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Requirements and Challenges for Profitable Practice Implementation by Smallholder Farmers

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ABSTRACT

Alternative Wetting and Drying (AWD), practiced by some in rice farming, is one approach where water use efficiency can be improved and gaseous emissions mitigated while productivity is maintained. However, it also involves intermittent irrigation, allowing the fields to dry out before re-irrigation, as opposed to continuous flooding. They discovered that it is possible to reduce water use by around 25–30% while increasing rice yields by improving root growth and tiller production. Researchers have also discovered that AWD offers significant environmental advantages, such as a 50% reduction in methane emissions. Even though AWD has good potential, smallholders face many challenges when implementing it. These issues stem from the stability of food yields, insufficient knowledge, and restricted access to available infrastructure or technology. Moreover, farmers are hesitant to switch from traditional methods due to concerns that it could be a high-risk activity and involve labor-intensive water management chores. In addition, AWD needs both dependable water delivery infrastructure and monitoring equipment that often do not exist in remote or resource-constrained regions. For the widespread adoption of AWD, we must implement capacity-building initiatives alongside policy backing and investments in irrigation infrastructure. We address the benefits and challenges of AWD for small farmers who want to explore sustainable rice farming.

Keywords: *Alternative Wetting And Drying, Climate Change Adaptation, Greenhouse Gas Emissions*

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INTRODUCTION

In the global rice is a crucial food for 2.7 billion people for food security. It is primarily cultivated in lowland rain-fed farms, which are vulnerable to climate change and produce lower yields compared to irrigated systems. Irrigated farms, however, offer higher wet-season yields and more consistent production cycles, but they are sensitive to climate change (Hunink et al., 2014). The Mekong Delta in Vietnam is particularly vulnerable to climate change and sea-level rise, with significant impacts expected by 2025. Due to irrigation, rice output is predicted to reach 3,720 kg/ha in Cambodia and 6,630 kg/ha in

Vietnam (Abdihk et al., 2021). Cambodia, located in Southeast Asia, experiences a tropical monsoon climate with distinct wet and dry seasons, making it susceptible to floods and droughts (Murphy et al., 2013). Cambodia's rice cultivation, primarily of Oryza sativa L., is concentrated in the Battambang region, known for its fertile soil. The agricultural sector is vital, covering 62% of the country's total land area. From 1988 to 2010, rice cultivation expanded from 100,000 ha to 300,000 ha in this region (Srean et al., 2018). The growing season runs from May to October, with over 90% of the Mekong basin's rice produced during the rainy season. More than 68% of this rice is harvested for consumption, and over 75% of the total crop, including other grains, is cultivated during this period (Kim et al., 2018). The Royal Government of Cambodia has always considered agriculture as a priority sector that contributes to ensuring food security, promoting economic development, and improving people's living standards. Agriculture contributes 22.1% (crop production 57%, livestock 11.2%, fisheries 24.8%, and forestry 7%) to GDP in 2023 Gross Value Added in Agriculture will increase annually from 19470 billion Riels in 2014 to 28,207 billion Riels in 2023 (current value). The agricultural sector faces several problems, such as a lack of modern technology, insufficient irrigation, high production costs, lack of markets, declining agricultural prices, lack of investment capital, climate change, and high transportation costs (MAFF & MOWRAM, 2023). However, paddy fields emit significant amounts of methane (CH_4), a potent greenhouse gas. Agriculture accounts for more than 13% of all greenhouse gas emissions, with CH_4 from organic matter like straw and manure being a major contributor (Zhao et al., 2019). Effective water management practices are essential to reduce CH_4 emissions. Cambodia's 2525 irrigation projects, which include small, medium, and large-scale systems, are crucial in this effort (Arvan & Malory, 2022). These topics aim to enhance water efficiency, particularly for dry-season rice farming. Despite these efforts, water management remains challenging due to mid-season droughts, sporadic irrigation, and alternating dry and wet periods (Shirithh, 2021). To address this, research on the effectiveness of the Alternative Wetting and Drying (AWD) technique is essential. This review aims to identify the condition of need and the difficulties assumed by smallholder farmers while practicing the AWD irrigation technique. This review aims to assess the possibility of improving water use efficiency and profitability of smallholders in water-limited zones by adopting AWD. It will also bring out the main challenges facing the uptake of AWD technology involving both technical factors and cost factors as well as general infrastructure constraints. Further, the review seeks to pinpoint policy measures that could facilitate the achievement of the above challenges, farming practices that can be adopted by farmers, and the development of affordable technologies that can support the expansion of biogas. In addressing these issues, it is the hope of the review that there will be a better understanding of how AWD can contribute to sustainable agriculture for smallholder farmers as well as on aspects touching on water use and emissions of greenhouse gases.

