Ecology and Evolutionary Biology
2024, Vol. 9, No. 4, pp. 106-110
https://doi.org/10.11648/j.eeb.20240904.13

Research Article

Determination of Optimum Irrigation Water Requirement of Wheat at Sayo District, Kellem Wollega, Oromia

Tamasgen Mosisa[1,*], Wegene Negese[2], Bedada Yadete[1]

[1]Irrigation and Drainage Engineering and Water Harvesting Research Team, Haro Sabu Agricultural Research Center of Oromia Agricultural Research Institute, Finfinne, Ethiopia

[2]Soil Fertility Improvement Research Team, Haro Sabu Agricultural Research Center of Oromia Agricultural Research Institute, Finfinne, Ethiopia

Abstract

Ethiopia needs 70-80 million quintals of wheat to feed 110 million people, but imports are a significant deficit. The government has implemented food and wheat security measures, including yield gap closure, area expansions, and irrigation. Wheat is a strategic commodity for Ethiopia's food security, agroindustry, import substitution, and job creation. An experiment was conducted at Dambi Dollo University campus in Sayo District, Kellem Wollega Zone, to determine wheat irrigation water demand. The study evaluated five irrigation depths in wheat cultivation, using soil parameters, meteorological data, and crop characteristics. The results showed that 90% of the net water requirement of wheat is optimal for normal physiological activities, including evapotranspiration and metabolic activities. The saved water, 10% of the total 191.9 mm, can be used to irrigate more command areas and prevent abandonment. The water productivity value of irrigated wheat is within the range of previous findings, and the average wheat yield is improved under irrigation conditions even in Ethiopia. The efficiency parameters (GY, WUE, and WP) generally perform significantly. The study recommends extension services to demonstrate this finding on farmers' fields for further evaluation and popularization, and Zonal/District Agricultural Offices to use this 172.71 mm to sustainably boost irrigated wheat production.

Keywords

Wheat, Irrigation, Water Productivity, WUE, Grain Yield, Deficit

1. Introduction

In Ethiopia, an individual consumes 70-80kg annually [1]. As such, 70 – 80 million quintals of wheat are needed to feed 110 million people when the Wheat production through Irrigation is initiated. A deficit of 12 – 17 million quintals imported from abroad annually [2]. About USD 700 million per year is spent to counterbalance the demand–supply gap. This incurs the limited hard currency earned by the country.

The government of Ethiopia introduced yield gap closure of demand and supply, area expansions, and irrigation as a strategy to ensure food and wheat security [3]. The yield gap closure and irrigation are likely to play a significant role in bridging the gap between demand and supply. Scientists

*Corresponding author: tamasgenmk@gmail.com (Tamasgen Mosisa)

Received: 16 October 2024; **Accepted:** 15 November 2024; **Published:** 29 November 2024

consistently agree on the fact that the Ethiopian wheat trade imbalance is unbearably negative, while the nation has unexploited potential for wheat production either through irrigation or a rain-fed system [2].

Most African countries – where agricultural practice is mainly dependent on rainwater – have only one growing season, and farmers have thus been vulnerable to erratic rainfall patterns and droughts that result in low yields and income [4-6].

Irrigated wheat through efficient use of water resources and the development of irrigation schemes and efficient irrigation technologies is very important. The current government of Ethiopia put in place structural, economic and sectorial reforms in 2019, with Wheat chosen as a strategic commodity for food security, raw material for the agroindustry, import substitution that transits to export, and job creation along the value chain [2].

The government started implementing this irrigated wheat initiative as a campaign where wheat production via irrigation was not common. Information regarding irrigated wheat – when to irrigate and how much water to apply – needs to be availed to sustain the initiative. This experiment was, therefore, carefully designed to determine the wheat irrigation water demand.

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted in the Dambi Dollo University campus (in Sayo District of Kellem Wollega Zone). The experimental site was located in the agro-ecological zone (AEZ) that lies at $8^0$32'59"N Latitude and $34^0$50'50"E Longitude. The elevation of the experimental site was 1561 m above mean sea level. The soil was acidic, textural class of clay loam. The organic matter content was 4.49.

