Study and analysis of Irrigation furrow measurement, Flow rate Soil moisture distribution and Gross depth at Melka Hida small scale irrigation scheme

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Abstract

Techniques of furrow preparation on a field are mostly traditional; farmers provide furrow shape and direction based on their experience without the concept of scientific information. The measurement, evaluation and optimization of furrow irrigation are restricted to the single furrow or small number of adjacent furrows. The measurement process is too intensive to be applied at the full field scale. Consequently; it is necessary to assume that the infiltration characteristics and inflow rates of the measured furrow(s) represent the remainder of the field. The field inflow and outflow rates of five irrigation events in experimental plots were planned. The gross applied and estimated depth of irrigation was determined for a scheme based on the available data of inflow rate, which was measured through the graduated bucket and CROPWAT 8 model, respectively. Soil specific calibration was made for the soil moisture reading and its error result is presented. Furrow parameters including; furrow slope, width, length, and shape were measured and presented. The results of soil moisture measurements showed that crops are water stressed during the experiment period. Application efficiency decreases with increasing steep slope and cutoff time, large applied depth, and high inflow rate in the study area. The Melka Hida small scale irrigation scheme was granted to farmers and empowered them occasionally to harvest twice in a year. With increased population growth and the erratic rainfall, competition of water users in this area is reported increasing from time to time. This limits water usage, crop production and overall living standard of farmers of this region.

Keywords: - Irrigation, Furrow measurement, Soil moisture, Gross depth, Flow measurement, Water management.

Introduction

Ethiopia has an irrigation potential of 5.3 million ha of which 3.7 million hectares can be developed using surface water sources, and 1.6 million ha using groundwater and rainwater. Water is the most important resource for the plant, since; it is a basic need for seedling plantation to the growth phase of the overall life cycle of crops. With the increased population of this country, limited water resources and the erratic nature of rainfall increased the competition from time to time. Irrigation is the oldest and most common method of applying water to these crops. It encompasses moving water over the soil in order to wet it completely or partially. The water flows over or ponds on the soil surface and gradually infiltrates to the desired depth. The source of water can be surface water or groundwater. Also; water can be abstracted from a river, lake, reservoir, borehole, well, spring, etc. The Irrigation efficiency refers to the amount of water removed from the water source that is used by the crop for the entire healthy growth. It depends on the geometry of furrow, soil moisture distribution, Flow rate, and gross depth of water stored in the root zone of a plant. This value is determined by irrigation system management, water distribution characteristics, crop water use rates, and weather and soil conditions. Irrigation efficiency pertains to the use of water for an entire growing season.

Irrigation development has been identified as an important tool to stimulate economic growth and the rural development; is considered as a cornerstone of food security and poverty reduction

in Ethiopia (Hagos *et al*., 2009). Efforts are being made to involve farmers progressively in various aspects of management of the small-scale irrigation system, starting from planning, implementation and management aspects, particularly, in water distribution, operation and maintenance to improve the performance of irrigated agriculture (Muleta, 2013). The furlong (meaning furrow length) is the distance a team of oxen could plough without resting. This is standardized to be exactly 40 rods or 10 chains. The furrow irrigation is suitable for a wide range of soil type, crop and land slope. Furrow irrigation is suitable for many crops, especially row crops, crops that would be damaged; if water covered their stem or crown should be irrigated by furrows. Furrow irrigation is also suited to the growing of tree crops. In the early stages of tree planting, one furrow alongside the tree row may be sufficient but as the trees develop then two or more furrows can be constructed to provide sufficient water.

Irrigation scheduling refers to the development of schedule for the application or distribution

of seasonal or total irrigation water requirement during the growing period of a given crop (FAO, 2002). It means that irrigation scheduling indicates how much irrigation water has to be given to the crop and how often or when this water is given. If the irrigation schedule is properly managed and applied there will be better crop production and water application efficiency. According to MoA (2011) the interval between irrigation should be as wide as possible to save irrigation water, without adversely affecting the crop growth and yield. Scheduling of irrigation is to minimize the losses of irrigation water, due to an evaporation, leaching, seepage etc, and to maximize the efficient use of available water resources.

