INITIATIVE ON Mixed Farming Systems

Alternate wetting and drying technology and tailwater recovery in rice production systems in the Northern and Ashanti regions of Ghana

Methodological Report

Amankwaa-Yeboah Patricia[1], Birhanu Zemadim Birhanu[2], Adebayo Oke[2], Yeboah Stephen[1], Okyere Harry[1], Adomako Joseph[1], Adabah Richard[1], and Olufunke Cofie[2]

Author affiliation [1]CSIR-Crops Research Institute
[2]International Water Management Institute

Published by International Institute of Tropical Agriculture

November, 2023

The Sustainable Intensification of Mixed Farming Systems Initiative aims to provide equitable, transformative pathways for improved livelihoods of actors in mixed farming systems through sustainable intensification within target agroecologies and socio-economic settings.

Through action research and development partnerships, the Initiative will improve smallholder farmers' resilience to weather-induced shocks, provide a more stable income and significant benefits in welfare, and enhance social justice and inclusion for 13 million people by 2030.

Activities will be implemented in six focus countries globally representing diverse mixed farming systems as follows: Ghana (cereal–root crop mixed), Ethiopia (highland mixed), Malawi: (maize mixed), Bangladesh (rice mixed), Nepal (highland mixed), and Lao People's Democratic Republic (upland intensive mixed/ highland extensive mixed).

Summary

As part of the Sustainable Intensification Mixed Farming Systems Initiative (SI-MFS), a collaborative team of researchers from the Council for Scientific & Industrial Research-Crops Research Institute (CSIR-CRI) and the International Water Management Institute (IWMI) conducted several stakeholder engagements and co-designing activities across the project implementation communities in the Northern and Ashanti Region of Ghana. The collaboration aims to improve resource use efficiency by demonstrating the Alternate Wet and Dry (AWD) and Tail Water Recovery (TWR) technologies at the project communities and boost rice production and saving water resources. The stakeholder engagements brought together farmers, extension staff, staff from municipal and district assemblies, staff from the Ghana Irrigation Development Authority (GIDA) as well as researchers and agricultural technicians to co-design a demonstration plan for the promotion of AWD as well as TWR systems. The demonstration is expected to accelerate the pathway to impact in the adoption of water-smart irrigation practices for sustainable resource use.

Contents

1. Background

The Sustainable Intensification of Mixed Farming System (SI-MFS) Initiative aims to validate and scale sustainable intensification options that improve efficiency, equity, and resilience in regions where mixed farming systems dominate the landscape. In Ghana, the SI-MFS initiative is working in vulnerable communities across the Savannah, Northern, Northeast, Upper East and Upper West regions of the country. In these areas, climate variabilities and degrading landscapes are negatively impacting food production systems (yield reduction, absence of diversified food crops and in some extreme cases, crop failure). Water scarcity is becoming a major challenge for crop production (rice, tomato, and vegetables) and reducing the full potential of the established irrigation schemes across the different regions. Fodder availability is another area impacted by climate variability, particularly during the dry season (Nikolaou et al., 2020). Animal productivity is already low and is made worse by seasonal feed shortages of good quality and by water sources affected by environmental deterioration. Farmers have adopted few cutting-edge technologies and best practices as a result. Sustainable intensification (SI), which is defined as increasing food production on the same area of land while minimizing adverse environmental effects, can help to address these issues (Muhie, 2022).

More than half of the world's population receives nourishment from rice (*Oryza sativa L.*), which is essential for supporting socioeconomic growth, food and nutritional security, income, and poverty alleviation (Fugakawa and Ziska, 2019). The AWD irrigation method intermittently floods and dries the field, conserving irrigation water while also increasing water use efficiency, lowering greenhouse gas emissions, and using less fertilizer, pesticide, and labor. Irrigation is administered if the soil reaches a particular lower moisture level (Chaudhary et al., 2023). The rice fields are changed from being continuously wet to being occasionally dry during the crop growth season. Water is delivered to a storage reservoir through ditches or pipes in tailwater recovery and reuse systems (tailwater systems). They are applicable to any irrigated agricultural system (usually flood or furrow irrigation) when a sizeable amount of irrigation water, due to the irrigation method, goes off the edge of the irrigated field. Tailwater is a useful resource that boosts the growth of crops and soils as well as utilized for raising cattle. Better access to irrigation technology has made it possible to intensify cropping methods and the inputs used, opening the door for the agricultural sector to be modernized to improve and sustain rural livelihoods by raising crop and livestock production (Iseyemi et al., 2021).

