Original Research Article

Evaluating the Irrigation Practice of Center Pivot Sprinkler Irrigation System at Hiwot Agricultural Mechanization, Ethiopia

ABSTRACT

Irrigation practice evaluation of center pivot sprinkler irrigation system at Hiwot Agricultural Mechanization farm, North/west Ethiopia was conducted. The aim of the study was evaluating the existing center pivot irrigation practice in terms of irrigation scheduling. Measuring flow rate of center pivot machines for existing irrigation practice and Crop water requirement based scheduling was used to evaluate the system. The highest value of crop water requirement at location m6, m7 and m12 was 5.24 mm/day in September at mid-stage and for location m4 and m8 in October at mid-stage equal to 4.99 mm/day. Whereas, the lowest crop water requirement at location m6, m7 and m12 was 2.52 mm/day in July at the initial stage which was and for location m4 and m8 in august at initial stage equal to 2.08 mm/day. The actual flow rate of center pivot machines varies from 0.7l/s for m7 to a maximum of 1l/s for m4 whereas estimated crop water requirement flow rate varies from 0.6l/s for m6 to a maximum of 0.8l/s for m4. Based on the study the actual flow rate of the nozzles was higher for the tested machines as compared to the required flow rate which has been estimated by crop water requirement, which creates excess runoff. Therefore Sustainable use of center pivot sprinkler irrigation system could be achieved by adjusting application depth as per crop water requirement of each stage crop growth using appropriate scheduling and by making functional the automatic control system.

Keywords: *Irrigation practice, Center pivot, Irrigation scheduling, Crop water requirement*

1. INTRODUCTION

CROPWAT is a computer program for irrigation planning and management, developed by the land water development division of FAO.Its basic functions include the calculation of reference evapotranspiration, crop water requirements and scheme irrigation. Though a daily water balance, the user can simulate various water supply conditions and estimate yield reductions and irrigation and rainfall efficiencies(1).

FAO-56 Penman-Monteith method was used by(2) for estimation of ETo for different center pivot machines. Crop water requirement is estimated using ETo values. Water requirement of crops under the command area of Hiwot agricultural mechanization was estimated by(3).

Cotton (Gossypium hirsutum L.) is an important row crop in Ethiopia. Ethiopia annually produces approximately 120,000 tons of cotton (Central Statistics Agency). Much of the cotton production in Ethiopia is from small-scale farmers, who cultivate about 39,600 hectares annually. The total area under cotton plantation by the private-owned enterprises is 54,000 hectares.

Hiwot Agricultural Mechanization (HAM) PLC is a private company established in 1999 and envisioned to excel in agribusiness through mechanized farming methods. HAM has been engaged in the production of industrial crops like cotton and sesame using mechanized farming system. Currently, the company is implementing a modern center pivot irrigation projects chosen based on its merits in meeting the growing market demand for agricultural products. Within the strategies to improve cotton yield, irrigation scheduling is an important management practice that can help to obtain high yield (4).

Therefore, the study was proposed and executed with Specific objective of evaluating the existing irrigation practice of the center pivot (CP) sprinkler irrigation system in terms of irrigation scheduling.

2. RESEARCH METHODOLOGY

2.1 Description of study area

The experiment was conducted at Hiwot agricultural mechanization (HAM) which is found in Northwest Ethiopia.

HAM is located at a distance of 1350 km from Addis Ababa. The average elevation is about 673 m.a.s.l and it lies between 13°16'30" and 13°50'30"N latitude and 36°36'30" and 37°44'30" E Longitude. The water source for the irrigation system is from the Kaza River which is found in the Tekeze basin.