Basem (2012) studied the efficiency of the application of furrow irrigation. He considered field parameters like, soil infiltration characteristics, flow resistance, required depth, soil moisture depletion, field slope, furrow spacing geometry and decision variables like, field dimensions, flow rate, cutoff time and cutback ratio in his study. Average irrigation efficiencies in the study area are found to vary between 31 and 52 %. Difference in efficiency was found to be directly related to farm design and specific management practices. The application efficiency was found to increase with decreasing cut-off time, 30 % and 43 % of the applied water would have been saved in field 1 and field 2 respectively.When surface irrigation methods are used, it is not found very practical to vary the irrigation depth and frequency too much. Within particular surface irrigation, variations in irrigation depth are only possible within limits. It is also very confusing for the farmers to change the schedule all time. Therefore, it is often sufficient to estimate or roughly calculate the irrigation schedule and to fix the most suitable depth and interval; in other words, to keep the irrigation depth and the interval constant over the growing season. Three simple methods to determine the irrigation schedule briefly elaborated are: plant observation method, estimation method and simple calculation method. According to FAO (2011) globally 60 % of the diverted fresh water for agriculture does not contribute directly to the food production. This amount of water is lost because of poor water control, inefficient irrigation systems with leaky conveyance and distribution, poor on-farm water management and application practices. It depicts that only about 40 % of global fresh water abstracted for irrigation is being effectively used for the consumptive use in agriculture. Part of the amount of the discharged water of these systems is lost to saline groundwater. According to Bekele and Beshir (2006) Ethiopia’s irrigation efficiencies are generally low, of the order of 25 to 50 %, and problems with rising water tables and soil salinization are now emerging. Chambouleyron *et al.* (1992) stress the importance of measuring irrigation application efficiency as a performance parameter in irrigation water, used to minimize wastage of water resources. Irrigation development constitutes a major requirement and benefits for the agricultural development and food security strategies. Unlikely to its advantage, irrigation schemes have the potential to degrade land, soil and other valuable water resources; if they are mismanaged. In recognition of both the benefit and hazards assessment and evaluation of irrigation schemes efficiency has now become a paramount importance not only to point out where the problem lies, but also helps to identify alternatives that may be both effective and feasible in improving system efficiency (Abebe, 2015). Abdelmoneim *et al* (2019) conducted a study to determine the soil moisture content down the profile and along the furrow run to evaluate the furrow irrigation The various techniques are applied on free end furrows and dike end furrows. The results indicated that irrigation techniques, soil depths, locations along the furrow and their interactions were found to have highly significant effects on soil moisture content on a depth basis at ($P \leq 0.01$). Whereas, the interaction of soil depth and furrow end conditions had no significant effects on soil moisture content. Surge technique resulted in significantly high moisture content at the two furrow end conditions, followed by bund, cut-back and cut-off technique. The results also showed that the highest application efficiency of 60.29 % was obtained with surge irrigation technique with dyked furrow end (at $P \leq 0.05$) and the lowest application efficiency of 29.21 % was obtained by cut-off irrigation technique with free end furrow. Surge technique resulted with highest value in all tested efficiencies within the dyked end and free end furrows compared to all other combinations. Saeed, *et al* (2019) measured the moisture content of the soil at three periods (before crop sowing, at mid-season and after harvest) and at four depths (0-15, 15-30, 30-60 and 60-90 cm). The results of this study showed that the soil and plant parameters were significantly influenced by the water harvesting techniques during both growing seasons through improving the structure, infiltrability and water storage capacity of the soil over control. Duba and Kolhe (2021) has conducted the experimental analysis of soil texture, furrow geometry and infiltration rate; performance showed variation based on plot and irrigation event variation in the system. Water application efficiency ranged between 57 % and 64 %, with an average of 61 % across the scheme.

2. Experimental procedure

The overall five irrigation events planned for furrow dimension measurement, Inflow and outflow measurements, soil moisture distribution and gross depth measurement of overall research work. The experimental setup and procedure is as elaborated below:

2.1 Furrow dimension measurements

The furrow dimension and direction is traditionally designed and constructed by farmers; with a number of shortcomings; like irregular furrow shape with depressions. Furrow dimension irregularity is increased from irrigation event to event in the scheme; the present method of measurement of furrow dimension is as depicted in fig. 1,

Figure 1: Furrow dimension measurements in the field

The furrow dimensions; such as furrow length, furrow depth and furrow spacing were measured properly in the experimental field. Three furrows (replica) were purposely selected from each of the three farms as Head, Middle, and Tail.

2.2 Inflow and Outflow Rate Measurement

The experimental setup for carrying inflow and outflow rates of measurement are as shown in fig. 2. The materials that are used in this experimental study are graduated bucket, core samplers, measuring tape, soil moisture sensor, rope, sprit level, GPS, double ring infiltro-meter, access tube, hammer, shovel, metal rod etc.

Figure.2. Materials used during the field experiment.

Figure 3: Inflow and outflow discharge measurement

During the conduction of actual experiments: the measurement location was first identified and then the bucket is installed firmly in a ground. Next, time elapsed to fill the bucket irrigation cut off time was recorded using a stopwatch (Ref. fig 3)

The inflow and outflow rates are calculated for five irrigation events in the experimental plot by using equation 1 and 2 suggested by Horst *et al.* (2005)., the outflow rate was measured little bit after runoff started,

$D_{in} = \frac{q_{in} \times t_{co}}{S \times L}$ (1) where D_{in} is the average depth of water applied (mm), Q_{in} is inflow stream size (l/s), S-is furrow spacing (m), t_{co} cutoff time in seconds and L-is the length of the furrow (m). Additionally, the amount of water that is lost in the tail end is estimated by using equation 2;

$D_{ro} = \frac{q_{out} \times t_{out}}{S \times L}$ (2) Where, D_{ro} is the depth of outflow from the tail of the furrow (mm), q_{out} is outflow discharge (l/s) at the tail end of the furrow; t_{out} is a time of outflow in seconds.