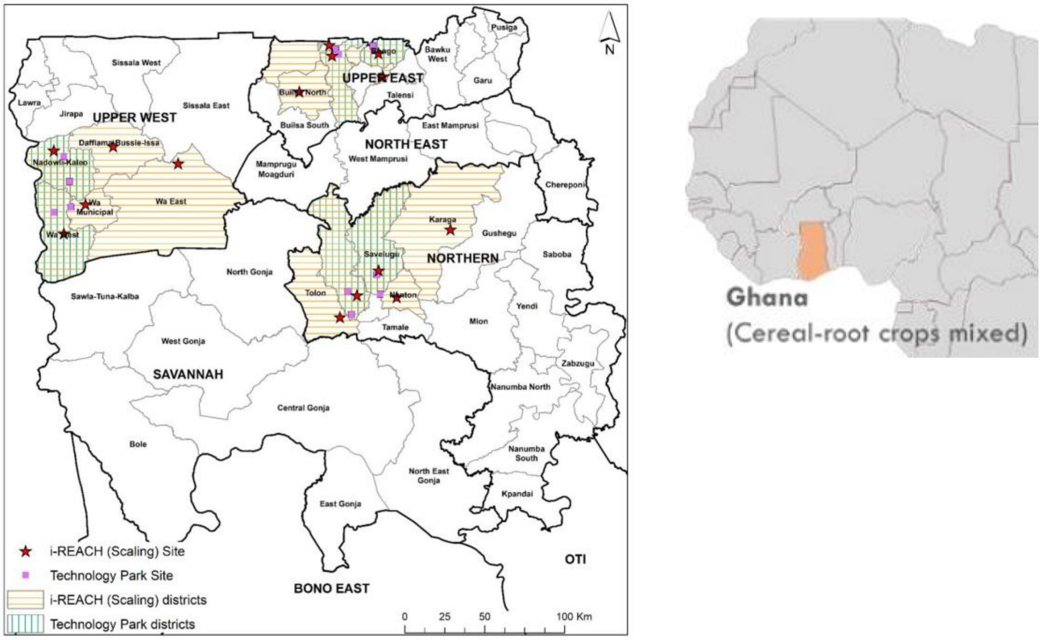


Figure 1: SI-MFS intervention areas in Ghana (Muthoni et al., 2017)

2. Demonstrating the AWD technology for grain and fodder production

The AWD technology, which has been evaluated across the country over the past six years is an irrigation scheduling technology utilizing simple retooled polyvinyl chloride (PVC) pipes to monitor the water table depth, allowing for the rice field to dry to a set of predetermined soil water depth before reflooding the field. The technology can save up to 30% of irrigation water, improve nutrient and water use efficiencies and reduce greenhouse gas emissions from rice fields. In irrigated schemes across the aforementioned regions of the country, tailwater is left unutilized and as such wasted on schemes. There is a need to quantify, analyze and recover tailwater for reuse by livestock and other crop producers downstream of available irrigation schemes. Any technique that maximizes the retention and collection of tailwater by minimizing the losses suffered is beneficial to the success of such water resources conservation (Omer et al., 2019). Tailwater harvesting should be viewed as a technique for climate adaptation in the early phases of the food system.

Rice straw is the main source of forage for animal feeding meeting the dry matter requirements and when offered in combination with legumes, molasses, and other concentrates it improves the protein content of the feed. Since irrigated rice production can occur year-round, rice straw remains a practical fodder source, particularly in critical periods when sources of fresh fodders are unavailable or insufficient for livestock feeding (Eeswaran et al., 2022).

3. Tailwater Recovery for improved resource use in rice production

Tailwater recovery (TWR) schemes are water conservation practices implemented to mitigate downstream nutrient losses, improve irrigation water use efficiency, improve offsite water quality, and reduce energy use. This recovery system is applicable to any irrigated agricultural system (typically flood or furrow irrigation) in which a significant quantity of irrigation water, because of the irrigation method, runs off the end of the irrigated field.

In irrigated schemes across the aforementioned (Northern and Ahafo Ano) regions of the country, tailwater is left unutilized and as such wasted on schemes. Any technique that maximizes the retention and collection of tailwater by minimizing the losses suffered is beneficial to the success of such water resource conservation. The reuse of this tailwater ties in well with the United Nations Sustainable Development Goal (SDG6) which emphasizes the efficient use of water and recycling of water. Since rice (*Oryza sativa L.*) is produced under flooded soil conditions, and pesticides and fertilizers are often applied directly to the water, their residual time in tailwaters is an important environmental consideration. These materials have the potential for impacting water quality both at nearby outlets and much further downstream. Hence it is important to assess the quality of the water sample (tailwater) before its reuse. Tailwater Harvesting should be viewed as a technique for climate change adaptation in the context of sustainable intensification of the food production systems. Hence CSIR-CRI and IWMI have co-designed and promoted the AWD technology and TWR under irrigated rice systems in the Kumbungu and Ahafo Ano enclaves of the Northern and Ashanti Regions respectively. This report outlines preliminary stakeholders' engagement activities, and, co-designing of pilot sites and protocols, to validate the AWD and TWR system in two regions of Ghana with the objectives of:

1. Promoting AWD as a farmer-led production system that is sustainable and more resilient (efficient use of resources such as water, labor, and nutrients) for rice and fodder production, and
2. Examining the water quality characteristics farms under the Botanga irrigation scheme in Northern Ghana and assess the potential reuse of the tail water by livestock and other crop producers downstream of the irrigation scheme.

