ORIGINAL ARTICLE

Assessment of Water Productivity for Small Scale Irrigation Schemes under Drip and Furrow Methods at Hormat-Golina Small Scale Irrigation Scheme, East Amhara Region, Ethiopia

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ABSTRACT

Hormat-Golina small irrigation scheme was found in Ethiopia that was contributes to enhancing food security and economic growth of the local society. This scheme have two types of irrigation systems. Drip and furrow irrigation types were practicing at Hormat-schemes, but water productivity of this irrigation type were not evaluated yet. Thus, the aim of this paper was to evaluate the water productivity under drip and furrow irrigation systems. CROPWAT8.0 tool was used to determine the crop water requirement for selected crops. The well discharge capacity were determined by regular field measurements. Under drip irrigation method crop water productivity resulted were 1.53, 1.02, 1.06 and 2.24 kg/m^3 for chickpea, garlic, onion, and watermelon respectively. Whereas, under the furrow irrigation method, the crop water productivity resulted were 0.52, 0.66 and 1.52 kg/m3 for chickpea, onion, and watermelon respectively at the first season. However, at season two it were resulted as 1.18, 1.03 and 2.29 kg/m^3 for chickpea, garlic, and watermelon respectively under drip irrigation system and 0.47, 0.57, 0.64 and 1.43 kg/m^3 for chickpea, garlic, onion, and watermelon respectively under furrow irrigation system. Moreover, the economic water productivity under drip irrigation method has resulted as 0.34, 1.29, 0.41 and 1.20 \$/m^3 for chickpea, garlic, onion, and watermelon respectively; and also 0.14, 0.25 and 0.85 \$/m^3 for chickpea, onion, and watermelon respectively under furrow irrigation system at the first season. But, in the second season, it becomes 0.4, 1.41 and 1.74 \$/m^3 for chickpea, garlic, and watermelon respectively and 0.15, 0.77, 0.31 and 1.06 \$/m^3 for chickpea, garlic, onion, and watermelon respectively with the respective of drip and furrow irrigation methods. Based on these results drip irrigation system is the advisable method for such irrigation schemes, and also it is the water saver irrigation mechanism in water scarce area.

Keywords: Crop yield, Evapotranspiration, Water use efficiency.

INTRODUCTION

The investigation of water requirement and irrigation management plays an important role in effectively and efficiently using the available water sources to meet the possible variation of cropping pattern. The estimation of crop water demand is an essential component for managing water effectively in the irrigated command area (Naidu & Giridhar, 2016). However, the estimation of the crop water demand has proved to be much more difficult as it requires data on irrigated areas, types of crops, cropping calendars and specific crop water demands (Todorovic, 2017). Given these data, it becomes possible to calculate the total crop water requirement for each system and compare this with the total amount of water applied into the field. CROPWAT8.0 model is developed by the FAO water and land management department (WLMD) for planning and management of irrigation as a practical tool to carry out standard calculations for reference evapotranspiration and irrigation water requirement (Allen et al., 1998).

Ethiopia is under the predominant rain-fed agricultural production and progressive degradation of the natural resource base in highly vulnerable areas of the highlands coupled with climate variability have aggravated the occurrence of poverty and food insecurity (Awulachew et al., 2012). Groundwater irrigation is being prioritized recently as the best alternatives for reliable and sustainable food security, income generation, livelihood improvement in the country (Awulachew, et al., 2012). In last two decades the government of Ethiopia has given great attention to the development of groundwater resources and it is a valuable resource in irrigation activity, agricultural food production and the development of nations and countries (Yazew et al., 2009; Tadesse et al., 2015).

Variable climate, absence of seasonal crop rotation, cropping pattern, poor irrigation water management, lack of skilled manpower, and awareness less of modern irrigation practice and irrigation technology are the causes for the reduction of agricultural product in many irrigation schemes in Ethiopia (Yazew et al., 2009). Even though both drip and furrow irrigation systems are practiced at the scheme, the problem under consideration is that the current cropping pattern is not economically efficient in the utilization of the available water resource and lack of information on the balance of crop water demand and field applied irrigation water, and also no water productivity evaluation of drip and furrow irrigation system at the scheme.

The main objective of this research was to assess water productivity for small scale irrigation schemes under drip and furrow methods at Hormat-Golina small scale irrigation scheme, East Amhara Region, Ethiopia. Specifically this research endeavors to evaluate the applied irrigation water and crop water demand at small scale irrigation scheme, to quantify crop water productivity of drip and furrow irrigation systems at the small scale irrigation scheme and to quantify economic water productivity of drip and furrow irrigation systems at the scheme.

This research is finding out to show the productivity of the crops depend on the developments of different irrigation mechanisms with advanced irrigation technology. The other finding is to show drip irrigation is the water saver irrigation system rather than furrow and or other traditional types of irrigation methods for the communities. It can be increasing the awareness of the communities on value giving for water to more productive under deficiency of water.

MATERIALS AND METHODS

Descriptions of study area

The Hormat-Golina irrigation small scale scheme is one of the schemes in the Kobo groundwater-based irrigation project, it is located between 11° 56' to 12° 08' N latitude and 39° 23' to 39° 47' E longitudes. Administratively, it is located in the northern Wollo Zone of the Amhara National Regional State, Kobo-Woreda, at kebele 05. It lies near to the Dessie-Mekele main road between Woldiya and Alamata town around 565 km distance from the capital city of Ethiopia which is Addis Ababa.

