Assessment of economic feasibility and farmers' perceptions on wetting front detector (WFD) irrigation scheduling tool for dry season vegetable production in the Upper East Region of Ghana

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The Africa Research In Sustainable Intensification for the Next Generation (Africa RISING) program comprises three research-in-development projects supported by the United States Agency for International Development (USAID) as part of the U.S. Government's Feed the Future initiative.

Through action research and development partnerships, Africa RISING is creating opportunities for smallholder farm households to move out of hunger and poverty through sustainably intensified farming systems that improve food, nutrition, and income security, particularly for women and children, and conserve or enhance the natural resource base.

The three regional projects are led by the International Institute of Tropical Agriculture (in West Africa and East and Southern Africa) and the International Livestock Research Institute (in the Ethiopian Highlands). The International Food Policy Research Institute leads the program's monitoring, evaluation and impact assessment.

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Cover photo: A farmer at Meki, Ethiopia points at a wetting front detector installed on his farm. Photo credit: IWMI/ Apollo Habtamu.

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Introduction

Agriculture contributes about 25% to Ghana's GDP, employs over 56% of the labor force and serves as the major source of livelihood for many rural communities in Ghana (Asamoah, 2018). In the Upper East Region of the country, rain-fed agriculture is predominant. Hence, water is the main determinant factor to increase agricultural production and improve agricultural water management (Lankford et al., 2016; Hussain and Hanjira, 2004).

A first step in agricultural water management is to ensure that the application of the right amount of water at the right time to avoid inefficient and unproductive use of water and energy. Unfortunately, many small-scale farmers do not have the knowledge and/or tools for determining the right amount and the time to apply water. Irrigation scheduling ensures that water is optimally available to the plant if applied according to crop requirements.

However, irrigation also entails increased costs for equipment/tools, labor and energy, optimal water allocation from the biophysical and crop production perspective should coincide with the economics of water productivity (Bjornlund et al., 2017; Balana et al., 2019). A simple decision support tools can guide farmers on when to irrigate and in what amount. Irrigation officers, agronomist, agricultural extension agents and some farmers, with minimal training, can use such devices/tools. Although scheduling tools are in use at some formal irrigation schemes in Ghana, the adaptability of the tools to smallholder single farm units is yet to be proven. International Water Management Institute (IWMI) introduced the wetting front detectors (WFD) during the first phase of Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) program in Ethiopia and Ghana.

The WFD is a funnel-shaped device buried in the soil with an indicator above the soil surface which guides irrigators when to turn the water off during irrigation and could assist farmers to improve their understanding of irrigation (Stirzaker, R. J. (2003). The tool could also be used to monitor nutrient leaching (Stirzaker et al., 2017). Results from Africa RISING phase 1 illustrate the technical feasibility of the WFD. For example, in Ethiopia, the use of the WFD in guiding supplementary irrigation of oats and vetch resulted in a 64 % yield increase (Schmitter et al., 2017). Similarly in Ghana, WFD improved water productivity in pepper and cowpea production (Adimassu et al., 2016b; Adimassu and Appoh, 2018). Moreover, there are limited social studies that have examined the economic feasibility and social acceptability of the WFD technology in the study areas. From the perspective of a smallholder farmer, attributes such as ability/technical knowledge, economic feasibility, compatibility with farmers' current practices and the management of risk are crucial factors for the adoption of mater management technology such as WFD (Stirzaker et al., 2010). Hence, this study was initiated to assess the economic feasibility and farmer perception of the WFD irrigation scheduling tool for dry season vegetable production using field data gathered from three communities in northern Ghana.

Methodology

Study sites

The study was conducted in three communities (Nyangua, Tekuru and Zanlerigu) of the Upper East Region of Ghana where Africa RISING and the Feed the Future (FTF) Innovation Lab for Small Scale Irrigation (ILSSI) projects were implemented. Africa RISING project was implemented in Nyangua and Tekuru while ILSSI project was implemented in Zanlerigu. Farmers in Nyangua and Tekuru grew pepper (Capsicum annuum) whereas farmers in Zanlerigu grew Onion (Allium cepa). The rainfall in the study areas exhibits a unimodal pattern and mainly occurs between May and September/October with a peak in August. The rainfall is highly variable with the average annual rainfall of 950 mm (Adimassu et al., 2016a). Temperature ranges from 23 to 35oC with an average of 29oC. The topography of the area is relatively flat with slope less than 5°. The dominant land cover types in the study areas are open cultivated and savanna woodland (Kadyampakeni et al., 2017).

Data sources and analysis

Economic feasibility

The data used in the economic analysis came from the field records of inputs and outputs data collected by the University of Development Studies (UDS) and IWMI researchers. Inputs and output data for onion production were recorded from 16 farmers' field during 2016 and 2017 at Zaleringu. Similarly, data for pepper production were recorded from 5 farmers' field during 2017 and 2018 growing season at Nyangua and Tekuru. The plot size for each farmer is very small ranging from 25m2 to 174m2. The total land size of the 16 onion farmers was 1480 m2 while that of pepper farmers was 360m2. Though cost-benefit analysis (CBA) was applied in this study, we found that conducting CBA at a level of 25m2 plot size is inappropriate because of measurement and valuation problems for such a small plot. Moreover, farmers often practice sharing of production inputs such as irrigation water, fuel and motor pumps. We cannot disaggregate the quantities and values of these shared inputs to an individual small plot level and undertake any meaningful economic analysis for such very small plots. Hence, the data was extrapolated into a 0.25ha plot size equivalent.

The number of WFD units for pilot farmers (i.e. use of 5 WFD per 0.25 ha) was set based on the maximum garden size farmers grow vegetable in the study area, which was about 500 m2. Therefore, the assumption was that if such a farmer uses 1 WFD per a 500 m2 plot which will be equivalent to 5 WFD units per 0.25 ha.