4. Project Location

4.1 Kumbungu District (The Botanga Irrigation Scheme)

The Kumbungu district in the Northern Region of Ghana, was formed from a break from the Tolon/Kumbungu District in 2011 (Kumbungu District Assembly, 2020). The district is surrounded by the Tolon and North Gonja Districts in the west, the Savelugu/Nanton District to the east, the Mamprugu/Moagduri District to the north and the Sagnerigu District to the South. The rainy season lasts from May to October with a long dry period in between, with flooding occurs in the months of July to September. Most of the remaining year is dry. The primary economic activity in the district is agriculture, which is primarily done at the subsistence and seasonal levels with a little amount of irrigation farming around the Botanga dam. It makes up around 60% of the labor force in the area, which is indicative of the agrarian nature of its economy. Within the Kumbungu district is where the Botanga Irrigation scheme is situated. The Botanga Irrigation Project is the largest gravity-fed project in northern Ghana. The cropping area under the scheme is separated into two sections: the upland, which is used to produce vegetables and the lowland, used to produce rice. The upland has free-draining soil with plots made for furrow irrigation (Sadick et al., 2015). The irrigation system has a potential area of 570 ha and all the areas have been developed. The system is gravity-driven, moving water from the dam through canals and laterals to different parts of the scheme. The reservoir has a maximum storage capacity of approximately 25 million m^3. There are two (2) canals and twenty-eight (28) laterals on the scheme. The scheme serves about thirteen communities in terms of production resources (land and water). These communities are: Tibung, Kumbungu, Kpasogu, Dalun, Wuba, Kukuo, Kpong, Saakuba, Yiplegu, Voggu, Kushibo, Zangbalwe and Bagli (Abdul Ganiyu et al., 2012).

4.2 Ahafo Ano Southeast District

Ahafo Ano Southeast District is one of the forty-three districts in Ashanti Region, Ghana. It was formerly a part of the larger Ahafo Ano South District, which was formed in 1988 from the former Ahafo Ano District Council. The district assembly's capital city is Adugyama, which is situated in the western part of the Ashanti Region. With Offinso North District to the north, Ahafo Ano Southwest to the south, Atwima Nwabiagya North District to the east, and Tano South Municipal in the Ahafo Region to the west, the district shares a border (Ahafo Ano South-East District Assembly, 2018). The major economic livelihood of the people is smallholder farming, major crops produced being cereals and vegetables.

4.3 Ahafo Ano Southwest District

A legislative Instrument 2323 in 2018 (LI 2323, 2018) separated the Ahafo Ano South-West District Assembly from the Ahafo Ano South District in March 2018. The district assembly's capital city is Mankranso, which is situated in the western portion of the Ashanti Region. It occupies 1190.7km^2 in total, which is 4.9 percent of the region's overall surface area. Tano North Municipal in the Ahafo Region, Ahafo Ano North Municipal in the north, Atwima Nwabiagya Municipal in the south, and Offinso North District in the east form its northern and western boundaries, respectively. According to the 2021 Population and Housing Census, there are 65,770 people living in the district, with 33,641 men and 32,129 women (Ahafo Ano South-West District Assembly, 2018).

4.3.1 Potrikrom Smale Scale Irrigation Scheme

Potrikrom is located 1 km from Adugyama and roughly 6 km from the district capital. Farmers in the area relied on rain for their vegetable and arable crop production (okra, rice, and maize) prior to the development of the Potrikrom weir (dam) irrigation project. Due to the excessive rains, the agricultural output was only marginally good. Due to the stream in the area frequently drying out, farmers in recent years were able to grow vegetables only from October to April. The government of Ghana is building a weir to retain more water for farmers in the area to use for the cultivation of dry season vegetables and arable crops as a means of resolving the issue. The plan was once intended to cover a significant region, however due to land issues, the project has been put on hold. The dispute has been resolved by the MoFA and other parties involved to increase the amount of irrigable land available to the local population. Sandy loam and clayey loam are the two types of soil found in the region.

4.3.2 Adugyama smale scale irrigation scheme

Adugyama is situated approximately 5 kilometers from the district capital on the north- eastern part of the Kumasi Road. The population of the community is about 4,000 approximately. Dunyan River flows through the neighbourhood. Potrikrom to the north, Amakom to the south, Biemso No. I and II to the east, and Kunsu-Wioso to the west form its borders. Dams, streams, and groundwater are the water sources used for small-scale irrigation during the dry season of farming. On the Kumasi-Sunyani Road, in the district's northeastern region. Dams, streams, and groundwater are the water sources used for small-scale irrigation during the dry season of farming. Weirs have lately been built to hold additional water to produce grains and vegetables. Together with the African Development Bank (ADB), MoFA is doing this. The region is known for its production of lettuce, cabbage, spicy peppers, tomatoes, okra, and garden eggs. The region has rice farms. During the dry season, water is lifted by pumps and applied to crops. The type of soil is sandy loam, while clayey loams are found in lowland places.

