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A Review of Rice Straw Waste Management in Sidorogo Area from the Perspective of Environmental Law

Mohammad Hafidz Sukanto[1*], Nur Qoilun[2]
[1-3] Universitas Maarif Hasyim, Indonesia
email: hafidzsukanto31@gmail.com[1]

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Abstract

Rice straw remains underutilized in Indonesia despite its considerable potential as a renewable biomass resource for sustainable agriculture. This study examines rice straw waste management in the Sidorogo area from the perspective of environmental law using an empirical legal research design with a descriptive qualitative approach. Primary data were obtained through field observations and semi-structured interviews with rice farmers, while secondary data were collected from legislation and relevant scientific literature. The findings indicate that open burning remains the dominant practice because of limited time for land preparation, inadequate waste-processing technology, and economic considerations. This practice contributes to soil degradation, air pollution, and potential health risks while reflecting limited implementation of environmental regulations. Composting, livestock-feed production, and biomass utilization offer sustainable alternatives that support resource efficiency and reduce environmental impacts. Strengthening environmental law implementation through technological support, farmer education, and institutional collaboration can improve sustainable waste management. Integrating the principles of reduce, reuse, and recycle (3R) with a zero-waste approach provides an effective framework for converting rice straw into valuable agricultural resources while promoting environmental sustainability and rural development.

Keywords: *Circular Economy, Environmental Law, Rice Straw Waste, Sustainable Agriculture, Waste Management.*

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INTRODUCTION

Indonesia is widely recognized as one of the world's major agrarian countries, whose equatorial geographical location provides favorable climatic conditions that enable rice cultivation to be carried out continuously throughout the year, positioning rice as an indispensable commodity for national food security, rural livelihoods, and socio-economic development (Singh & Patel, 2022). Continuous increases in rice production have inevitably generated enormous quantities of rice straw, transforming what was traditionally regarded as agricultural residue into a strategic environmental issue that requires integrated management within the broader framework of sustainable development and circular resource utilization (Bressan et al., 2022). Beyond its economic significance, rice cultivation also represents an important social and cultural institution because farming practices preserve local wisdom, strengthen community cooperation, and sustain the livelihoods of millions of Indonesian households across rural regions. Recent studies increasingly argue that rice straw should no longer be viewed merely as agricultural waste because it possesses substantial potential to be converted into renewable energy, bio-based materials, organic fertilizer, livestock feed, and other value-added products capable of supporting low-carbon rural development (Singh et al., 2024). The expansion of national agricultural production simultaneously increases the volume of agricultural residues, creating growing environmental challenges whenever straw management continues to rely on inefficient disposal practices rather than sustainable resource recovery (Prawira et al., 2024). These developments indicate that rice straw management has evolved from a purely technical agricultural concern into a multidimensional issue involving environmental governance, community participation, and legal accountability.

Previous studies consistently demonstrate that environmentally sound rice straw management contributes not only to pollution prevention but also to economic diversification through compost production, livestock feed, biomass utilization, and various forms of green innovation that strengthen

rural resilience (Santoso et al., 2023). Systematic reviews further reveal that technological advancement has significantly expanded opportunities for transforming rice straw into commercially valuable products while simultaneously reducing greenhouse gas emissions associated with conventional disposal practices (Singh & Patel, 2022). Numerous community-based initiatives implemented in Indonesia have successfully introduced straw fermentation, composting, ammoniation technology, and straw paper production as practical alternatives capable of improving farmers' welfare while minimizing environmental degradation (Dewi et al., 2024). Educational and extension programs have likewise strengthened farmers' knowledge regarding sustainable residue utilization, although their long-term effectiveness remains strongly influenced by institutional support and local governance capacity (Bimasri et al., 2025). Nevertheless, the practical adoption of these innovations differs considerably among rural communities because technological accessibility, economic feasibility, and behavioral acceptance remain highly context-dependent. This pattern suggests that sustainable rice straw management cannot be explained solely through technological innovation but must also be understood through the interaction between social institutions, environmental governance, and regulatory implementation (Rhofita et al., 2024).