Cost-benefit Analysis (CBA) was used to assess the economic feasibility of the WFD as an irrigation scheduling tool. CBA is a quantitative analytical tool used to determine the worth of a technology, project, program or policy. It is used in appraising the economic feasibility of available options and making investment decisions. This aids decision-makers in the efficient allocation of resources. The most common decision criteria in CBA are the net present value (NPV), internal rate of return (IRR) and benefit-cost ratio (B/C). NPV is defined as the difference between the monetized sum total of the present value of benefit streams and that of cost streams over the life of the project. Equation 1 presents the mathematical expression of the NPV computation. Projects with positive NPV are accepted while projects with negative NPV are rejected.

$$NPV = \frac{\sum_{t=0}^{T} B_t}{(1+d)^t} - \frac{\sum_{t=0}^{T} C_t}{(1+d)^t} = \sum_{t=0}^{T} [(\mathrm{B_t}\text{-}\mathrm{C_t})\,(1+d)^{-t}]$$

B_t: value of benefit streams in period ‘t’ (i.e., cash flow benefits at each period)
C_t: value of cost streams in period ‘t’ (i.e., cash flow of costs at each period)
d: discount rate
t: time periods (usually in years) (t = 1, 2,… T) where ‘T’ is the life span of the project.

Benefit-Cost Ratio (B/C) is the ratio of the present value of the benefits to the present value of the costs. The decision rule reading B/C is that if the ratio is greater than one, the project is accepted. The IRR is defined as the discount rate at which NPV is zero. The decision criteria are to accept the investment or a given technology if its IRR exceeds the cost of capital i.e., the chosen discount rate). A 3 and 5 year life spans were considered in the analysis for watering-can (onion production) and fuel-powered motorized pumps (pepper production) for water lifting, respectively.

As in most rural areas of the developing world, we encountered difficulties in estimating the cost of family labor involved in the production activities. This is because of the labour market imperfections or absence labour markets. In some localities, seasonal labor markets may exist, in other localities labor market may not exist, and hence the opportunity cost of labour could be zero. Thus, in this study we undertook the cost-benefit analysis under two plausible scenarios: (i) when the opportunity cost of unpaid family labour was accounted for using the local daily wage rate for unskilled labour; and (ii) when the opportunity cost of unpaid family labour was considered to be zero.

Framers perception

Questionnaire-based survey (Annex II) was conducted to understand farmers’ perception on the WFD technology. The respondents were purposively selected from the three communities where the technology was introduced by the project for evaluation purposes. During the evaluation of WFD, there were two categories of farmers: lead and non-lead farmers. Lead framers were those who undertook actual field experiment on their own plots while the non-lead farmers were indirectly involved and frequently visited the lead farmers’ experimental sites. All the lead and non-lead farmers were included in the study. In total, 50 farmers (26 lead and 24 non-lead farmers) were involved in the interview. A field survey was administered using four trained enumerators who were recruited from the study areas. Enumerators were supervised by lead researchers to ensure data quality standard. Descriptive statistics such as frequencies, percentages and means were computed to address the stated objectives.

Results and discussion

Economic feasibility of WFD

CBA of onion production in Zaleringu

Cost-benefit analysis was undertaken under two scenarios: (i) when the opportunity cost of unpaid family labour was accounted for, and (ii) when the opportunity cost of unpaid family labour was considered to be zero. Table 1 summarizes the results for the CBA of onion production using WFD irrigation scheduling under the first scenario. As shown in Table 1, the imputed cost of family labour, including nursery, land preparation, digging shallow wells, weeding/cultivation and irrigation labour; accounted for more than 95% of the total cost for onion production. The results indicate that even when the cost of unpaid family labour is valued and accounted for in the analysis, the use of WFD is still economically feasible - with a NPV of 6549 GHS[1] IRR of 210% and B/C of 3.5 (all results are based using 5 WFD units per 0.25 ha).

Table 1. CBA of Onion production using shallow ground water and watering can (when the cost of unpaid labor is accounted for)

Cost items (per 0.25 ha)	**Years**			
	0	**1**	**2**	**3**
Labour cost for nursery management		667	667	667
Labour cost for land preparation		600	600	600
Labour cost for digging shallow ground water		1250	1250	1250
Labour cost for weeding and cultivation		1320	1320	1320
Labour cost for harvesting		200	200	200
Labour cost for irrigation		1200	1200	1200
Cost of fertilizer		600	600	600
Cost of pesticide		167	167	167
Cost of WFD (5 per 0.25 ha: 20 WFD per ha basis)	-1875	0	0	0
Maintenance of WFD (GHS 50/WFD unit after yr1)		0	250	250
Total annual cost		6004	6254	6254
Total annual crop value (0.25ha)		10154	10154	10154
Net annual cash flow	-1875	4150	3900	3900
Discount factor for each year		0.8333	0.6944	0.578 7
Discounted net annual cash flow		3458	2708	2257

Decision parameters
NPV= 6549 (at a discount rate of 20% based on Bank of Ghana current base rate)
IRR= 210%
B/C Ratio = 3.5
Pay-back-Period=<1 year

[1] GHS= New Ghana cedis (the legal currency in Ghana). 1USD = 5.0 GHS during the writing of this report.

Table 2 depicts the cost-benefit analysis of onion production when family labour was not accounted for. The results (Table 2) show that with an NPV of GHS 17580 GHS per 0.25 ha, (ca. USD 3516/0.25ha), IRR of 496%, and C/B of 9.4, onion production using WFD (5 WFD per 0.25 ha) was economically feasible and generate higher economic returns as as compared to the first scenario (cf. Table 1 and 2).

Table 2. CBA of onion production using shallow ground water and watering cane application (when unpaid labor was not accounted for)

Cost items (per 0.25 ha)	Years			
	0	1	2	3
Cost of fertilizer		600	600	600
Cost of pesticide		167	167	167
Cost of WFD (5 per 0.25 ha: 20 WFD per ha basis)	-1875	0	0	0
Maintenance of WFD (GHS 50/WFD unit after yr1)		0	250	250
Total annual cost		767	1017	1017
Total annual crop value (0.25ha)		10154	10154	10154
Net annual cash flow	-1875	9387	9137	9137
Discount factor for each year		0.8333	0.6944	0.5787
Discounted net annual cash flow		7822	6345	5287

Decision parameters
NPV= 17580, discount rate of 20% based on Bank of Ghana current base rate
IRR= 496%
B/C Ratio = 9.4
Pay-back-Period= <1 year

The major question that both farmers and researchers ask is: 'How many WFD units can potentially be installed per a given plot and yet be economically feasible?' The CBA of this study was conducted based on 5 WFD per 0.25 ha (equivalent to 20 WFDs per ha). The number of WFD units to be installed varies mainly according to the variability of the soil and irrigation systems. Figure 1 depicts the effect of increasing the number of WFD on NPV and IRR for onion production. If unpaid labour cost was included, putting up to 22 WFD units per 0.25 ha (about 90 WFD units per ha) could be economically feasible (Figure 1 A, Figure 1B).

