational level, the weakening of the coordination mechanism is further reflected in the mismatch between the allocation of authority and responsibilities and the execution chain. Grassroots organizations assume organizational functions in resource allocation and constraint enforcement, but lack incentive and constraint mechanisms aligned with business entities, making it difficult to consistently implement ecological governance requirements at the production level. At the same time, the absence of stable interest-linking structures between cooperative organizations and market entities, coupled with the lack of a linkage mechanism between resource allocation and profit distribution, keeps collaborative relationships in a loosely connected state, making it difficult to support continuous ecological governance activities.

3.3. Inadequate Institutional Enforcement and Constraint Mechanisms

There is a disconnect in the transmission of constraints during the institutional enforcement process. While ecological governance-related regulations are formulated as indicators and standards, they lack a direct mapping relationship with specific land parcels, production activities, and input intensities during grassroots implementation. Consequently, institutional constraints cannot be precisely applied to specific operational stages. No automatic verification mechanism has been established between monitoring data and institutional rules. The identification of violations relies on manual patrols and ex post facto verification, and the enforcement chain exhibits characteristics of infrequent triggering and delayed response, making it difficult to embed institutional constraints into continuous production processes. Furthermore, this manifests as a lack of dynamic adjustment capabilities in the constraint mechanism [5]. Existing systems primarily rely on static threshold settings and lack adaptive adjustment logic for variations in seasons, crop types, and resource carrying capacity, resulting in deviations from the same constraint standards across different scenarios [6]. No real-time coupling relationship has been established between resource usage limits and environmental capacity, and constraint intensity cannot be synchronously adjusted in response to changes in monitoring data. Consequently, institutional enforcement exhibits rigid mismatches during both high-load and low-load phases, making it difficult to form a stable closed-loop constraint system [7,8].

4. Constructing a Governance Pathway Guided by Eco-Marxism

4.1. Embedding Governance Principles Guided by Ecological Priority

The integration of the "ecology-first" orientation is first reflected in the establishment of upfront constraints within the resource allocation process. Using individual plots as the basic unit, key parameters such as water quotas, fertilizer application rates, and tillage frequency are incorporated into the production planning phase [9]. By establishing a three-way mapping relationship between "resource thresholds---crop structure---input schemes," production decisions are subject to ecological constraints from the very outset [10]. In practice, leveraging plot codes and monitoring data interfaces, environmental capacity indicators are converted into actionable parameters and embedded into cropping models and input decision algorithms, enabling the automatic identification and restriction of high-water-consumption and high-load production methods. At the operational level, by establishing a real-time monitoring and rule-based linkage mechanism, the principle of ecological priority is transformed into a dynamic regulatory logic. The monitoring system collects daily data on water consumption, soil nutrients, and non-point source pollution indicators and compares them with preset thresholds. When key indicators approach the upper limit, adjustment commands are triggered to synchronously modify irrigation frequency, fertilizer application rates, and operational intensity [11]. This process relies on a rule engine to perform automatic judgment and scheduling, ensuring that ecological constraints continuously influence the production process and forming an embedded operational structure that spans from plan generation to execution and regulation. To achieve the coordinated optimization of agricultural production factor constraints and decision-making regulation, a closed-loop operational framework integrating resource thresholds, decision control, and dynamic feedback adjustment has been established, as shown in Figure 2.

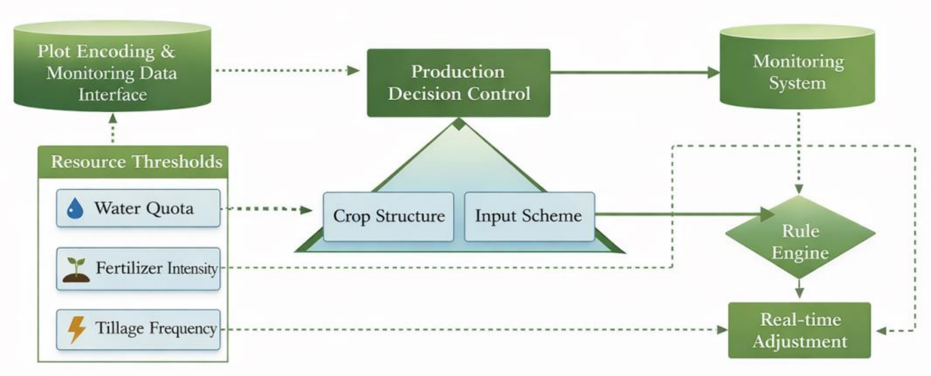

Figure 2. Flowchart of Ecology-First Orientation Embedded in Production Decision-Making

