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Barriers and Opportunities of Alternate Wetting and Drying (AWD) Irrigation System in Bangladesh: A Comparative Study among Major Rice Growing Countries

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Abstract

Alternate wetting and drying (AWD) irrigation technique is an intellectual irrigation schedule management system for rice cultivation. It's reduced irrigation water use, methane emission, production cost but increases the production and profits. The systems introduce in Bangladesh long time ago but still its implementation rate is very low. This study is an attempt to find out the barriers to adopt AWD irrigation system and suggest the strategies with compare the others rice growing countries. The relevant studies on AWD irrigation have been investigated and explored the barriers and opportunities of AWD irrigation system. The findings show that, due to the proper strategies within the existing infrastructure the adoption rate is very low in the country. The outcome could be very helpful for the academician, policy maker to dissimilated AWD irrigation system in wide scale.

Keywords: Rice; Greenhouse gases; Socio-economical; Environmental; Action plan

Introduction

Background of the study

Agriculture is estimated to be one of the largest sources of GHG emissions in Bangladesh, estimated at 78 Tera-gram (Tg) carbon di-oxide (CO_2)-eq. in 2016, to which rice cultivation contributes approximately 30% of total GHG (CO2-eq.) emitted from agriculture [1]. Rice paddy is a well-known source of methane emission, which accelerated the climate change impacts. Bangladesh is the 4th largest rice producing country in the world and greenhouse gas emission from rice paddy is a severe challenge for the country. Among the greenhouse gas from agriculture, methane is the most emitted gas. Although Methane is a short living greenhouse gas in atmosphere but it has 28-36 times global warming potential (GWP) than CO_2 within the 100 years lifetime [2]. Along with the methane nitrous oxide (N_2O) also emitted from rice paddy field which has 265-298 times GWP than CO_2 within 100 years lifetime. Annually methane emission from rice paddy field increased from 1037 Gg in 1990 to 1138 Gg in 2019. The country total methane emission was 57.2 MtCO2e in 2018, whereas the emission from agriculture and rice paddy was 33.5 MtCO2E and 23.53 MtCO2e, respectively. Bangladesh as a climate vulnerable country and methane emission from rice paddy accelerating the climate change impacts.

As a signatory country of Paris Agreement, the country committed to reduce the emission. Bangladesh Climate change Strategic Action Plan (BCCSAP) is developed to mitigate and resilience towards the climate change. In section 5 of this action plan, the country proposes low carbon emission strategy from agriculture with rising irrigation and water use efficiency through improved agronomic practices [3]. Recently the country achieved the first step status towards the developing country and committed to adopt strategy to climate change adaptation besides mitigation. The country submit 1st Intended Nationally Determination Contributions (INDC) report to United Nation Framework Convention on Climate Change (UNFCCC) and committed to reduce emission from energy, transportation, and industrial sectors conditionally 15% and unconditionally 5% by 2030 [4]. The plan mentioned If the world fails to take ambitious action, the costs to Bangladesh of climate change could amount to an annual loss of 2% of GDP by 2050 and 9.4% of GDP by 2100. Bangladesh therefore wants to play its part in the global collective action to reduce future emissions as part of a robust and ambitious international agreement. Agriculture is one of the leading emissions sectors, but it does not pay much attention in the action plan. Although, there is huge potential to reduce GHG emissions from agriculture. To adopt the greenhouse gas emission reduction from agriculture, the AWD irrigation techniques could be a very useful tool. AWD irrigation system was first introduced in Bangladesh in 2004 with the assist of International Rice Research Institute (IRRI). Initially, Bangladesh Rice Research Institute (BRRI) and Bangladesh Agriculture Research Council (BARC) applied AWD irrigation on their farm [5]. In 2008-09, the Department of Agriculture Extension (DAE) under ministry of agriculture (MoA) started a project on AWD irrigation. The AWD irrigation system started to implement in farmer level from 2012. Currently, BRRI, BARC, DAE, Rural Development Academy (RDA), Barrind Multipurpose Development Authority (BMDA), Rangpur Dinajpur Development Rural Service (RDRS) are working on accelerating the AWD implementation in field level. The government target to bring 20% of total rice area under AWD irrigation within 2025. But still now the AWD irrigation application rate in field level less than 8% of total rice area. Hence, the objectives of this study are as follows-

(i) To explore the current status of AWD irrigation implementation in major rice growing countries,

(ii) To investigated the barriers and overcome policies of the countries,

(iii) To find out the proper strategy to adopt AWD irrigation in Bangladesh.

Alternate Wetting and Drying (AWD) irrigation technique

International rice research institute (IRRI) introduced alternate wetting and drying (AWD) irrigation system is applying successfully for rice water use and methane emission reduction. Traditionally, paddy

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rice cultivated under fully flooded conditions throughout the entire growing period expect few days before harvesting. But it's don't need continuous flooded except rooting and flowering stage [6]. In AWD irrigation system, whereby the rice paddy field allowed intermediately flood up 5 to 15 cm and to naturally declined water level below up to 15 cm of soil surface except the critical stages (Figure 1). Normally, after 14 to 21st day of transplanting and 2 to 3 weeks before to the rice harvested time the AWD irrigation cycle repeated several times. The AWD cycle means the time between the watering to dry up and re-watering period. The length of AWD cycle and the number of AWD of AWD cycle depends on the rice cultivated regions, land and soil types, cultivation practices, weather condition and farmer's attitude.

The amount of water apply for rice irrigation is not fully used for the crop growth. The rice paddy only could accept the amount of water loss through the evapotranspiration. The excess amount of water used for rice paddy field keep always flooded condition is loss through the drainage loss, leaching, percolation, and evaporation. As a result, the irrigation water supply based on the rice crop water requirement does not affect the crop growth or yield. Furthermore, due to the periodic irrigation in midseason for rice cultivation, the irrigation water use decreased significantly (Figure 2).

