International Journal of Advance Research and Innovation
Vol. 8(4), Oct-Dec 2020, pp. 35-41
Doi: 10.51976/ijari.842007

Article Info

Received: 29 Jul 2020 | Revised Submission: 20 Oct 2020 | Accepted: 28 Oct 2020 | Available Online: 15 Dec 2020

Golda Small Scale Irrigation Scheme Evaluation using Internal Performance Indicators: in Assosa District, Benishangul Gumuz Regional State, Ethiopia

Miniebel Fentahun Moges and Tewodros Assefa***

ABSTRACT

Evaluation of irrigation schemes helps to know the present status of the scheme and to apply possible measures for improvement. Golda small scale irrigation scheme was found in Assosa, Benishangul Gumuz regional state, Ethiopia and had a service of six years. The performance of Golda Small Scale Irrigation Scheme had not been evaluated before this study. Therefore, this study was conducted to evaluate the scheme by considering on field water management performance. Primary data collected through field measurements and secondary data from different sources were used. Internal indicators were used for evaluating on field water management performance like conveyance efficiency, application efficiency, storage efficiency, distribution uniformity and deep percolation ratio. The result of conveyance efficiency, application efficiency, storage efficiency, distribution efficiency and deep percolation ratio, were 53%, 51.6%, 91.6%, 80.76% & 40% respectively. Generally, the scheme requires improvement measures.

Keywords: *Efficiency, Internal Indicators, Performance, Small scale irrigation schemes.*

1.0 Introduction

Evaluating and improving the performance of existing schemes is an attractive way for sustainable development and used as a bench mark or point of entry for further irrigation development [1-10]. The Irrigation schemes are being under low productivity due to absence of experience in design, operation, maintenance and limitation on modern irrigation water management, (irrigation scheduling techniques, water saving irrigation technologies, water measurement techniques), and low irrigation performance of schemes [11-14]. The performance of the entire irrigation scheme is not according to the intended objectives if the scheme is not managed and operated properly. Many irrigation schemes, particularly in least developed and emerging countries, are characterized by a low level of overall performance [15].

The evaluation of existing functional and non-functional small scale irrigation schemes is relevant for improving its performance, increasing the productivity and water productivity. More generally, there are many factors accountable for the poor performance of irrigation schemes at the existing conditions. Despite the poor performance of the irrigation schemes in the Woreda, evaluation of small scale irrigation schemes and benchmarking of the results is not common; this is particularly true in using the performance indicators. This study aims to undertake performance evaluation of Golda small scale irrigation scheme using internal indicators.

2.0 Material and Methods

2.1 Description of the study area

The study was conducted at Assosa district, Benishangul gumuz Regional state, found in the Upper Blue Nile (Abay) River Basin, Ethiopia. It is located at a distance of about 665 km to the North West of Addis Ababa. It is located at 9°40’0’’ N - 10°23’20’’ N latitude and 34°8’20’’ E-34°51’40’’ E longitude at about 1560 meters above sea level (m.a.s.l).The scheme is located at a distance of about 18km from Assosa to the west direction, the capital city of the region. Golda catchment lies between Latitude 9°50’25.77” and 9°56’58.2”N and Longitude 34°33’4.7”and 34°38’35.5”E. It has an area of about 53km2.

**Corresponding author; Ethiopian Institute of Agricultural Research, Irrigation and Drainage Research Division, Assosa Agricultural Research Center, Ethiopia (E-mail: minif2005@gmail.com)*
***Department of Water Resources and Irrigation Engineering, Institute of Technology, Hawassa University, Ethiopia*

The agro-climatic zone of the area is hot to warm moist lowland plain with unimodal rainfall distribution pattern. The rainy season starts at the end of April and lasts at the end of October with maximum rainfall in June, July, August and September. The mean annual minimum and maximum temperatures of the area for the same years were 14.63 and 28.61˚C respectively.

2.2 Data collection and analysis

The data was collected from secondary and primary sources. Secondary data like, long time average climatic data of mean monthly minimum and maximum temperature, rain fall, relative humidity, wind speed and sunshine hours were collected from Assosa meteorological station. Kc, maximum rooting depth, length of growing season and MAD were collected from reports and research publications.

Primary data was collected through field measurements. Field observations were taken to assess both the structural integrity of system components and their fitness to convey flows and how farmers control and manage irrigation water during irrigation events.