Despite the growing body of literature concerning rice straw utilization, existing research remains predominantly concentrated on technological innovation, biomass conversion, agricultural productivity, and community empowerment, while comparatively limited attention has been devoted to examining how environmental law shapes farmers' waste-management behavior and institutional compliance (Alauddin et al., 2024). Studies addressing the environmental consequences of open burning consistently report declining soil quality, increased air pollution, and ecosystem degradation, yet these environmental findings are rarely integrated with analyses of legal enforcement and regulatory effectiveness (Dwicahya et al., 2024). Indonesian environmental legislation has established comprehensive legal obligations concerning environmental protection and waste management, yet implementation frequently encounters institutional fragmentation, weak supervision, and inconsistent law enforcement across local administrative levels (Hardi et al., 2024). Similar observations indicate that environmental law enforcement continues to face structural challenges associated with governance coordination, monitoring mechanisms, and community compliance despite increasingly comprehensive regulatory frameworks (Alauddin et al., 2024). Such conditions become particularly significant in agricultural regions where farmers often prioritize immediate economic efficiency over long-term environmental sustainability because regulatory implementation remains uneven across local contexts. Consequently, an important conceptual gap persists regarding how environmental law interacts with local waste-management practices, especially in rice-producing communities such as the Sidorogo area where agricultural residue generation continues to increase.

The unresolved discrepancy between the increasing availability of sustainable straw management technologies and the continued prevalence of environmentally harmful disposal practices highlights the necessity of examining environmental governance beyond technical intervention alone (Prateep Na Talang et al., 2024). In Indonesia, environmental protection has been normatively regulated through Law Number 32 of 2009 concerning Environmental Protection and Management, which establishes legal responsibilities for preventing pollution and ensuring sustainable natural resource management (Undang-Undang Nomor 32 Tahun 2009 tentang Perlindungan dan Pengelolaan Lingkungan Hidup). These legal obligations are further operationalized through Government Regulation Number 22 of 2021, which emphasizes environmental protection planning, pollution control, and integrated environmental management as essential components of sustainable development (Peraturan Pemerintah Nomor 22 Tahun 2021 tentang Penyelenggaraan Perlindungan dan Pengelolaan Lingkungan Hidup). Several recent studies nevertheless reveal that open burning of rice straw remains widely practiced because regulatory implementation is frequently constrained by limited institutional supervision, inadequate public awareness, and insufficient coordination among local stakeholders (Agustiani et al., 2025). Community empowerment programs involving composting, livestock-feed production, administrative strengthening, and technology-based village development have demonstrated promising outcomes, although these initiatives often remain fragmented and insufficiently connected to environmental law implementation (MGB et al., 2026). Examining the Sidorogo area from the perspective of environmental law therefore becomes scientifically and practically important because it provides an opportunity to understand how legal norms, institutional arrangements, and community practices interact in shaping sustainable agricultural waste management.

Current scholarship has produced extensive evidence regarding the environmental characteristics of agricultural waste, the economic potential of rice straw utilization, and various community-based innovations designed to promote sustainable residue management, yet these discussions remain largely disconnected from legal analyses that evaluate whether environmental regulations effectively influence local behavioral change (Arista, 2024). Research concerning composting, organic fertilizer production, livestock feed, business capacity strengthening, and environmentally friendly agricultural practices has consistently demonstrated the technical feasibility of rice straw valorization without comprehensively explaining the institutional conditions necessary for ensuring long-term regulatory compliance (Narju et al., 2025). Comparable findings have been reported in studies examining straw processing into compost, fermented feed, straw paper, and other value-added products, where technological success has not always been accompanied by sustained environmental governance at the local level (Nurcahyanti et al., 2024). Investigations focusing on farmer capacity development and agricultural entrepreneurship similarly indicate that economic incentives encourage innovation, although legal awareness and environmental responsibility remain uneven among farming communities (Saragih, 2024). Other studies also confirm that ammoniation technology and agricultural innovation significantly improve the utilization of rice straw for livestock production, while renewable-energy development further strengthens the strategic value of agricultural residues within the circular economy (Syaiful & Siva, 2022; Priscillia et al., 2025). Positioning this study within the intersection of environmental law, rural governance, and community waste-management practices offers a broader analytical perspective that complements the predominantly technological orientation of previous rice straw research.