5. Stakeholder Engagements

To aid in the implementation of activities in proposed project areas, a team of researchers from CSIR-CRI and IWMI visited the proposed project areas with the objective of iidentifying, sensitizing, introducing, and building partnerships with relevant stakeholders (Table 1).

Table1: Relevant stakeholders engaged in proposed project locations in the Northern Region

Project Location (Region, District, Community)	Community	Stakeholder	Contact person
Northern Region, Kumbungu District	Kumbungu	Department of Agriculture	Madam Abibah Musah (District Director of Agriculture)
	Botanga Irrigation Scheme (Botanga)	Ghana Irrigation Development Authority	Mr Stephen Y. Adegle (Scheme Manager)
		Farmer Based Organisation (FBO)	Amadu Alhassan (Lead Farmer)

An initial meeting held at the district office of the Department of Agriculture in Kumbungu brought together the research team from CSIR-CRI, IWMI and staff of the Department of Agriculture, led by the District Director of Agriculture, Madam Abibah Musah. Present also at the meeting were extension agents for crop and animal production. The team briefed the DDA staff about the SI-MFS project and the reasons why the district has been selected as a beneficiary. The team explains that the project intends to demonstrate the AWD and tailwater recovery technologies at the Botanga Irrigation Scheme to help boost rice production in the region whilst saving on the already scarce water resource. The DDA welcomed the team and added that the project was good for the scheme and was hopeful for the added value that it would bring to beneficiary farmers and the district and the region. She willingly availed the extension in the district to support the project. She however asked the project to train all the extensions in the district in the technology to keep them abreast and capable to train other extension and end-users on the technologies. At the end of the meeting, she asked her staff to accompany the team to the Botanga Irrigation Scheme for a meeting with the Scheme management and farmers.

Figure 2: (Left) A section of staff and visiting team at the Department of Agriculture office at Kumbungu, (Right) A section of farmers and visiting team at the GIDA office at Botanga. *Credit: Patricia/CSIR-CRI, 2023*

The SI-MFS initiative was introduced to the staff of the Ghana Irrigation Development Authority (GIDA) at the Botanga irrigation scheme. The manager of the scheme Mr Stephen Adegle was very supportive of the project. He believed if all farmers at the scheme could embrace the AWD and tailwater recovery technologies, the water use efficiency across the scheme would be enhanced, with improved scheme productivity.

A meeting with farmers at the scheme was held where the proposed technologies were explained to them. A section of the farmers who were involved in an initial demonstration of the AWD by the CSIR-Crops Research Institute was happy to get the chance to learn more about the technology and eventually use in their fields. Other farmers were willing to avail their land for project activities. Later a meeting was held between the visiting team and the country convener for the SI-MFS Project, Dr Nurudeen Abdul-Rahman at the IITA office in Tamale. The team briefed the convener on their engagement activities so far and the other impending engagement activities as scheduled. Dr Abdul-Rahman advised the team to select beneficiary farmers from the list of farmers who had already been interviewed as part of the baseline survey for the SI-MFS project. The team asked to get the list that aid in the selection of farmers who would use their fields for the individual farmer learning plots.

In the Ahafo Ano South East District, the team visited the Inland Valley Rice Development Project at Potrikrom. The farmers present led the team to tour facilities at irrigation site. Several challenges with leaking channels were reported by the farmers. The farmers were of the view that if the AWD technology would become successful under the scheme, then the project should come to their aid and help seal some of the leaking channels. The farmers were happy to have the team visiting their site. During a visit to the office of Ahafo Ano South East District, the

District Coordination Director, Mr. Kaleem Adam, welcomed the team and also invited to meet with the District Director of Agriculture, Mr. Martin Amoah. The meeting deliberated on the two inland valley development projects at Adugyama and Potrikrom and was of the view that the SI-MFS initiative would help to boost rice production in the district. Mr. Amoah also welcomed the team and was willing to avail the extension agents in the district to support project implementation.

A visit was made to a farmer at Bronikrom in the Ahafo Ano South West District. The farmer, Nana Yaw Agyemang Atwereboando operated a mixed farming system where he had three fishponds with tilapia and catfish, a piggery, some goats and sheep, and ducks alongside rice, maize and vegetable production. He also had a tree cop plantation of coconut and oil palm trees. The farmer is currently involved with the Black Soldier Fly (BSF) project being implemented by the International Institute of Tropical Agriculture (IITA). The team discussed how his farm could be used for potential demonstration of AWD and tailwater recovery technologies. The farmer was willing to avail part of his land for the project activities.