To avoid the soil erosion problem, the inflow rate size was designed according to field slope. According to Booher (1974) recommendation, the empirical relation developed by USDA-SCS for the maximum non-erosive stream size is shown in equation (3).

$$Q_{\max} = \frac{C}{S} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

where Q_{max} refers to maximum non-erosive stream size (l/s), S is ground slope down the furrow in %, C is empirical constant (= 0.6 ℓ/s).

2.3 Soil moisture distribution

Soil moisture distribution was measured by using soil moisture sensor RR2 and its use in an experimental plot is depicted in figure 4. The PR2 soil moisture probe is built around patented sensing technology which provides unprecedented performance in all soil types, with minimal influence from either salinity or temperature. The PR2/6 measures at 6 depths down to 100 cm, **length** 1350 mm, diameter 25.4 mm diameter, weight 1.2 kg

Error *per cent* of experimental moisture measured by profile probe as shown in table 1. Also the experimental location of soil moisture measurement along a furrow ridge is also shown in figure 5. The soil moisture was measured by applying two types of temporal sampling.

Figure 4: The soil moisture sensor (PR2) and its use in the field

Those include daily measurement and measurement at each irrigation event. Soil moisture was monitored at 9:00 am on daily base for a period of 36 days, which was between 18/02/2017-25/03/2017 at the study area. Soil moisture data before irrigation is measured at 10 to 5 minutes before irrigation. Soil moisture after irrigation was measured after two days. This continuous moisture monitoring is applied for all three farm plots at the head (H_1), middle (M_1) and tail (T_1) plots. Irrigators followed the constant irrigation schedule that rotates among users.

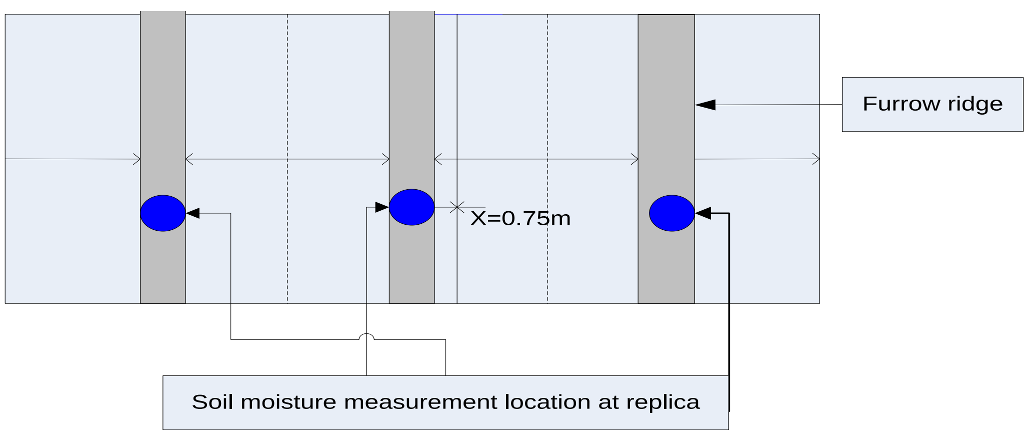

Figure 5**: Location of soil moisture measurement along a furrow ridge**

Table 1: Error *per cent* of experimental moisture measured by profile probe

Sensor reading interval (%)	0-10	10-20	20-30	30-40	40-50
% of errors	15	20	21	15	16

Error *per cent* of experimental moisture measured by profile probe as shown in table 1. The schedule was not improved with increasing of evaporative demand and growth stage of crops across the field.

2.4 Gross Depth of Irrigation

Basically depth units are used to refer to the amount of water required for irrigation. Depth units (inches) are used because soil water-holding capacity is typically measured in inches (of water) per foot (of soil depth), and irrigations are scheduled after a fraction of the soil water in the plant root zone has been depleted. CROPWAT is a decision support tool developed by the Land and Water Development Division of FAO. CROPWAT 8.0 for Windows is a computer program for the calculation of crop water requirements and irrigation requirements based on soil, climate and crop data. The gross applied and estimated depth of five irrigation events were determined for the scheme based on data of inflow rate; which are measured through the graduated bucket and CROPWAT 8 model, respectively.

3. Results and Discussion

3.1 Furrow measurement dimensions.

Furrow irregularity and direction, which is designed and constructed by farmers was identified as main factor that hinders scheme performance. The measurement results of furrow dimensions; like Replica length, depth and spacing for experimental plots; head (H1) Middle (M1) and Tail (T1) depicted in Table 2.