RESEARCH METHODOLOGY

This review gives insight into why farmers are still hesitant to abandon AWD as a practice by synthesizing scientific material on water management and the hydrology of paddy soils when AWD is used in accordance with climate change. This research gathered scientific data from journal publications on paddy-rice farming and water management in Asia considering climate change for this paper.

RESULT AND DISCUSSION

Asia's rice production being increasingly hampered by water scarcity is supported by the findings which highlight the urgent need for water-saving practices in rice cultivation due to the alarming scarcity of groundwater resources in regions like Punjab, India (Arora, 2006). Phengphaengsy & Okudaira, 2008 they reported that rice cultivation in the region is limited by low water productivity and a lack of rainfall during the dry season. Improving the efficacy of irrigation projects would allow farmers to improve yield. There is potential for irrigation expansion in the LMB, but investments are required to modify existing irrigation systems, improve irrigation efficiency, and increase water yield. Irrigation efficiency, a measure of good water resource management, varies widely across the LMB and is typically poor. enhanced water distribution will allow farmers to use less water to achieve higher yields while leaving more water in the river basin's ecosystem and environment, resulting in enhanced regional livelihoods (MAFF&MOWRAM,2023) the main challenge of agricultural rice cultivation is climate change. Climate change is causing droughts, water shortages, floods, crop failures, declining soil quality, and changes in river regimes, affecting fisheries resources and biodiversity. The combination of planning and development of orderly agriculture and water resources is limited. Irrigation systems are still insufficient to meet the needs for intensification and diversification of agriculture, with a lack of water in the dry season.

Overview of Alternative Wetting and Drying (AWD)

AWD is a water-saving strategy in rice farming that involves intermittent irrigation, allowing the field to dry out before rinsing again. This strategy is in contrast to the more common method of continual flooding. When applied to suitable soils, AWD can delay irrigation while also reducing the overall frequency and amount of water utilized. Irrigation is scheduled during important crop growth stages (Alauddin et al., 2020). AWD calls for delaying re-irrigation until the water table falls below a certain threshold. Even when ponded water evaporates, the rice plant's roots can still reach water, guaranteeing a sufficient water supply during crucial phases (Rejesus et al., 2011). AWD reduces irrigation frequency and water use when applied to suitable soils. Irrigation water is applied at important times of crop growth, with a delay when surface water becomes unavailable (Alauddin et al., 2020).

The field water tube, also known as a pani pipe, is composed of plastic tubing that is 30 to 40 centimeters long and has a diameter of 10 to 15 centimeters. This allows for easy soil removal and visibility of the water table. Make several holes in the sides of the tube (up to 15-20 cm long) to allow water to easily enter and exit. The tube's perforated section should extend 15-20 cm above the soil's surface after being hammered into the ground. Be aware not to go through the bottom of the plow pan. Remove the soil from the inside of the tube until the bottom is visible. When the field is flooded, ensure the water level within the tube matches the outside. If it isn't the same after a few hours, the holes are most likely blocked by compacted earth, and the tube must be carefully reinstalled. The tube should be put in an easily accessible area of the field, adjacent to a bund, to allow for easy monitoring of the ponded water depth (Kumar & Rajitha, 2019).