Table 2: Relevant stakeholders engaged in proposed project locations in the Ashanti Region

Project Location (Region, District, Community)	Community	Stakeholder	Contact person
Ashanti Region (Ahafo Ano Southeast district)	Potrikrom	Farmer Based Organisation (FBO)	Mr Karikari, (Member, FBO)
	Adugyama	FBO	Mr Kankam Boadu (Member, FBO)
	Adugyama	Ahafo Ano Southeast District Assembly	Mr Kaleem Adam (District Coordinating Director)
	Adugyama	Department of Agriculture	Mr Martin Amoah (District Director of Agriculture)
Ashanti Region, Ahafo Ano Southwest district)	Mankranso	Ahafo Ano Southwest District	Mr Atsu Agbezudor (District Coordinating Director)
	Bronikrom	Private farmer	Nana Yaw Agyemang Atwereboando

6. Co-designing and protocol development for AWD and TWR with farmers and relevant stakeholders

The initial concept for the AWD technology and tailwater recovery technique and demonstration setup was explained to farmers for their input and aid to co-design the demonstration plan and strategy. The team explained that it would involve a mother demonstration with three (3) improved rice varieties under AWD and a farmer's practice. Each treatment (AWD and farmer's practice) would involve an area of not less than half (½) an acre. At least 5 farmers willing to test and adopt the technology can do similar treatment on their fields using one of the improved rice varieties. Several farmers were willing to partake in the test demonstration on their fields. To bring a distinction between the 2 levels of demonstrations, the mother demonstration involving the 3 rice varieties was termed the mother demonstration plot whilst the other testing to adopt plots was termed individual farmer learning plots (IFLP). It was explained that farmer learning plots were intended to aid farmers learn and gain hands-on experience in the implementation and management of the AWD technology. It was also to serve as peer-to-peer training plots. The demonstration plot would serve as the converging points for farmer field schools (a learning site) and the exposition of other project activities that need to be conducted on the field.

The interest in the individual farmer learning plots was high and as such, though the initial plan was to have 5 of those, the team had to agree to double the participation to 9 farmer fields. These 9 farmers were to be provided with rice seed, fertilizer and field management, and technical support for the implementation of their individual farmer learning plots. They would in turn take for the project, data on the water table height in the rice fields as well as allow for other agronomic and phenological data to be taken on their IFLPs. Three farmers would form an aggregate farm (block) by using different rice genotypes as shown in Figure 3.

Block 1	**F2G2**	**F7G1**	**F3G3**
Block 2	**F6G3**	**F5G2**	**F4G1**
Block 3	**F1G1**	**F8G2**	**F9G3**

Figure 3: Field layout for IFLP (F1=Farmer 1, F2=Farmer 2.......F9=Farmer 9; G1=Rice genotype 1, G2=Rice Genotype 2, G3=Rice genotype 3)

The scheme manager and staff of the Ghana Irrigation Development Authority in the district were willing to share with the team the production calendar for the season to aid the team in planning the implementation of activities. The capacities of the extension officers would be built to gather relevant data from the individual farmer fields.

7. Field Protocol for demonstrating alternate wetting and drying technology for rice and fodder production

Site Selection and Validation

The sites selected for the establishment of demonstration plots should be areas suitable for the production of rice. The area can be either lowland, lowland irrigated, or irrigated. Soils in selected areas should be clay or clayey loam, to hold moisture for rice-based flooding. In irrigation schemes, a diversity of land should be reflected in the selection to cover a wider area of the scheme. Thus, purposive selection of fields should be conducted. The locations and number of demonstrations to be conducted therein are presented in Table 3.

Table 3: Number of demonstrations to be established in identified communities

Region	District	Communities	No of demonstrations
Northern	Kumbungu	Botanga	9 (IFLP)* 1 (Demo)**
Ashanti	Ahafo Ano South East	Potrikrom	2 (IFLP)
		Adugyama	2 (IFLP)
	Ahafo Ano South West	Bronikrom	1 (Demo)

*IFLP = Individual Farmer Learning Plot, **Demo = Mother demonstration

The mother demonstration plot should be situated in an easy-to-access location. It should be large enough to accommodate two treatments measuring 34 x 22 m each with an alley of 2 m between the two treatments. The selected fields should be sufficiently large to allow for the establishment of a minimum 1 demo plot each with 2 treatments each measuring 10m x 10m, while leaving sufficient land for the farmer to continue with normal cropping activities. The field should be located at the edge of a bigger field to minimize interference in the future management of the IFLP and other portions of the field.

The demonstration site and individual farmer learning Plot selection prior to planting, the sites will be validated by a team from CSIR-Crops Research Institute (CRI) to ensure that selected sites are suitable for the establishment of rice system demonstrations.