4.2. Construction of a Multi-Stakeholder Collaborative Governance Mechanism

The multi-stakeholder collaborative governance mechanism is constructed using a three-tier structure of "data-driven---authority-based modeling---collaborative scheduling." The system comprises a data access layer, a collaborative computation layer, and an execution feedback layer: First, the access layer integrates government regulatory data, enterprise production data, and farmer behavioral data, standardizing the interface format (JSON) and setting a sampling period of 1 day; subsequently, the computation layer constructs a vector of stakeholder participation intensity, quantifying and normalizing each stakeholder's resource input, decision-making frequency, and execution response; based on this, a collaboration degree evaluation framework is established by aggregating participation intensity and inter-entity interaction relationships, forming a unified measurement of collaborative performance [12].

where the collaboration level index reflects the overall coordination among stakeholders; the participation intensity of each entity captures its resource input, decision frequency, and response capability; the inter-entity collaboration weight is derived from information sharing frequency and resource complementarity; and the number of entities determines the scope of interaction. The model is updated weekly; when the collaboration level falls below 0.5, a collaboration enhancement strategy is triggered, automatically adjusting resource allocation priorities and reconstructing collaboration pathways. By introducing a coupled calculation method for the multi-agent interaction weight matrix and participation intensity in the mechanism design, we achieve a transition from static connections to dynamic quantitative regulation of collaborative relationships, thereby constructing a computable collaborative governance model. The coupling relationships and operational structure among multi-agents during data interaction, collaborative computation, and execution feedback are shown in Figure 3.

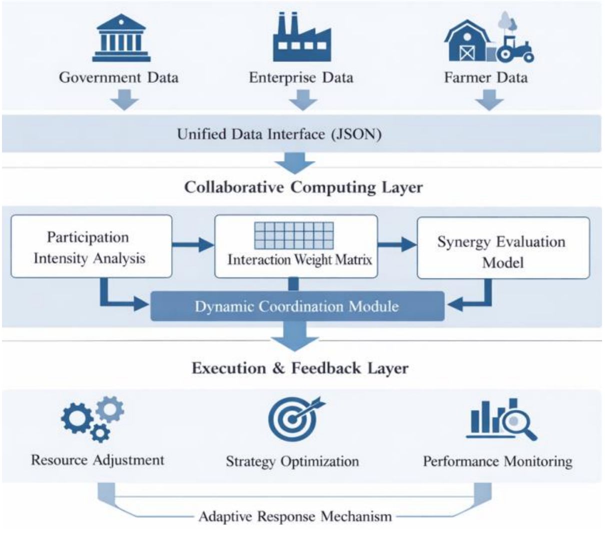

Figure 3. Operational Structure Diagram of the Multi-Agent Collaborative Governance Mechanism

4.3. Ecological Transformation of Production and Lifestyle

The ecological transformation of production and lifestyle must be synchronously embedded into the operational chains of both the production and living sectors. On the production side, operational methods should be restructured based on resource consumption constraints, incorporating processes such as irrigation, fertilization, and tillage into refined control units. By implementing plot zoning, quantitative application, and process monitoring, the inertia of high-input production is reduced, shifting agricultural activities from extensive expansion to a state of controllable load. Adjustments to crop structures should no longer be determined solely by market returns but should be linked to land and water carrying capacities, pollution thresholds, and waste recycling conditions, ensuring that production organization reflects ecological constraints in input selection, operational frequency, and output pathways. On the living side, the ecological transformation manifests as the coordinated reorganization of consumption, housing, and waste disposal practices. Rural domestic sewage, household waste, and energy use must be incorporated into grid-based management units. Through sorted collection, tiered treatment, and end-use recycling, a closed-loop system is formed to reduce the continuous environmental impact of daily living processes. Simultaneously, the improvement of village public spaces, the adoption of clean energy alternatives, and the standardization of resident behavior are integrated to align daily living norms with ecological governance requirements, thereby promoting the synchronized adjustment of living order, spatial environments, and resource recycling practices. The coupled operational pathways between the production and living sectors in terms of resource constraints, behavioral adjustments, and recycling processes are illustrated in Figure 4.