This means that installing WFD beyond 90 units per ha could result in a negative NPV and an IRR value below the chosen discount rate. On the other hand, when zero opportunity cost of labour was considered, installing up to 50 WFD units per 0.25ha (about 200 WFD units per ha) could be economically feasible. This doesn't necessarily mean that 200 WFD can be installed in one ha of onion field. However, this implies that a farmer with plot size of 50-100 m^2 onion garden can install and use a WFD.

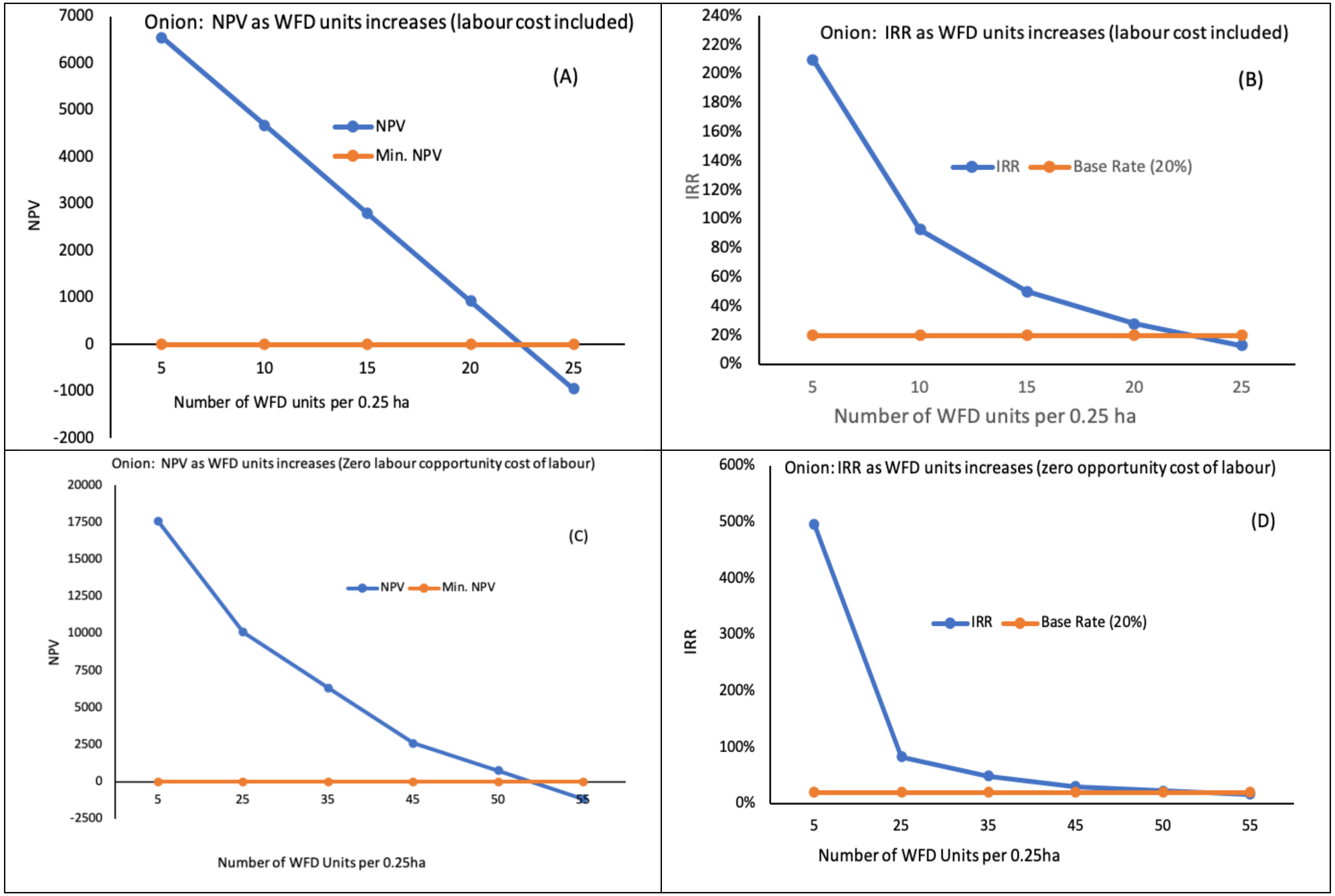

Figure 1. Effects of increase in WFD units per unit area on the NPV and IRR (Onion production in Zanlerigu).

CBA of pepper production in Tekuru and Nyangua

Table 3 depicts the CBA results for pepper production using WFD irrigation scheduling when the opportunity cost of unpaid family labour was accounted for. Like onion production, the majority of the total imputed cost of family labour for pepper production was used for nursery, land preparation, digging shallow wells, weeding/cultivation and irrigation. The results indicate that even when the cost of unpaid family labour is valued and accounted for in the analysis, the use of WFD is still economically feasible - with an NPV of 8387 GHS[2] IRR of 76% and B/C of 1.3 (all results are based using 5 WFD units per 0.25 ha).

Table 4 depicts the cost-benefit analysis of pepper production when family labour was not accounted for. The results (Table 4) show that with an NPV of GHS 19551 GHS per 0.25 ha, IRR of 139%, and C/B of 3.1, pepper production using WFD (5 WFD per 0.25 ha) was economically feasible and generate higher economic returns as compared to the first scenario (cf. Table 3and 4).

[2] GHS= New Ghana cedis (the legal currency in Ghana). 1USD = 5.0 GHS during the writing of this report.