The research area is the drought-prone regions in Ethiopia. The summer is very short and hot, lasting from July through September, with maximum air temperature ranging from 30.1°C to 35.5°C; winter lasts from December through February, with maximum air temperature ranging from 27.4°C to 28.9°C during the daytime. The rainfall of the study area is seasonal. The soil of the study area is developed on recent alluvial-colluvium sediments derived from the adjacent mountain ranges provide the basic land resources for improvement of agricultural productivity. In general, two different major soil types have been identified: Vertisols (black heavy clay soils) and Fluvisols (medium-textured soils with characteristic stratification). The major crops were grow in the study area before the Kobo-Girana valley development program was implemented, Teff, Sorghum, Maize, and other cereals from July through November (ADSWE, 2013).

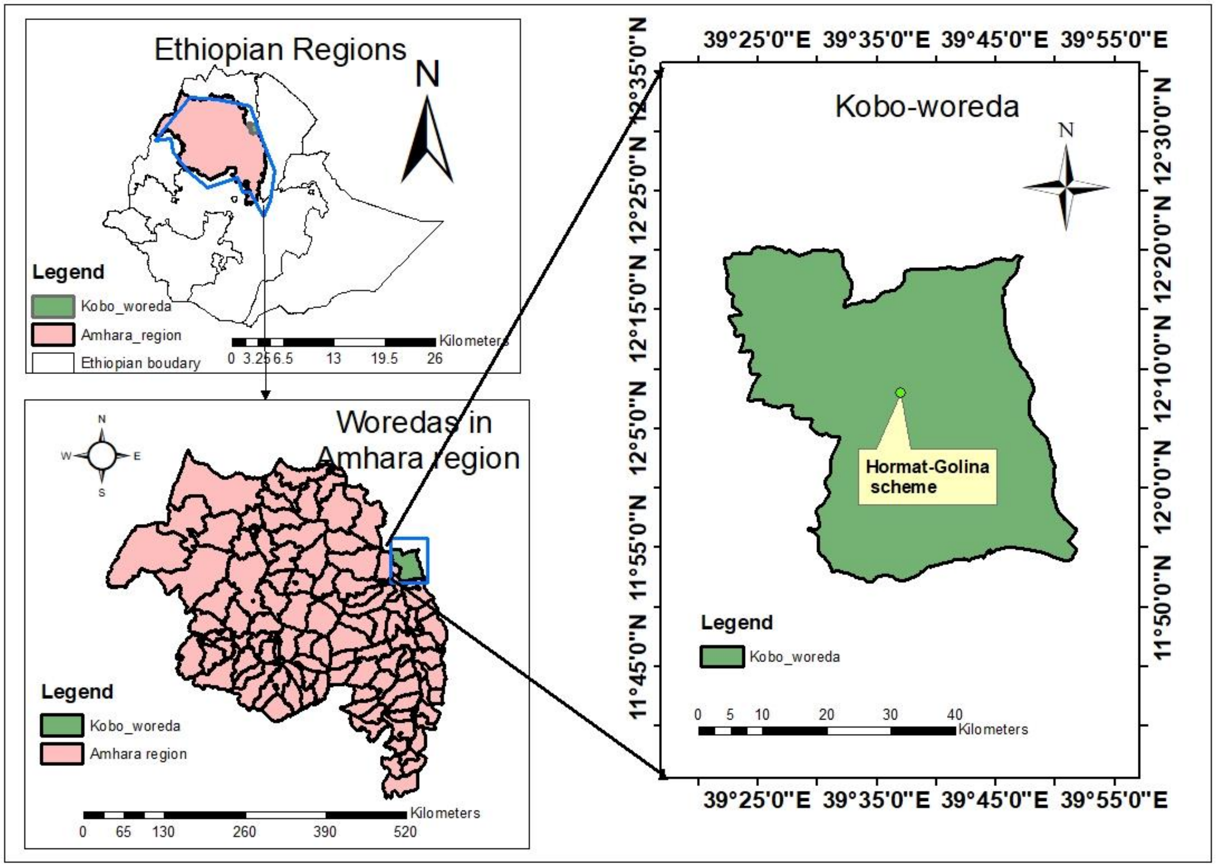

Figure 1. Location map of research area developed by Arc-GIS

Data collection

The discharge capacities of the wells were collected during field measurement. In season of, Dec 2018 to, May 2019 the discharge capacity of the wells were measured. The average measured values of the wells were 42.47 l/sec or 152.89 m^3/hr. and 44.25 l/sec or 158 m^3/hr. for drip and furrow irrigation system respectively. For determination of crop and economic water productivity of drip and furrow irrigation system and to estimate the crop water requirement in CROPWAT 8.0 Model, various quantitative and qualitative data were collected from secondary data sources.