Field Characterization

Detailed characterization of all selected plots will be conducted prior to the establishment of the AWD plots. Site-specific information such as GPS coordinates, cropping history, fallow period, etc. should be provided as shown in Table 4.

Table 4: Site-specific information for AWD demonstration plots

Parameter	Information
Site name, GPS coordinates	
Slope (gentle slope, flat land)	
Site cropping history	
Crops grown previous 5 seasons	
Fertilizer use (type and quantity)	
Organic resource use history	
Crop residue use and management	
Fallow period	
Other previous uses/conditions (including animal sheds, manure storage, portion large tree rot on, etc)	
Soil type including texture and general soil condition	
Soil depth	

During site validation and demarcation, soil samples will be obtained using an auger from a 0 – 15 cm, 15-30cm depth from five (5) spots within the demarcated area using a zig-zag pattern. A composite sample of about 500 g shall be collected and pre-processed. The soil samples shall be air-dried in shallow trays in well-ventilated rooms. Tools needed for soil sampling are soil auger, soil samples packaging bags, sample collection basins, marker pens, and sharp devices for scrubbing soil off the soil augers.

Demonstration Plot Treatment and Layout

The AWD demonstrations would have two split-plot treatments: (i)AWD, and (ii) a farmer's practice. In each plot, three improved rice genotypes would form the sub-plots. With the exception of the water scheduling treatment being varied, all other agronomic operations (weeding, pest, and disease control, and harvesting) are the same. The treatments are presented in Table 5.

Table 5: Main and subplots treatment for mother demonstration

Treatments	
Main Plots	Alternate wetting and Drying (AWD) Continuous flooding
Sub Plots (Rice varieties)	CRI-Agra Rice Gbewaa Red Jasmine 85

Land Preparation and Bunding Procedure

- Demarcate an area of 22 m x 34 m for the mother demonstration and 22 m x 10 m for the individual farmer learning plots (IFLPs).
- Pond the demarcated field for 2 days before ploughing to allow for the loosening of the soil and leave good moisture for the land preparation activities.
- Plough and level the demarcated area to eliminate slope in the field. After ploughing and leveling, demarcate within the area, 10 x 10 m plots leaving 2 m between plots as alleys. Bund the demarcated 10 x 10 m plots. The layout for the demonstration and individual farmer learning plots are shown in Figures 4 and 5 respectively.

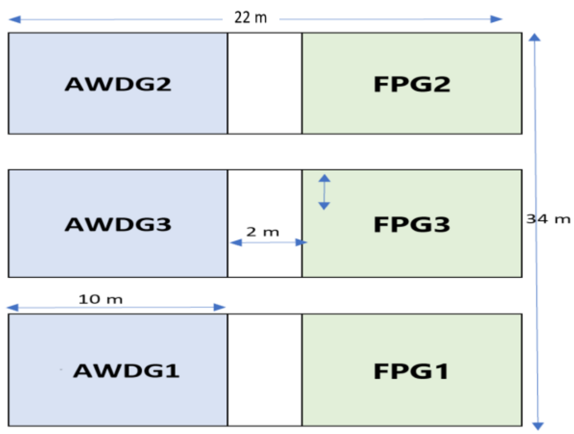
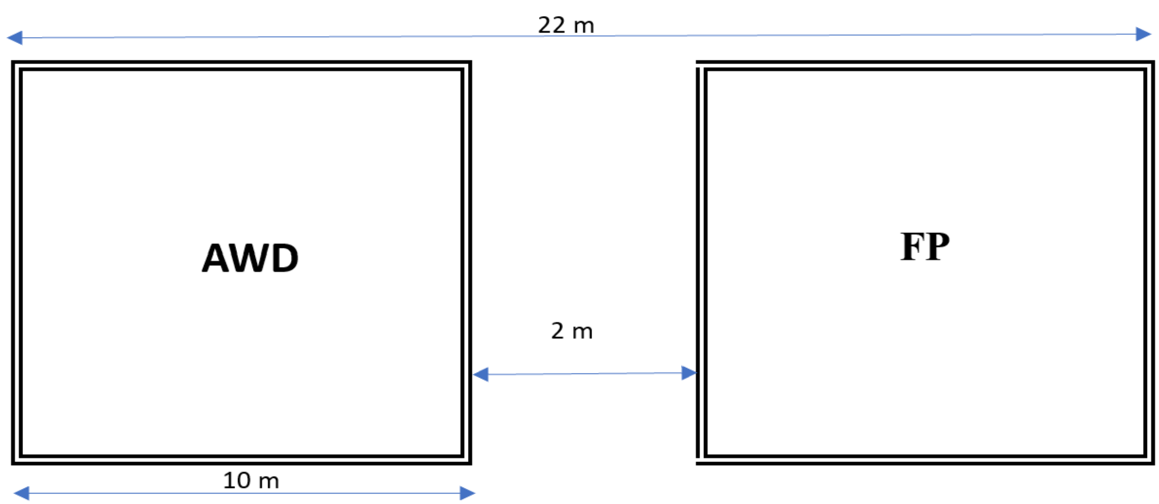


Figure 4: Layout of demonstration plot showing split plot design



FP = Farmer practice   N.B: Figures not drawn to scale

Figure 5: Layout for individual farmer learning plots

Nursery establishment

- Seeds for the mother and baby demonstration would be nursed on well-prepared soil close to the plot to be used.
- All good agronomic practices would be observed to ensure viable seedlings for the demonstration.