Technical Aspects of AWD

- **Water Management**: With AWD, the yield of the rice crop is not impacted when the water level drops 15 to 20 cm below the soil's surface. This strategy uses greatly less water and goes against the conventional wisdom that rice fields should never be flooded.
- **Implementation:** A perforated field water tube, made from materials like PVC or even locally available resources like perforated soda bottles, is inserted into the soil 10-15 days after transplanting. This tube allows farmers to visually monitor the water level, ensuring that the field is not constantly flooded.
- **Agricultural Impact:** AWD enhances water efficiency, strengthens rice plant root and shoot systems, and has the potential to increase output by increasing the number of productive tillers. In addition, it is proposed that AWD may boost the content of critical dietary micronutrients in grain (Cullingworth, 2015).

Scheduling of rice irrigation stages for Alternate Wetting and Drying (AWD)

Early Stages: The soil is kept wet for the first three weeks after transplantation to help seedlings develop themselves. Following this initial phase, the water depth is maintained at 5 cm, and the AWD treatments are implemented.

Flowering Stage: All AWD procedures are stopped around the flowering stage (67-73 days after transplanting), and the water depth is kept between 3 and 5 cm to prevent the danger of spikelet sterility caused by water-deficit stress.

Post-Flowering: During flowering, AWD begins again and is sustained for two weeks before harvest (Lampayan et al., 2015).

Grain quality and heavy metals accumulation

Applying mild-AWD/safe-AWD during non-critical stages, such as tillering, mid-tillering, and post-anthesis, will boost grain filling rate and yields. However, in some conditions, severe AWD may diminish final grain yield (such as light textured soil). On the other hand, overlapping the AWD drying cycle at important stages, such as stand establishment and panicle initiation to grain formation, may reduce the ultimate crop stand, growth, and assimilate transfer to decrease yield. Switching from conventional to water-saving rice cultivation systems may cause variations in grain quality. Aside from high water demands, the CF system degrades grain quality by accumulating heavy metals. Using fertilizers, micronutrients, and drought-tolerant cultivars can improve rice quality without compromising yield. The method, along with water-saving rice production technologies, enhanced yield while also improving rice grain setting and quality. Drought-tolerant genotypes in AWD showed lower abortive, chalky, and opaque kernels, as well as high protein content, possibly because of a favorable association between total nitrogen intake and grain protein content (Ishfaq et al., 2020).

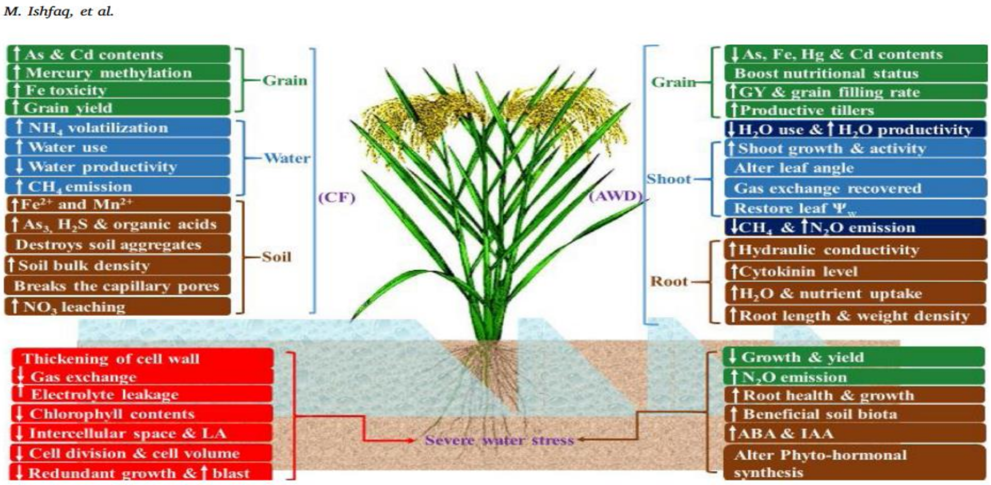

Fig. 1. Influence of continuously flooded (CF), alternate wetting and drying (AWD), and severe water stress conditions on soil properties, rice growth, yield, quality, and GHG emission. As = Arsenic, Cd = Cadmium, Fe = Iron, LA = leaf area, Hg = Mercury, Downward arrow head = Decrease, Upward arrow head = Increase, GY = Grain yield, ABA = Abscisic acid, IAA = Indole acetic acid.

