

POLICY PATHWAYS FOR MANAGING AND SCALING ALTERNATE WETTING AND DRYING FOR METHANE MITIGATION IN INDONESIAN RICE SYSTEMS

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Abstract—Rice cultivation is a major source of methane emissions due to continuous flooding practices that create anaerobic soil conditions. In Indonesia, where rice systems are central to food security and rural livelihoods, reducing agricultural methane emissions is essential to achieving national climate targets without compromising productivity. Alternate Wetting and Drying (AWD) has been widely recognized as an effective irrigation practice that significantly reduces methane emissions while maintaining or improving rice yields and water-use efficiency. Nevertheless, large-scale adoption of AWD in Indonesia remains limited, mainly due to policy, institutional, and economic constraints rather than technical limitations. This study analyzes policy pathways for managing and scaling AWD as a national methane mitigation strategy in Indonesian rice systems. Using a qualitative synthesis of scientific literature, policy documents, and international benchmarking, the study proposes a phased National Roadmap for AWD implementation (2025–2029) aligned with Indonesia’s Nationally Determined Contribution (NDC) and Monitoring, Reporting, and Verification (MRV) requirements. An extended THIO-E framework is applied to examine the complementary roles of government, academia, and the private sector in creating an enabling ecosystem for AWD adoption. The findings emphasize the importance of regulatory coherence, participatory extension, and performance-based incentives. Based on these insights, the study formulates S.M.A.R.T.-based policy recommendations to support the institutionalization and sustainable scaling of AWD in Indonesia.

Keywords— Alternate Wetting and Drying, methane mitigation, rice systems, climate policy, irrigation management, MRV, sustainable agriculture

1. INTRODUCTION

Rice-based agriculture is central to global and national food security, supplying staple calories for a large proportion of the world’s population. In Indonesia, rice cultivation underpins food availability, rural livelihoods, and socio-economic stability. However, conventional rice production practices present a critical environmental paradox. Continuous flooding of paddy fields creates anaerobic soil conditions that stimulate methanogenic microbial activity, resulting in substantial methane (CH₄) emissions (Zhao et al., 2024). As a greenhouse gas, methane has a global warming potential approximately 27–30 times greater than carbon dioxide (CO₂) over a 100-year horizon, positioning flooded rice systems as a significant contributor to climate change. Globally, rice cultivation accounts for approximately 8–12% of anthropogenic methane emissions, a warming impact comparable to that of the entire aviation sector (Dahlgreen & Parr, 2024). This challenge is particularly pronounced in Indonesia due to its status as one of the world’s leading rice producers. Agricultural emissions, dominated by rice-based systems, represent a major component of the national greenhouse gas inventory, originating mainly from anaerobic soil processes and nitrogen fertilizer use (Kementerian Pertanian Republik Indonesia, 2025b). At the same time, rising food demand places pressure on agricultural systems to sustain or increase productivity, intensifying the trade-off between food security and climate mitigation, especially in light of Indonesia’s commitment to achieving Net Zero Emissions by 2060 or earlier.

Alternate Wetting and Drying (AWD) has emerged as a promising approach to reconcile these competing objectives. By periodically allowing paddy fields to dry to a defined threshold before re-irrigation, AWD disrupts prolonged anaerobic conditions, thereby suppressing methane production while maintaining suitable conditions for rice growth (Li et al., 2024). In addition to its mitigation potential, AWD improves irrigation efficiency, with reported water savings of 15–35%, making it highly relevant for regions experiencing increasing water stress (Bo et al., 2024). A growing body of field experiments and global meta-analyses consistently demonstrates that AWD can reduce methane emissions substantially while maintaining or slightly increasing rice yields (Li et al., 2024; Rafy et al., 2025). Although AWD may increase nitrous oxide (N₂O) emissions under more aerobic soil conditions, the net climate effect remains strongly positive, as reflected in significant reductions in Global Warming Potential (GWP) and greenhouse gas emission intensity per unit of production (Zhao et al., 2024).