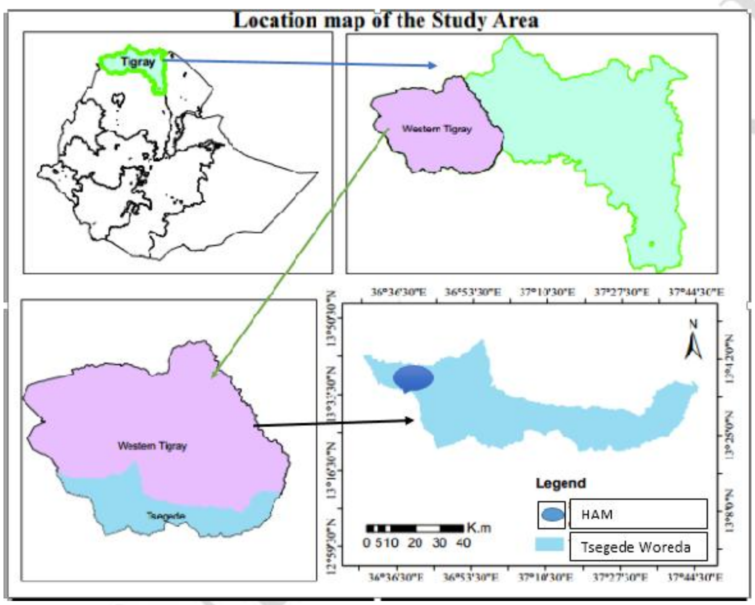

Figure 1.study area map (Prepared by Kasa m. and Pratap s.)

2.2 Sample size and technique

There were about 32 center pivot machines to irrigate 1730 hectare of land. The area to be irrigated by different CP sprinkler irrigation machines varied from 20 to 70 ha. For this study only five machines were used because these were only under operation for the season, those were m4 (50ha), m6 (30ha), m7 (40ha), m8 (50ha) and m12 (60ha). The machines used for the study included almost machines of all sizes.

2.3 Estimation of Crop Water Requirement

Reference crop evapotranspiration was estimated by using CROPWAT 8.0 software based on the formula of the Penman-Monteith method.

$$ETo = \frac{0.408\Delta(Rn-G)+\gamma\frac{900}{T+273}U2(es-ea)}{\Delta+\gamma(1+0.34U2)} \quad \ldots\ldots\ldots\ldots\ldots\ldots1$$

Where: ETO = reference crop evapotranspiration, mm day^{-1}; Rn= net radiation at the crop surface, MJ $m^{-2}d^{-1}$;

G = soil heat flux density, MJ $m^{-2}d^{-1}$; T = mean daily air temperature at 2 m height, °C;

U2= wind speed at 2 m height, m s^{-1}; es = saturation vapor pressure, kPa;

ea = actual vapor pressure, kPa; es- ea= saturation vapor pressure deficit, kPa;

Δ = slope of the vapor pressure curve, a $°C^{-1}$; γ= psychometric constant, kPa $°C^{-1}$

The monthly values of reference crop evapotranspiration (ETo) were estimated from CROPWAT 8 software using mean monthly values of climatic data. The dominant crops grown in the region was cotton. The crop water requirement for cotton crop was estimated from ET0 and crop coefficient (Kc) expressed as follows(5).

$$ETc = Kc \times ETo \quad \text{---------------------------------------}2$$

Where:

ETc = crop water requirement in mm per unit of time

Kc= crop coefficient

ETo = reference crop evapotranspiration, in mm per unit time

Also, gross depth of irrigation, net application depth per growing stage and effective rainfall were estimated from CROPWAT 8.0 software.

2.2.1 Net irrigation requirement

Net irrigation water requirement for the crop is the depth of water, which is exclusive of other water sources, such as effective precipitation, groundwater contribution.

The actual net irrigation water requirement of the study area was estimated using the method outlined by (6) for each month.

NIR = ETc- Pe- Gw--3

Where NIR is the net irrigation water requirement of the crop, Pe is effective rainfall, and GW is groundwater contribution. However, the effect of groundwater contribution was assumed zero.

2.2.2 Irrigation interval

Irrigation interval is the frequency of applying irrigation water. The actual irrigation interval of the study area was determined for each month, growth stages, using equation 4.

$$I(days) = \frac{\text{net application depth(mm)}}{\text{crop water requirement}(\frac{mm}{day})} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots4$$

3. RESULTS AND DISCUSSION

3.1Soil physical properties

Table 1. Soil physical properties result

		parameters										
		FC (%) soil sample depth(cm)				PWP (%) soil sample depth(cm)				TAW (%)	Bulk density g cm-3	soil texture
s/n	sites	0-30	30-60	60-90	Average	0-30	30-60	60-90	Average			
1	m4	42.66	43.12	44.98	43.59	28.69	27.99	35.69	30.8	12.80	1.2	clay loam
2	m6	42.5	43.5	44.2	43.40	28.3	28.5	33	29.9	13.47	1.1	clay loam
3	m7	43.1	42.9	43.8	43.27	29	27.2	33.4	29.9	13.40	1.2	clay loam
4	m8	42.91	43.4	44.1	43.47	27.6	28.4	31	29.0	14.47	1.2	clay loam
5	m12	43.1	43.7	43.6	43.47	28.1	29	32.2	29.8	13.70	1.1	clay loam
	Average									13.57	1.15	

3.2 Crop water requirement and scheduling

Crop water requirement, net irrigation requirement, gross irrigation requirement, and irrigation interval were estimated for cotton crop for different crop growth stages such as initial, development, mid and late using CROPWAT software. The cotton crop at location m4 and m8 was sown on July 24, 2016, whereas at location m6, m7and m12 the crop was sown on August 11, 2016. The duration for different crop growth stage periods were as follows.