Socio-economic benefits of AWD irrigation

The major cost of rice cultivation is irrigation cost (water fees and fuel used for pumping) in irrigated rice cultivation in Bangladesh [7,8]. As AWD irrigation is a water saving technology and it is also reduced the irrigation cost. The AWD irrigation cost were $23-42$/ha less than the continuous flooded irrigated rice paddy [7,8]. In Bangladesh, the AWD irrigation increased the farmers income up to 32% than the continuous flooded (CF) irrigated farmers (Lampayan, 2014) and decrease the production cost 4% [8]. Moreover, the AWD irrigated rice did not decreased the per unit yield. Some studies found that the AWD irrigation decreased water use without production lost [6]. In CF irrigated rice yield 4.6-5.4 ton/ha and in AWD irrigated yield 5.1-6.2 ton/ha in Bangladesh and increased rice yield 10-15% compare with CF irrigated rice in Bangladesh [9].

Environmental benefits of AWD irrigation

The environmental benefit of AWD irrigation in terms of water saving and low emission is the great advantage for climate change mitigation. The AWD irrigation technique save water is 20-40% in Bangladesh. Several studies found that the water savings from AWD to be 22-26%, representing 2,580–3,590 m3 of water saved per ha [10,11]. Ali et al. reported that conventional puddled rice caused emissions of 3.3 tCO2e/ha and that implementation of AWD reduced emissions to 2.5 tCO2e/ha. This is a reduction of 0.8 tCO2e/ha, a 24% decrease. However, the authors did not calculate the GHG emissions associated with diesel fuel used for pumping water. By using fuel savings results from other studies [12-14]. it can be estimated that AWD may decrease emissions by 0.032–0.106 tCO2e/ha via fuel savings alone. The overall AWD application benefit shows in Figure 3.

Comparison of AWD adoption rate among major rice growing countries

China is the most populated country in the world. Rice is the staple food and the country is the top rice producing and 3rd largest importing

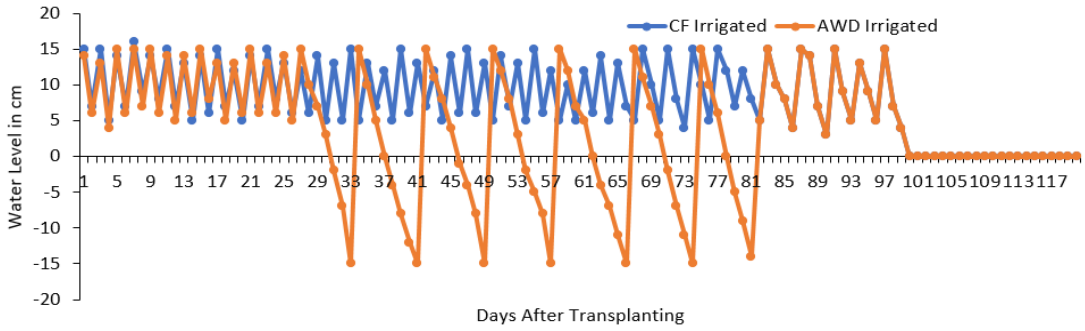

Figure 1: Conceptual Irrigation schedule of AWD and CF irrigation technique.

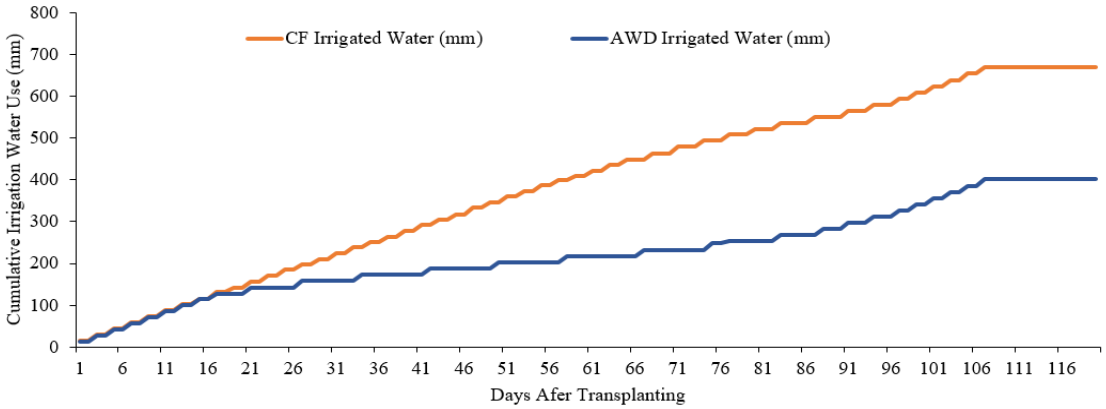

Figure 2: Conceptual framework of irrigation water use for AWD irrigated rice and the traditional CF irrigated rice.

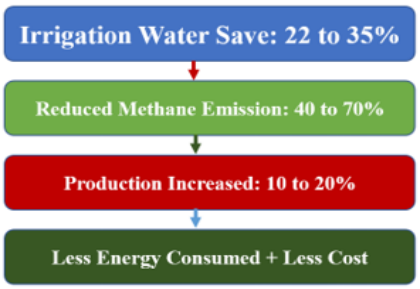

Figure 3: The environmental and socio-economic benefit of AWD irrigation technique compared to the CF irrigation technique.

country in the world [15]. Rice cultivation facing challenges of scarcity of irrigation water and the country reforms institutional reforms, policies and goals to water saving rice production. China introduces water saving irrigation (WSI) system in early 1990's decades as almost similar forms of AWD irrigation system. The major water saving technologies are (i) engineering technologies, such as canal lining, drip irrigation, underground pipe irrigation, and intermittent irrigation which is the modified form of AWD irrigation; and agronomic practices like as water-matched production, biological water saving technologies, and soil moisture conservation NN [16]. AWD irrigation save water use up to 50%, methane emission reduction 60%, increase farmer profit and some extended yield [17]. In last decades China expanded the effective irrigation area more than 10 million hectares and increased to 68.27 million hectares in 2018. Almost half of them were based on water saving irrigation technologies. Recently, Chinese government planned 'National Agricultural Sustainable Development Plan, 2015-2030' to increase the proportion of water-saving irrigation areas to 75% of the total effective irrigated areas and the level of water use efficiency for irrigation to at least 0.6 by the end of 2030 [18]. In the western and northern region of China 40% - 50% of total rice area under AWD irrigation and others forms of water saving system. The institutional arrangement, volumetric water pricing, governmental strong influence, and policies making successful adoption of AWD irrigation at wide scale [19].