Despite robust scientific evidence supporting AWD, its large-scale adoption remains limited, particularly in developing countries. Existing studies predominantly focus on agronomic and biophysical outcomes at the plot scale, while comparatively little attention has been given to the policy, institutional, and economic mechanisms required to operationalize AWD at national scale (Dahlgreen & Parr, 2024). In Indonesia, the integration of AWD into key climate policy instruments—including the Nationally Determined Contributions (NDC), the National Action Plan for Greenhouse Gas Emission Reduction, and national monitoring, reporting, and verification (MRV) systems—has yet to be translated into a coherent and implementable framework (Kementerian Pertanian Republik Indonesia, 2025a). As a result, the mitigation potential of AWD risks remaining underexploited in the absence of coordinated governance, incentives, and multi-actor engagement.

This study addresses this gap by advancing a transdisciplinary analysis that positions AWD not merely as a technical irrigation practice, but as a strategic climate mitigation instrument within Indonesia's agricultural policy landscape. The novelty of this research lies in its integration of scientific evidence with policy analysis to develop a phased national implementation roadmap aligned with NDC targets, MRV requirements, and institutional capacities, while explicitly mapping the complementary roles of government, academia, and the private sector through an extended THIO-E framework (Technoware, Humanware, Infoware, Orgaware, and Environment). Accordingly, this study aims to synthesize evidence on the mitigation and productivity impacts of AWD, identify key institutional and economic barriers to its management and scaling, and formulate implementable policy recommendations to support the transition toward a low-emission, climate-resilient, and productive rice farming system in Indonesia.

2. LITERATURE REVIEW

This literature review synthesizes current scientific and policy-oriented scholarship on Alternate Wetting and Drying (AWD) in rice agriculture, with particular emphasis on its role as a methane mitigation strategy and its relevance for policy implementation. The review is structured to integrate empirical evidence on environmental and productivity outcomes with analyses of policy frameworks, institutional arrangements, and implementation experiences across different national contexts.

2.1. Alternate Wetting and Drying in Rice Agriculture as a Strategic Solution

Based on the Nationally Determined Contribution Implementation Plan (NDCIP) 2020–2030, Indonesia has outlined a clear pathway to meet its climate commitments, in which the agricultural sector plays a critical role with a targeted contribution of 21% of the total national emission reduction (Kementerian Pertanian Republik Indonesia, 2025a). To achieve this target, Alternate Wetting and Drying (AWD) has been designated as one of the priority mitigation actions under the National Action Plan for Greenhouse Gas Emission Reduction (RAN GRK). AWD directly supports the operational objectives of the NDCIP in the food crop subsector, particularly through improved water management and flood control by shifting irrigation practices from continuous flooding to intermittent irrigation (Kementerian Pertanian Republik Indonesia, 2025a). When properly documented, AWD implementation can be integrated into the national monitoring, reporting, and verification (MRV) system to ensure that its mitigation outcomes are measurable and internationally reportable.

In addition to AWD, achieving the 21% emission reduction target in the agricultural sector is supported by a set of complementary innovations, most notably the promotion of biodigesters for livestock manure management. The combined implementation of these measures addresses two major emission sources: methane emissions from flooded rice fields and methane emissions from livestock waste. Coordinated implementation through the NDCIP framework is therefore intended not only to reduce greenhouse gas

emissions, but also to foster a more resilient and resource-efficient agricultural system, in line with the principles of sustainable development.

2.2. Policy Analysis and International Benchmarking

Lessons learned from the implementation and study of Alternate Wetting and Drying (AWD) across different countries provide valuable empirical and policy-relevant insights for Indonesia. This comparative analysis not only confirms the effectiveness of AWD in reducing greenhouse gas emissions, but also highlights incentive mechanisms, regulatory frameworks, and implementation approaches that can be adapted to national contexts. Table 1. summarizes key findings from selected international studies, with the country referring to the primary institutional affiliation of the authors, and outlines their implications for policy formulation in Indonesia.