Climate data

Most of the rainfall is concentrated during Ethiopian wet season (Kiremt). The climatic data were collected from 2002-2017. And also, temperatures data in the study area were taken from Ethiopian meteorological agency for kobo station and analyzed in Microsoft Excel. The mean minimum monthly temperature was recorded in the month of January, which was 13.2 °c and the mean maximum temperature got in March that was 35.5°c. Available data of relative humidity were taken from Ethiopian meteorological agency for kobo station and were analyzed. The mean monthly maximum and minimum values of relative humidity exist in September (73.7 %), and February (39.8 %) respectively and this is attributed to the rainy and dry season of Ethiopia respectively. Although data of wind speed taken from Ethiopian meteorological agency for kobo station. In addition to this sunshine hour plays a significant role in affecting evapotranspiration. Longer sunshine hour increases the evaporation rate and amount that in turn is depend on the intensity of solar radiation. The minimum hour for the sunshine was 6.5 hour per day that was recorded in July. Crop coefficient, initial soil moisture depletion, number of growing days and maximum root depth of chickpea, garlic, onion, and green watermelon were recorded at the field.

Table 1. Materials and Software used for this study

Nr.	Name	Source	purpose
1	Water meter (sensor)	Rented	Measuring water depth
2	CROPWAT V8.0	www.FAO.org/softwares	Calculate ETC
3	Tape Meter	Bought	Measuring crop root depth

Methods of the analysis

Determination of applied irrigation water at the scheme

According to Martin (2011), to calculate the amount of applied irrigation water or depth of water applied in to the field, regular well discharge measurement was required. From the collected primary and secondary data the amount of applied irrigation water to the field of Hormat-Golina number-7 and Hormat-Golina number-24 groundwater based irrigation schemes were computed using regular field well discharge measurement with in time intervals of fifteen days.

The amount of water used for the development of different crops on the schemes was various; Due to different crop characteristics, irrigation method, irrigation technology, management practice, and climatic condition. The applied irrigation water or irrigation water used to the field practice with drip and furrow irrigation methods is calculated by the following irrigator's equation below (Martin, 2011).

(Q*t)= (d*A)…………… eq.1.

Where: Q is the flow rate, (m3/hr.), t is the set time or total time of irrigation (hr.), d is the depth of irrigation water per unit area (m3/ha), and A is the area irrigated (ha). The calculation of the volume of applied irrigation water was used to estimate crop water productivity and economic water productivity of drip and furrow irrigation system in the scheme.

Estimation of crop water demand using CROPWAT 8.0 Tool

Crop water requirement

It is defined as the depth of water needed to meet the water loss through evapo-transpiration (ET crop) of a disease-free crop growing in a large field without the restricting soil situations, including soil water and fertility, and attaining full production in a given growing environment (Endalamaw, 2009). For the calculations of the crop water requirements (CWR), the crop coefficient approach is used (Allen et al., 1998). When the rainfall is unsatisfactory and soil water storage depleted, the difference is the deficit that should be supplied by irrigation.

$$IWR = \sum_{i=1}^{n} (ET_o * K_c - P_{eff}) \dots \dots \dots . eq. 2$$

where: IWR= irrigation water requirement (mm), ETo= reference evapotranspiration (mm/day), Kc crop coefficient, Peff= effective precipitation (mm).

To estimate the irrigation water requirement of major crops in the study area CROPWAT 8.0 was used. CROPWAT 8.0 is developed based on the various versions of CROPWAT 5.7 of 1992 and CROPWAT 7.0 of 1999. The model takes into account the reference evapotranspiration using Penman-Monteith method and precipitation for calculation of irrigation water requirement (Allen et al., 1998).

Effective precipitation

It is the portion of rainfall that is useful directly and/or indirectly for crop production at the site where it falls which depends on soil slope, soil texture and structure, plant cover or crop residue, storm intensity and duration, etc. Effective precipitation in this study was calculated according to the method of (USDA) United State department of agricultural soil conservation service. The reason to select this method is simple to use on a monthly, decade or daily basis and worldwide method.

$$P_{eff} = \frac{P * (125 - 0.2 * 3 * P)}{125}, \text{if } P \leq \frac{250}{3} \text{mm} \dots eq. 3. a$$

$$P_{eff} = \frac{125}{3} + 0.1 * P, \text{if } \ P > \frac{250}{3\text{mm}} \dots . eq. 3. b$$

Where, P_{eff} is the average monthly effective rain (mm); monthly mean precipitation.

Reference Evapotranspiration

It is computed based on a hypothetical reference crop with a height of 0.12 m, a surface resistance of 70 s/m and an albedo of 0.23, it approaching with uniform height green grass, actively growing and completely shading the ground and with adequate water (Allen et al., 1998). The Penman-Monteith method is the most extensively used methodology for assessing ET from terrestrial surfaces and is preferred when the requisite data are available. FAO, in the 56th crop and irrigation paper, developed a modified form of this equation that can be modified for use with most vegetation.

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T+273}U_2(e_s - e_a)}{\Delta + \gamma(1 + 0.43U_2)} \ldots eq. 4$$

Where: ETo: the Reference evapotranspiration in [mm day-1], R_n: the net radiation at the crop surface in [MJ m-2 day-1], G: Soil heat flux density in [MJ m-2 day-1], T: Mean daily air temperature at 2m height in [°C], U_2: Wind speed at 2 m height in [m s-1], e_s: Saturation vapor pressure in [kPa], ea: Actual vapor pressure [kPa], $e_s - e_a$: Saturation vapour pressure deficit [kPa], Δ: Slope vapor pressure [kPa °C-1], and γ : Psychrometric constant [kPa °C-1].