This study is designed to examine the management of rice straw waste in the Sidorogo area by positioning environmental law as the principal analytical framework for understanding the relationship between legal norms, institutional implementation, and community practices. Rather than evaluating straw utilization solely from technological or economic perspectives, this research investigates how environmental governance influences the effectiveness and sustainability of agricultural waste management at the local level. The study seeks to explain the extent to which existing regulatory arrangements are translated into practical implementation within farming communities and how these arrangements shape environmental responsibility among local stakeholders. Such an approach enables a more comprehensive understanding of the interaction between legal institutions, social behavior, and environmental sustainability within rural agricultural systems. The expected theoretical contribution lies in strengthening interdisciplinary discussions that connect environmental law, social governance, and sustainable agricultural development into a unified analytical framework. The methodological contribution is reflected in the use of a legal-review approach integrated with contextual analysis of local waste-management practices, thereby providing a more holistic perspective for future studies concerning agricultural waste governance in Indonesia.

RESEARCH METHODS

This study employed an empirical legal research design with a descriptive qualitative approach to examine rice straw waste management practices in the Sidorogo area from the perspective of environmental law (Alauddin et al., 2024). Primary data were collected through field observations and semi-structured interviews with rice farmers and landowners directly involved in rice cultivation and rice straw management, while secondary data were obtained from legislation, scientific journals, books, and other relevant legal documents, including Law Number 32 of 2009 and Government Regulation Number 22 of 2021 concerning environmental protection and management (Undang-Undang Nomor 32 Tahun 2009 tentang Perlindungan dan Pengelolaan Lingkungan Hidup; Peraturan Pemerintah Nomor 22 Tahun 2021 tentang Penyelenggaraan Perlindungan dan Pengelolaan Lingkungan Hidup). Informants were selected using purposive sampling to ensure that participants possessed direct experience related to rice straw generation and environmental management practices (Rhofita et al., 2024). Data collection was conducted through observation, interviews, and documentation, enabling the researcher to compare empirical findings with applicable environmental legal provisions (Hardi et al., 2024). This approach facilitated a contextual understanding of the implementation of environmental law in local agricultural waste management.

The research instruments consisted of observation guidelines, interview protocols, and documentation sheets designed according to the objectives of the study (Arista, 2024). Data credibility

was strengthened through source and method triangulation by comparing information obtained from interviews, observations, documentation, and relevant legal sources (Agustiani et al., 2025). The collected data were analyzed using an interactive qualitative analysis technique involving data reduction, data presentation, interpretation, and conclusion drawing to identify the relationship between rice straw management practices and environmental law implementation (Alauddin et al., 2024). The analytical process also involved comparing empirical findings with the legal framework governing environmental protection and agricultural waste management in Indonesia (Peraturan Pemerintah Nomor 22 Tahun 2021 tentang Penyelenggaraan Perlindungan dan Pengelolaan Lingkungan Hidup). Ethical principles were maintained by obtaining participants' informed consent, protecting confidentiality, and ensuring that all collected information was used solely for academic research purposes.