Table 1. International Evidence on AWD and Policy-Relevant Implications for Indonesia

Country	Title, Author(s) and Year of Publication	Main Focus/Key Findings	Benchmark Policy Implications
China	Alternate wetting and drying maintains rice yield and reduce global warming potential: A global meta-analysis (Li et al., 2024)	A meta-analysis of 72 global studies shows that AWD increases rice yield by an average of 1.52%, while reducing CH ₄ emissions by 43.23% and Global Warming Potential (GWP) by 36.84%. Optimal benefits were achieved with nitrogen fertilizer rates of 100–150 kg/ha.	Provides strong scientific evidence that AWD represents a “win-win” solution. Indonesian policy can use these findings to develop national technical guidelines emphasizing the integration of AWD with site-specific nutrient management to maximize GWP reduction.
China	Effects of Alternate Wetting and Drying Irrigation on Methane and Nitrous Oxide Emissions from Rice Fields: A Meta-Analysis (Zhao et al., 2024)	Confirms substantial reductions in CH ₄ emissions under AWD, while also reporting an increase in N ₂ O emissions of 42.59%. Nevertheless, the net reduction in GWP remains significant at 36.84%.	Highlights the importance of integrated management. AWD policies in Indonesia should be combined with appropriate nitrogen fertilizer strategies (e.g., deep fertilization or slow-release fertilizers) to mitigate N ₂ O increases and optimize net climate benefits.
United Kingdom	Exploring the Impact of Alternate Wetting and Drying and the System of Rice Intensification on Greenhouse Gas Emissions: A Review of Rice Cultivation Practices (Dahlgreen & Parr, 2024)	A literature review concluding that AWD and SRI substantially reduce CH ₄ emissions per hectare. The study also notes that 28 countries have incorporated rice management practices (13 explicitly SRI) into their Nationally Determined Contributions (NDCs).	Offers strategic insights into climate policy integration. Indonesia could strengthen its agricultural NDC commitments by explicitly recognizing AWD as a key mitigation action and developing a robust MRV (Measurement, Reporting, and Verification) framework to support its implementation.
China and Pakistan	Meta-Analysis of Alternate Wetting and Drying (AWD) Irrigation Effects on Methane and Nitrous Oxide Emissions Across Different Climates and Soil Types (Rafy et al., 2025)	A meta-analysis of 47 studies indicates that AWD reduces CH ₄ emissions by an average of 64.5% and lowers GWP by 42.1%. CH ₄ reduction is greater in tropical regions (68.2%) than in temperate regions.	Reinforces the high relevance and mitigation potential of AWD under tropical conditions. Policy design in Indonesia can prioritize implementation guidelines tailored to dominant soil types (e.g., clay soils) to maximize emission reductions.

3. METHODS

To fulfill the research objectives and maintain analytical robustness, this study applies a structured methodological design that combines qualitative synthesis, relevance assessment, and policy-focused analysis. The methodological framework is intended to ensure a clear alignment between the research questions, analytical tools, and evidence sources, thereby enabling the formulation of policy recommendations that are grounded in evidence and feasible for implementation in the context of Alternate Wetting and Drying (AWD) management and scaling in Indonesia.

3.1. Research Design and Data Sources

This research adopts a policy-oriented and recommendation-driven approach that focuses on developing evidence-based strategies to support the management and expansion of Alternate Wetting and Drying (AWD) as a methane mitigation practice in rice-based agricultural systems. Instead of producing new experimental or field-level data, the study prioritizes the synthesis and qualitative interpretation of existing scientific and policy knowledge, an approach commonly used in policy research addressing multifaceted environmental and governance issues.

Data collection was conducted through a comprehensive desk-based review of peer-reviewed academic publications, national laws and regulations, government policy documents, and reports from international initiatives related to AWD and climate-smart agriculture. These materials were selected to capture both the scientific foundations of AWD and the broader institutional, economic, and governance contexts influencing its adoption. Qualitative analysis was applied to all sources to identify enabling factors, structural constraints, and potential leverage points for national-scale implementation.

3.2. Relevance Analysis and Policy Benchmarking

A relevance assessment was undertaken to evaluate the appropriateness and practicality of AWD implementation within Indonesia's agricultural and institutional setting. This assessment employed an expanded THIO-E framework—covering Technoware, Humanware, Infoware, Orgaware, and Environment—to systematically examine technological readiness, human capacity, information infrastructure, organizational arrangements, and incentive environments associated with AWD adoption. The analysis considered the interactions among key stakeholder groups, including research institutions, private-sector actors, and government agencies involved in rice production and water governance.