Evaluation of Crop water productivity of drip and furrow irrigation system

Determination of crop yield at the scheme

For this research the yield of each crops cultivated on both drip and furrow irrigation methods with respect to two consecutive irrigation seasons was determined. The first irrigation season, from the third week of, December 20/2017 to the end of, May 25/2018 and the second irrigation season also from the second week of December, 15/2018 to May, 20/2019 was covered. The yield of each crops in the Hormat-Golina irrigation scheme, that practiced with both drip and furrow irrigation methods was determined through the following simple equation (Kasahun, 2017). The crop water productivity (CWP) of the scheme was determined as the amount or the yield of the crops over the volume applied irrigation water which was calculated in the above section, and the following equation used, for the calculation (Molden et al., 2007; Igbadun et al., 2018; Hellegers, 2006).

$$Yi = Yi.ave * A \ldots\ldots\ldots\ldots\ldots eq.5$$

Where: Yi is the yield of crop i in (kg), Y_{iave} is the average product per unit hectare for crop i in (kg/ha), and A is the irrigated cropped area (ha)

$$. CWPi = \frac{Yi}{WUi} \ldots\ldots\ldots eq.6$$

Where: CWP i. is crop water productivity per cropping season (kg/m^3); Yi is the yield of crop i (kg) and WU i. is applied irrigation water used for the development of crop i (m^3).

Evaluation of Economic water productivity of drip and furrow irrigation system

Economic water productivity (EWP) is expressed in net income in US$ per irrigation water supplied in m^3. EWP was computed after the grain and straw yield from the field were harvested and measured. In addition to this, the net income gained from the sale of grain (main product) and the straw (by-product) were referred from seasonal local market price and Ethiopian trading& business activities in birr and then changed in to United states dollar (US$).Generally, the average grain yield per given irrigated area plus the product of the price of the crops per kg of the season and the average crop yields per given irrigated area and total cost of crop production were considered in the computation of economic water productivity for each crops in each irrigation systems. The overall calculation of the economic water productivity was showed by the following equation. (Hellegers et al, 2009).

$$EWP = \frac{[\ GVPi - CTi]}{wui} \ldots\ldots\ldots eq.7.$$

Where: EWP is economic water productivity in ($/m3); GVPi is the gross value from the yield of crop i (birr or dollar); CTi is the total production cost of crop i ($) and WUi is irrigation water used for crop i (m^3). The determination of the gross value of crop yield and the estimation of the total cost requirement of crop production was necessary for the evaluation of economic water productivity in the scheme.

Determination of gross value of crop product

The gross value of crop production in the study area of Hormat-Golina small scale irrigation scheme was estimated based on the yield and seasonal local market price of each crop. The following equation was used to compute the gross value of each crop on the schemes (Luhach et al., 2004).

$$GVPi = Yi * Pi \ldots\ldots eq.8.$$

Where: GVPi is the gross value of crop product ($); Yi is the yield of each crop on the scheme (kg) and Pi is the market price of each crop (birr/kg it changes to $/kg).

Determination of total cost of crop production

The calculation of the cost with each component of the irrigation system allows us to look at the total cost per hectare of irrigation (Hogan et al., 2011). The total cost is the sum of each individual cost of crop production, and it was calculated through the following equation.

$$Ti = [Cs + Cf + Csp + Cl + Ct + Cp] \ldots \ldots eq.9$$

Where: CTi is the total cost for crop i in (birr or dollar); Cs is the cost of seed (birr or \$), Cf is the cost of fertilizer (birr or \$), Csp is the cost of spray (birr or \$), Cl is the cost of labor (birr or \$), Ct is the cost of transport (birr or \$) and Cp is the cost of a pump (birr or \$) to produce crop i.

RESULTS AND DISCUSSION

Determination of applied irrigation water at Hormat-Golina small scale irrigation scheme (HSSIS)

The water requirements for each crops at HSSIS was determined and it compare with the applied water used in the field. Based on the collected primary and secondary data of this research, the amount of applied irrigation water or water delivered to the field of the scheme was determined with the help of the irrigator's equation (Martin, 2011). As said by wells operators, "the discharge capacity of the wells is equally distributed for each block". These blocks have their own irrigated area. The following table shows the wells discharge capacity and its distribution for drip and furrow irrigation methods at two consecutive irrigation seasons.

Table 2. Wells discharge capacity per unit hectare of irrigable land.

Method	Drip irrigation			Furrow irrigation		
Irrigation season	**Block Name**	**Well capacity (m^3/hr/ha)**	**Irrigated Area (ha)**	**Block Name**	**Well capacity (m^3/hr/ha)**	**Irrigated Area (ha)**
Dec,2017 to May,2018	DI-B1	3.2625	12	FI-B1	3.2776	10
	DI-B2	3.2625	12	FI-B2	3.2776	10
	DI-B3	3.2625	12	FI-B3	3.2776	10
	DI-B4	3.2625	12	FI-B4	3.2776	10
				FI-B5	3.2776	10
Total	4		48	5		50
Dec,2018 to May,2019	DI-B1	3.1852	12	FI-B1	3.186	10
	DI-B2	3.1852	12	FI-B2	3.186	10
	DI-B3	3.1852	12	FI-B3	3.186	10
	DI-B4	3.1852	12	FI-B4	3.186	10
				FI-B5	3.186	10
Total	4		48	5		50