Transplanting and field management

- Seedlings should be transplanted after 21 days to the demonstration plots at a planting distance of 20 x 20 cm.
- Ponding should be done to aid with plant establishment. At the next irrigation, the AWD treatments would be imposed.
- Flow meters should be installed on farmers' fields to measure the amount of water used at every irrigation event.
- Records and data should be taken for all irrigation events including the amount of water and date of water application to both the AWD and farmer practice.
- The capacity of farmers should be built to measure water table height in their various demo fields.
- Basal fertilizer application should be done 21 days after transplanting at a rate of 60kgN/ha using NKP fertilizer.
- The second fertilizer application should be done 42 days after transplanting at a rate of 30kgN/ha using Urea.
- All other agronomic practices including pests and disease management should be adhered to.

Labelling of sub-plots

- Immediately after the plot layout, labels should be printed, laminated, and placed in sub-plots during the initial field activities by the research team.
- The labels will help in planting the Rice crop to the randomly assigned sub-plot and assignment of treatments such as varieties and water treatment.
- For each plot, the labels should include:

Plot #:
Rice genotype:
Planting Date:

Figure 6: Field label information

Data collection campaign

- Growth and development measurements: Plant height, no of tillers, etc…
- Physiological measurements: Relative Water Content, Stomatal Conductance, Chlorophyll using SPAD, etc.

- Yield and yield components measurements; Biomass sampling at 30, 60, and 90 days after transplanting, straw yield, final harvest, number of tillers, number of productive tillers, panicle length, etc.
- Soil sampling at transplanting, tillering, and at harvest.
- Straw and grain sampling and analysis.
- A complementary social survey would be conducted during field days (Planting and harvest).

Field days and capacity-building activities

- At transplanting where AWD technology is explained alongside the use of the water table cylinder for monitoring the water level in the soil.
- At tillering where blind preference studies would be conducted for irrigation technology and rice genotype.
- At the final harvest blind preference studies and yield evaluations are conducted.

8. Tailwater recovery for improved resource use in rice production

Site Selection

The selected site should be an irrigation scheme/field that has well-laid out channels for water distribution and in-field drainage. Drainage channels should be well laid to drain excess and unwanted water from the plots. At the Botanga irrigation scheme, mother and baby plots being used for the demonstration under the AWD should be characterized and used. Site-specific information for the distribution of lateral (inlet to the field) and drainage outlet should be taken recorded as shown in Table 6.

Table 6 Site-specific information for tailwater demonstration plots

Parameter	Information
Site name/Number,	
Fertilizer use (type and quantity)	
Insecticide use (type and quantity)	
Weedicide use (Type and quantity)	
Previous crop	

Water sampling

Two water samples should be picked from each identified field at the inlet from the distribution canal supplying the field and outlet to the drainage canal.

Table 7 Water sampling information

Parameter	Information
Site name/Number	
Date and time of sample collection	
Name and contact of the person taking the sample	
GPS coordinates for inlet	
GPS coordinates for outlet	

Water sampling procedure

- Use at least 1.5 litre bottles for the sample collection. Glass bottles are much preferred.
- The bottle should be washed with sample water twice before the sample is finally collected.
- The opening of the sampling bottle should be pointed upstream whilst hands are pointed downstream to avoid contamination when sampling from a body of running water

- Fill the bottle as full as possible to push out oxygen which can promote degradation of the collected sample.
- Take data on pH, EC and temperature of the sample. EC and pH meters should be calibrated prior to data collection.
- Seal samples and store them in an ice chest with ice to maintain a low temperature (<4 °C) and transported them to the laboratory for analysis.
- Following parameters should be analyzed at the laboratory: nitrate and nitrite (Hydrazine reduction method), Potassium (Flame photometric method), Mercury, (Cold vapour atomic absorption spectrophotometry), Potassium, E. coli, and Total coliform.

Storage and Sedimentation Tanks

- Small storage earth reservoirs of capacity 12 m^3 (3 m x 3 m x 2m) should be dug at the edge of the field containing the outlet that leads to the drainage channel.
- Wastewater from the plots would be channeled into the reservoirs for storage and sedimentation.
- Water would be sampled from time to time to test its quality and appropriateness for irrigation.
- Water from other fields on the scheme would be allowed to flow and join the major drainage channels on the scheme.
- This water would also be sampled using procedures as described in section 2.2.1.