Crop growth stage	initial	Development	Mid-season	Late season
Duration in days	20	20	60	40

Table 2.Stage wise cotton crop growing period

The required flow rate, daily crop water requirement was estimated for cotton crop using CROPWAT 8.o software. But the actual applied water was beyond the required which leads to unnecessary losses.

The estimated daily ETo and ER (effective rainfall) values on a monthly bases are shown in Figure 2. The ER was excess than ETo for July and August months only.

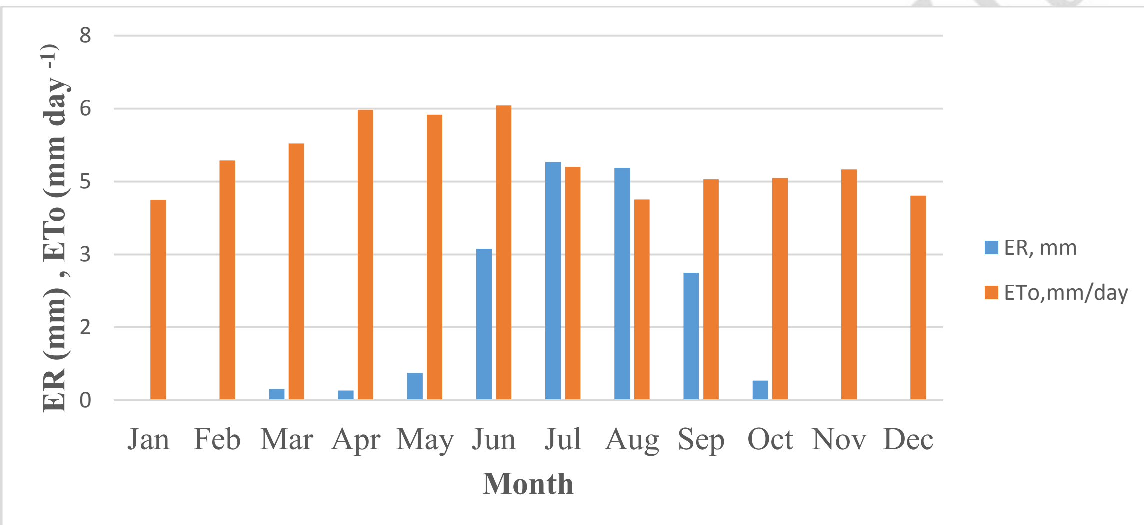

Figure 2.The monthly variation of ETo and effective rainfall

The actual flow rate of the nozzles was excess in all of the test machines as compared to the required flow rate which has been estimated by crop water requirement as given in table3. Statistically, there is a significant difference among all test machines for actual flow rate and estimated CWR flow rate for ($P<0.05$).

Table 3.Required nozzle flow rate and actual flow rate

CP machines	CWR, l/s	Actual flow rate l/s
m6	0.6	0.8
m12	0.7	0.9
m4	0.8	1
m8	0.75	0.87
m7	0.65	0.7
P-value	*0.01*	

The daily effective rainfall for initial and development stages was higher as compared with crop water requirement for location m6, m7 and m12, hence no irrigation was required (Table 4).

The irrigation interval varied from 1 day to 1.7 days depending on each stage of growth. The irrigation interval for initial and development stages was zero as no irrigation was required during these stages (Table 4).

The daily effective rainfall for the initial stage at locations m4 and m8 was higher as compared with crop water requirement, hence no irrigation was required during the initial stage (Table 5). The irrigation interval varied from 1.1 days up to 1.6 days for different stages of growth. There was no irrigation required for initial stage hence the irrigation interval was zero (Table 5).