2.2. Experimental Treatment and Design

Five irrigation depths (70%, 80%, 90%, 100% and 110% of ET_c) were selected to be evaluated. The experiment was designed in 'Randomized Complete Block Design' with three times replication. Important parameters of soil data for the model input were tested. The basic infiltration rate was identified. Secondary data of meteorology (solar radiation, minimum and maximum air temperatures, humidity and wind speed) were used. Crop characteristics (root depth, growth period, critical depletion) were used from FAO guidelines [7].

FAO CROPWAT 8 was employed to compute evapotranspiration based on the crop characteristics, soil properties, and weather conditions [7, 8]. The result obtained from this computer program/model was used as a benchmark (100% ET_c).

A three-inch Parshall Flume was used to measure water depth [9], from where discharge, (l/s) is determined (1mm depth is equivalent to a discharge of 1l/s). A conventional furrow irrigation method (all furrows at a time) was used to irrigate the field.

A double-line plantation per ridge (Figure 1) was used in order to maintain plant spacing; it's commonly practiced in irrigated wheat. The variety used was *Ogolcho*. All agronomic requirements such as 100 kg/ha NPS and 150 kg/ha UREA fertilizer were uniformly applied for all treatments.

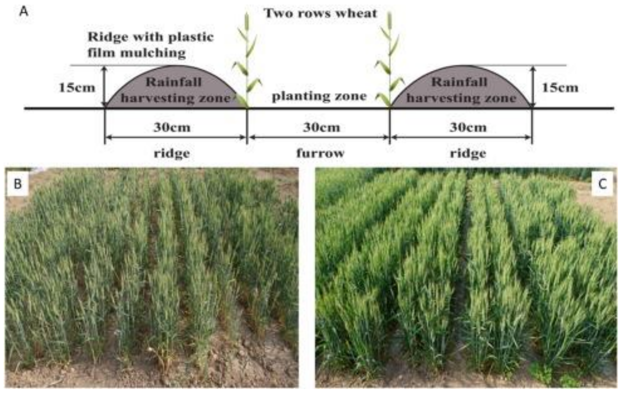

Figure 1. *Furrow irrigated wheat.*

2.3. Input Data

Depth of water applied, irrigation date, soil infiltration rate, some soil physical properties (before planting), soil moisture (before and after irrigation) were collected. In order to assess the effect of treatments on crop yield, the yield and yield-related data of wheat were collected from central ridges only for the sake of avoiding border effects. The results of the yields were then weighed, averaged and converted onto a hectare basis for estimation of yield per hectare.

Water productivity (kg/m^3) along with other performance evaluation parameters (yield and water use efficiencies) were used to judge the optimum crop water requirement.

2.4. Statistical Analysis

The data was subjected to analysis of variance (ANOVA) and analyzed by SAS V.9 [10, 11]. Fisher's LSD was used for mean comparison at P<0.05 significance level following standard procedure [3]. Based on the meteorological data, the experiment was executed during the dry season (Nov – Feb.).

3. Result and Discussion

Table 1. Soil test result of the study site.

Parameter	pH	OC	OM	TN	CEC	Clay (%)	Silt (%)	Sand (%)	Texture
Value	5.79	2.61	4.49	0.22	32.06	39	30	31	Clay loam

Derived information of the soil is filled from the "Soil Water Characteristics" tool – the 'SPAW Hydrology' [12]. The FC and PWP were 38 and 24.5% respectively. The compaction level of the soil is normal (not loose, not dense) as the bulk density is 1.31 gm/cm^3 [13].

Table 2. Soil attributes derived from SPAW Hydrology.

Parameter	PWP (%)	FC (%)	Saturation (%)	Bulk Density (gm/cm^3)
Value	24.5	38	47.8	1.39

FC = Field Capacity, PWP = Permanent Wilting Point.

This soil parameters of the surface, crop root depth layer (60 cm depth) has such results, which was directly consumed for the CROPWAT Model to compute the crop water need.

Table 3. Year 2014 – 2015 (over-year) data analysis result.