Environmental and Economic Benefits

The productivity of rice crops sees a boost with the use of alternate wetting and drying (AWF) improving both phosphorus efficiency and water use effectiveness without compromising quality when contrasted with continuous flooding (CF). This method enhances the yield by increasing the number of grains and spikelet's, per panicle. Furthermore, AWD irrigation used around 27% less water, which increased production while requiring less water (Song et al., 2021). AWDs were responsible for a 51% reduction in methane emissions while increasing rice yields by 8% which was probably caused by better translocation of carbohydrates from leaves to panicles. In addition, the practice of AWD technology also caused a reduction in greenhouse gas emissions by 11%, due to a reduction of straw use as the production rate of straw decreased significantly by 10% through improved transport systems. (Arai, H. (2022). Both wetting and drying (AWD) and proper nitrogen management are crucial strategies in rice farming. Research has shown that these methods work well together to boost rice yield and nitrogen use efficiency by balancing the relationship, between supply and demand (Wang et al., 2016; Aziz et al., 2018; Cao et al., 2021). These practices also depend on enhancing the population and diversity of soil microbes that break down matter and cycle nitrogen in the soil. AWD Irrigation has become a preferred method of irrigation in the paddy fields for positively impacting water productivity as compared to traditional irrigation at a global level in water use has been found very effective (Akter et al., 2018; Biswas et al., 2021). Norton et al. AWD increased the grain yield through a higher number of productive tillers (Carrijo et al., 2017) and (Sriphirom, P., & Ekasingh, B. (2018) (2018) positive effects on tillers and panicle numbers and grain yield. Rice cultivation produces a variety of greenhouse gas (GHG) emissions, including methane (CH4), and nitrous oxide (N2O), which are two important represented members. These GHGs are not much and contribute very negatively to global warming by Global Warming Potentials 28 to 273 times that of carbon dioxide (CO2)(Echegaray-Cabrera et al., 2024).