India is the 2nd largest populated country in the world. The country is also the 2nd largest rice producer (169 million tonnes) and top rice exporting country in the world [20]. The rice production of the country also facing challenges of climate change impacts on agriculture especially change of precipitation pattern, temperature anomalies, global warming, and irrigation water shortages. To cope the climate change impacts the country introduce several management practices for rice cultivation such as Direct Seeds Rice (DSR), System of Rice Intensification (SRI), Alternate Wetting and Drying (AWD) Irrigation, irrigation at Minimum Depth (IMD), Drip Irrigation (DI), Supplementary Irrigation, Integrated Pest Management (IPM) etc. India is country with diverse physiography and socio-economic environment and there is huge variation of agricultural practices among the states. Among these, AWD is the proven climate smart technology which reduced water use 30%, reduce methane emission up to 60%, yield increased and reduced fuel cost in the country [21]. AWD adoption rate also varied among the regions such as in West Bengal 11%, Tamil Nadu 23%, Karnataka 35%, Eastern Region 6%, Northern Region 31% of total rice area [22], and Western Region 80% farmer adopt AWD irrigation in India [23]. The Central Government also trying to adopt water saving technologies as a climate change mitigation option for the country.

Vietnam is the 5th largest rice producing and 3rd topmost rice exporting country in the world. Rice is the most important agricultural crops in the country. The Red River delta and Mekong River delta is the major rice growing region in the country. The almost similar physiographic and socio-economic condition like as Bangladesh. The rice production of the country tackling challenges of climate change, drought, and water scarcity. Like the others rice growing country, the Vietnam also introduced AWD irrigation with IRRI in 2005. Its reduced 30% water use, 68% CH_4 emission reduction, farmer income increased 6% - 42%, labour and fuel cost reduced 1% - 46% compared to the CF irrigated rice paddy [24]. The Vietnam's Ministry of Agriculture and Rural Development (MARD) highlighted AWD as one of the most promising irrigation techniques and planned to adopt 3.2 million hectares of rice area by 2020 [25]. The MARD launches a) AWD and b) 3G3R programme; Three Reduction (fertilizers, pesticides, and seeds), Three Grain (income, yield, and quality) for country's NDC plan in 2006. Subsequently, the country launces 1M5R; one must do (quality seeds) and five reductions (sowing seeds, N-fertilizer, pesticide, irrigation water, and post-harvested loss) as a national policy to promoted and wide scale implementation in the field level. The AWD adoption rate in the An Giang province almost 52% and at 0.68, 0.66 and 0.67 at 1 scale during winter, summer and autumn season, respectively. Similarly, 0.68. 0.68 and 0.63 in Dong Thap province and 0.73, 0.04 and 0.25 in Bac lieu province, respectively [26]. Eventually, some farmers applying AWD irrigation in wet season for the yield increasing purpose [27]. The Vietnam government takes several steps to dissemination AWD irrigation as a climate change mitigation strategy in the country. The government combinedly focus on AWD with 1M5R, 3G3R programme in the agricultural NDC execution plan; evaluate the existing irrigation network and determine AWD suitable area; and finally integrated the investment plan for AWD rice production as well as provides financial support to local farmers from national, international aids and private sector [28].

Philippine is the 8th largest rice producing and 5th largest rice importer country in the world [15]. AWD irrigation have been introduced in 2001 in the country. It's reduced irrigation water use up to 30%, reduced methane emission 48% with keep N2O emission same level as CF irrigation [29]. Moreover, AWD irrigation save fuel cost, upper and lower stream irrigation conflicts, increases farmers income and no production los. The AWD irrigation was introduced in 2001 but the adoption rate is very slow and only 8% of total rice area under AWD irrigation adoption [30]. But the government planned to adopt AWD irrigation up to 50% of total irrigated rice area within 2020 and reduced methane emission approximately 12,151 ktCO2e/yr of emission reductions within the time. IRRI and Lampayan et al., reported that although AWD irrigation grows positive perception to adopt but some farmers give up AWD irrigation after the project finished and revert to the CF irrigation. Although, the country has abundant water resources but in future decades it will face water challenges and government seeking to adopt more rice area under AWD irrigation.

Japan is the 9th top ranked rice producing and 10th rice importing country in the world [15]. Among the developed countries, Japan is the only country where rice agriculture competing with the others industrial and service sector. The country is a Paris Agreement Signatory and committed to reduce GHG's. As a developed country, the rice cultivation practices, and management also developed and well managed. The country's rice irrigation and drainage infrastructure are highly advanced and fully controlled. It is found from "Seiryoki" published in 17th century that the country practicing midseason drainage as almost similar management of AWD irrigation. Although there is no water shortage problem in the country but the midseason drainage and AWD has been widely adopted as GHG's reducing techniques and reported 39% of CH4 emission in Japan [31]. The midseason drainage adoption rate in Japan is very high and overall adoption rate 87% of total rice area. The adoption rate in norther region is comparatively low (25% at Hokkaido) and high at southern region (92%) [32]. The government policies such as economic incentives for "Direct payment for environmentally friendly agriculture" programme which the prolonging of midseason drainage is a regionally approved alternative in several prefectures helps to disseminate the water saving irrigation system in the country.

In Thailand, 40% of total agriculture land under rice cultivation. The country is in the top three ranked countries for rice exporting and the 4th largest GHG emitter related to rice, especially methane. Moreover, some province facing challenges to produce rice due to the water scarcity. The country adopting AWD irrigation system as GHG's mitigation option. Chidthaisong et al., reported that the AWD irrigation reduce irrigation water by 42% compared to CF irrigation and reduce methane emission 49% than CF irrigation without yield loss and maintaining the level of N_2O emission. The Thailand Ministry of Agriculture and cooperatives and Ministry of Natural Resources and Environment along with the international agencies working to promote AWD adoption in farmer level at wide scale. The National Appropriate Mitigation Action (NAMA) introduce Sustainable Rice Programme (SRP)/ Good Agricultural Practices (GAP) plan to disseminate AWD irrigation amon 100,000 farmers with in 2021. The country switch to low emission practices from conventional method and plan to avoiding emissions of 1.664 Mt CO2e cumulative over the 5-year lifespan of the NSP with increasing annual mitigation potential, reducing baseline emissions from irrigated rice by more than 26 per cent (Thailand - Thai Rice NAMA, 2017).