Table 3. CBA of pepper production using deep ground water and motorized pump for water lifting (when the cost of unpaid labor is included)

Cost Items (Cost/0.25ha)	Years					
	0	**1**	**2**	**3**	**4**	**5**
Cost of motor pump (investment cost)	-2000	0	0	0	0	0
Cost of pump maintenance	0	0	100	100	100	100
Cost for the borehole (assumption: 5 years life)	-2500	0	0	0	0	0
Seed cost		350	350	350	350	350
Fuel cost for water lifting		833	833	833	833	833
Labour cost for nursery management		733	733	733	733	733
Labour cost for land preparation		600	600	600	600	600
Labour cost for weeding and cultivation		700	700	700	700	700
Labour cost for harvesting		200	200	200	200	200
Labour cost for irrigation		1500	1500	1500	1500	1500
Cost of fertilizer		500	500	500	500	500
Cost of pesticide		300	300	300	300	300
Cost of WFD (5 per 0.25 ha: 20 WFD per ha basis)	-1875	0	0	0	1875	0
Maintenance of WFD (GHS 50/WFD unit after yr1)		0	250	250	0	250
Total annual cost (0.25ha)		5716	6066	6066	7691	6066
Total annual crop value (0.25ha)		11167	11167	11167	11167	11167
Net annual cash flow	-6375	5451	5101	5101	3476	5101
Discount factor for each year		0.8333	0.6944	0.5787	0.4823	0.4019
Discounted net cash flow		4542	3542	2952	1676	2050

Decision parameters

NPV= 8387, discount rate of 20% based on Bank of Ghana current base rate

IRR= 76%

B/C Ratio = 1.3

Pay-back-Period= < 2 years

Table 4. CBA of pepper production using deep ground water and motorized pump for water lifting (when unpaid labor was not accounted for)

Cost Items (Cost/0.25ha)	Years					
	0	1	2	3	4	5
Cost of motor pump (investment cost)	-2000	0	0	0	0	0
Cost of pump maintenance	0	0	100	100	100	100
Cost for the borehole (assumption: 5 years life)	-2500	0	0	0	0	0
Seed cost		350	350	350	350	350
Fuel cost for water lifting		833	833	833	833	833
Cost of fertilizer		500	500	500	500	500
Cost of pesticide		300	300	300	300	300
Cost of WFD (5 per 2500m2: 20 WFD per ha basis is used). Lifetime of WFD is assumed to be 3 years.	-1875	0	0	0	1875	0
Maintenance of WFD (GHS per unit WFD device after yr1)		0	250	250	0	250
Total annual cost (0.25ha)		1983	2333	2333	3958	2333
Total annual crop value (0.25ha)		11167	11167	11167	11167	11167
Net annual cash flow	-6375	9184	8834	8834	7209	8834
Discount factor for each year		0.8333	0.6944	0.5787	0.4823	0.4019
Discounted net cash flow		7653	6134	5112	3476	3550

Decision parameters

NPV= 19551, discount rate of 20% based on Bank of Ghana current base rate

IRR= 139%

B/C Ratio = 3.1

Pay-back-Period= < 1 year

Figure 2 shows the change in NPV and IRR when number of WFD increases per a given field. For irrigated pepper production (labour cost included), installing more than 17 WFD units per 0.25 ha (≈70 WFD units per ha) could result in a negative NPV and IRR value below the discount rate (Figures 2A and 2B). Similarly, assuming a zero-opportunity cost of labour), installing more than 35 WFD per 0.25ha (≈140 WFD units per ha) for irrigated pepper production could result in a negative NPV and IRR value below the discount rate.

As the imputed cost of labour accounts for a significant portion of production cost for both crops and in all the study areas; it is intuitive to imply that economic returns could be more sensitive to changes in the number of WFD units per unit area when labour cost is included as against a zero-opportunity cost of labour is assumed. As highlighted in the preceding paragraph and depicted in figures 1a and 1c or figures 2a and 2c, the CBA results are sensitive (i.e., in terms of accommodating more WFD units with economic feasibility) when labour costs are included. With labour costs included in pepper production, a maximum of 70 WFD units per ha can be installed with non-negative economic returns; but if a zero-opportunity cost of labour is assumed; one can install up to 140 WFDs units per ha and can still operate without economic loss. This means a farmer with plot size of 70-140 m^2 pepper gardens can install one WFD.