Table 2: The furrow dimension measurements of the experimental plots

Experimental Plot	Replicas	Furrow length (m)	Furrow depth (m)	Furrow spacing (m)

Head (H_1)	R_1	7	0.09	0.6
	R_2	6.2	0.11	0.65
	R_3	6	0.10	0.62
Middle (M_1)	R_1	6.1	0.12	0.63
	R_2	7	0.15	0.6
	R_3	6.3	0.13	0.62
Tail (T_1)	R_1	6.2	0.13	0.65
	R_2	6	0.12	0.61
	R_3	6.1	0.13	0.64

From the above table; the maximum furrow length of 7 m, furrow depth of 0.12 m and furrow spacing of 0.65 m is noted for Head (H1) plot. Furthermore for the Middle plot (M1) furrow length of 7 m, furrow depth of 0.15 m and furrow spacing of 0.63 mm are noted. However; for tail plot (T1), the furrow length of 6.2 m, furrow depth of 0.13 m and furrow spacing of 0.65 is noted.

3.2 Inflow and out flow rates of experimental plots

Table 3 and 4 show the results of field inflow and outflow rates of five irrigation events of the experimental plots. The inflow rates vary from 0.51 to 0.71(l/s) for the head, 0.5 to 0.69 (l/s) for the middle and 0.51 to 0.69 (l/s) for the tail end plots (table 5).

Table 3: Inflow rates (l/s) measurement at the experimental plots for the different irrigation events

Table a**:** Head (H_1) irrigation inflow rate (l/s)						Table b: Middle (M_1) irrigation inflow rate (l/s)					
Event	1	2	3	4	5	Event	1	2	3	4	5
R_1	0.71	0.64	0.61	0.59	0.53	R_1	0.69	0.65	0.58	0.56	0.53
R_2	0.64	0.67	0.63	0.57	0.51	R_2	0.64	0.58	0.54	0.52	0.51
R_3	0.68	0.65	0.64	0.54	0.53	R_3	0.66	0.62	0.53	0.55	0.50
	0.69										
Table c: Tail (T_1) irrigation inflow rate (l/s)						Table d: Average inflow rate (l/s)					
event	1	2	3	4	5						
R_1	0.69	0.65	0.60	0.55	0.5	Plots	min		max		average
R_2	0.64	0.62	0.58	0.54	0.5						
R_3	0.66	0.64	0.56	0.55	0.5						

	H_1	0.51	0.714	0.612
	M_1	0.5	0.69	0.595
	T_1	0.51	0.69	0.600
	All	0.5	0.714	0.607

Source: Field data, 2017

The permissible maximum flow rate of the study area is calculated using equation 3. The average value of the inflow rate noted for experimental field is 0.607 l/s which is greater than the permissible maximum flow rate 0.4 l/s of furrow irrigation. This implies that the irrigation water applied to the plots is erosive stream size which was not balanced with furrow slope. Moreover, it was observed that the inflow discharge resulted in soil erosion in the experimental plots. Applied inflow rate was significantly larger than the soil infiltration capacity. This indicates that applied inflow rate was one of factors that reduce irrigation efficiency in the scheme. The next important issue is that, the irrigators considered long cutoff time as optimum irrigation. Due to this consideration, they allow long irrigation time until the furrow breaks with flooding. The cutoff time has slight variation from plot to plot and event to event. Relatively average cutoff time increases from head (17 min) plot to tail end (19 min) plot in the study area (table 4). This long cutoff time was also considered as main factors affecting irrigation application efficiency in the scheme.

The outflow rate has no significant variation for different experimental plots and irrigation events (Table 5.). The outflow rates are relatively high compared to the inflows (table 6). The averagely maximum outflow rate obtained was 0.38 l/s. This is likely caused by steep furrow slope which is outside the recommended values. The uniformity of outflow rate across the experimental plots was due to similarity of inflow rate for all experimental plots. The tail end plot outflow rate was relatively small. Irrigation users are not currently using the tail water runoff. Lack of the experience of the reusing tail water runoff is strong factor that increase irrigation water losses in the study area.

Table 4:- Inflow rates at the upstream of the furrow

		Inflow discharges				
Farm	replica	Irrigation events	Cut-off Time(min)	bucket filling time(s)	Bucket volume(l)	Discharges(l/s)
H_1	R1	Irrigation event 1	15.8	29	20	0.689655172
	R2		16.2	30	20	0.666666667
A=34m*15m= 510m2	R3		15	29	20	0.689655172
	R1	Irrigation event 2	16.7	31	20	0.64516129
	R2		17.9	31	20	0.64516129
	R3		19	29	20	0.689655172
	R1	Irrigation event 3	19.2	33	20	0.606060606
	R2		18.8	32	20	0.625
	R3		17.9	31	20	0.64516129
	R1	Irrigation event 4	19	34	20	0.588235294
	R2		18	35	20	0.571428571
	R3		18.5	37	20	0.540540541
	R1	Irrigation event 5	19.3	34	20	0.588235294
	R2		19	32	20	0.625
	R3		18.7	31	20	0.64516129
M_1	R1	Irrigation event 1	19.5	29	20	0.689655172
	R2		17	33	20	0.606060606
A=32m*21m= 672m2	R3		18	32	20	0.625
	R1	Irrigation event 2	16.5	31	20	0.64516129
	R2		18.6	34	20	0.588235294