The block irrigated by drip irrigation system was represented by (DI-B) for four numbers of blocks and the block that was irrigated by furrow irrigation system was represented by FI-B for five numbers of blocks. The total volume of applied irrigation water used in the field was calculated for both drip and furrow irrigation methods separately. The capacity of the wells that released water into the field that was irrigated by drip irrigation system was equally distributed for each block. In the same ways the blocks that was irrigated by furrow irrigation system was shared uniformly for each block. The growth stages and irrigation time per unit hectare of land were needed for the calculation of applied irrigation water used in the field. These data were collected from FAO irrigation and drainage paper 56 and FAO Irrigation and Drainage Paper No. 24 provides general lengths for the four distinct growth stages and the total growing period for various types of climates and locations (Allen et al., 1998; Doorenbos et al., 1977). The required time to irrigate the unit hectare of land was collected from respondent. So, the total irrigation time was calculated by multiplying crop irrigated area with time to irrigate per unit hectare of land. Based on the calculated volume of irrigation water used by the farmer in the above table, and cultivated area proportion, the applied irrigation water depth can be estimated for the entire irrigation seasons. The amount of applied water and irrigation depth was depending on irrigated area, time of irrigation, methods of irrigation and well discharge capacity at the scheme.

Table 3. Volume of applied irrigation water for drip and furrow irrigation system in the scheme.

Season	,Dec 2017- may, 2018	,Dec 2018- may, 2019		
Methods	Drip irrigation	Furrow irrigation	Drip irrigation	Furrow irrigation
Crops:	(m^3)	(m^3)	(m^3)	(m^3)
Chickpea	60134.4	106600.0	85318.2	97328.0
Garlic	14563.8	No cultivated	30274.2	25122.0
Onion	101476.8	167280.0	No cultivated	196236.0
Watermelon	17382.6	39360.0	33943.8	16748.0

Table 4. Estimated applied irrigation water depth for each cultivated crop in the scheme.

Seasons	**Crops:**	**Methods**	**Irrigated area ($x10^4$ m^2)**	**Volume (m^3)**	**irrigation depth per season (mm/season)**
Dec, 2017 to May,2018	Chickpea	drip	24	60134.4	250.6
		furrow	25	106600.0	426.4
	Garlic	drip	3	14563.8	485.5
		furrow	non	non	non
	Onion	drip	18	101476.8	563.8
		furrow	20	167280.0	836.4
	Watermelon	drip	3	17382.6	579.4
		furrow	5	39360.0	787.2
Dec, 2018 to May,2019	Chickpea	drip	36	85318.2	237.0
		furrow	22	97328.0	442.4
	Garlic	drip	6	30274.2	504.6
		furrow	3	25122.0	837.2
	Onion	drip	non	non	Non
		furrow	23	196236.0	853.2
	Watermelon	drip	6	33943.8	565.7
		furrow	2	16748	837.4

Estimation of crop water demand using CROPWAT 8.0

The crop water demand of the crops was calculated monthly basis. Planting dates for these crops were chosen in such a way that the dates coincided with the local cropping calendar. Weather data like maximum and minimum temperature, relative humidity, wind speed and sunshine hours were obtained from the Ethiopian national meteorological agency (ENMA) and the respective crop coefficients for chickpea, garlic, onion and watermelon, crops were selected based on FAO irrigation and drainage paper 56 (Allen et al., 1998). The determination of crop water demand was done with the software of CROPWAT 8.0 for window.

Reference evapotranspiration (ETo))

It can be computed by CROPWAT8.0 window software, which uses the Penman-Monteith formula. As shown below in the table 5, the lowest ETo was obtained in November and it was about 4.01 mm/day; while the highest ETo occurs during May and was about 5.5 mm/day. The annual average ETo was obtained as 4.88 mm/day. Basically, the water requirement of the crops depends on the crop characteristics, length of the growth stage of each crops, and method of irrigation (Tibebe, 2015). The estimated irrigation requirement for chickpea was 328.7 mm and 438.2 mm with drip and furrow methods respectively. From the CROPWAT result, the irrigation water requirement of chickpea crop varies from 1.6 mm/Dec during December to 46.8 mm/Dec during February. Crop evapotranspiration varies from 1.6 mm/Dec to 56.7 mm/Dec during the whole stage of development.

Irrigation water requirement of garlic was estimated as 592.6 mm of water with drip irrigation system, for the entire growing season of, December 2017 to, May 2018. Irrigation water requirement of garlic crop varies from 2.9 mm/Dec during December to 46.9 mm/Dec during February, and its crop evapotranspiration varies from 2.9 mm/Dec in December to 58.0 mm/Dec during March. The variation is due to the stage and the presence of rainfall. Moreover, the irrigation water requirement for onion was 635.9 mm with drip and 847.8 mm with furrow method for the entire growing season of, December 2017 to, May 2018. And also, the irrigation water requirement for Watermelon was 417.8 mm and 557.1 mm with drip and furrow respectively for the entire growing season.

Table 5. Reference evapotranspiration (ET_O), Rainfall and Effective rainfall of the study

Month	ETo (mm/day)	Mean monthly Rain fall (mm)	Eff rain (mm)	Percentage effective rain fall (%)
January	4.37	9.6	9.5	99.0
February	5.48	29.4	28	95.2
March	5.29	48.7	44.9	92.2
April	5.13	62.1	55.9	90.0
May	5.5	80.7	70.3	87.1
June	5.39	13.5	13.2	97.8
July	4.83	142.8	110.2	77.2
August	4.77	184	129.8	70.5
September	4.88	55.2	50.3	91.1
October	4.86	34.3	32.4	94.5
November	4.01	36.9	34.7	94.0
December	4.1	32.7	31	94.8
Average	4.88	60.83	50.85	83.6

Crop water requirement and irrigation water requirement of the Hormat-Golina small scale irrigation scheme (HSSIS)

Table 6. Crop water demand and irrigation water requirement from CROPWAT8.0.