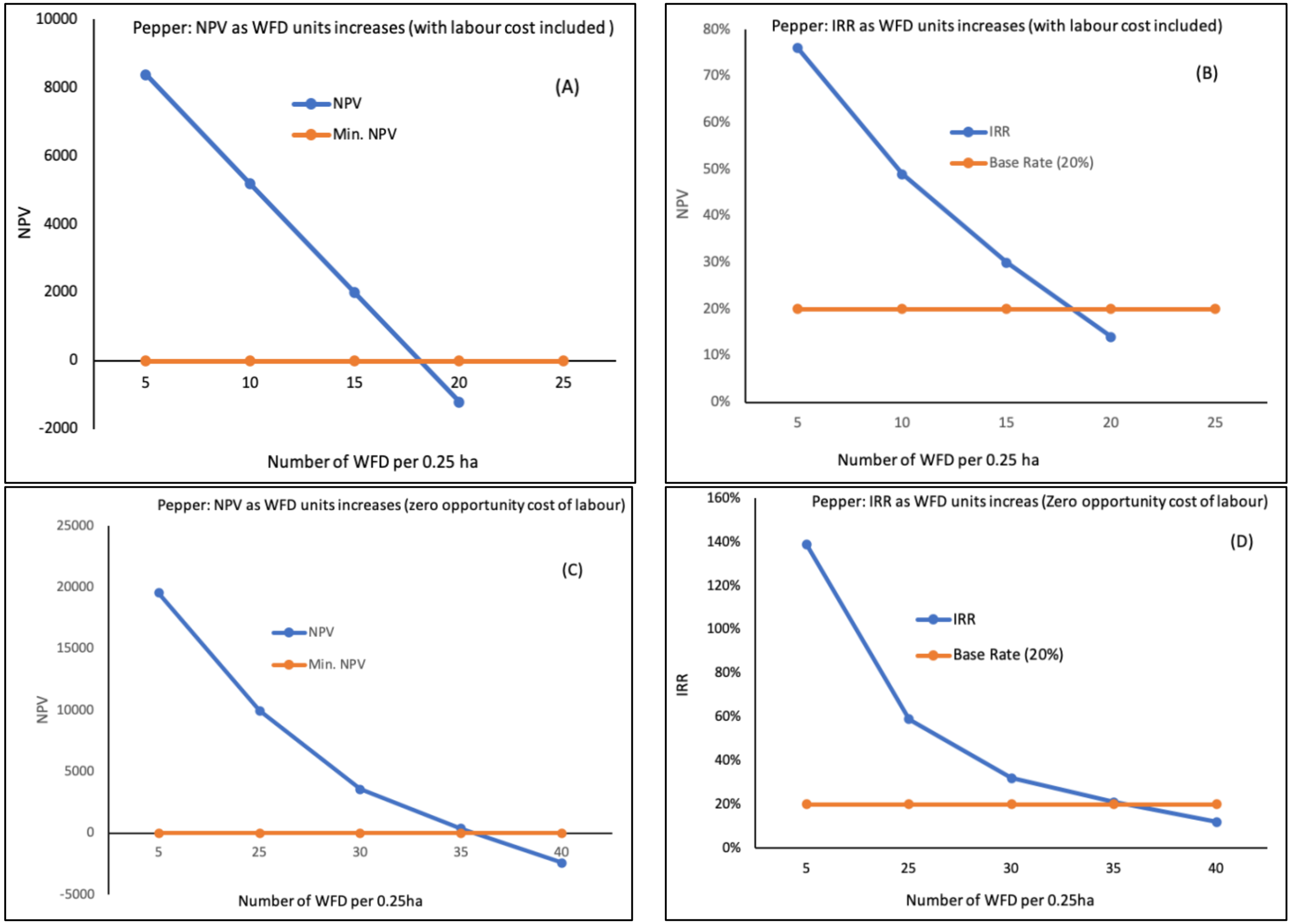

Figure 2. Effects of increase in WFD units per unit area on NPV and IRR (Pepper production in Tekuru and Nyangua)

Farmers' perceptions on the use of WFD

Characteristics of respondents

Table 5 depicts the major characteristics of the respondents. 72% the respondents were male-headed and 28% female-head. The sex composition of respondents varied between farmer categories – among the lead farmers, 92% of the respondents were male headed. The average age of the respondents was 46.8 years with the minimum and maximum age of 27 and 82 years, respectively. The average household size for the respondents was 6.9 with minimum and maximum values of 1 and 15, respectively. The educational status of the respondents showed that only 40% of the respondents attended education.

Table 5. Major characteristics of the respondents

Characteristics of respondents	Lead- farmers	Non-lead farmers	Total
Sex (%)			
Male	53.8	91.7	72.0
Female	46.2	8.3	28
Marital status (%)			
Married	73.1	79.2	76
Single	7.7	16.7	12.0
Divorced	19.2	4.2	12.0
Education status (%)			
Not schooled	76.9	41.7	60.0
Primary	7.7	16.7	12.0
Junior high	7.7	16.7	12.0
Secondary	7.7	20.8	14.0
Tertiary	0.0	4.2	2.0
Age (yrs)			
Mean	50.96	42.21	46.76
Minimum	27.0	20.0	20
Maximum	82.0	67.0	82
Household size			
Mean	7.23	6.38	6.9
Minimum	1	1	1
Maximum	15	13	15
Sample size	26	24	50

Constraints in relation to small scale irrigation

Both lead-and non-lead farmers were asked to identify major constraints they experienced for the expansion of irrigation agriculture. According to farmers, there is a growing interest to expand irrigation agriculture in the study areas. However, farmers are affected by several constraints in relation to irrigation agriculture (Table 6). On average, the majority of the respondents (80%) perceived that water shortage is the main constraint hindering irrigation agriculture in the area. Of the lead farmers, 85% perceived water shortage as the main constraint of irrigation.

The highest cost of agricultural inputs such as fertilizer and fuel was also perceived as the second important constraint (Table 6) for the expansion of irrigation agriculture. Accordingly, 34% of the respondents (38.5% lead farmers and 29.2% non-lead farmers) mentioned that the high cost of farm inputs and free grazing (damage by livestock) were major problems in relation to irrigation. Similarly, 28% of the respondents mentioned free grazing (damage by livestock) as major constraints that affect irrigation agriculture. As shown in Table 6, only a few respondents considered labour and land shortages as constraints of irrigation agriculture.

Table 6. Major constraints in relation to irrigated agriculture in the study areas (% of respondents)

Major constraints	Lead-farmers	Non-lead farmers	All farmers
Water shortage	84.6	75.0	80.0
High cost of farm inputs such as fertilizer, pesticide, fuel	38.5	29.2	34.0
Damage by livestock/free grazing	30.8	25.0	28.0
Lack of knowledge how much to irrigate	26.9	8.3	18.0
Lack of knowledge when to irrigate	3.8	16.7	10.0
Lack of finance to purchase inputs and water lifting pumps	26.9	0.0	14.0
Lack of market for vegetable product	7.7	8.3	8.0
Land shortage	3.8	8.3	6.0
Labour shortage	0	8.3	4
N	26	24	50

Farmers' views on the urgency of water saving and irrigation scheduling

To understand the perception of farmers on irrigation water, they were asked whether water saving is urgent in the study areas or not. In total, more than half of the respondents (52%) claimed that water saving was urgent/very urgent. The perception varied among farmer categories, of which 65% were lead farmers and 37% were non-lead farmers (Table 7). Farmers were also asked how often they undertook the common irrigation scheduling before the introduction of the WFD. Almost half of the respondents in both farmer categories irrigated their plots randomly, mainly based on water availability and crop need. As shown in the Table, the other half of the respondents irrigated at fixed irrigation intervals: every day (20%), every two days (14%) and every three days (10%).

Table 7. Farmer's opinion regarding the urgency of water saving for irrigation in the study areas (% of respondents)

Questions and responses	Lead-farmers	Non-lead farmers	Total
How is the urgency of water saving?			
Very urgent	30.8	4.2	18.0
Urgent	34.6	33.3	34.0
Slightly urgent	26.9	41.7	34.0
Not urgent	7.7	20.8	14.0
How often you undertook irrigation scheduling			
Random/as required/	50.0	58.3	54.0
Fixed-two times a day	3.8	0.0	2.0
Fixed-once a day	19.2	20.8	20.0
Fixed-every two days	19.2	8.3	14.0
Fixed-every three days	7.7	12.5	10.0
N	26	24	50

Farmers' awareness and motivation on WFD

Table 8 depicts the farmers' awareness and motivation on WFD. In total, more than half (56%) of the respondents were aware of the WFD through the project team working in the study areas. Of the total respondents, 24% (all lead-farmers) got the information about the WFD via extension officers (MoFA). The result also showed that non-lead farmers heard about the tool from lead farmers and other non-lead farmers (Table 8). Respondents were asked 'why they got motivated to participate in the experimentation / demonstration of the WFD'. The main motivation to get involved in the experiment was to learn how the WFD works, particularly among the lead farmers who did the actual field experiment on their plots. Of the respondents, 18% of them were motivated because they wanted to help and collaborate with the project team. Only a few respondents (6%) claimed that the motivation to get involved in the experimentation/demonstration was their desire to save water using the tool.