RESULTS AND DISCUSSION

Characteristics and Distribution of Rice Straw Waste in Sidorogo Area

Field observations indicate that rice straw constitutes the largest biomass residue generated during post-harvest activities in the Sidorogo area, with an estimated fresh biomass production ranging from 6 to 8 tons per hectare during each harvesting season. The quantity and spatial distribution of straw were strongly influenced by the harvesting method adopted by farmers, resulting in different waste-management patterns and operational challenges during land preparation. Manual harvesting generally produced concentrated piles of straw along field boundaries, whereas combine harvesters fragmented and dispersed the residues across the entire paddy surface, creating a dense organic layer that delayed subsequent cultivation activities. These observations demonstrate that residue distribution, rather than merely residue quantity, significantly determines farmers' waste-management decisions. Comparable findings have been reported by Singh and Patel (2022), who argued that harvesting technology substantially influences the efficiency of rice straw collection and subsequent biomass utilization.

The morphological characteristics observed in the field showed that rice straw consisted primarily of stems, leaves, and residual panicles, with stems representing the largest proportion of the biomass and exhibiting greater structural rigidity than other plant components. Several interviewed farmers explained that the coarse texture of mature straw complicated manual handling and accelerated their preference for field burning as a practical solution before the next planting season. Laboratory findings reported in previous studies classify rice straw as a lignocellulosic material containing high proportions of cellulose, hemicellulose, lignin, and silica, characteristics that naturally slow biological decomposition under ordinary field conditions (Arista, 2024; Bressan et al., 2022). The relatively high carbon-to-nitrogen ratio further limits rapid decomposition unless microbial activators or composting technologies are introduced. These physical and chemical characteristics explain why rice straw frequently accumulates in agricultural fields despite its considerable potential as a renewable biomass resource.

Table 1. Distribution Characteristics of Rice Straw Biomass in the Sidorogo Area

Harvesting Method	Straw Distribution Pattern	Estimated Biomass (Fresh Weight)	Implications for Land Preparation
Manual harvesting	Concentrated piles near field edges	6–8 tons/ha	Easier collection but requires transportation
Combine harvester	Evenly scattered across field surface	6–8 tons/ha	Accelerates harvesting but complicates residue management

The results presented in Table 1 demonstrate that mechanized harvesting does not reduce the quantity of straw generated but instead alters its spatial distribution, creating additional challenges for farmers attempting to prepare land within a relatively short planting interval. Interviews revealed that scattered residues frequently interfere with tractor operations because straw becomes entangled around tillage equipment, increasing operational time and fuel consumption. This practical constraint explains why residue burning continues to be perceived as the most efficient short-term alternative despite its adverse environmental consequences. Similar observations were documented by Rhofita et al. (2024),

who emphasized that farmers' decisions regarding straw utilization are strongly shaped by operational efficiency, labor availability, and local agricultural conditions rather than environmental considerations alone.

Another important finding concerns the persistence of straw residues after harvest, particularly during consecutive planting cycles where the interval between harvesting and land preparation generally ranges from ten to fourteen days. Farmers consistently reported that natural decomposition could not occur within such a limited timeframe, making residue accumulation a significant obstacle to synchronized planting schedules across neighboring fields. Previous studies similarly indicate that the slow degradation of lignocellulosic biomass represents one of the principal barriers preventing sustainable rice straw utilization, particularly in intensive rice production systems (Singh et al., 2024). From an agronomic perspective, the accumulation of undecomposed straw reduces operational flexibility and increases the perceived urgency for rapid residue removal before the following cultivation cycle begins. These conditions illustrate that technical constraints constitute an important determinant of waste-management behavior and cannot be separated from broader environmental governance issues.

Although many farmers recognized that rice straw possesses economic value, direct field observations suggested that only a limited proportion of the available biomass was utilized for livestock feed or organic fertilizer production. Most respondents acknowledged that the absence of affordable shredding equipment, limited access to composting facilities, and insufficient technical assistance discouraged them from adopting more sustainable management practices. Comparable experiences have been reported in several Indonesian rural communities where straw utilization remains constrained by inadequate technological infrastructure, institutional support, and extension services (Hanafi et al., 2023; Pratama, 2022). The observed conditions indicate that rice straw in Sidorogo should not be interpreted merely as agricultural residue but rather as an underutilized biological resource whose management depends on the interaction between technological capacity, socio-economic considerations, and institutional support. This empirical evidence provides the basis for examining how environmental governance and legal implementation influence farmers' waste-management practices, which is explored further in the following section concerning the environmental impacts of rice straw management.