International experiences with AWD were reviewed to contextualize Indonesia's position within the global evidence base. In this study, international benchmarking was used as an analytical reference to assess policy relevance and contextual compatibility rather than as a template for direct policy transfer. Selected cases from countries where AWD has been evaluated or promoted were examined with particular attention to implementation mechanisms, incentive structures, and linkages with climate policy instruments and monitoring, reporting, and verification (MRV) systems. Insights derived from this process informed the relevance assessment and policy design for Indonesia.

3.3. Legal, Social, and Economic Framework Analysis

To complement the relevance assessment, the study conducted a qualitative analysis of the legal, social, and economic contexts affecting AWD adoption in Indonesia. The legal analysis examined existing national policies and regulatory frameworks related to rice cultivation, irrigation management, and climate mitigation to identify institutional gaps and opportunities for policy alignment across sectors. The social analysis focused on farmer adoption behavior, highlighting the importance of participatory extension methods, demonstration-based learning, and trust-building within collective irrigation and water management arrangements.

The economic analysis explored incentive structures and potential value creation associated with AWD adoption, including productivity resilience, improvements in water-use efficiency, and opportunities linked to methane mitigation and climate finance mechanisms. Together, these analytical components provide a coherent foundation for developing policy recommendations that are context-sensitive, feasible, and aligned with Indonesia's agricultural development priorities and climate commitments.

4. RESULT AND DISCUSSION

This section presents the key findings of the study and discusses their implications for the implementation of Alternate Wetting and Drying (AWD) as a national strategy for methane emission reduction in the rice sector. The analysis integrates policy review, stakeholder mapping, and system-based assessment to translate conceptual frameworks into an operational implementation pathway. Particular emphasis is placed on institutional readiness, stakeholder roles, and the sequencing of interventions required to ensure effective scaling and long-term sustainability of AWD adoption at the national level.

4.1. National Roadmap for AWD Implementation (2025–2029)

The proposed National Roadmap is structured into four sequential and progressive phases spanning the period 2025–2029, aimed at establishing a robust institutional foundation, demonstrating technical and socioeconomic feasibility, enabling large-scale dissemination, and ultimately ensuring sustainable integration of Alternate Wetting and Drying (AWD) into Indonesia's national agricultural system. Each phase builds systematically upon the achievements of the preceding phase, with clearly defined outputs and performance indicators to ensure accountability and measurable progress toward methane emission reduction targets in the rice sector. A detailed overview of the roadmap phases, activities, and expected outcomes is presented in Table 2.

Table 2. National Roadmap for AWD Implementation in Indonesia (2025–2029)