	R3		17.5	32	20	0.625
	R1	Irrigation event 3	19	35	20	0.571428571
	R2		18.4	37	20	0.540540541
	R3		17	38	20	0.526315789
	R1	Irrigation event 4	17.7	36	20	0.555555556
	R2		18.5	38	20	0.526315789
	R3		18	36	20	0.555555556
	R1	Irrigation event 5	18	37	20	0.540540541
	R2		16.6	29	20	0.689655172
	R3		19	28	20	0.714285714
T_1	R1	Irrigation event1	18	29	20	0.689655172
	R2		17.8	31	20	0.64516129
A=15m*25m= 375m2	R3		19	30	20	0.666666667
	R1	Irrigation event 2	18	31	20	0.64516129
	R2		19	32	20	0.625
	R3		19	31	20	0.64516129
	R1	Irrigation event 3	18.3	33	20	0.606060606
	R2		17.5	34	20	0.588235294
	R3		19	35	20	0.571428571
	R1	Irrigation event 4	18	36	20	0.555555556
	R2		18	37	20	0.540540541
	R3		19	37	20	0.540540541
	R1	Irrigation event 5	19.5	38	20	0.526315789
	R2		18	35	20	0.571428571
	R3		18.7	32	20	0.625

Table 5: Outflow rates (l/s) in the experimental fields

Plots	Irr. events	1^{st}	2^{nd}	3^{rd}	4^{th}	5^{th}
Head (H_1)	R_1	0.37	0.39	0.36	0.39	0.37
	R_2	0.36	0.35	0.37	0.38	0.37
	R_3	0.39	0.38	0.38	0.37	0.39
	Avg.	**0.38**	**0.37**	**0.37**	**0.38**	**0.38**
Middle (M_1)	R_1	0.37	0.36	0.36	0.37	0.36
	R_2	0.35	0.35	0.37	0.37	0.35
	R_3	0.39	0.37	0.34	0.35	0.38
	Avg.	**0.37**	**0.36**	**0.36**	**0.36**	**0.365**
Tail (T_1)	R_1	0.35	0.36	0.34	0.36	0.34
	R_2	0.34	0.35	0.35	0.35	0.36
	R_3	0.37	0.35	0.37	0.37	0.35
	Avg.	**0.35**	**0.35**	**0.36**	**0.36**	**0.35**

Source: Field data, 2017

Table 6: Outflow rate at the tail end of the furrow

		Outflow discharges				
Farm	replica	Irrigation events	bucket filling time(s)	Bucket volume(l)	Discharges(l/s)	Tout(min)
H_1	R1	Irrigation event 1	53	20	0.377358491	5
	R2		55	20	0.363636364	5.5
A=34m*15m=510 m2	R3		56	20	0.357142857	5
	R1	Irrigation event 2	51	20	0.392156863	6
	R2		53	20	0.377358491	5
	R3		51	20	0.392156863	5
	R1	Irrigation event 3	54	20	0.37037037	6.1
	R2		53	20	0.377358491	5.6
	R3		54	20	0.37037037	6
	R1	Irrigation event 4	51	20	0.392156863	5.2
	R2		52	20	0.384615385	6.2
	R3		53	20	0.377358491	5.8
	R1	Irrigation event 5	54	20	0.37037037	6
	R2		53	20	0.377358491	5
	R3		51	20	0.392156863	6

M_1	R1	Irrigation event 1	53	20	0.377358491	6
	R2		52	20	0.384615385	5.5
A=32m*21m=672 m2	R3		51	20	0.392156863	5.8
	R1	Irrigation event 2	54	20	0.37037037	6.3
	R2		53	20	0.377358491	5
	R3		54	20	0.37037037	5.2
	R1	Irrigation event 3	52	20	0.384615385	5.1
	R2		53	20	0.377358491	6.1
	R3		54	20	0.37037037	5.9
	R1	Irrigation event 4	52	20	0.384615385	5
	R2		53	20	0.377358491	5
	R3		54	20	0.37037037	5
	R1	Irrigation event 5	55	20	0.363636364	6
	R2		53	20	0.377358491	5
	R3		51	20	0.392156863	6
T_1	R1	Irrigation event1	50	20	0.4	6
	R2		53	20	0.377358491	6.2
A=15m*25m=375 m2	R3		54	20	0.37037037	6.1
	R1	Irrigation event 2	55	20	0.363636364	5.6
	R2		51	20	0.392156863	5
	R3		52	20	0.384615385	5
	R1	Irrigation event 3	52	20	0.384615385	5.5
	R2		54	20	0.37037037	5.4
	R3		54	20	0.37037037	5.6
	R1	Irrigation event 4	52	20	0.384615385	6
	R2		53	20	0.377358491	6.2
	R3		54	20	0.37037037	5
	R1	Irrigation event 5	52	20	0.384615385	5.4
	R2		52	20	0.384615385	6
	R3		54	20	0.37037037	5.5
						15.1