Environmental Impacts of Rice Straw Management Practices

Field observations revealed that open burning remained the dominant post-harvest practice among rice farmers in the Sidorogo area despite widespread awareness that the activity generated environmental degradation. Interviews indicated that the short interval between harvesting and the next planting season encouraged farmers to prioritize rapid land clearance over environmentally sustainable residue management. The observed burning process generally lasted between 20 and 45 minutes for each large straw pile, with flame intensity reaching its peak approximately ten minutes after ignition and producing considerable heat that penetrated the upper soil layer. This pattern illustrates that farmers' management decisions are largely driven by operational efficiency rather than environmental considerations. Similar tendencies have been identified by Prateep Na Talang et al. (2024), who concluded that time constraints and production efficiency remain the principal drivers of agricultural residue burning in intensive rice-producing regions.

Direct observation further demonstrated that thermal exposure extended beyond the combustion of surface biomass and affected the physical condition of the surrounding soil. Areas subjected to burning remained noticeably warm for almost two hours after the flames had disappeared, suggesting that heat penetrated into the topsoil and altered its physical characteristics. Several burned plots developed a compact surface crust with lower moisture retention than neighboring plots covered by straw mulch, making subsequent tillage more difficult during land preparation. Previous investigations similarly reported that open burning reduces soil quality by damaging soil structure and accelerating the loss of organic matter essential for long-term agricultural productivity (Dwicahya et al., 2024). The field evidence indicates that repeated burning has cumulative consequences that extend beyond immediate residue removal and influence the sustainability of paddy cultivation.

Table 2. Environmental Conditions Observed Before and After Rice Straw Burning

Indicator	Before Burning	After Burning
Soil color	Dark brown	Greyish brown with ash layer
Soil fauna	Earthworms and insects observed	No visible soil fauna
Soil surface	Loose and moist	Hard, compact, thin crust
Air visibility	Normal	Reduced to <150 m
Air quality	Clear	Dense smoke and soot particles

The findings presented in Table 2 demonstrate that environmental degradation occurred simultaneously in both terrestrial and atmospheric components following straw burning. The disappearance of visible soil organisms suggests that elevated temperatures disrupted biological activity responsible for nutrient cycling and natural decomposition processes. Changes in soil color and surface texture further indicate the oxidation of organic matter, reducing the capacity of agricultural land to maintain biological fertility over repeated cultivation cycles. Comparable evidence has been reported by Arista (2024), who emphasized that environmentally inappropriate management of agricultural residues accelerates ecosystem degradation while reducing the ecological functions of productive farmland.

Atmospheric observations also revealed substantial deterioration in local air quality during the peak post-harvest period. Dense smoke accumulated above agricultural fields under low-wind conditions and formed localized smog that reduced visibility to less than 150 meters along village access roads, while soot particles were observed dispersing toward nearby residential areas within an estimated radius of approximately one kilometer. Individuals remaining near burning sites for more than fifteen minutes frequently reported eye irritation, coughing, and mild respiratory discomfort during field observation. These observations correspond with broader environmental assessments indicating that open burning releases particulate matter and greenhouse gases capable of affecting both ecosystem integrity and public health (Singh et al., 2024). The findings suggest that environmental impacts generated by rice straw burning extend beyond agricultural land and directly affect surrounding communities.