Table 4.Crop water requirement and irrigation interval for m6, m7and m12

Month	Decade	Stage	ETc	Eff rain	Net IRR. Req.	Gross Irrg. Req.	Irrigation interval
			mm/day	mm/day	mm/day	mm/day	day
Jul	3	Init	2.52	3.11	0	0	0
Aug	1	Init	2.31	4.92	0	0	0
Aug	2	Deve	2.68	5.38	0	0	0
Aug	3	Deve	4.3	4.03	0.7	1.11	0
Sep	1	Mid	5.24	2.28	2.96	4.7	0.9
Sep	2	Mid	5.15	1.03	4.11	6.52	1.3
Sep	3	Mid	5.03	0.69	4.34	6.89	1.4
Oct	1	Mid	4.92	0.01	4.9	7.78	1.6
Oct	2	Mid	4.8	0	4.8	7.62	1.6
Oct	3	Mid	4.53	0	4.98	7.9	1.7
Nov	1	Late	4.12	0	4.12	6.54	1.6
Nov	2	Late	3.62	0	3.62	5.75	1.6
Nov	3	Late	3.33	0	3.33	5.29	1.6
Dec	1	Late	3.04	0	3.04	4.83	1.6

Table 5.Crop water requirement and irrigation interval for m4 and m8

Month	Decade	Stage	ETc	Eff rain	Net IRR. Req.	Gross Irrg. Req.	Irrigation interval
			mm/day	mm/day	mm/day	mm/day	day
Aug	2	Init	2.1	5.38	0	0	0
Aug	3	Init	2.08	4.03	0	0	0
Sep	1	Deve	2.35	2.28	0.06	0.09	0
Sep	2	Deve	3.5	1.03	2.47	3.69	1.1
Sep	3	Mid	4.66	0.69	3.97	5.93	1.3
Oct	1	Mid	4.99	0.01	4.98	7.43	1.5
Oct	2	Mid	4.87	0	4.87	7.27	1.5
Oct	3	Mid	4.6	0	5.06	7.55	1.6
Nov	1	Mid	4.32	0	4.32	6.45	1.5
Nov	2	Mid	4.05	0	4.05	6.04	1.5
Nov	3	Late	3.98	0	3.98	5.94	1.5
Dec	1	Late	3.75	0	3.75	5.6	1.5
Dec	2	Late	3.46	0	3.46	5.16	1.5
Dec	3	Late	3.27	0	3.6	5.37	1.6
Jan	1	Late	3.06	0	2.14	3.19	1

The highest value of crop water requirement at location m6, m7 and m12 was 5.24 mm/day in September at mid-stage and for location m4 and m8 in October at mid-stage equal to 4.99 mm/day. Whereas, the lowest crop water requirement at location m6, m7 and m12 was 2.52 mm/day in July at the initial stage which was and for location m4 and m8 in august at initial stage equal to 2.08 mm/day.

Likewise(8) investigated that the variation of water need for cotton crop is dependent on cultivar, length of growing season, temperature, sunshine hours, the amount & distribution of rainfall and the characteristics of soil. The dynamics of water use pattern for cotton (with 160 days duration) shows that with the advancement in crop growth, the water use increases progressively from 2.5 mm/day in seedling stage, 2.5 to 6.2 mm/day from squaring to first bloom, and goes to a maximum of 6.2 to 10 mm/day in peak flowering and decreases to 5.1 mm/day thereafter during boll development and falls below 2.0 mm/day during boll bursting stage.

The net irrigation water requirement of Dp 90 cotton variety for the m4 and m8 experimental site estimated using CROPWAT8 software was 467 mm. This amount includes the assumption of 75% of existing irrigation efficiency.
The net irrigation water requirement of Dp 90 cotton variety for the m6, m7 and m12 experimental site estimated using CROPWAT8 software was 409 mm. This amount includes the assumption of 75% of existing irrigation efficiency.

4. CONCLUSIONS AND RECOMMENDATIONS

Evaluation of irrigation practice for center pivot sprinkler irrigation is the best method to know the status of irrigation system.

The system can operate under different rotational speeds. This makes it flexible to be changed according to the crop water requirements.

According to the study the actual flow rate of the nozzles was higher for the tested machines as compared to the required flow rate which has been estimated by crop water requirement, which creates excess runoff.

Sustainable use of center pivot sprinkler irrigation system can be achieved by adjusting application depth as per crop water requirement of each stage crop growth using appropriate scheduling and by making functional the automatic control system. Regular checkup for all the systems must be adopted to enhance the uniformity of water application. The sprinkler nozzles should be also checked for blockages, wear and tear, and application rates.

Conflicts of Interest. The authors declare no conflict of interest.

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