3.3 Soil moisture distribution.

Soil specific calibration is made for the soil moisture reading and its error result is presented in Table 7. The result shows differences exist between the sensor and laboratory data of soil moisture. The soil moisture recorded through the profile probe in the field is calibrated using the laboratory data.

Table 7. : Error percent of experimental moisture measured by profile probe

Sensor reading interval (%)	**0-10**	**10-20**	**20-30**	**30-40**	**40-50**
% of errors	15	20	21	15	16

The results of Soil moisture distribution at head (H1) plot, Middle (M1) plot, Tail (T1) plot are presented in figure 6 to 8. Figure 6, depicts the continuous soil moisture content of the head (H_1) plot for the clay loam soil in the MelkaHida irrigation scheme. The average soil moisture data of each replica in the plot is measured and evaluated continuously. It can be seen from the figure that five irrigation events are applied, the plot received irrigation water at an interval of 6-8 days. The applied amount of water brought soil moisture level above the FC for all events. Particularly, the fourth irrigation event is relatively received more water due to furrow maintained. The moisture level decreases at constant rate, immediately after each irrigation event. There is no significant difference between the soil moisture distributions in the three replicas of the head plot. The three last irrigation events are applied when moisture level reached at the permanent wilting point level. At this soil moisture level, it is difficult for crops to extract adequate water to meet the transpiration demand. This may result in reduced production. Irrigation users have experienced observation techniques to identify irrigation time. They have no concept of moisture of allowable depletion level which is applying of irrigation water before soil moisture fall to the level of permanent wilting point in the soil.

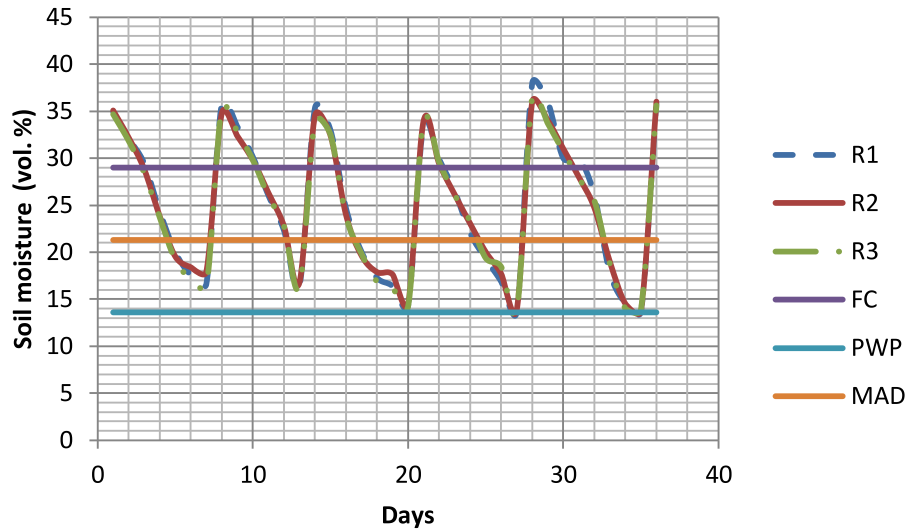

Figure 6: Soil moisture distribution at head (H1) plot,

Like the head plot, the middle plot has also received irrigation water five times for the total time of experiment, which is 36 days (Figure 7). The plot received irrigation water at an interval of 5 to 8 days which is slightly different from the head (H_1) plot. Plot is irrigated more than the actual amount of irrigation required by crop demand for all events. Water application shows consistency almost for irrigation. This is obtained due to common irrigation schedule and the same stream size for all irrigation events. The second and fourth irrigation event has received water by the interval of five and eight days respectively. The constant irrigation frequency of the users is seven days. Even though approved schedule is seven days, sometimes there is a disturbance of irrigation schedule. When next water user is not available, there are muchcompetent to pick up the opportunities without their normal schedule.

Soil moisture is dropped to wilting point before the slightly before usual irrigation schedule at the time of experiment. The case might be the increasing of evaporative demand across the field at the time of experiments. Inappropriate scheduling is the general challenges for the all experimental plots in the scheme. Applied irrigation depth is always more than the actual soil moisture deficiency of the soil in the study area for all plots.