Not all observed impacts were negative, as several farmers demonstrated alternative residue-management practices capable of improving environmental quality while generating economic benefits. Small quantities of straw were incorporated into the soil as mulch, processed into compost, or utilized as livestock feed, allowing agricultural biomass to remain within local production systems rather than becoming atmospheric emissions. Previous studies have shown that composting, microbial decomposition, livestock-feed production, and biomass valorization enhance soil fertility while creating additional economic opportunities for farming households (Santoso et al., 2023). Similar innovations involving composting, straw processing, and community-based waste management have strengthened sustainable rice straw utilization in Indonesian rural communities (Narju et al., 2025). These empirical findings indicate that the environmental consequences of rice straw management are strongly determined by farmers' management choices, technological accessibility, and institutional support, providing an important foundation for evaluating legal compliance and environmental governance in the subsequent section.

Sustainable Optimization of Rice Straw Waste Management

The empirical findings indicate that the principal obstacle to sustainable rice straw management in the Sidorogo area is not the lack of biomass resources but the limited capacity to process straw within the narrow interval between harvesting and the subsequent planting season. Most interviewed farmers explained that the decomposition of untreated straw requires a considerably longer period than the available land preparation schedule, making open burning the most practical alternative despite its environmental consequences. This situation demonstrates that technical constraints significantly influence farmers' decision-making and often outweigh ecological considerations during agricultural production. Previous studies have similarly reported that slow lignocellulosic degradation remains one of the major barriers to sustainable rice straw utilization in intensive rice cultivation systems (Singh et al., 2024). The field evidence suggests that technological intervention should focus on reducing decomposition time while maintaining the ecological value of agricultural residues.

Several respondents expressed interest in utilizing rice straw for productive purposes but acknowledged that limited access to affordable technology prevented wider adoption of sustainable management practices. Mechanical shredders, microbial decomposers, and composting facilities were generally unavailable at the farmer-group level, resulting in low utilization of biomass despite its considerable economic value. Previous investigations have demonstrated that introducing appropriate technologies substantially improves the efficiency of converting rice straw into valuable agricultural inputs while reducing dependence on environmentally harmful disposal methods (Prawira et al., 2024). Similar findings indicate that biological decomposition using functional microorganisms accelerates nutrient release and enhances the quality of organic fertilizer produced from rice straw (Narju et al., 2025). These observations illustrate that technological accessibility remains a decisive factor influencing farmers' willingness to adopt environmentally responsible waste-management practices.

Table 3. Sustainable Alternatives for Rice Straw Waste Management

Management Alternative	Environmental Contribution	Economic Contribution
Composting	Improves soil organic matter and nutrient cycling	Reduces expenditure on chemical fertilizers
Livestock feed	Reduces agricultural waste accumulation	Supports livestock productivity
Bioenergy production	Decreases biomass burning and carbon emissions	Generates additional household income
Straw-based products	Extends biomass utilization	Creates rural business opportunities

The alternatives presented in Table 3 indicate that rice straw possesses multiple utilization pathways capable of generating environmental and economic benefits simultaneously. Composting contributes to soil restoration by increasing organic matter content, whereas livestock-feed production and bioenergy utilization convert agricultural residues into productive resources rather than environmental pollutants. The diversity of utilization options also reduces dependence on a single waste-management strategy, thereby increasing the resilience of local agricultural systems. Similar conclusions have been reported by Singh and Patel (2022), who emphasized that diversified biomass utilization represents an important component of sustainable agricultural development and circular bioeconomy implementation.

Beyond technological innovation, the optimization of rice straw management also requires institutional support capable of strengthening farmers' technical knowledge and organizational capacity. Interviews revealed that many respondents had limited information regarding compost production, microbial decomposition, and alternative biomass utilization despite expressing interest in adopting such practices. Previous community-based programs have demonstrated that farmer training, extension services, and participatory education significantly improve the adoption of sustainable straw management technologies while increasing local economic resilience (Hanafi et al., 2023). Comparable initiatives involving straw processing into paper, compost, and livestock feed likewise illustrate that continuous technical assistance encourages long-term behavioral change among farming communities (Nurcahyanti et al., 2024). These findings indicate that knowledge transfer functions as an essential complement to technological availability in promoting environmentally sustainable agricultural practices.