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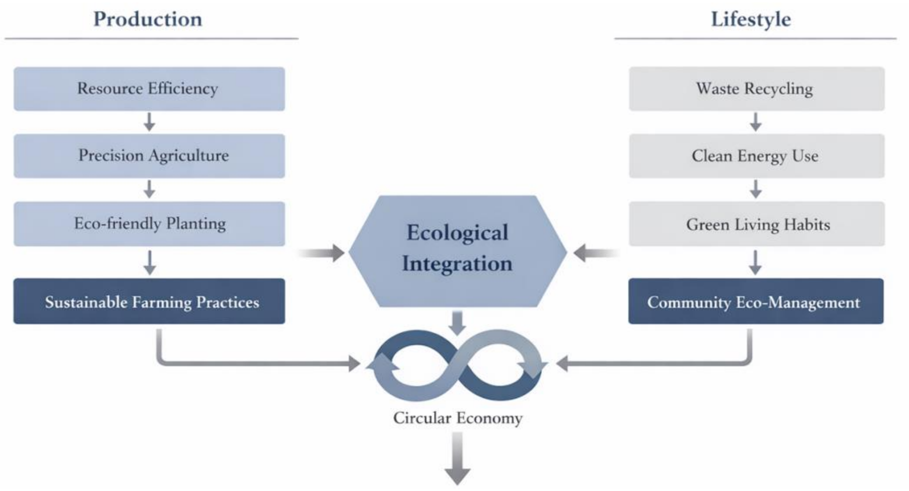

Figure 4. Operational Pathway for the Ecological Transformation of Production and Lifestyle

5. Operational Mechanisms for Implementing Governance Pathways

5.1. Reconstruction of the Grassroots Governance System and Institutions

The reconstruction of the grassroots governance system should be carried out simultaneously across organizational units, execution chains, and data interfaces. In practice, village-level organizations, grid units, and cooperative organizations can be incorporated into a tiered governance structure, establishing a closed-loop process following the sequence of "monitoring and data collection---task distribution---process verification---result feedback. "At the village level, authorities are responsible for issuing regulations and coordinating resources; grid units undertake plot inspections, behavior logging, and reporting of anomalies; and cooperative organizations are responsible for embedding ecological constraints into planting, irrigation, and input management processes. This transforms governance tasks from abstract requirements into actionable checklists, establishing clear correspondences regarding timelines, responsible parties, and response measures. The restructuring of governance systems must be further implemented at the levels of rule coding and execution verification. Parameters such as arable land utilization intensity, input limits, and wastewater treatment requirements can be converted into parametric constraints and embedded into village-level governance ledgers and production management forms. Through standardized coding, this enables object identification, behavior tracking, and violation comparison. By establishing linked fields for inspection records, monitoring data, and disposal outcomes, a mapping chain is formed between institutional provisions, implementation actions, and feedback results, ensuring continuous coordination within the grassroots governance system regarding organizational collaboration, rule transmission, and process control.

5.2. Mechanism for Enhancing Ecological Governance Capabilities

The enhancement of ecological governance capabilities should be advanced simultaneously across three key phases: perception, analysis, and execution. At the perception stage, indicators such as water quality, soil nutrients, non-point source emissions, and domestic wastewater treatment must be incorporated into routine data collection. A foundational data chain is established by combining fixed monitoring points with grid-based patrols. At the analysis stage, classification rules are established based on village-level ledgers, plot codes, and historical records to screen and prioritize high-load plots, abnormal discharge points, and frequent violations. At the execution stage, identification results should be converted into rectification lists, dispatch orders, and process records, ensuring a one-to-one correspondence between governance actions and identified issues, thereby preventing capacity-building efforts from remaining at the level of training or publicity. Further improvements must be implemented through the coordinated allocation of personnel, tools, and processes. Grassroots officials, grid patrol officers, and key members of partner organizations should be assigned roles based on three categories of responsibilities---monitoring and data entry, problem verification, and measure implementation---and provided with standardized forms, record templates, and response deadlines; Establish standard operating procedures (SOPs) for irrigation scheduling, input material control, waste sorting, and wastewater treatment to minimize discretionary decision-making. Simultaneously, implement a phased review mechanism to continuously verify issue detection rates, task completion rates, and recurrence rates of anomalies, thereby gradually institutionalizing governance capabilities in data utilization, process execution, and on-site resolution [13].