Table 8. Framers awareness about the WFD (% of respondents)

Questions and responses	Lead-farmers	Non-lead farmers	Total
Who/what was the source of information for the WFD?			
Project team (IWMI, UDS, WorldVeg, IITA)	53.8	58.3	56.0
Extension officers (MoFA)	46.2	0.0	24.0
Lead-farmer	0.0	25.0	12.0
Non-lead farmer	0.0	16.7	8.0
Why did you show interest for WFD trial/participation?			
To learn how WFD works	80.8	70.8	76.0
To save water	3.8	8.3	6.0
To help the project team	15.4	20.8	18.0
N	26	24	50

Relative advantage of WFD over farmers' practices

Table 9 shows farmers' views on the relative advantage of the WFD. Relative advantage is the degree to which the farmers perceived the WFD to be better over their current irrigation scheduling practices. The result indicated that the majority of farmers (60%) cited that the WFD as an irrigation-scheduling tool had a relative advantage over their traditional practices. However, one third of the respondents and 50% of the non-lead farmers were unsure about the relative advantage of the WFD. Fewer farmers (6%) perceived that WFD had no relative advantage over their traditional practices. A study in South Africa showed similar results that more than 80% of the respondents felt that WFD had a relative advantage (Stirzaker et al., 2010).

As shown in Table 9, water saving, labour saving, fuel saving and yield increase were cited as the main relative advantages of the WFD. Accordingly, 69% of the lead farmers and 46% of the non-lead farmers perceived that water saving was one of the main advantages of the WFD. Half of the lead farmers and 12.5% of the non-lead farmers claimed that fuel saving was the relative advantage of the WFD.

Respondents were asked 'for what purpose does the water saved due to the use of the WFD can be used?'. According to the farmers, the water saved due to WFD can be used for expanding irrigation farming and improve water for drinking and domestic purposes. The response varied among farmer categories, of which 61.5% of lead farmers and 37.5% non-lead farmers claimed that the water saved due to the use of WFD could be used for expanding irrigation.

Table 9. Relative advantage of WFD over farmers' practices (% of respondents)

Questions and responses	Lead-farmer	Non-lead farmer	Total
Does WFD have an advantage over farmers 'practices?			
Yes	73.1	45.8	60.0
No	7.7	4.2	6.0
I don't know/not decide/	19.2	50.0	34.0
What are the relative advantages?			
Water saving	69.2	45.8	58.0
Labour saving	26.9	8.3	18.0
Fuel saving	50.0	12.5	32.0
Yield increase	19.2	0.0	10.0
Does water saved can be used for other purposes?			
Yes	61.5	37.5	50
No	0.0	0.0	0.0
I do not know/not sure	7.7	8.3	8.0
For what purpose does the saved water can be used?			
Expand irrigation farming	61.5	37.5	50.0
More water for livestock drinking	12.5	13.3	12.8
More water for domestic use	4.2	0.0	2.6
N	26	24	50

Perceived risks associated with WFD

In order to understand the perception of farmers on WFD, they were asked to give their opinion regarding any risk associated with the use of WFD. More than 50% of the respondents perceived no additional risk in using the WFD (Table 10). However, one third of the respondents (34.7%) were not sure about any risk associated with WFD. Only few farmers (8%) were doubtful that using WFD is risky. Main risks mentioned include the tool may not work properly and it may be damaged by strong wind and livestock.

Table 10. Perception of respondents regarding risks of using WFD (% of respondents)

Questions and responses	Lead farmers	Non-lead farmers	Total
Is there any risk associated with WFD to use it in the field?			
Yes	7.7	8.3	8.0
No	69.2	43.5	57.1
I do not know	23.1	47.8	34.7
What are perceived risks associated with the use of the WFD?			

It may not work properly	0	8.3	4.0
Strong wind may destroy it	3.8	0	2.0
Animals may damage it if it is not fenced properly	3.8	0	2.0
N	26	24	50

Easiness, compatibility and adoption of WFD

To understand the perception of farmers on the easiness and compatibility of using the WFD as an irrigation-scheduling tool, respondents were asked two questions (Table 11). As shown in the Table, 56% of the respondents think that WFD is easy to use as a scheduling tool. However, 40% of the respondents claimed that using WFD is difficult, mainly during assembling and installation of the device. Similarly, 56% of the respondents reported that WFD is compatible/highly compatible to use in the study areas (Table 11).

Table 11. Perception of respondents on easiness and compatibility of using WFD (% of respondents)

Questions and responses	Lead farmers	Non-lead farmers	Total
How easy is to use WFD?			
Very easy	50.0	8.3	30.0
Easy	19.2	33.3	26.0
Difficult	15.4	25.0	20
Very difficult	11.5	29.2	20
I don't know	3.8	4.2	4
Is the WFD Compatibility to be used?			
Highly compatible	38.5	12.5	26.0
compatible	34.6	25	30.0
slightly compatible	15.4	41.7	28.0
Not compatible	11.5	20.8	16.0
N	26	24	50

Farmers interest in the use and adoption of the WFD technology

Farmers were asked about their interest to continue to use WFD in the future and whether they would be interested in to buy the device. Table 12 presents farmers' perception on the adoption (continuous use) of WFD and their interest to by the tool. The result showed that, on average, majority of the farmers (95.7%) expressed their interest to use the tool in the future. Similarly, majority of them (86%) were interested in to buy the WFD and use it in future. As shown in the table, 44% of the respondents were interested in to buy the tool and offered a bid from 1-10 GHS per WFD. Only 16% of the respondents were interested in to buy the tool for 50-100 GHS which is still below the market price of the device. Although farmers were interested in to buy WFD, their price quote is much lower than the market price of the tool.