Phase	Period (Year)	Key Focus and Activities	Expected Outcomes
Phase 1: Integrated Preparation and Pilot Implementation	2025	1. Policy and Capacity Development: Drafting and issuance of a Ministerial Regulation on National AWD Technical Guidelines, training of master trainers (agricultural extension officers and plant pest observers), development of standardized training modules, identification and mapping of 4–6 priority regions based on irrigation infrastructure and institutional readiness. 2. Integrated Piloting: Establishment of demonstration plots in each priority region equipped with soil moisture monitoring devices and perforated field water tubes; initiation of baseline data collection on rice productivity, water use efficiency, and estimated methane emissions.	1. Official national AWD technical regulation issued 2. More than 200 master trainers certified 3. Six pilot villages established with active demonstration plots 4. Basic Monitoring, Reporting, and Verification (MRV) protocols implemented at pilot sites.
Phase 2: Managed Dissemination and Adaptive Learning	2026–2027	1. Controlled Scale-Up: Expansion of AWD implementation to 30–50 villages surrounding Phase 1 pilot locations using a “core-spread” dissemination model; facilitation of the establishment and strengthening of Water User Associations (WUAs). 2. Strengthening of Support Systems: Introduction of initial incentive mechanisms, such as selective subsidies for energy-efficient irrigation pumps and monitoring tools; development of simple digital platforms (e.g., mobile-based communication tools) for farmer mentoring and technical consultation.	1. AWD adoption on approximately 5,000 ha of rice fields 2. At least 20 farmer or water management groups collectively implementing AWD 3. Pilot incentive schemes operational in two provinces 4. Empirical field evidence on yield performance and water savings documented and disseminated. One nationally validated methodology for biochar-based carbon projects.
Phase 3: Adoption Acceleration and Policy Integration	2028	1. National Acceleration: Integration of AWD into large-scale national agricultural programs and tertiary irrigation rehabilitation initiatives; promotion of local government support through the issuance of regional regulations or policy directives. 2. Performance-Based Incentive Development: Design and pilot testing of Payment for Ecosystem Services (PES) mechanisms and/or carbon certification schemes for AWD-adopting farmers; establishment of partnerships with financial institutions to develop green agricultural credit schemes.	1. AWD adoption expanded to approximately 100,000 ha across more than 10 provinces 2. At least two provinces adopt formal regional legal frameworks supporting AWD 3. First PES or carbon-based pilot projects implemented involving a minimum of 500 farmers 4. Verified methane emission reductions from areas under AWD implementation since Phase 1.
Phase 4: Consolidation and Market Integration	2029	1. Institutionalization and Sustainability: Integration of AWD as a standard practice within farmer field schools and agricultural extension curricula; establishment of a national AWD MRV system integrated with the National Climate Change Registry System (SRN). 2. Economic Value Creation: Development and promotion of certification and labeling schemes for “Low-Emission Rice” targeting premium domestic and export markets; review and strengthening of incentive policies based on comprehensive national evaluations.	1. AWD implemented on approximately 250,000 ha of rice fields 2. One national Low-Emission Rice Certification scheme officially launched 3. National evaluation reports demonstrate AWD contributions to agricultural sector NDC targets 4. Sustainable business models for AWD adoption (e.g., PES, carbon credits, green labeling) demonstrated to be economically viable.

4.2. THIO Analysis and Multi-Actor Roles

The successful implementation of the National AWD Roadmap requires strong synergy among all relevant stakeholders. An analytical framework based on THIO (Technoware, Humanware, Infoware, and

Orgaware), extended by an Environmental dimension (environmental outcomes and economic incentives), is applied to elucidate the distinct yet complementary contributions of the three principal actor groups involved in AWD deployment. This framework enables a systematic assessment of how technological, human, informational, institutional, and incentive-based components interact to form a comprehensive and sustainable enabling ecosystem for AWD adoption. Table 3. summarizes the strategic roles of each actor across the extended THIO dimensions.

Table 3. Stakeholder Roles in Building a Sustainable AWD Ecosystem Based on the Extended THIO Framework

THIO Dimension	Roles and Contributions of Academia / Researchers	Roles and Contributions of Corporations / Private Sector	Roles and Contributions of Regulators / Government
Technoware (Technical Devices and Technologies)	Development and validation of AWD protocols tailored to diverse agroecosystems (e.g., wetlands, tidal lowlands, and rainfed systems). Design of simple, accurate, and low-cost field water level monitoring devices.	Commercial production, distribution, and marketing of AWD-related devices (e.g., perforated field water tubes) and supporting technologies, including energy-efficient pumps and sensors. Investment in research and development of precision irrigation technologies.	Establishment of technical standards and quality regulations for AWD-supporting equipment. Provision of fiscal incentives for the production and adoption of water-saving technologies. Ensuring that tertiary irrigation infrastructure rehabilitation supports AWD implementation.
Humanware (Human Capacity and Skills)	Development of curricula, training modules, and scientifically grounded educational materials on AWD. Implementation of training programs for master trainers, extension officers, and farmers through farmer field schools.	Implementation of training and technical assistance programs for partner farmers or communities surrounding operational areas through corporate social responsibility (CSR) initiatives and business partnerships. Provision of agronomic experts as technical consultants.	Integration of AWD modules into national and regional agricultural extension systems. Allocation of public budgets for large-scale training and capacity-building programs for extension officers and pioneer farmers.
Infoware (Data, Knowledge, and Information Systems)	Generation of primary data and scientific analyses on AWD impacts, including productivity, water-use efficiency, and methane emission reductions. Development of context-specific MRV and emission calculation models.	Development of digital platforms and applications for field monitoring, farm record-keeping, and traceability systems for low-emission rice value chains. Establishment of data-driven early warning systems.	Development and management of an integrated National AWD Information System to monitor implementation progress. Establishment of standardized national MRV protocols. Provision of open-access data and spatial information to support planning and decision-making.
Orgaware (Institutions, Networks, and Coordination)	Conduct of institutional studies to strengthen farmer organizations and Water User Associations. Facilitation of stakeholder dialogues and multi-actor coordination forums.	Formation and empowerment of contract-farming or plasma farmer groups under structured business partnership schemes. Development of sustainable rice business alliances from upstream to downstream segments.	Issuance of regulations and policy guidelines to institutionalize AWD practices. Strengthening of farmer organizations through financial and legal support. Establishment of cross-ministerial and inter-regional coordination mechanisms.
Environment (Environmental Compliance and Impacts)	Research on the holistic environmental impacts and ecosystem service values of AWD. Design of feasibility studies and business models for incentive mechanisms, such as Payment for Ecosystem Services (PES).	Creation of market demand through green procurement schemes, premium pricing mechanisms (green premiums), and investment in carbon credit projects. Implementation of ESG principles across agricultural value chains.	Design and implementation of direct and indirect financial incentive schemes for farmers. Development of certification, labeling, and standards for “Low-Emission Rice.” Establishment of regulatory frameworks for domestic agricultural carbon markets.