Field observations further suggest that optimizing rice straw management requires integration between technological innovation, institutional assistance, and environmental governance rather than relying on isolated interventions. Farmers generally demonstrated a positive perception toward sustainable straw utilization when practical solutions could reduce production costs without delaying the next planting cycle. Similar experiences from community empowerment programs reveal that strengthening local institutional capacity encourages wider adoption of environmentally friendly agricultural innovations while supporting sustainable rural development (MGB et al., 2026). The empirical evidence indicates that rice straw should be regarded as a strategic biological resource capable of contributing to soil conservation, renewable energy development, and rural economic diversification when supported by appropriate technology and effective institutional collaboration. These findings

provide an important foundation for evaluating the extent to which existing environmental regulations facilitate or constrain the implementation of sustainable rice straw management, which is discussed in the following section from the perspective of environmental law.

Environmental Law Perspective on Rice Straw Waste Management in the Sidorogo Area

Field observations indicate that the continued practice of open rice straw burning in the Sidorogo area is primarily influenced by operational efficiency rather than deliberate disregard for environmental protection. Most interviewed farmers explained that the interval between harvesting and the next planting season generally ranges from ten to fourteen days, leaving insufficient time for natural straw decomposition before land preparation begins. The accumulation of approximately 6–8 tons of straw per hectare further encourages farmers to select burning because it is perceived as the fastest and least expensive method for clearing agricultural land. These findings demonstrate that compliance with environmental regulations is closely associated with practical agricultural constraints rather than solely with legal awareness. Similar challenges have been identified by Alauddin et al. (2024), who argue that the effectiveness of environmental law enforcement depends not only on regulatory completeness but also on institutional capacity, technical feasibility, and community participation.

The empirical findings reveal that existing agricultural practices are not fully aligned with the objectives of Indonesian environmental legislation concerning pollution prevention and sustainable natural resource management. Law Number 32 of 2009 concerning Environmental Protection and Management establishes the obligation to prevent environmental pollution and environmental degradation through responsible management of natural resources. Government Regulation Number 22 of 2021 further emphasizes pollution control, environmental preservation, and the implementation of sustainable environmental management as essential elements of national environmental governance. Field observations nevertheless identified recurring smoke emissions, soil degradation, and declining biological activity following straw burning, indicating that preventive environmental measures have not yet been effectively implemented. The discrepancy between legal norms and field practices illustrates that regulatory implementation remains less effective when technical alternatives and institutional assistance are insufficient.

Table 4. Legal Assessment of Rice Straw Burning Practices in the Sidorogo Area

Legal Instrument	Main Regulatory Objective	Field Observation	Level of Compliance
Law No. 32 of 2009	Environmental protection and pollution prevention	Open straw burning continues	Low
Government Regulation No. 22 of 2021	Integrated environmental management	Air pollution and soil degradation observed	Low
Law No. 18 of 2008	Prohibition of inappropriate waste burning	Open burning without technical controls	Low
Government Regulation No. 4 of 2001	Prevention of land fires	Routine post-harvest burning	Low

The legal comparison presented in Table 4 demonstrates that several observed practices remain inconsistent with the environmental objectives established by Indonesian legislation. The persistence of open burning indicates that legal compliance cannot be measured solely through the existence of statutory provisions but should also consider the availability of practical mechanisms enabling farmers to fulfill their environmental obligations. Comparable observations have been reported by Hardi et al. (2024), who emphasize that environmental law enforcement frequently encounters implementation barriers arising from limited supervision, institutional coordination, and inadequate support for regulated communities. The empirical evidence suggests that regulatory effectiveness depends on the interaction between legal certainty, administrative capacity, and accessible environmental technologies. This interpretation reinforces the view that environmental governance should integrate preventive, educational, and facilitative approaches rather than relying exclusively on punitive enforcement.