In Bangladesh, AWD irrigation introduced in 2008 as pilot project and in farmer level adoption started on 2012. Several governmental organization, NGO's and international organization and donor agencies are working to disseminated AWD irrigation in Bangladesh. Several studies reported the advantages of AWD irrigation implementation. It's reduced water use up to 30%, reduced methane emission maximum 70%, increases N2O emission, increased yield up to 15%, increases farmer income 15-30% and as well as reduced fuel consumption compare to CF irrigated rice [7,9,5,33-38]. But the AWD adoption rate is very low in farmer level. IRRI, BRRI, BARC and several government institutions, and NGS's working for AWD dissemination in Bangladesh. Despites of environmental and economic benefits of AWD irrigation system adoption, the farmers are reverting to the CF irrigation system just immediately the AWD irrigation uptake project end. Moreover, some farmers apply AWD irrigation partially like only in the early stages of rice growth [8]. Due to some socio-economical structural complexity, irrigation water rental system and lack of awareness are the probable causes. Although the AWD irrigation system is proven as water saving and production increased irrigation method, but the adoption rate is less than 10% of total irrigated rice area. But the government committed to bring 20% of total rice growing area under AWD irrigation by 2030 according to the UNFCC national determined contributions [39].

AWD adoption rate among the major rice growing countries varied. The socio-economic and environmental condition also differ among the countries. The AWD adoption rate in Japan, China, India, and Vietnam is very high, whereas the adoption rate in Thailand, Indonesia and Bangladesh is very low. The irrigation water availability in Indonesia and Thailand comparatively higher than Bangladesh. In Bangladesh perspectives; (i) the physio-climatic condition is highly suitable for AWD irrigation, AWD irrigation, (ii) the country experienced severe irrigation water scarcity, (iii) highly vulnerable to climate change impacts, (iv) AWD irrigation demonstrated good environmental and economic advantages. As a result, wide scale adoption of AWD irrigation could be highly potential technology to cope the rice production challenges for the country. The detailed AWD adoption rate among the major rice growing countries shows in Figure 4.

Barriers and potential solutions for AWD uptakes in Bangladesh

There are numerous advantages and opportunities of AWD irrigation implementation in Bangladesh. Although the AWD irrigation technique is advantageous but the implementation rate in farmer level is very slow. We conducted a meta-synthesis analysis to find out the reason behind it and found some barrier to adopt it as follow.

Fixed rate irrigation water pricing: Generally, the rice irrigation system in Bangladesh depends on pump ownership. Most of the case the landowner and pump owner are different personnel except some STW's irrigation scheme. Only 2% farmers have their own irrigation map and used as services to the others farmers [40]. The rice and wealthier farmers are belonging to DTW with huge irrigation command area and the middle income and poor farmers used irrigation water by paying money or the portion of produced rice [36,37,39]. The pricing system is fixed by season and not fluctuated on "How much water used?". In AWD irrigation case, farmers need less water than the CF irrigation rice paddy, but the payment amount is fixed, and AWD irrigation farmer did not get any direct feedback. As a result, the irrigation water rented farmers are not interested to adopt AWD irrigation practices.

Land ownership and farm size: Bangladesh is a small country with huge population and per capita land is only 0.04915 ha (FAO, 2017). Moreover, only 37% farmers have their own land, 34% are poor tenants and 29% cultivated their own land plus tenant lands [41]. Moreover, the average rice paddy field size is very small and farmers land are not located in same place or irrigation scheme. Besides the land holding sizes, the plantation date, rice varieties, land location from pump such types of heterogeneity in an irrigation pump command area makes difficulties to apply AWD irrigation. The average irrigation command area under STW's varies from 3-4 ha and 26 ha for DTW's [42-45]. In case of landless poor farmer who rent land from the landowner and have not the rights for long time. These lands less farmer could not establish irrigation facilities for rice cultivation and fully depends on rental irrigation water. Moreover, it's very difficult to control irrigation water in a small spices of rice paddy within a large irrigation scheme. As a result, farmer could not apply AWD irrigation even though have wiliness.

Incentive: The primary interest of farmer to adopt AWD irrigation for saving water cost as well as production cost. But, due to the rental irrigation water system, the farmer did not get any benefit of water saving even saved huge amount of irrigation water [10,42,46]. Moreover, the Ministry of agriculture gives direct subsidies on irrigation fuel (electricity and diesel) and the pump own got this benefit and the tenants farmer deprived from it [47]. Although the government

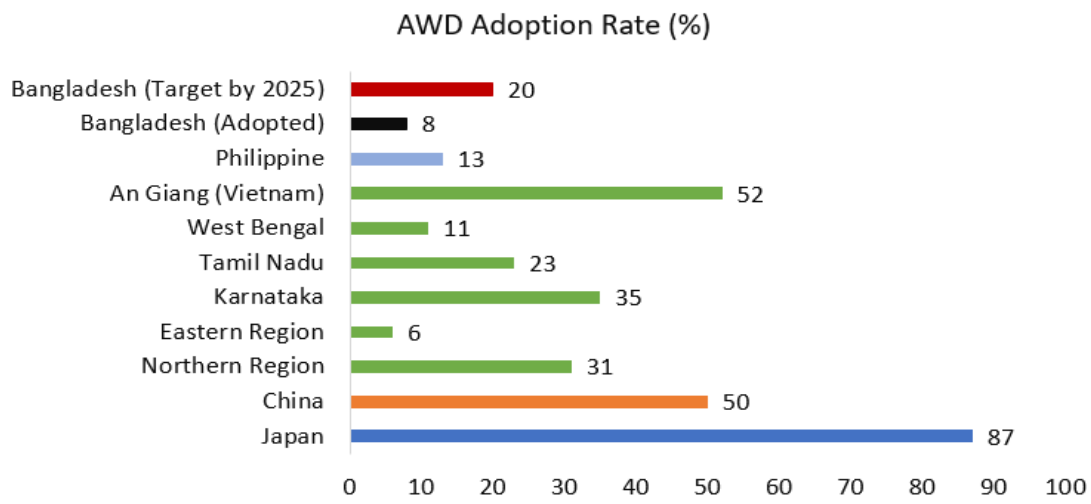

Figure 4: AWD adoption rate in major rice growing countries in the world.