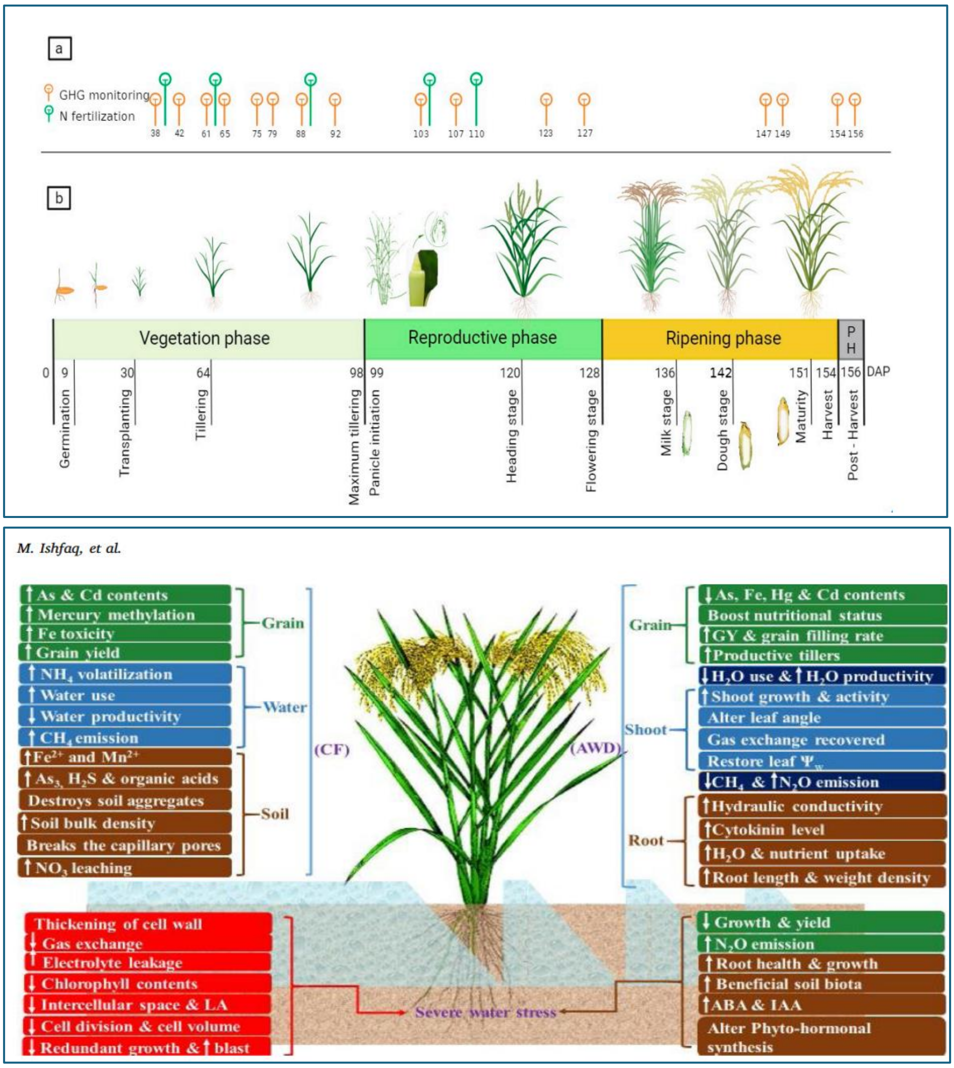

Fig. 2. **a.** (GHG) Greenhouse gas monitoring and nitrogen fertilization, **b.** Crop phenology

Financial Requirements

As a result, AWD technology helps farmers cut the cost of irrigation. The AWD farmers spent an average of 164 dollars per hectare on irrigation, which is 28.8% less than the average cost of 230 dollars per hectare during the period for non-AWD farmers. This is because of lower irrigation frequency and irrigation water use efficiency. All of this includes payment to pump owners which is based on gross profit per hectare and determined by the size of landholding and frequency scheduling irrigation. Fuel Costs: Fuel costs are a large part of the overall irrigation expenses, especially for diesel-operated machines. For example, we spend less on fuel than farmers using the continuous flooding methods because we do not irrigate as often. Electricity Charges: There are two ways in which electricity is charged for the operation of electric pumps; either at a flat rate or, in some instances through prepaid meters. This can also bring cost savings to AWD farmers. Frequency of Pumping: AWD needs fewer irrigations; therefore, it saves fuel and energy for pumping in comparison to the traditional method of irrigation (Hong Trang et al., 2023).

Challenges to adopting AWD

Though the practice of Alternate Wetting and Drying (AWD) can be advantageous, it has been successfully adopted only to a limited extent because several constraints act as impediments. One such barrier is the resistance to change among farmers who are accustomed to flooded conditions and fear that their crops will not do well under AWD because there will be more weeds and pests. This kind of thinking is difficult to sway until a more powerful stimulus can be provided to gain awareness of the long-term benefits that AWD would bring. Additionally, to have the ability to match returns with say, Greenhouse gas emissions reduction economic benefits do not appear overnight and therefore farmers as such call it difficult. It also means that there will be more labor deployment for water monitoring and management, more so if the farmers have to manage more than one plot. The kind of irrigation system also makes population difficult; in irrigation systems that are gravity-fed and with water using charges fixed or even free, it is unreasonable for farmers to want to use less water. Apart from differences in the availability of water for two requesting ends that is upstream and downstream, there might be interesting enmities if engagement in the contraction of AWDs may be easy at upstream. Finally, there is the problem of lack of necessary infrastructure and little assistance that local authorities provide to up-scale AWD in the absence of targeted investments in irrigation structures and strengthening organizational capacity (Nakamura et al., 2022).