Additional legal implications emerge from the wider environmental and social impacts documented during field observation. Dense smoke generated during simultaneous burning reduced

visibility along village access roads and caused temporary respiratory discomfort among nearby residents, creating potential risks extending beyond agricultural land. Such conditions are relevant to Law Number 18 of 2008 concerning Waste Management, which prohibits waste burning that does not comply with prescribed technical standards, while Government Regulation Number 4 of 2001 establishes preventive obligations concerning fires occurring on land. Community health considerations are likewise reflected in Law Number 36 of 2009 concerning Health, which recognizes the right of every individual to a healthy environment free from pollution sources that may threaten public well-being. The observed reduction in road visibility also demonstrates the potential relevance of Law Number 38 of 2004 concerning Roads, particularly where smoke interferes with transportation safety and the normal function of public roads.

The empirical findings further indicate that improving legal compliance requires more than strengthening sanctions because farmers continue to perceive open burning as the only feasible solution under existing production conditions. Respondents consistently associated environmentally friendly management with higher labor requirements, additional production costs, and limited technological availability, reducing their willingness to adopt alternative practices despite recognizing their environmental benefits. Similar experiences have been documented in studies highlighting that community education, technical assistance, and institutional collaboration significantly increase farmers' acceptance of sustainable rice straw management while improving environmental outcomes (Agustiani et al., 2025). This perspective suggests that environmental law should operate not only as a regulatory instrument but also as a framework that facilitates behavioral change through extension programs, technological support, and collaborative governance. Integrating legal enforcement with capacity-building initiatives would create a more balanced approach capable of strengthening environmental protection while remaining responsive to the practical realities of agricultural production in rural communities.

CONCLUSION

The findings demonstrate that rice straw waste in the Sidorogo area, Trosobo Village, Taman District, represents a substantial agricultural biomass resource whose management continues to be dominated by open burning because of operational constraints, limited technological accessibility, and short intervals between harvesting and the subsequent planting season. Field observations confirmed that this practice contributes to soil degradation, declining biological activity, reduced air quality, and potential disturbances to public health and surrounding communities. The empirical analysis also indicates that current management practices have not been fully aligned with the objectives of Indonesian environmental legislation, particularly those concerning environmental protection, pollution prevention, and sustainable waste management. Alternative utilization strategies, including composting, livestock-feed production, and other biomass-based applications, offer more environmentally sustainable options while simultaneously generating additional economic value for farming households. The study further reveals that farmers' decisions are influenced not only by environmental awareness but also by practical production considerations that require appropriate technological and institutional support. Environmental law should therefore be interpreted as an instrument that facilitates sustainable agricultural practices through integrated governance rather than relying solely on regulatory enforcement. These findings confirm that effective rice straw management requires the integration of technological innovation, institutional collaboration, and environmental legal implementation to achieve sustainable rural development.

Future efforts should prioritize expanding environmentally friendly rice straw utilization through the adoption of appropriate processing technologies capable of accelerating biomass decomposition and increasing the economic value of agricultural residues. Strengthening farmer education, extension services, and institutional cooperation will be equally important for improving the practical implementation of environmentally responsible waste management within local farming communities. The application of the principles of reduce, reuse, and recycle (3R) together with a zero-waste approach provides an appropriate framework for transforming rice straw from an environmental burden into a productive agricultural resource. Public policies should also encourage greater accessibility to composting technologies, biomass-processing equipment, and community-based waste management programs that correspond to the operational realities of rice farming. A stronger integration between environmental governance and rural development initiatives has the potential to improve both

ecological sustainability and farmers' economic resilience. The analytical framework developed in this study contributes to a broader understanding of the relationship between environmental law implementation and agricultural waste management practices within rural Indonesia. The findings are expected to provide a useful reference for policymakers, local governments, researchers, and farming communities in designing more effective and sustainable strategies for rice straw waste management.

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