subside 602.68 billion BDT in fertilizer, irrigation fuel, rehabilitation, and agricultural mechanization sector in last 9 years but there are no additional incentives for former to adopting AWD irrigation [48]. In Figure 5 shows the government subsides in different agriculture sector from 2009-2017. As a result, the farmers are not interested to adopt AWD irrigation willingly.

Awareness: AWD irrigation is a knowledge-based water management system and need to use properly for maximum benefits. Traditionally illiterate, or comparatively less educated people are engaged in agricultural activities in Bangladesh. Most of them are not so much concern about environmental impacts. The farmers perceptions on AWD irrigation is only economic benefits like- water saving, production cost decreased and yield increased. The others direct and indirect benefits of AWD adoption as like methane emission reduction, arsenic contamination reduction, precious groundwater saving is not pay attention to the farmers. Although, some government institution and NGO's are working to disseminate AWD irrigation in farmers level but it's not up to the mark. Moreover, in some case the farmers whose are adopt AWD irrigation during pilot study or project and after end of the project tenure again swap in to the CF irrigation [24]. As a result, lack of farmers awareness is another major limiting factor to adopt AWD irrigation.

Weed increase and Yield decrease concepts: Due to the lack of proper knowledge about AWD irrigation application especially when to start AWD and stop AWD impacts on production. Sometimes it is decreased rice production per unit yield [8,24,38]. Moreover, due to the dry up cycle in AWD irrigation, the paddy field weed increased and need more labour cost for rice production. Although, proper AWD application increased yield and weed management with herbicide in not a major problem. But, such concept in farmers mind makes them not interested to adopt AWD irrigation.

Government policy: The national agriculture policy of the country mainly production oriented. The major agricultural plan also emphasis on the rice production increase and become self-sufficient in food production. The latest fifth year planning 'Seventh Five Year Plan (7FYP 2016-2020)' which approved in 2015, mainly focused on food security, nutrition security, sustainable intensification and diversification of climate resilience agriculture production, crop sub-sector development for raise rural people income and employment opportunities [49]. Along with 7th fifth year plan, Government also introduce 'National Agriculture Policy (NAP 2013)' aims to improve food and nutrition security to improve quality of life through increased production and agriculture diversification. The Government of Bangladesh also drafted the 'National Agricultural Extension Policy (NAEP, 2015) for providing integrated agricultural extension service of Department of Agriculture Extension, Department of Fisheries, Department of Livestock and Department of Forestry under one umbrella through "National Agriculture Extension System (NAES)". Besides that, the digitized (E-agriculture) extension service promotes to assist farmers provisioning valuable information, integrated pest management [49]. All the national agricultural plan adopted to emphasis on increase food production, crop diversification and nutrition security and not concerned about the climate change mitigation.

Bangladesh is a signatory country of "Paris Agreement "and committed to reduce greenhouse gases. Recently the country listed into developing country from least developed country and need to reduce GHG's. The country submitted "Intended Nationally Determined Contribution's (INDC)" to United Nations Framework Convention on climate change (UNFCC) and proposed two-fold strategy (Conditional and Unconditional) (MoEF, 2012). The plan emphasis on GHG's emission reduction from Power, Industry and Transportation sector and did not considered agriculture sector. The country has also introduces ten years plan of "Bangladesh Climate Change Strategy and Action Plan (BCCSAP) as climate change mitigation action plan [4]. Although the food security and low carbon mitigation considered among six targets but there is also no guideline to reduce emission from agriculture. Most of the policies focused on production increased and adoption strategies. Agriculture is the second largest GHG's emission sector and rice paddy cultivation is the major emission sector and there is huge potential to reduce emission. So, the Government should include agriculture sector to the national mitigation plan and focused on AWD implantation as mitigation tools.

Proposed potential solutions: The problems associate with AWD adoption in Bangladesh have been discussed at above sections should be sought for dissemination it. We proposed some solutions within the existing structure, modifying the policy and very few additional investments for adoption. In Figure 5 shows the barriers and proposed solutions for AWD adoption in Bangladesh.

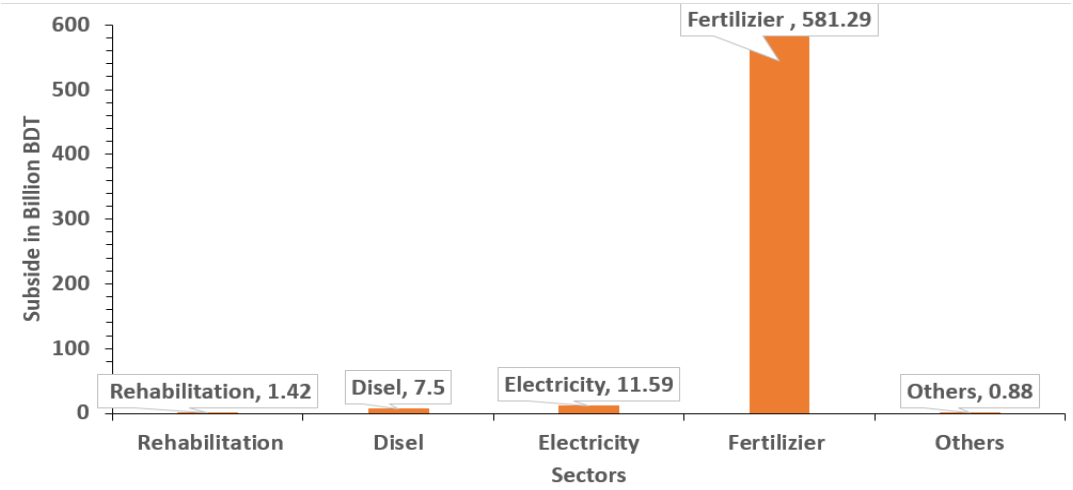

Figure 5: Bangladesh government subsidies in agriculture sector from 2009 to 2017.