Technical requirements to be adopted by AWD

- **Irrigation Infrastructure**: AWD requires an ample supply of water; the soil has to dry up to a standard depth which in AWD is set at 15cm before it is irrigated again. This is very challenging, particularly for structures such as; small gravity-fed distributed canals known as Kulo or tube Wells commonly used in Nepal. Irrigation demands a reliable source of water to control the utilization of water in production.

- **Water Management Governance**: Like any other aspect water management in the communities used by farmers in Nepal for irrigational purposes is not very specific. it is centralized and looked after by user committees. That is why for AWD to be implemented successfully some change in the water policy is needed, such as water rationing or an increase in water tariffs to use water more efficiently.
- **Field Preparation**: This requires an arrangement of bunds around fields and the use of Soil Water Tubes which are perforated plastic bottles applied to ascertain in which depth of the soil water depth is. These practices help the farmers to control the water levels during various available AWD cycles.
- **Farmer Education and Extension Services:** The take up of AWD has been relatively slow up to this time due to several reasons which include for instance; no incentives and poor awareness of the existence of such a technology among farmers. Education activities and several tests and trials are necessary to ensure that people adopt the new type of AWD by realizing that yields do not drop when water is saved. Farmers: PR for contextualization of AWD Farmers will also benefit from Participatory Research for contextualization of AWD.
- **Soil and Climate Considerations:** AWD is not effective when used on all the soils; the sandy soils may drain off the water so quickly, that the water conservation will not be much; on the other hand, the heavy clay soils which have shallow water the AWD will not have any significant impact. The rainfall also contributes to the success rate, and must also be adjusted depending on the changes in weather in a certain season(Howell et al., 2015)

Strategies for Overcoming Challenges

AWD (Alternate Wetting and Drying) dissemination is primarily achieved through:

- **Participatory Field Demonstrations:** Farmers participated in field trials where AWD was demonstrated alongside traditional irrigation methods. This hands-on experience helped build trust among farmers by showing the benefits of AWD, such as water savings and input cost reductions.
- **Capacity Building Programs:** Training programs were established for farmers, technicians, and trainers to promote AWD. These programs included educational workshops and demonstrations on properly implementing the AWD technique.
- **Incentive Models:** Incentives were introduced to encourage farmers to adopt AWD. In some cases, farmers were compensated for potential yield losses or provided with fuel subsidies to help with the costs of operating irrigation equipment.
- **Policy Support:** Government policies played a crucial role in scaling the dissemination of AWD. The Department of Agriculture (DA) and National Irrigation Administration (NIA) actively promoted AWD as part of national irrigation programs. Policies were also put in place to align irrigation scheduling with AWD practices.
- **Scaling in Both Pump and Gravity Systems:** AWD was tested in both pump-based and gravity-based irrigation systems. Despite gravity-based system challenges,

particularly water pricing, and infrastructure, AWD dissemination efforts continued with targeted policies and collective action in irrigation management (Enriquez et al., 2021).