Supplementary irrigation

- Upon demand, a siphon should be used to draw water from the storage tanks in section 2.3 to the rice fields for irrigation.
- Part of the water can also be used to water other vegetables grown close by.

9. References

Abdul-Ganiyu, S., Amaanatu M.K. and Korese, J.K. 2012. Water use efficiency and productivity for rice (Oryza Sativa) in the Botanga irrigation scheme of northern region of Ghana. Agricultural Science Research Journal 2(7): 362–368. Available at: http://resjournals.com/ ARJ/Pdf/2012/July/Abdul-Ganiyu%20et%20al.pdf.

Ahafo Ano South-East District Assembly. 2018. District Medium-Term Development Plan (2018 – 2021) Under The Agenda For Jobs (2018 – 2021) Available at

Ahafo Ano South-West District Assembly. 2018. District Medium-Term Development Plan (2018 – 2021) Under The Medium-Term National Development Policy Framework: "An Agenda For Jobs: Creating Prosperity And Equal Opportunity For All (2018 – 2021)". Available at https://ndpc.gov.gh/media/AR_Ahafo_Ano_South-West.pdf.

Armah, M., Aboagye, P.O. (2020). Opportunity to influence and impact policy on Mechanization, and Infrastructure Delivery for Rice Production-Ghana. *Ghana rice mechanization report*. https://agra.org/wp-content/uploads/2020/10/Ghana-Rice-Mechanization-Report.pdf

Chaudhary, A., Venkatramanan, V. and Kumar Mishra, A. 2023. Agronomic and Environmental Determinants of Direct Seeded Rice in South Asia. *Circ.Econ.Sust*. 3, 253–290. https://doi.org/10.1007/s43615-022-00173-x.

Eeswaran R, Nejadhashemi AP, Faye A, Min D, Prasad PVV, Ciampitti IA. Current and Future Challenges and Opportunities for Livestock Farming in West Africa: Perspectives from the Case of Senegal. *Agronomy*. 2022; 12(8):1818. https://doi.org/10.3390/agronomy12081818

Fukagawa, N.K., and L.H. Ziska. 2019. Rice: Importance for Global Nutrition. Journal of Natural Science and Vitaminology (Tokyo) 65(Supplement): S2–S3.

Iseyemi, O., Reba, L.M., Haas, L., Leonard, E. and Farris, J. 2021.Water quality characteristics of tailwater recovery systems associated with agriculture production in the mid-southern US. *Agricultural Water Management*. 249, 106775:(0378-3774) https://doi.org/10.1016/j.agwat.2021.106775.

IDH 2023. Transforming Ghana's Rice Sector: Stepping Up with Inclusive Solutions. Available at https://www.idhsustainabletrade.com/news/transforming-ghanas-rice-sector/

Kumbungu District Assembly. 2020. Annual Progress Report 2020. Available at https://ndpc.gov.gh/media/NR_Kumbungu_APR_2020.pdf.

Ministry of Finance, Ghana (2019). Ahafo Ano South-East District Assembly. https://mofep.gov.gh/sites/default/files/composite-budget/2019/AR/Ahafo-Ano-South-East.pdf.

MOFA. (2020) Rice Production: A priority to Ghana. https://mofa.gov.gh/site/media-centre/agricultural-articles/393-rice-production-a-priority-to-ghana

Muhie, H.S 2022.Novel approaches and practices to sustainable agriculture. *Journal of Agriculture and Food Research*. 10; 100446 (2666-1543). https://doi.org/10.1016/j.jafr.2022.100446.

Nikolaou, G., Neocleous, D., Christou, A., Kitta, E. and Katsoulas, N. 2020. Implementing Sustainable Irrigation in Water-Scarce Regions under the Impact of Climate Change. *Agronomy*. *10*, 1120. https://doi.org/10.3390/agronomy10081120

Omer, A.R., Henderson, J.E., Falconer, L., Kröger, R. and Allen, P.J. 2019.Economic costs of using tailwater recovery systems for maintaining water quality and irrigation. *Journal of Environmental Management*.235,186-193: 0301-4797. https://doi.org/10.1016/j.jenvman.2019.01.038.

Rejesus, R.M., Palis, F.G., Rodriguez, D.G.P., Lampayan, R.M., Bouman, B.A. (2011). Impact of the alternate wetting and drying (AWD) water-saving irrigation technique: evidence from rice producers in Philippines. *Food Policy* 36, 280-288.

Sadick, A., Ansah, I., Badu, A., Nketia, K., Asamoah, E., Asaana, J., Amfo-Otu, R. 2015. Estimation of Potential Evapotranspiration at Botanga Irrigation Scheme in the Northern Region of Ghana. 70. *Environmental Research, Engineering and Management* 10.5755/j01.erem.70.4.7752

INITIATIVE ON
Mixed Farming Systems

cgiar.org/initiative/mixed-farming-systems