Volumetric water pricing: The main barrier to adoption is fixed rate water pricing for AWD and CF irrigated rice paddy. We proposed volumetric water pricing means the farmer will pay for only the amount of water used rather a fixed amount. In this case, the AWD practicing farmer need to pay up to 35% less water and money for irrigation inputs which will add benefits of AWD adoption. In China already adopted volumetric water pricing and some part of Vietnam also adopting it [26]. In Bangladesh case, already introduced Pre-Paid Credit (PPC) for irrigation water use in Brrind regions [42]. Moreover, the country already converting the surface irrigation open drain into underground pipe drain which is very efficient for water flow gauge installation. Volumetric water pricing system will give direct financial benefit to the AWD practices farmer and helps to adopt it.

Land ownership and farm size

Due the small size of land and heterogenic plantation date and AWD irrigation cycle for individual farmer is another constraint for AWD adoption. Now AWD irrigation adopted by individual farmer level and we proposed to adopt AWD irrigation at community level. Moreover, in some case the landowner and the farmer are different person and incentives goes to the landowner. So, the incentives should give to the farmers not to the landowner. Like, under an irrigation pump command area 10 to 100 farmers cultivated rice paddy and all the farmers should practice AWD irrigation. So, in planning and policy phases should focused on irrigation scheme based AWD adoption rather individual farmer level.

Financial and technical support: Incentive is the key factor for adopting new technology. In Bangladesh, every year government subsidies huge amount of money in fertilizer, irrigation, seeds, machineries, fuels, tax exceptions and technical training for the farmers. Generally, all farmers directly and indirectly get the government incentives. Government already introduces "Smartcard" for the farmer to gives the incentives. Within the existing incentives system, government should give priorities to the AWD adopted farmer. Moreover, the Government directly bought rice paddy from farmers and in this case the AWD farmer should be priorities. Such types of economic incentive system could encourage farmer to adopt AWD irrigation technique.

Proper training and guidelines: The weeds increase due to the AWD application but in early stages of AWD implantation period. The weed can easily remove by applying herbicide with low cost. In yield decrease case, AWD practices yield decreases only in case of severe or improper AWD application. Due to the lack of proper knowledge about AWD application, farmer could not apply it properly and decreases yield. But proper AWD application increased per unit yield up to 15% compare to CF irrigation in Bangladesh [41,42-50]. In some region of Rajshahi division more than 50% farmer applied AWD irrigation without proper training [42]. Proper and number of trained farmers could help to solve the yield decreased problem. Moreover, complete guideline for region and rice varieties specific guideline could be helpful for the farmers.

Government policy: The government should include agriculture sector in GHG's emission reduction strategies and AWD as a potential tool of mitigation. Although, the government aims to increased AWD irrigation implementation but there is no proper plan. Within the existing administrative structure and incentive scheme, just changing some policies could be very efficient to AWD dissemination. Like, in "Smartcard" AWD farmers information could added and introduce "Carbon Credit Certificate (CCC)" in similar way of Japan and USA. The farmer with CCC will priorities for financial incentives, tax exemption and bank loan similar to the Japan and USA [8,27]. The graphical framework of the barriers to adoption and proposed solutions shown in Figure 6.

Recommended strategies for AWD adoption

AWD irrigation dissemination is very important for Bangladesh to reduce methane emission, water use as a climate mitigation tool. To implementation of a technology is always difficult as the recipient always in doubt about its impacts. In the country, several project and initiative already running to adopt AWD irrigation by national and international agencies. But an integrated and long-term strategy is very important to sustain it. There are already some farmers who already adopt AWD irrigation under a project and swap to no AWD irrigation after completion of the project tenure. As a result, we proposed a sustainable strategy within the existing infrastructure to adopt AWD irrigation in wide scale as follow Figure 5.

Stage-1: Suitable area and seasons selection: Department of Agriculture Extension (DAE) under Ministry of Agriculture is the largest agricultural institution in Bangladesh. Along with DAE, some other autonomous, commercial, government and non-government

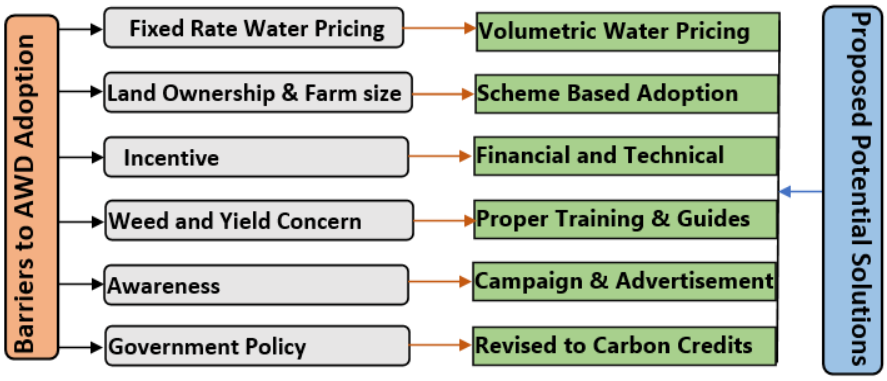

Figure 6: Constraints to adopt AWD irrigation and proposed potential solution to overcome the problems in Bangladesh.