WUAs provided rule and regulation for irrigation water management in the scheme. According to regulation, next user (water receiver) has a responsibility to check and control the first irrigation user to prevent over irrigation. But due to unavailability of next irrigation water user, users applied the irrigation water up to saturation level. Therefore, even if the next water user is not available, user cut off irrigation water when the overflowing started to break the furrow structure.

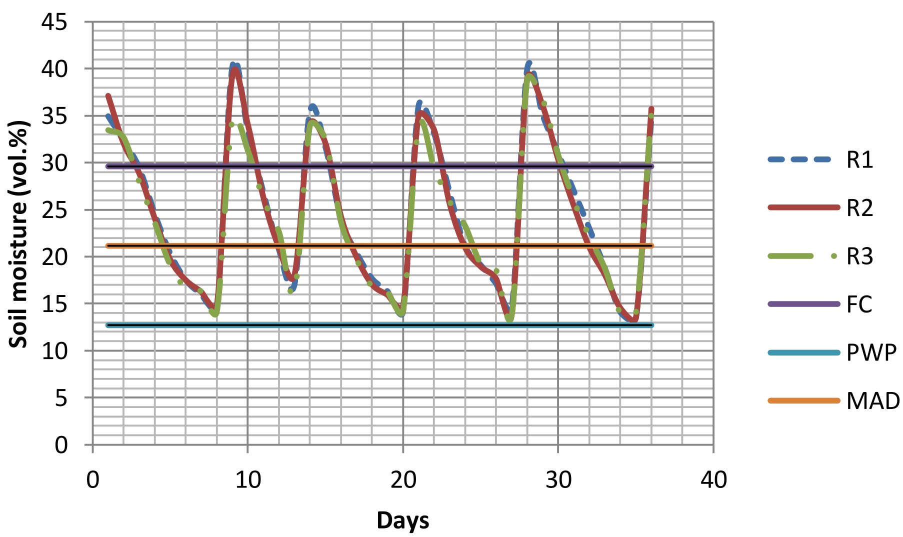

Figure 7: Soil moisture distribution at middle (M1) plot

The tail end plot (T_1) has also received irrigation event five times having a range of interval 6 to 8 days of irrigation (Figure 8). The irrigation users applied more water than the actual amount of water required by crop almost all the time of irrigation events. There is consistency and uniformity of water application among replicas. This might be obtained due to almost the same stream size applied all over the plots. The amount of stored moisture shows variability from event to event based on cut off time different. The soil moisture is dropped to the wilting point level before seven days of their usual schedule. Since all irrigation events are irrigated after soil moisture level dropped to the permanent wilting point, relatively the more water stressed area is a tail end plot.

Irrigators did not take into account the soil type, crop type, crop growth stage and climate condition for their constant schedule. There is variability of the normal schedule between irrigation events, due to the weakness of water users association in the scheme. Relatively the tail end plants face the more challenge of water stressing, which is difficult to retrieve to normal growth. This water stress is not the challenge of water availability but mismanagement of irrigation system. The soil moisture distribution across the plots exceedingly provides the inappropriate irrigation schedule and poor estimation of irrigation amount over the scheme which resulted in significant water losses.

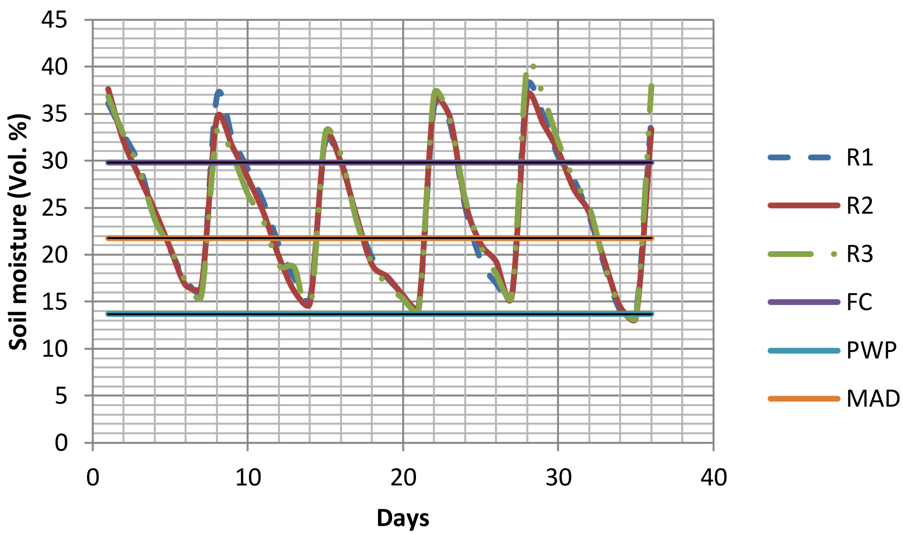

Figure 8: Soil moisture distribution at tail (T1) plot

Muse (2016) evaluated soil moisture distribution status using soil moisture sensor for loam sandy soil at the head plot and sandy loam at tail end of Meki-Ziway irrigation scheme. At the each of irrigation application time, the amount of water stored in the soil shows variation based on field position. At the head and middle plots the soil moisture distribution has consistency and uniformity while the soil moisture distribution at tail end plot shows variation from the upstream field. According to his suggestion, this variation is obtained due to tail end plot far away from the main canal. Unlikely, in Melka Hida soil moisture distribution shows uniformity and consistency across the all experimental plots. Factors that contributes for this uniformity of moisture across the field were replicas length, stream size and plots position. Almost three plots have the same distance from main canal. The replicas length and stream size were almost the same across the plots.