Seasons	Crops:	ETc (mm/season)	Gross Irrigation water requirement (mm/season)	
			Drip	Furrow
December 2017 to, May 2018	Chickpea	364.7	328.7	438.2
	Garlic	691.5	592.6	Not cultivated
	Onion	727.7	635.9	847.8
	Watermelon	474.9	417.8	557.1
December2018 to, May, 2019	Chickpea	326.2	335.0	446.7
	Garlic	636.4	685.7	914.2
	Onion	669.7	Not cultivated	967.4
	Watermelon	432.4	458.6	611.5

Generally, the above table shows us that based on CROPWAT 8.0, the values of crop water demand depended on the climatic data available and it varies from season to season, and the net irrigation requirement of each cultivated crop was estimated and it also depended on methods of irrigation practice. Based on FAO guidelines the indicative value of field application efficiencies of drip and furrow irrigation is 80 % and 40 % respectively and the research area has experimented application efficiencies that was approximately similar with FAO guideline.

On the basis of the calculated applied water and irrigation water requirement resulting from the CROPWAT 8.0 was shown in the next table 7, there was a scarce of water in the cultivated crops like, chickpea, garlic, and onion in the scheme. However, the crops irrigated with drip irrigation system have a minimum percentage of deficits relative to furrow irrigated crops in the field. But, in the case of watermelon there was excess water at both drip and furrow irrigation systems in the scheme. So, this research was addressed percent of exceeded and deficit irrigation in the Hormat-Golina irrigation scheme, which used to balance the demand and supply of irrigation water in the scheme.

Crop water productivity of drip and furrow irrigation system at Hormat-Golina small scale irrigation scheme (HSSIS)

Determination of crop yield at the scheme

The yield of each crops that practice with drip and furrow irrigation systems were calculated separately and the data included two irrigation seasons. The first irrigation season was covered from, December 2017 to, May 2018 and the second irrigation season also from, December 2018 to, May 2019 was covered. Based on the information from Kobo woreda agriculture office and responded local farmers the average crop yield per unit hectare of irrigated land for the cultivated crops in the scheme was collected as secondary data. The reason that average yield under drip irrigation system is more than furrow irrigation system, because the soil water moisture is retained for long time due to dripping rather than furrowing.

Table 7. Applied water used and irrigation water requirement from CROPWAT 8.0

Irrigation Seasons	Crops	Method	Applied irrigation (mm/season)	Gross irrigation requirement (mm/season)	Water saved by drip (%)
	chickpea	Drip	250.6	328.7	41.2
		Furrow	426.4	438.2	
	garlic	Drip	485.5	592.6	
		Furrow	non	non	non
Dec,2017 to May,2018	onion	Drip	563.8	635.9	32.6
		Furrow	836.4	847.8	
	watermelon	Drip	579.4	417.8	26.4
		Furrow	787.2	557.1	
	chickpea	Drip	237.0	335.0	46.4
		Furrow	442.4	446.7	
	garlic	Drip	504.6	685.7	39.7
		Furrow	837.2	914.2	
Dec,2018 to May,2019	onion	Drip	non	non	non
		Furrow	853.2	967.4	
	watermelon	Drip	565.7	458.6	32.4
		Furrow	837.4	611.5	

Table 8. The estimated crop yield of drip and furrow irrigation methods in the scheme

Methods		Drip irrigation			Furrow irrigation		
Irrigation season	**Crop:**	**Yi.ave (qt/ha)**	**Area (ha)**	**Yield (kg)**	**Yi.ave (qt/ha)**	**Area (ha)**	**Yield (kg)**
Dec,2017 to May,2018	chickpea	30	24	72000	22	25	55000
	Garlic	50	3	15000	-	-	-
	onion	60	18	108000	55	20	110000
	watermelon	130	3	39000	120	5	60000
	Total		48	234000		50	225000
Dec,2018 to May,2019	chickpea	28	36	100800	21	22	46200
	Garlic	52	6	31200	48	3	14400
	onion	-	-	-	55	23	126500
	watermelon	130	6	78000	120	2	24000
	Total		48	210000		50	211100

The total product of the crops in the season of, December 2017 to, May 2018 from drip irrigation method was determined as 2340 quintal or 234 ton over 48 hectares of irrigated land. In the same irrigation season, product of the crops from furrow irrigation method estimated as 2250 quintal or 225 ton over 50 hectare of irrigated land. Similarly, at the season of, December 2018 to, May 2019 the total yield of the crops from drip irrigation system was 2100 quintal or 210 ton over 48 hectare and from furrow irrigation method also determined as 2111 quintal or 211.1 ton over 50 hectares of irrigated land.

The crop water productivity (CWP) of drip and furrow irrigation was estimated. The estimated crop water productivity (CWP) of drip and furrow irrigation systems in the Hormat-Golina irrigation scheme was vary with different irrigation seasons. In the season of, December 2017 to, May 2018, the crop water productivity of drip irrigation system for the crop of chickpea, garlic, onion, and watermelon was estimated as 1.53, 1.02, 1.06 and 2.24 kg/m^3 respectively, and also with the method of furrow irrigation the crop water productivity was resulted as 0.52, 0.66, and 1.52 kg/m^3 for chickpea, onion and watermelon respectively. This value indicates that the crop water productivity of drip irrigation system is more than furrow irrigation system.