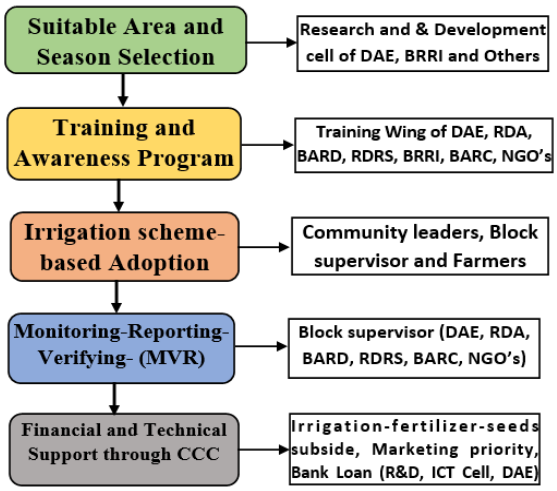

Figure 7: Proposed conceptual strategy for AWD irrigation dissemination in Bangladesh.

institutions like BARC, BRRI, RDA, BARC, RDRS, SYNGENTA, BARD etc are working in agriculture sector especially in rice paddy sub-sector. All the institution should bring under an umbrella and centrally operating the implementation strategy. Initially, should select the suitable area and time for AWD irrigation implementation. Expert body could be formed by the researcher from different institutions to makes a concrete plan. Based on suitability, set out the target to adoption rate and priorities for next 5 to 10 years. Like;

(1) Physio-climatically suitable (48%) rice area could be target -1,

(2) Physio-climatically high suitable boro season could be target-2,

(3) Physio-climatically high suitable amon season could be target-3,

(4) Socio-economical suitable area (58%) under AWD irrigation could be target-4,

Stage-2: Training and awareness program: Centrally, should launched awareness program like farmers field school, skill enhanced training, creating master trainer from farmers, trained the pump owner farmers etc. Besides, the advertisement and awareness program through print and electronic media, hand leaflet, small drama could be helpful. DAE and other institutions training wing could play vital role for this stage.

Stage-3: Irrigation scheme-based adoption: Based on the suitable area selection (stage-1), trained the pump owners and farmers (stage-2) to adopt AWD irrigation. Emphasis should give to implement based on irrigation pump command area rather the individual farmers level. Block supervisor and field supervisor from different institution could be responsible person for community level.

Stage-4: Monitoring-Verifying and Reporting (MVR): MVR is an important tool for climate changes mitigation action for enhancing transparency, tracking of climate finance and mitigation action [50]. In this case MRV will considered as monitoring tool for AWD adoption in farmer level. The block/field supervisor associated with the community leader will monitoring, verifying, and reporting to the central authority about the farmer information and AWD practices result. The central ICT division will include in Smartcard as "CCC" and this information will be used to gives incentive.

Stage-5: Financial and technical support: Although proper AWD irrigation application is itself offer benefits to the cultivar. But the financial and technical support will be encouraged farmer to adopt AWD. In farmers smartcard, there should be added a CCC option for further incentives. Within existing financial and administrative structure, the CCC holder farmer should be priorities on case of fertilizer, irrigation, seeds, machineries, and fuels subsides, tax

exceptions and technical training. Moreover, the farmers should get priorities to get interest free bank loan for production. Such types of opportunities could attract farmer to adopt AWD irrigation for rice cultivation. The conceptual framework for proposed implementation strategies shows in Figure 7.

Conclusion

The AWD rice irrigation system successfully implemented in the major rice growing countries in the world. The Japan and China are the pioneer in AWD implementation followed by Vietnam and India. Bangladesh is the least implemented country. Within the existing infrastructure and financial support system, the country could increase the AWD irrigated rice area. The major barriers to disseminated AWD irrigation system is social infrastructure and lack of motivation. To overcome the constraint government needs to reform policies within the existing administrative structure and financial capacity.