5.3. Dynamic Assessment and Feedback Control Mechanism

The dynamic assessment and feedback control mechanism should operate according to the "data collection---status determination---deviation correction---result feedback" chain. In practice, water quality compliance rates, input intensity per unit of cultivated land, timely waste collection rates, and sewage treatment compliance rates are incorporated into the daily data collection sequence, aggregated daily, verified weekly, and uniformly mapped to governance status parameters; Subsequently, deviation levels are calculated based on target thresholds and actual values, generating a tiered warning list for indicators exceeding limits, which is pushed to village-level governance ledgers and responsible units. For indicators showing abnormalities over two consecutive cycles, the system directly triggers a re-verification process and reassignment of tasks, ensuring that assessments do not remain at the level of static records. A dual-determination rule of "weekly verification + tracking of continuous abnormalities" is embedded in the operational structure, transforming point-based monitoring into a process-oriented dynamic identification mechanism. The feedback and control phase must be synchronized with the execution chain to form a closed loop. Upon receiving an alert, each responsible entity invokes the corresponding response template based on the issue type to adjust parameters for irrigation frequency, input application, discharge point remediation, and household waste transfer. They then upload the rectification results, verification status, and secondary monitoring data back to the system; the system subsequently updates risk levels and task priorities based on the uploaded results, forming the basis for the next round of control. By directly incorporating feedback results into the task priority update module, a closed-loop control pathway of "assessment---response---reassessment" is established, enabling the adaptive adjustment of governance intensity in response to changing conditions. The closed-loop operational relationship between dynamic assessment, early warning triggering, and feedback control, along with the data flow paths, is shown in Figure 5.

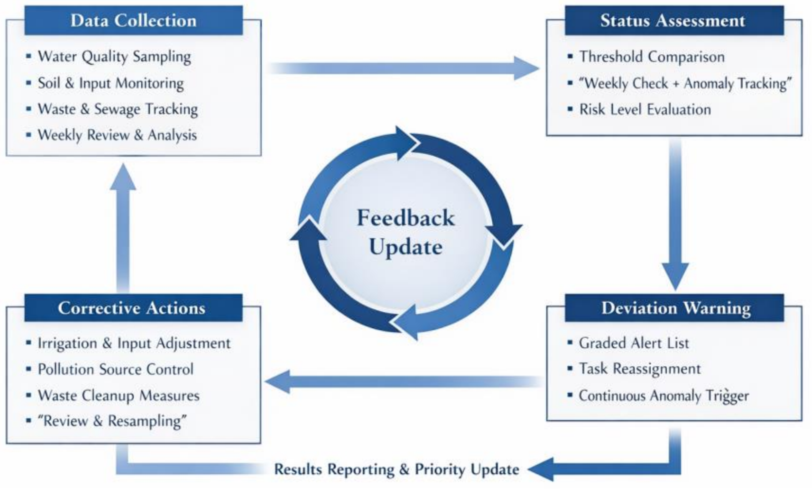

Figure 5. Closed-Loop Flowchart of Dynamic Assessment and Feedback-Based Control

6. Conclusion

Eco-Marxism provides a central analytical framework for rural ecological governance that integrates resource allocation, institutional constraints, multi-stakeholder collaboration, and feedback-based regulation. Addressing practical challenges such as the misallocation of ecological resources, the weakening of collaborative mechanisms, and imbalances in institutional implementation, this paper proposes a comprehensive framework encompassing the embedding of governance principles, the construction of multi-stakeholder collaboration, the transformation of production and lifestyle patterns, and the optimization of operational mechanisms, while incorporating dynamic assessment and closed-loop regulation into the governance process.Future research could further integrate regional variations, digital monitoring tools, and long-term tracking data to promote the tiered adaptation and continuous refinement of governance models.

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