4.3. Legal, Social, and Economic Frameworks

While the National Roadmap provides a structured and phased pathway for scaling up Alternate Wetting and Drying (AWD) at the national level, its effective implementation ultimately depends on the broader enabling environment within which the roadmap is operationalized. This subsection therefore examines the legal, social, and economic frameworks that shape the feasibility, adoption dynamics, and long-term sustainability of AWD implementation in Indonesia. These interrelated frameworks determine how policy commitments are translated into enforceable regulations, how innovations are socially accepted and institutionalized at the community level, and how economic incentives align farmer behavior with national climate and agricultural objectives. Analyzing these dimensions is essential to identify structural constraints and leverage points that may either hinder or accelerate the realization of the proposed roadmap.

4.3.1. Legal Framework

At present, the implementation of Alternate Wetting and Drying (AWD) in Indonesia lacks a dedicated and comprehensive legal framework, despite being broadly aligned with national commitments articulated in the Presidential Regulation on the National Action Plan for Greenhouse Gas Emission Reduction and Indonesia’s Nationally Determined Contribution (NDC) documents. Existing technical regulations issued by the Ministry of Agriculture related to low-emission rice cultivation remain largely advisory in nature and have not yet been operationally integrated with irrigation management policies under the authority of the Ministry of Public Works and Housing. A key challenge lies in bridging the gap between national-level policy commitments and subnational regulations, as well as translating policy objectives into practical technical guidelines at the field level. Establishing a clear legal basis that provides regulatory certainty and dedicated budgetary allocations for AWD programs is therefore essential to enable systematic implementation and long-term sustainability.

4.3.2. Social Framework

Social acceptance of AWD is strongly influenced by the capacity to transform deeply rooted cultivation norms and practices, where continuous flooding is often perceived as synonymous with soil fertility and yield security. Successful adoption thus depends on participatory approaches that respect local knowledge and practices while strengthening farmer institutions, such as farmer groups and Water User Associations (WUAs), which constitute the backbone of collective water management. Consequently, AWD dissemination should be conceptualized as more than a mere process of technology transfer. Rather, it represents a form of social learning that builds trust, demonstrates tangible benefits through field-level evidence, and empowers farmers as active agents of change within their communities.

4.3.3. Economic Framework

From an economic perspective, the adoption of AWD is closely linked to its perceived impacts on farm-level profitability and risk. While AWD has the potential to reduce irrigation costs and increase water-use efficiency, farmers may face short-term adjustment costs, uncertainty regarding yield outcomes, and additional labor or monitoring requirements during the transition phase. The absence of clear economic incentives further constrains adoption, particularly among smallholder farmers with limited financial resilience. Therefore, the successful scaling of AWD requires the development of incentive mechanisms that align private economic benefits with public environmental objectives. These mechanisms may include input subsidies, performance-based payments, access to green financing, price premiums for low-emission rice, and participation in carbon credit or Payment for Ecosystem Services (PES) schemes. Embedding AWD within a viable economic framework is critical to ensuring sustained adoption beyond pilot and donor-supported interventions.