References

1. FAOSTAT (2019) Metane Emission from Paddy Rice in Bangladesh 2001-2018.
2. US EPA O (2018) Understanding Global Warming Potentials.
3. MOEF: Climate Change Strategy and Climate Change Strategy 2008.
4. INDC (2015) Ministry of Environment and Forests (MOEF) Government of the People's Republic of Bangladesh. Pp: 1-15.
5. Rahman MS (2017) Sander BO Application of Alternate Wetting and Drying (AWD) in Bangladesh Agriculture: Findings from case studies. Pp: 310-332.
6. van der Hoek W, Sakthivadivel R, Renshaw M, Silver JB, Birley MH, et al. (2001) Alternate Wet/Dry Irrigation in Rice Cultivation: A Practical Way to Save Water and Control Malaria and Japanese Encephalitis?
7. Alam MS, Islam M, Salam M, Islam M (2010) Economics of Alternate Wetting and Drying Method of Irrigation: Evidences from Farm Level Study. Agric Pp: 82-89.
8. Carrijo DR, Lundy ME, Linquist BA, Sander BO, Wassmann R, et al. (2018) Rice yields and water use under alternate wetting and drying irrigation: A meta-analysis. F Crop Res 19: 1-10.
9. Basak R (2016) Benefits and costs of climate change mitigation technologies in paddy rice: focus on Bangladesh and Vietnam. CCAFS Work Pap P: 52.
10. Kurschner E, Henschel C, Hildebrandt T, Leineweber M, Paul C (2010) Water Saving in Rice Production–Dissemination, Adoption and Short Term Impacts of Alternate Wetting and Drying (AWD) in Bangladesh.
11. Lampayan RM, Rejesus RM, Singleton GR, Bouman BAM (2015) Adoption and economics of alternate wetting and drying water management for irrigated lowland rice. F Crop Res 170: 95-108.
12. Satar MA, Moniruzzam M, Kashem MA (2009) National Workshop Proceedings on AWD Technology for Rice Production in Bangladesh; Bangladesh Rice Research Institute, Gazipur.
13. Alam ASAF, E Choy, Begum H (2015) Malaysian oil palm industry: Prospect and problem. J Food Agric Environ 13: 143-148.
14. Hasan K, Habib A, Bhattacharjee D, Afrad SI (2016) Impact of Alternate Wetting and Drying Technique on Rice Production in the Drought Prone Areas of Bangladesh. Indian Res. J Ext Educ P: 16.
15. IRRI (2015) World Rice Statistics Online Query Facility.
16. Wang H, Liu C, Zhang L (2002) Water saving agriculture in China: An overview. Adv Agron 75: 135-171.
17. Li Y, Bark R (2004) Increasing water productivity for paddy irrigation in China. Paddy Water Environ 2: 187-193.
18. Du L, Xu L, Li Y, Liu C, Li Z, et al. (2009) China's Agricultural Irrigation and Water Conservancy Projects: A Policy Synthesis and Discussion of Emerging Issues. Sustain P: 11.
19. Yao L, Zhao M, Xu T (2017) China's water saving irrigation management system: Policy, Implementation, and challenge. Sustain P: 9.
20. Top countries based on production of milled rice, Statista (2020).
21. Mondal D (2017) Prospects of Alternate Wetting and Drying (AWD) Methodology of Irrigation through System Intensification on Productivity of Summer Transplanted Rice (Oryza sativa L.) Int J Pure Appl Biosci 5: 629-634.
22. Palanisami K, Kakumanu KR, Nagothu US, Ranganathan C (2020) Climate Change and Future Rice Production in India: A Cross Country Study of K Palanisami, Krishna Reddy Kakumanu, Udaya Sekhar Nagothu, C. R. Ranganathan.
23. Richards M, Sapkota T, Stirling CT, Verhulst N, Friedrich JK (2020) Improved water management in irrigated rice through Alternate Wetting and Drying (AWD) | Climate-Smart Agriculture Guide.
24. Rejesus RM, Martin AM, Gypmantasiri P (2020) Meta-impact assessment of the irrigated rice research consortium.
25. Richard M (2020) Alternate wetting and drying for more efficient rice farms in Vietnam.
26. Lovell RJ (2019) Identifying alternative wetting and drying (AWD) adoption in the Vietnamese Mekong River delta: A change detection approach. ISPRS Int J Geo Information P: 8.
27. Yamaguchi T, Luu MT, Minamikawa K, Yokoyama S (2016) Alternate Wetting and Drying (AWD) Irrigation Technology Uptake in Rice Paddies of the Mekong Delta, Vietnam: Relationship between Local Conditions and the Practiced Technology Asian and African Area Studies 15 (2): 234-256.
28. The T Van, Trinh M Van; Trinh NTD, Anh LH, Richards MB, et al. (2019) An investment plan for low-emission rice production in the Mekong River Delta region in support of Vietnam's Nationally Determined Contribution to the Paris Agreement. CCAFS Work Pap P: 20.
29. Arnaoudov V, Sibayan E, Caguioa R (2015) Adaptation and Mitigation Initiatives in Philippine Rice cultivation. United Nations Dev Program 1: 84.
30. Siopongco JDLC, Wassmann R, Sander BO (2013) Alternate wetting and drying in Philippine rice production: feasibility study for a Clean Development Mechanism. Tech Bull P: 14.
31. Kajiura M, Minamikawa K, Tokida T, Shirato Y, Wagai R (2018) Methane and nitrous oxide emissions from paddy fields in Japan: An assessment of controlling factor using an intensive regional data set. Agric Ecosyst Environ. 252: 51-60.
32. Minamikawa K (2019) Dissemination of water management in rice paddies in Asia. 19-36.
33. Chidthaisong A, Cha-un N, Rossopa B, Buddaboon C, Kunuthai C, et al. (2018) Evaluating the effects of alternate wetting and drying (AWD) on methane and nitrous oxide emissions from a paddy field in Thailand. Soil Sci Plant Nutr 64: 31-38.
34. Thailand Thai Rice NAMA (2020).
35. Karim M, Alam M, Ladha J, Islam M (2014) Effect of different irrigation and tillage methods on yield and resource use efficiency of boro rice (Oryza sativa). Bangladesh J Agric Res 39: 151-163.
36. Carrijo DR, Akbar N, Reis AFB, Li C, Gaudin ACM, et al. (2018) Impacts of variable soil drying in alternate wetting and drying rice systems on yields, grain arsenic concentration and soil moisture dynamics. F Crop Res 222: 101-110.
37. Oo AZ, Sudo S, Inubushi K, Mano M, Yamamoto A et al. (2018) Methane and nitrous oxide emissions from conventional and modified rice cultivation systems in South India. Agric Ecosyst Environ 252: 148-158.
38. Begum K, Kuhnert M, Yeluripati J, Ogle S, Parton W, et al. (2018) Model based regional estimates of soil organic carbon sequestration and greenhouse gas mitigation potentials from rice croplands in Bangladesh. Land P: 7.
39. Joven Bernadette P (2020) Farmers in Northwestern Bangladesh learn to grow climate friendly rice | Climate & Clean Air Coalition
40. Mottaleb KA, Krupnik TJ, Erenstein O (2016) Factors associated with small-scale agricultural machinery adoption in Bangladesh: Census findings. J Rural Stud. 46: 155-168.
41. Pearson KA, Millar GM, Norton GJ, Price AH (2018) Alternate wetting and drying in Bangladesh: Water-saving farming practice and the socioeconomic barriers to its adoption. Food Energy Secur 7: 1-12.
42. BADC Minor irrigation survey report 2017-2018.
43. Pandey S, Yadav S, Hellin J, Balié J, Bhandari H, et al. (2020) Why technologies often fail to scale: Policy and market failures behind limited scaling of alternate wetting and drying in rice in Bangladesh. Water Switzerland P: 12.

44. Carrijo DR, Lundy ME, Linquist BA (2017) Rice yields and water use under alternate wetting and drying irrigation: A meta-analysis. F Crop Res 203: 173-180.

45. Babu SC, De Pinto A, Paul N (2019) Strengthening Institutional Capacity for Disaster Management and Risk Reduction through Climate-Resilient Agriculture. Int Food Policy Res Inst Pp: 01-22.

46. The Financial Express Govt provides Tk 602.68b as subsidies for agriculture in 9 yrs (2018).

47. FAO F. Country fact sheet on food and agriculture policy trends - United Republic of Tanzania (2016).

48. MOEF (2012) GOB-Second National Communications.

49. Barmon BK, Tarafder SK (2017) Impacts of Alternate Wetting and Drying (AWD) Irrigation System on Water Productivity, Profitability and Household Income of Modern Varieties (MV) of Paddy Producer in Bangladesh. Pp: 250-274.

50. Wartmann S, Larkin J, Eisbrenner K, Jung M (2013) Knowledge Product: Elements and Options for National MRV Systems.