Table 12. Perception of respondents to adopt and willingness to buy WFD tool (%)

Questions and responses	Lead-farmers	Non-lead farmers	Total
Would you interested to use the tool in the future?			
Yes	96.2	95.0	95.7
No	3.8	5.0	4.3
Are you interested to buy the WFD?			
Willing	96.2	75.0	86.0
Unwilling	3.8	25.0	14.0
If you are interested, what is the maximum amount you would like to pay for a WFD unit?			
1-10 GHS/WFD	30.8	58.3	44.0
15-20 GHS/WFD	23.1	12.5	18.0
30-40 GHS/WFD	11.5	4.2	8.0
50-100 GHS/WFD	30.8	0.0	16.0
N	26	24	50

Limitation of the study

Ideally, the study should have included a comprehensive assessment of the willingness to pay (WTP) for the WFD tool among the smallholders in the area. However, due to a small sample size and insufficient quantitative data set, we were not able to apply standard econometric tools to estimate the WTP. Essentially, estimation of willingness to pay (WTP) presupposes a data generation process carefully designed and based on behavioral theoretical economics. WTP is not a simple summary statistics based on data from few individuals. Thus, the results reported here can’t be considered as WTP values for the population; rather the results are snapshot observations of few individuals and their perceived expressions to buy the WFD tool. This is the major shortcoming of the study.

Conclusion

This report provides the examples of economic feasibility assessment of wetting front detector as an irrigation scheduling tool and farmers' perceptions on the use of the device in the Upper East Region of Ghana. The use of WFD as the irrigation scheduling tool is economically feasible for smallholder farmers to grow onion and pepper in the study areas. The majority of the smallholder farmers reported a positive perception towards the use of WFD as a scheduling tool. Accordingly, farmers perceived the WFD as a low-risk and compatible to use. The result suggests that the majority of the farmers are interested in to adopt and buy the tool. Although farmers expressed their interest to buy the tool, their quote price (an average of about GHS 100 per WFD) is much lower than the market price of the tool. Nevertheless, the study didn't include full-fledge willingness to pay due to lack of sufficient sample households (beneficiaries) and inadequate quantitative data for estimating WTP parameters using econometric tools. Therefore, we suggest further research to understand the true WTP of farmers for the WFD using large sample size, large data set and rigorous estimation method.

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Appendices

Appendix I. Cost of production of onion and pepper production the Upper East Region of Ghana

Activities/inputs	**Onion production in Zaleringu**	**Pepper production in Tukuru and Nyangua**
Nursery	Onion was nursed in September. On average, nursery takes 5 weeks before transplanting. Family labour was used to undertake nursery activity and no hired labour was involved. In total, 10 days were required to manage the nursery which covers 300m^2 plot. This costs 667 GHS for 2500 m^2 plot if hired labour is used.	Pepper was nursed at the beginning of October and takes 6 weeks before transplanting. Family labour was used to undertake nursery activity and no hired labour was involved. In total, 11 days were required to manage the nursery which covers 300m^2 plot. This costs 733 GHS for 2500 m^2 if hired labored is used.
Seed	Farmers used their own local seed for onion production in Zaleringu and they said it is insignificant in monetary terms.	Farmers purchased pepper seed which costs 42 GHS to prepare seedlings for 300 m^2. 350 GHS was required to purchase pepper seed for 2500m^2 plot.
Land preparation	Land clearing, ploughing and bed preparation for onion production was done in October using family labour. It can cost 72 GHS (9 days) for 300 m2 if hired labour is used. This costs 600 GHS for 2500 m^2 plot if hired labour is used.	Land clearing, ploughing and bed preparation for pepper production was done in October using family labour. It can cost 72 GHS (9 days) for 300 m2 if hired labour is used. This costs 600 GHS for 2500 m^2 plot if hired labour is used.
Digging wells	Farmers use shallow ground water and dig every year using family labour. If hired labour is used 150GHS per 300m2 plot is required, which is equivalent to 1250 GHS per year for 2500 m^2.	Farmers use existing wells relatively permanent well of deeper ground water with a cost of 300GHS per farmer (300m^2). It costs 2500 GHS for 2500 m$^{2.}$
Weeding and cultivation	Farmers weed/cultivate using family labour and labour sharing. Six persons were required to weed/cultivate 300 m2 for each weeding. In total, 158GHS per 300m^2 can be used throughout the growing period. It was estimated that 1320 GHS per 2500m2 for weeding and cultivation.	Farmers weed/cultivate using family labour and labour sharing. In total, 84GHS per 300m^2 can be used throughout the growing period. It was estimated that 700 GHS per 2500m2 for weeding and cultivation.
Irrigation	-Watering cane was used for water lifting and application in Zaleringu. Family members were involved in irrigation.	Motor pump was used for lifting water and Pump cost-provided by the project. One pump costs 4000 GHS (one pump for 0.5ha). Capital cost of 2000 GHS was assumed for 0.25 ha. A maintenance cost of 100GHS per year after year 1 was assumed. Farmers use watering cane for irrigation water application.

	-Labour: Family labour, no hired labour involved. -Irrigation frequency – Once a day throughout the growing period for 90 days. Which costed 1200GHS/0.25ha to grow onion.	-Labour: Family labour, no hired labour involved. -Irrigation frequency – Once a day throughout the growing period for 120 days. Which costed 1500GHS/0.25ha to grow onion.
	Fuel cost: No fuel cost was involved for onion production as farmers used watering cane for water lifting and application.	-Fuel cost: on average, one pumping machine per lead farmer 10 gallon per month to irrigate 0.25 ha for 4 months was recorded. This is equivalent to 833 GHS/0.25 ha.
Fertilizer	NPK fertilizers were used to grow onion and it costed 600GHS per 0.25 ha	NPK and Fortifier fertilizers were used to grow pepper. It costed 500 GHS per 0.25 per ha
Pesticides	300 GHS per 0.25 ha was used	167GHS/0.25ha was used
Harvesting	Harvesting is usually done early February. Farmers grow onion variety with a maturity period of 3 months. It took three person (24 GHS) to harvest 300m^2 which costs 200 GHS to harvest onion from o.25ha	Harvesting is done in March and April. Farmers grow onion variety with a maturity period of 3 months. It takes three person (24 GHS) to harvest 300m^2 which costs 200 GHS to harvest pepper from 0.25ha.
WFD	On average 1 WFD was installed for 500m^2 and two WFDs cost ed150 USD (750 GHS). Annual cost of 10 USD (50 GHS) can be used as a maintenance cost particularly for indicator cap, foam float and filter sand after year 1.	Similar assumption was used to grow pepper
Yield	The average yield of onion bulb was about 16.24 ton/ha. This is equivalent 4061 kg per 2500 m^2.	The average yield of pepper was 5.585 t/ha which is equivalent to 1400 kg per 2500 m^2.
Price	The price of onion bulb ranged from 1.5-3.5 GHS/kg with an average value of 2.5 GHS/kg	The price of pepper fruit ranged from 6-10 GHS/kg with an average price of 8 GHS/kg.