5. CONCLUSIONS AND POLICY RECOMMENDATIONS

The conclusions of this study are articulated in the form of policy recommendations structured under the S.M.A.R.T. framework, translating the analytical findings into concrete, measurable, and time-bound actions. The proposed recommendations are designed to accelerate the adoption of Alternate Wetting and Drying (AWD) in the rice sector while ensuring regulatory coherence, economic viability, and social acceptance. A summary of the proposed policy recommendations is presented in Table 4.

Table 4. Policy Recommendations Based on the S.M.A.R.T Framework

Policy Recommendation	National Roadmap and Mandatory Certification-Based Standards	Targeted Fiscal Incentives and Dedicated Financing for Biochar Value Chain Development	Integrated “Biochar Desa” Program Linked to Extension Services and Carbon Markets
Specific	Issue a single National AWD Guideline Document comprising: 1. Standardized AWD technical protocols tailored to four major agroecosystems (fully irrigated systems, wetlands, tidal lowlands, and rainfed rice systems) 2. Institutional models for farmer groups and Water User Associations (WUAs/P3A) to support collective water management	Establish a national AWD adoption incentive fund combined with a performance-based green premium mechanism that rewards farmers for verified AWD implementation, water savings, and methane emission reductions. Incentives may include direct payments, input subsidies, or price premiums for low-emission rice.	Upgrade the existing Digital Farmer Card (Kartu Tani Digital) to include AWD-specific functionalities, such as field-level AWD monitoring records, linkage with MRV systems, and facilitated access to green financing instruments (e.g., green credit, PES payments, or carbon revenues).

Measurable	3. Mandatory instructions to integrate AWD modules into more than 80% of Farmer Field School (FFS) activities and agricultural extension programs.		
	Success indicators include: 1. Formal adoption of the guideline by 100% of provincial agricultural offices 2. A minimum of 5,000 agricultural extension officers trained and actively recording AWD-related extension activities in the national extension information system (SIMLUH) within two years 3. Integration of AWD modules into at least four major national training programs (e.g., READSI).	Performance is measured by: 1. The number of participating farmers and total area under verified AWD adoption 2. Documented reductions in irrigation water use and methane emissions through MRV systems 3. The volume of low-emission rice marketed under premium pricing schemes.	Indicators include: 1. The proportion of AWD farmers registered in the digital system 2. The number of AWD plots with verified digital monitoring records 3. The volume of green financing disbursed to AWD-adopting farmers.
	The guideline can be developed by harmonizing existing technical references from the Ministry of Agriculture's research units and FAO guidelines through an expert-led consolidation process. Integration into the existing extension system enables rapid dissemination without the need to establish new institutional structures.	The scheme can be piloted by reallocating existing agricultural subsidy programs and integrating them with climate finance instruments, including Payment for Ecosystem Services (PES) and voluntary carbon markets, without introducing parallel funding mechanisms.	The enhancement can leverage existing digital agricultural platforms and banking infrastructure, requiring functional expansion rather than the creation of new systems.
	This recommendation directly addresses social and institutional barriers by providing an authoritative technical reference and strengthening the central role of extension officers as agents of change. Consistent guidelines also form a foundation for standardized training and future certification schemes.	This recommendation addresses economic barriers to AWD adoption by reducing transition risks for farmers and aligning private economic incentives with public climate mitigation objectives.	Digital integration enhances transparency, reduces transaction costs, and strengthens farmer access to financial incentives, thereby reinforcing both accountability and long-term adoption of AWD practices.
Time-bound	The national guideline should be issued within 10 months. Provincial-level master trainer programs should be completed within 15 months, and field-level implementation of AWD modules should reach at least 50% of targeted regions within 24 months.	Pilot incentive schemes should be launched within 12 months, expanded to at least two provinces within 24 months, and evaluated for national scale-up within 36 months.	System design and pilot testing should be completed within 12 months, followed by phased implementation covering at least 40% of AWD target areas within 30 months.

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