Table 9. The Calculated crop water productivity of both irrigation systems at the scheme

Irrigation seasons		Dec 2017 – ,May 2018		,Dec 218 – May 2019	
Crops:	Method	CWP (kg/m³)	CWP % by drip	CWP (kg/m³)	CWP % by drip
Chickpea	Drip	1.53	66.01	1.18	39.83
	Furrow	0.52		0.47	
Garlic	Drip	1.02		1.03	55.34
	Furrow	Non		0.57	
Onion	Drip	1.06	37.74	Non	
	Furrow	0.66		0.64	
Watermelon	Drip	2.24	32.14	2.29	62.45
	Furrow	1.52		1.43	

Table 10. Gross value of crop product of drip and furrow irrigation system at the scheme

Methods of irrigation			**Drip**		**Furrow**	
Irrigation seasons	**Cultivated crops**	**Price (birr/kg)**	**Yield (kg)**	**GVP (birr)**	**Yield (kg)**	**GVP (birr)**
Dec, 2017 to May,2018	Chickpea	8.5	72000	612000	55000	467500
	Garlic	35	15000	525000	Non	Non
	Onion	11	108000	1188000	110000	1210000
	Watermelon	15	39000	585000	60000	900000
Dec, 2018 to May,2019	Chickpea	10.5	100800	1058400	46200	485100
	Garlic	40	31200	1248000	14400	576000
	Onion	14.5	Non	Non	126500	1834250
	Watermelon	22	78000	1716000	24000	528000

For the season of, December 2018 to, May 2019, the crop water productivity of drip irrigation system was calculated as 1.18, 1.03, and 2.29 kg/m^3 for the crops chickpea, garlic, and watermelon respectively, in the same manner with the method of furrow irrigation system estimated as 0.47, 0.57, 0.64 and 1.43 kg/m^3 for chickpea, garlic, onion, and watermelon respectively. These values also indicates that drip irrigation system again beyond furrow irrigation system.

Economic water productivity of drip and furrow irrigation system

Determination of gross value of crop product at the scheme

The gross value of crop product depend on the yield and seasonal local market price of the crop that grown on the scheme.

Determination of total cost of crop production at the scheme

The total cost of crop production in the Hormat-Golina irrigation scheme were includes, cost of seed, cost of fertilizer, cost of spray, labor cost (land preparation, lateral layout, weeding removing and harvesting cost), cost of transport, and pumping cost but not includes installation cost. The components of irrigation system allows us to determine the total cost per unit hectare of irrigated land (Hogan et al., 2011). However, this cost is not including irrigation installation cost. Finally, the economic water productivity (EWP) was calculated by multiplying beneficial biomass and the market price minus the total production costs and allover divided by irrigation water used in the schemes.

Table 11. Total cost for chickpea and garlic with drip and furrow irrigation on, December 2017-, May 2018

Methods of irrigation		Drip	Furrow
	Cultivated crops	**Total cost (Birr)**	**Total cost (Birr)**
Dec,2017 to May, 2018	Chickpea	53117.00	56744.00
	Garlic	9442.26	Not cultivated
	Onion	50522.26	64118.00
	Watermelon	10354.00	13011.31
Dec,2018 to May, 2019	Chickpea	80184.53	67172.23
	Garlic	15797.00	14614.05
	Onion	Not cultivated	9021.38
	Watermelon	14805.74	16697.20

Table 12. The economic water productivity of drip and furrow irrigation system at the scheme

Season	crops:	Method	water used (m^3)	Net Income (Birr)	EWP (Birr/m3)	EWP ($/m3)	EWP by drip (%)
Dec, 2017 to May, 2018	Chickpea	Drip	60134.40	558882.26	9.29	0.34	58.54
		Furrow	106600.00	410755.52	3.85	0.14	
	Garlic	Drip	14563.80	515557.84	35.40	1.29	
		Furrow	non	non	-	-	
	Onion	Drip	101476.80	1137477.74	11.21	0.41	38.89
		Furrow	167280.00	1145882.14	6.85	0.25	
	Watermelon	Drip	17382.60	574646.03	33.06	1.20	31.83
		Furrow	39360.00	886988.69	22.54	0.82	
Dec, 2018 to May, 2019	Chickpea	Drip	85318.20	978215.47	11.47	0.40	62.55
		Furrow	97328.00	417927.68	4.29	0.15	
	Garlic	Drip	30274.20	1232203.00	40.70	1.41	45.10
		Furrow	25122.00	561385.95	22.35	0.77	
	Onion	Drip	non	non	----	----	
		Furrow	196236.00	1744030.63	8.89	0.31	
	Watermelon	Drip	33943.80	1701194.26	50.12	1.74	39.09
		furrow	16748.00	511302.80	30.53	1.06	