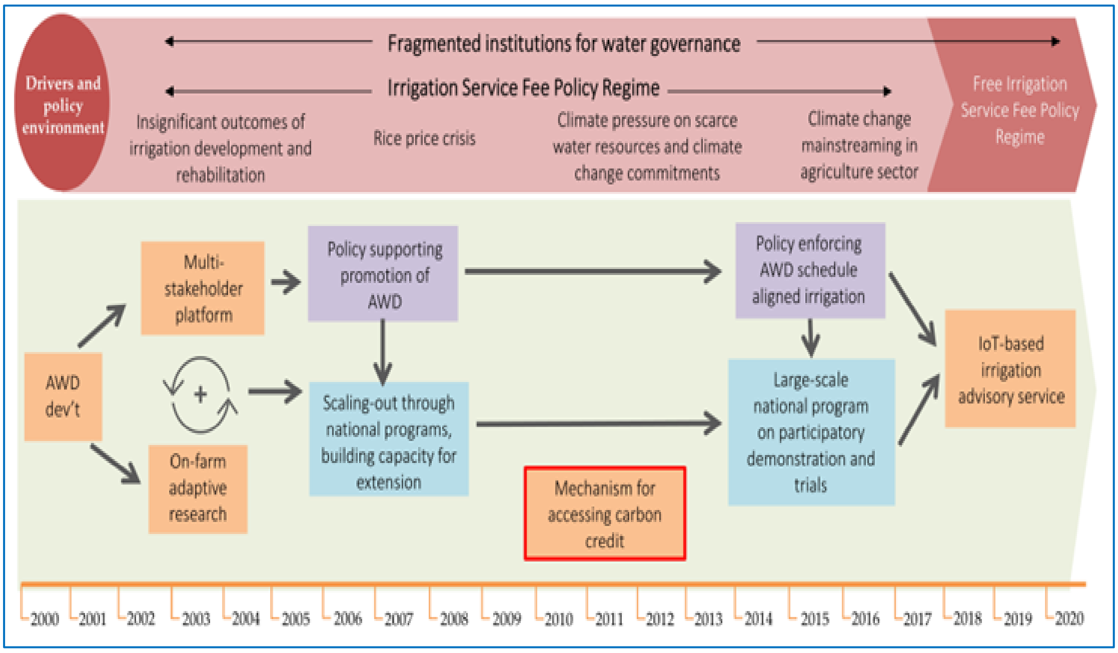

Fig. 3. Scaling trajectory of AWD in the Philippines, 2000-2020

Organization of irrigation water management and AWD

The aspects concerning the arrangement of the water management institutions or distribution of water resources are of critical importance in adopting and enhancing Alternate Wetting and Drying (AWD). As much as AWD depends on water control, it is largely impractical in most regions such as Asia, where wet and dry cycles are difficult to implement without outsiders overseeing the fields. For this reason, water has to be channeled through irrigation structures or Water User Groups (WUGs) in a coordinated manner following the cycles of AWD. These groups release the members from the amounts of water supplied to the crops as they can simply control the delivery and upkeep of irrigation systems like ditches, engines, and gates. In some instances, those organizations may rely on designated individuals to serve as water managers, who would manage the delivery of water, and control the AWD rotation. In that vein, WUGs also manage irrigation conflicts and disputes between users, notably the users in the reach upstream and those downstream when water is limited. WUGs assist in developing tree coordination amongst groups of farmers to make participatory water management a rational endeavor; participatory management efforts are well established in other nations, such as Japan, Egypt, and Korea. Organized water management strategies may enhance water efficiency and aid farmers in managing AWD through techniques that alleviate the burden of responsibility on individual farmers and increase compliance and efficiency in the irrigation schedule (Nakamura et al., 2022).

CONCLUSION

The present review established alternative Wetting and Drying (AWD) has great potential as a sustainable water management practice in rice production, especially for regions confronting increasing constraints on water resources. Water usage is also reduced by as much as 30% with AWD and it does not have any effect on rice yields which are either kept stable or increased thanks to improved root growth, and the greater number of productive tillers. Not only can it reduce methane emissions drastically, which is a very important environmental factor in the context of climate change mitigation. Similarly, the large number of smallholder farmers who could benefit from AWD on their farms across Africa still face a few hurdles before increased adoption can be realized. It also identifies key barriers, including limited access to reliable irrigation infrastructure coupled with low awareness and understanding of the benefits of long-term pilferage or yield risk. Although AWD can save water and energy, many farmers are doubtful about changing from traditional flooding methods even if it presents them with apparent advantages both in terms of complexity as well as laboriousness. To scale out AWD, the wider adoption must be enabled through farmer capacity development and supported by evidence of success in field trial plots; as well as policy incentives promoting water-saving technologies. The investment will need to include reliable irrigation systems and local governance structures. AWD can help overcome these challenges and transform water savings for higher ecological, lower emissions rice production which benefits smallholder farmers through the development of efficient, durable (conducive to climate change) farming systems that are also profitable. AWD ultimately reinforces global efforts to conceive resilient agriculture in the phase of climate variability and scarce resources.

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