Water level	SL (cm)	TGW	BY (t/ha)	GY (qt/ha)	IWUE	CWP (kg/m^3)
70%	8.65^{c}	32	22.13	30.83^{b}	16.08^{b}	2.21^{a}
80%	8.75^{bc}	31.2	21.15	33.72^{ab}	17.57^{ab}	2.20^{a}
90%	9.42^{a}	31.6	21.80	39.75^{a}	20.71^{a}	2.30^{a}
100%	9.20^{ab}	31.2	21.53	39.81^{a}	20.75^{a}	2.08^{a}
110%	8.93^{abc}	34.9	24.33	27.72^{b}	14.45^{b}	1.31^{b}
$LSD_{0.05}$	0.54	3.85	3.53	6.47	3.37	0.37
CV	5.08	10.1	13.40	15.83	15.83	15.45

SL=spike length, TGW= thousand grain weight, BY= biomass yield, and GY= grain yield, IWUE = Irrigation Water Use Efficiency, CWP = Crop Water Productivity

The model output was 274.1 mm gross irrigation with 210.8 mm effective rainfall where the total net irrigation is 191.9 mm. The efficiency (IWUE) and productivity (GY) parameters show that the 90% ETc (net) is optimum. Spike length may directly be contributed for this yield advantage.

The saved water (10%) can be used to irrigate more command area; hence offers an opportunity for sustaining wheat production with 10% less water than the crop water need computed by the CROPWAT Model. Besides irrigating more command area, the saved water can save the area under cultivation from abandoning as the irrigation water is harmful regardless of its quality. The ninety percent (90%) of the net ET_c at the context of the study site was 172.71 mm, whereas it ranges from 214.8 mm – 251.4 mm in Pakistan [14]. This difference might be due to the weather conditions as this study site is humid, with low wind speed.

The Water Productivity value of irrigated wheat ranges from 0.6 – 1.7 kg/m^3 [14]; and is from 1.47 – 2.93 kg/m^3 [15]. Therefore, this result (1.48 – 2.65 kg/m^3) shows the productivity (WP) is within the range of the previous findings; which agrees particularly with the recent study.

The average wheat yield was 2.4 tons/hectare in 2012-13 under rain-fed conditions [16]. Wheat yields are 3.0 t/ha in Kenya and 3.5 t/ha in South Africa [17]. However, one can conclude from the above table that production is improved (3.98 t/ha) under irrigation conditions even in Ethiopia, which is comparable with the neighboring countries.

4. Conclusion and Recommendation

From the result, one can conclude that 90% of the net water requirement of wheat already computed by the CROPWAT Model (191.9mm) is optimum for carrying out normal physiological activities of the crop; the quantity of water required to meet the demands of evapotranspiration and the metabolic activities i.e., consumptive use (CU) of the crop. At this point, the efficiency parameters (GY, WUE and WP) generally perform significantly.

This shows that 10% of the net irrigation water (19.19 mm out of the total 191.9 mm) is saved while yield is insignificantly penalized at the 5% significance level. It is better if the extension services demonstrate this finding on the farmers' field for further evaluation and popularization. Zonal/District Agricultural Offices of similar agro-ecologies are advised to use this 172.71 mm to sustainably boost the irrigated wheat production initiative.

Abbreviations

AEZ	Agro-Ecological Zones
CU	Consumptive Use
FAO	Food and Agriculture Organization of the UN
GY	Grain Yield
IQQO	Oromia Agricultural Research Institute
IWUE	Irrigation Water Use Efficiency
LSD	Least Significant Difference
SAS	Statistical Analysis System
SPAW	Soil, Plant, Atmosphere, Water
WP	Water Productivity
WUE	Water Use Efficiency

Acknowledgments

For his commitment to carrying out the trial and field management, we are grateful to Mr. Kebbena Blude. We also thank the Agricultural Engineering Directorate of the Institute (IQQO) and the Haro Sabu Agricultural Research Centre for administering this activity. Besides, Nekemte Soil Research Center is duly acknowledged for analyzing soil samples. Finally, we would like to thank the review team for their effort on this task for publishing.

Author Contributions

Tamasgen Mosisa: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Visualization, Writing – original draft, Writing – review & editing

Wegene Negese: Formal Analysis, Software, Visualization

Bedada Yadete: Data curation, Investigation, Supervision, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Senbeta, A. F. and Worku, W. (2023) 'Ethiopia's wheat production pathways to self-sufficiency through land area expansion, irrigation advance, and yield gap closure', *Heliyon*, 9(10), p. 13. Available at: https://doi.org/10.1016/j.heliyon.2023.e20720