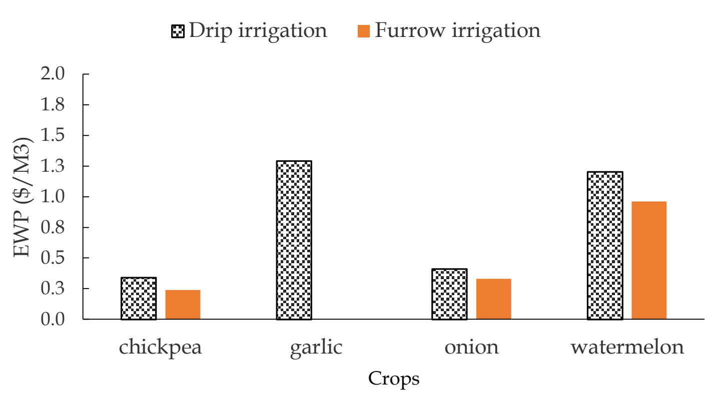

Figure 2. Economic water productivity in Dec, 2017 to May 2018

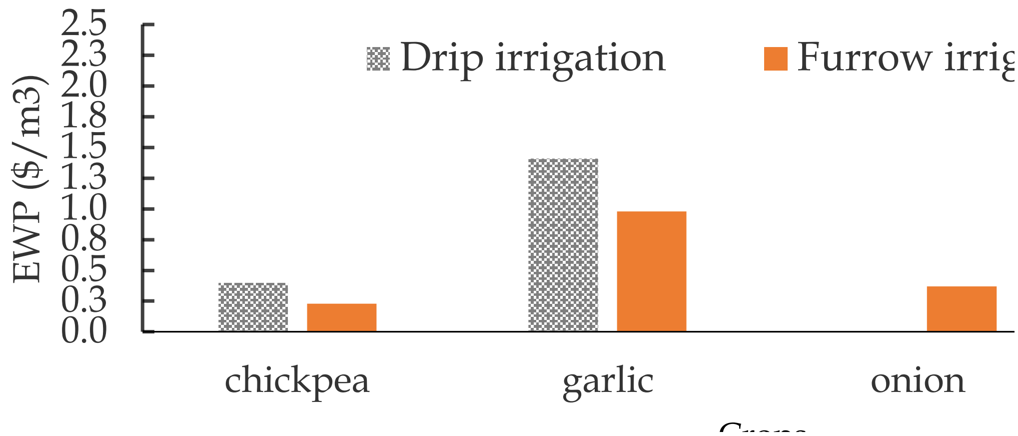

Figure 3. Economic water productivity in Dec 2018 to May 2019

The economic water productivity for drip irrigation system in the season Dec, 2017 to May, 2018 was estimated as 0.34, 1.29, 0.41 and 1.20 $/m3 for chickpea, garlic, onion, and watermelon respectively; and also in the season, Dec 2018 to, May 2019 it was calculated as 0.4, 1.41 and 1.74 $/m3 for chickpea, garlic, and watermelon respectively. In addition, the economic water productivity for furrow irrigation system in the season, Dec 2017 to, May 2018, was evaluated as 0.14, 0.25 and 0.85 $/m3 for chickpea, onion, and watermelon respectively; and also in the season Dec, 2018 to May, 2019 it was estimated as 0.15, 0.77, 0.31 and 1.06 $/m3 for chickpea, garlic, onion, and watermelon respectively. Generally, the evaluated economic water productivity of the study area under drip irrigation practice was higher than furrow. The reason that drip irrigation practice wisely uses of available water and no land loss due to filed channels. For more information we can show that in the above chart. Based on aforementioned reason in the previous section of this document and the limited water used and higher average crop yield under drip irrigation system, the economic water productivity value is higher than furrowing practice. So this system is advisable rather than furrow irrigation methods at the scheme of this study area (Hormat-Golina irrigation scheme).

CONCLUSIONS

Water productivity evaluation of the scheme was shown as to give re-medial measures of the problems of the scheme. The crop water productivity and economic water productivity evaluation of drip and furrow irrigation system was essential to provide suitable irrigation practice and to implement the system at the scheme. The drip irrigation system again beyond furrow irrigation system with a percent of crop water productivity 37.29 %, 30.10 % and 23.14 % for the crops chickpea, garlic, and watermelon respectively in the scheme. The values of crop water productivity for drip and furrow irrigation system for cereal crops within the range from 0.72 to 1.78 kg/m^3.

The economic water productivity for drip irrigation system in the season, Dec 2017 to, May 2018 was estimated as 0.34, 1.29, 0.41 and 1.20 $/m3 for chickpea, garlic, onion, and watermelon respectively; and also in the season, Dec 2018 to, May 2019 it was calculated as 0.4, 1.41 and 1.74 $/m3 for chickpea, garlic, and watermelon respectively. In addition, the economic water productivity for furrow irrigation system in the season, Dec 2017 to, May 2018, was evaluated as 0.14, 0.25 and 0.85 $/m3 for chickpea, onion, and watermelon respectively; and also in the season Dec, 2018 to May, 2019 it was estimated as 0.15, 0.77, 0.31 and 1.06 $/m3 for chickpea, garlic, onion, and watermelon respectively. A range of CWP and EWP values for both irrigation methods, which may be caused by so many factors that influence soil–water–plant relationship, including time (growth stage at which stress was imposed), sequence of water stress. Considerable variations in CWP and EWP values are observed not only for different irrigation methods but also for the same irrigation system with different season. Therefore, it is recommended that crop production in the study area should be increased and expanded to satisfy the wider regional market demand; farmers should have gain continuous training and extension services that given by the respective stakeholders.

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