Gross depth of irrigation:

The actual gross measured and estimated irrigation water of the study area is depicted in Table 8. The average applied irrigation water is much larger than accurately required irrigation water for the irrigation scheme. The gross applied depth at the head, middle and tail end plots are 12.3, 12.3 and 12.5 mm/day while the actual required by crop demand is 6.5 mm/day across the field. This shows almost a half of applied depth is wasted without benefits. Irrigators are uses traditional water control like soil, stone, leaves, and grasses. Starting from tertiary canal to field ditch still it is earthen canal which increases water losses along the canal. Unavailability of irrigation water control structure increases water losses in the scheme. Irrigation users are financial incapable to construct the water control structures which reduce losses in the study area. This indicates that unavailability of water control structure and financial incapability of irrigators are main factors affecting irrigation performance in the scheme.

Table 8: The gross actual applied and estimated irrigation depth in the scheme

Farm plot	Replica	Average gross applied depth (mm/day)	Average estimated depth (mm/day)	Difference (mm/day)
	R_1	11.9	6.5	5.4
Head (H_1)	R_2	12.3	6.5	5.8
	R_3	12.7	6.5	6.2
	average	12.3	6.5	5.8
	R_1	13	6.5	6.5
Middle (M_1)	R_2	12	6.5	5.5
	R_3	11.7	6.5	5.2
	average	12.3	6.5	5.7
	R_1	12.5	6.5	6
Tail (T_1)	R_2	12.2	6.5	5.7
	R_3	12.9	6.5	6.4
	Average	12.5	6.5	6

Conclusions

From this study the following conclusions are made:

1) Irrigation Furrow measurement dimensions: Among three farms furrows length have slight differences, which is 6-7 m. Additionally furrow depth and spacing has also insignificant differences. The irrigators divided the plot into three sub plots to minimize the soil erosion due to steep slope. Furrow length in the scheme is dictated by the small size of land holdings and subplots in the scheme which range between 0.04 and 0.5ha.

2) Inflow and outflow rate: The average value of the inflow rate noted for the experimental field is 0.607 l/s which was greater than the permissible maximum flow rate 0.4 l/s of furrow irrigation. Also applied inflow rate noted significantly larger than the soil infiltration capacity. This indicates that the applied inflow rate was one of factors that reduce irrigation efficiency in the scheme.

The average maximum outflow rate noted was 0.38 l/s, the outflow rate was relatively high compared to the inflow. Also the outflow rate has no significant variation for different experimental plot and irrigation events.

3) Soil moisture distribution: There is continuous soil moisture content of the Head (H1) plot for the clay loam soil, the plot received irrigation water at an interval of 6-8 days. The moisture level decreases at constant rate immediately after each irrigation level. Also no significant difference between the soil moisture distributions in the three replicas of the H1 plot observed.

The Middle plot (M1) received water at an interval of five and eight days respectively. Water application shows consistency almost for irrigation. Also soil moisture is dropped to welting point before the slightly usual irrigation schedule.

The tail end plot (T_1) has also received irrigation events five times, having a range of interval 6 to 8 days. At the head and middle plots the soil moisture distribution has consistency and uniformity, while the soil moisture distribution at tail end plot shows variation from the upstream field. The amount of stored moisture shows variability from event to event based on cut off time difference. The soil moisture is dropped to the wilting point level before seven days of their usual schedule. Since all irrigation events are irrigated after soil moisture level dropped to the permanent wilting point, relatively the more water stressed area was a tail end plot.

4) Gross depth:

The gross applied depth noted at the head, middle and tail end plots are 12.3, 12.3 and 12.5 mm/day while the actual required by crop demand is 6.5 mm /day across the field. The unavailability of irrigation water control structure increases water losses in the scheme.

The Melka Hida small water irrigation scheme acts as a unique model for the farmers of Oromia region of Ethiopia, that will helps the farmers of this region to adopt the furrow preparation geometry by using scientific basis for a particular crops plots, that will also help the farmers community to improve overall irrigation efficiency, reduce the waters losses and save the efforts of the farmers. The study of flow analysis, soil moisture distribution and depth of irrigation will help the farmers to know how much water is essential for his overall plot for the healthy growth of plants. So that it will help to save the excess supply of water.

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