[2] Kefena Effa, Daniel Muleta Fana, Mandefro Nigussie, Diriba Geleti, Nigusie Abebe, Nigussie Dechassa, Chimdo Anchala, Getu Gemechu, Teshome Bogale, Dejene Girma, Feto Esimo Berisso (2023) 'The irrigated wheat initiative of Ethiopia: a new paradigm emulating Asia's green revolution in Africa', *Environment, Development and Sustainability* [Preprint], (0123456789). Available at: https://doi.org/10.1007/s10668-023-03961-z

[3] Senbeta, A. F.; Worku, W.; Gayler, S.; Naimi, B. (2024). Unveiling Wheat's Future Amidst Climate Change in the Central Ethiopia Region. Agriculture 2024, 14, 1408. https://doi.org/10.3390/ agriculture14081408

[4] Intergovernmental Panel on Climate Change (IPCC). (2022). *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Edited by H.-O. Pörtner, D. C. Roberts, M. Tignor, et al. Cambridge University Press. Available at: https://www.ipcc.ch/report/ar6/wg2/

[5] Food and Agriculture Organization of the United Nations (FAO). (2018). *The state of food security and nutrition in the world 2018: Building climate resilience for food security and nutrition*. Rome, Italy: FAO. Available at: http://www.fao.org/3/I9553EN/i9553en.pdf

[6] World Bank. (2020). *Africa's Pulse: An Analysis of Issues Shaping Africa's Economic Future* (Vol. 21). Washington, DC: World Bank Group. Available at: https://www.worldbank.org/en/region/afr/publication/africas-pulse

[7] Food and Agriculture Organization of the United Nations (FAO). (1998). *Crop Evapotranspiration – Guidelines for Computing Crop Water Requirements*. FAO Irrigation and Drainage Paper No. 56. Rome, Italy: FAO.

[8] Food and Agriculture Organization of the United Nations (FAO). (1979). *Yield Response to Water*. FAO Irrigation and Drainage Paper No. 33. Rome, Italy: FAO.

[9] Heiner, B. J. (2009). *Parshall Flume Staff Gauge Location and Entrance Wingwall Discharge Calibration Corrections*. Master's Thesis, Utah State University. Available at: https://digitalcommons.usu.edu/etd/480

[10] Gomez, K. A., & Gomez, A. A. (1984). Statistical Procedures for Agricultural Research (2nd ed.). John Wiley & Sons, New York.

[11] SAS Institute Inc. (2018). *SAS/STAT 15.1 User's Guide*. Cary, NC: SAS Institute Inc.

[12] Saxton KE, Willey PH. 2006. The SPAW model for agricultural field and pond hydrologic simulation. Watershed models. p.401—435. In book: Watershed Models, CRC Press. https://doi.org/10.1201/9781420037432.ch17

[13] Food and Agriculture Organization (FAO). (2015). *Healthy soils are the basis for healthy food production*. FAO. Retrieved from https://www.fao.org.

[14] Widaa, A. and Elamin, M. (2023) 'Crop Water Productivity in the Main Irrigated Schemes of Sudan ISSN : 1858-9863', (February), pp. 0–9.

[15] Hasan, M. M. *et al.* (2017) 'Water productivity and yield performances of wheat under different irrigation and tillage treatments', *Fundamental and Applied Agriculture*, 1(1), pp. 28–32. Available at: https://doi.org/10.1007/978-94-017-7478-9

[16] FDRE-MoFED (2002) 'Ethiopian Sustainable Poverty Reduction Program 2002-2005', *Ministry of Finance and Economic Development* [Preprint], (July). Available at: https://www.imf.org/external/np/prsp/2002/eth/01/073102.pdf

[17] Allen, R. G., Pereira, L, S., Raes, D., Smith, M. Guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper, *Remote Sensing of Environment*. 2006, 300 (No. 56), p. 173. http://www.scscourt.org/complexcivil/105CV049053/volume3/172618e_5xAGWAx8.pdf

Biography

Tamasgen Mosisa: Senior Researcher of Irrigation and Drainage Engineering at Haro Sabu Agricultural Research Center, IQQO. He completed his MSc in Irrigation Engineering from Haramaya University in 2016, and his BSc in Soil and Water Engineering from Wollega University in 2010.

Wegene Negese | Researcher|Master of Soil Science ResearchGate: https://www.researchgate.net |Cited by 14| |Read 12 publications|

Bedada Yadete (BSc in water Resources and Irrigation Engineering) is an Irrigation Engineer, conducted field experiment and data collection.