Appendix II. Semi-structured questionnaire to assess farmers' perceptions on the wetting front detector in the upper east region of Ghana

International Water Management Institute, Ghana
Semi-structured questionnaire for Africa RISING (AR) Project, January 2019

This data collection instrument is designed to gather socio-economic data to assess the economic feasibility and farmers' views/preferences on the wetting front detector (WFD) irrigation scheduling tool for dry season vegetable production system in selected communities in northern Ghana. The WFD technology was introduced by ILSSI and AR project as an irrigation scheduling tool, i.e., guide farmers on the 'right time' to irrigate and 'right amount' of water to apply. However, the economic feasibility, willingness to pay (WTP), and compatibility/acceptability of the technology from the perspective of smallholder farmers were not investigated. Thus, the purpose of this study is to investigate the economic feasibility, farmer's preferences & WTP for the wetting front detectors technology. The data will be handled confidentially and be used only for the research purpose. Research is expected to produce decision support evidence for irrigation technology adoption and improve livelihoods.

Community/village___________________________________

Date of interview: _______/________/________ (DD/mm/yyyy)

Enumerator's Name: __________________________________

1. Background Information

1.1 Name of Respondent	1.2 Sex 1 = Male 2= Female	1.3 Marital Status 1 = Single 2=Married 3= Others (specify)	1.4 Age (years)	1.5 Highest level of education completed (Code - a)	1.6 Household size including head	
					Children (age < 15 years	Adults ≥ 15 years

Code (a) level of education
[0] =Not schooled; [1] = Primary; [2] = Junior high; [3] Secondary; [4] =Tertiary; [5] =Others (Specify) ----------

1.7 How many years of experience you have in irrigation agriculture?
___________________________ (years)

1.8 What is your (household's) main livelihood activity? [If main activity (more than one); choose the top two]

[1] Irrigated agriculture [2] Rain-fed agriculture
[3] Livestock rearing [4] Mixed crop-livestock system
[5] Business/trade [6] employee (public/private sector)
[8] Pensioner [9] Other (Specify) _____________

1.9 Do you own irrigable land? [0] =No [1] = Yes
1.10 If 'Yes' to (Q1.9) above, what is the size of irrigable land you own? _____________ (hectares).
1.11 If 'No' to (Q1.9 above, how do you access irrigable land?
[0] I don't have access [1] Rent-in [2] family/kinship [3] Communal land [4] Others (specify) ___________________________

2.Farmers' perceptions of irrigation scheduling tool (WFD)

2.1 In your view, what is (are) the major constraints in relation to irrigated agriculture?

[Top three in order of priority]
[1] Water shortage: ___ [2] land shortage: ____ [3] lack of knowledge when to irrigate: _____
[4] lack of knowledge on how much to irrigate: ____ [5] Others (Specify)________________

2.2 Do you have any prior information about WFD or any other irrigation scheduling technology before its introduction by the project? [0] No [1] Yes

2.3 Who/what was the source of information for the WFD?
[1] Project team (IWMI and UDS) [2] Extension agent (MoFA) [3] Lead farmers [4] NGO
[5] Others

2.4 Why did you show interest for WFD trial in your field?
[1] To learn/understand how WFD works [2] To save water [3] To help project team test WFD
[4] I didn't have interest to test WFD [5] Others __________________________

2.5 How often did you undertake the common irrigation scheduling practice before the introduction of WFD?
[1] Randomly (as required) [2] Fixed numbers of times (every _________days)

2.6 In your view, does the irrigation scheduling tool (WFD) have advantage over your usual practice?
[0] No [1] Yes [2] I don't know

2.7 If Yes to Q2.6, what are the major advantage(s) of WFD? (The top three).
[1] Water saving [2] Labour saving [3] Yield increase [4] Fuel saving [5] I don't know

2.8 If your answer to Q2.7 is 'Water saving', do you think the 'water saved' can be used for other purposes?
[0] No [1] Yes [2] I don't know

2.9 If Yes to Q2.8, for what purpose could you use the 'water saved'?
[1] Expand irrigated farming [2] more water for livestock drinking [3] more water for domestic use
[4] I don't know [5] Others _____________________________

2.10 In your view, how easy is it to use WFD?
[1]Very easy [2] Easy [3] Difficult [4] Very difficult
2.11 In your view, is there any risk associated to the use WFD for irrigation scheduling compared to the current practice? [0] No [1]Yes [2] I don't know
2.12 If Yes to Q2.11 above, what are the risks associated to the use of WFD?______________________________

2.13 In your view, is the use WFD compatible with or acceptable for you compared to the irrigated-farming you commonly currently?
[1] Not compatible [2] Slightly compatible [3] Compatible [4] highly compatible

2.14 In your view (in a 4-point scale), how urgent is the need to make more effort to save/use irrigation water efficiently?
[1] Not Urgent [2] Slightly Urgent [3] Urgent [4] Very Urgent

3. Assessment of 'Willingness to buy the wetting front detector (WFD)

Background

The aim of this section is to assess the smallholder farmers'/irrigators' willingness to buy the irrigation scheduling technology (WFD). Adopting irrigation scheduling WFD technology could improve irrigation efficiency and water saving. As a SSI irrigator, you will be the beneficiary from increased irrigation efficiency if you adopt a WFD technology. You are requested to provide, as much as possible, accurate and true response whether you are interested in and willingness to pay for WFD.

Willingness to buy question

You have been introduced the WFD tool for irrigation scheduling in the project. We suppose that you gained sufficient knowledge on the advantages/benefits and possible drawbacks of the use of WFD. Here, we are asking you to understand whether you are interested in to continue using the WFD technology and buy the tool.

1. Would you be interested in to adopt the WFD technology in irrigated farming? [1]= Yes [2]= No

2. If 'Yes' to Q.1, would you be willing to pay to cover the cost of WFD? [1]= Yes 2]= No
3. If 'Yes' to Q.2, what is the maximum amount you are willingness to pay per WFD device? __________ (GHS)
4. If, 'No', why are not willing to pay for the WFD technology?

a. ____
b. ____
c. ____