2.2.1 Soil data

a) Texture: The particle size distributions in the soil profiles were determined using the hydrometric method.

b) Bulk density: Bulk density of the soil profile was determined using undisturbed soil samples at 0 - 30 cm depth interval collected by using 4.8cm internal diameter and 4cm height, 4.4cm internal diameter and 4cm height and 4.6cm internal diameter and 4cm height core sampler from head, mid and tail reaches respectively. The bulk density was determined using equation 1.

$$BD = \frac{Ws}{Vc} \quad \ldots(1)$$

Where:
BD : soil bulk-density (g/ cm^3)
Ws : mass of dry soil (g) and
Vc: volume of soil in the core (cm^3)

c) Soil pH**:** Soil pH was determined for the identification of whether the soil has acidity or salinity problem. It was measured in 1:2.5/soil: water mixture by using pH meter. Distilled water was used as a liquid in the mixture. Ten gram air dried < 2 mm soil was weighed into 100 ml beakers and 10 ml distilled water was added to 1:2.5/ soil: water suspension and transferred to an automatic stirrer, to be stirred for 30 minutes and pH on the upper part of the suspension was measured.

d) Soil field capacity and permanent wilting point**:** Field capacity and permanent wilting point of the soil were analyzed through pressure plate apparatus in the laboratory. After getting soil moisture values, available water holding capacity of the soil was calculated. The total available water (TAW) for crop use in the root zone was calculated using [1] equation.

The total available water in percent based:

$$TAW(\%) = \Sigma(FC\% - PWP\%) \quad \ldots(2)$$

Where: TAW(%): total available water in percent

FC%: soil moisture at field capacity in percent

PWP%: soil moisture at permanent wilting point in percent

e) Soil moisture determination**:** Samples for soil moisture determination were taken by auger at the head, center and tail end of the furrows of the selected head, mid and tail reach of farms at depths of 0 – 30, 30-60, 60-90 and 90-120cm. Its gravimetric water content was then determined using equation 3.

$$\theta dw = \frac{Wws - Wds}{Wds} \quad \ldots(3)$$

where: Wws: weight of wet soil (g)
θdw: water content expressed on weight basis in (%)
Wds: weight of dry soil (g) and the volumetric water content was calculated from the gravimetric water content using the following expression

$$\theta V = \frac{\rho b}{\rho w} * \theta dw * 100 \quad \ldots(4)$$

Where:θv: volumetric moisture content in (%) , ρb : soil bulk density(g/cm^3) and ρw: water density g/cm^3 (1g/cm^3)

f) Organic matter content (OMC): Applying organic matter is one of the best methods in achieving and maintaining a fertile soil for this improves the cohesiveness of the soil, increases its water retention capacity and promotes a stable aggregate structure [12].Titration method was used.

Total Nitrogen (N) and available Phosphorus (P) [13] suggested that nutrient availability, particularly nitrogen and phosphorus, are critical to high yield and water productivity. Total Nitrogen was determined by Kjeldhal method in the laboratory. Phosphorous is known as the master key to agriculture because lack of available P in soil limited the growth of both cultivated and uncultivated plant [5]. Available phosphorus was determined by Olsen method.

2.2.2 Rainfall data

The precipitation data required for CROPWAT 8.0 was monthly rainfall, commonly available from Assosa climatic station.

Effective rainfall refers to that portion of rainfall that can effectively be used by crops. This is to say that not all rain is available to the crops as some is lost through runoff and deep percolation. It was computed using CROPWAT 8.0 model, USDA Soil Conservation Service method.

2.2.3 Determination of crop water and irrigation water requirement

The crop water requirement of different crops in the study area was calculated using CROPWAT 8.0 model. Crop water requirement or ETc can be calculated as:

$$ETc = Kc \text{ x } ETo \quad \ldots(5)$$

Where:ETc: crop evapotranspiration/crop water requirement (mm/day),

Kc: crop coefficient, which is a function of crop type and stage of growth

ETo: reference evapotranspiration (mm/day)

$$IR_n = ETc - P_{eff} \quad \ldots(6)$$

Where: IRn: net irrigation water requirement (mm) Peff: effective rainfall (mm)

2.2.4 Internal indicators

The discharge in the canal was measured with floating method. The method consists of estimating the average flow velocity and measuring the area of the cross-section. The discharge was calculated by continuity equation.

$$Q = V * A \quad \ldots(7)$$

where: Q: the discharge (m^3/s)

V: the average flow velocity (m/s)

A: the area (m2) of the wetted cross-section.

To estimate the average flow velocity, the surface velocity was first determined.

$$Vs = \frac{L}{t} \quad \ldots(8)$$

where: Vs: the surface velocity (m/s)

L: the distance in meters between selected points and

t: the travel time in seconds between selected points

Since the velocity of the float on the surface of the water was greater than the average velocity of the stream, it was necessary to correct the measurement by multiplying by a constant factor which was usually assumed to be 0.85 [7].

$$V = 0.85 * Vs \quad \ldots(9)$$

where: V: the average flow velocity (m/s)

The area was calculated from measurements of the surface water width and the water depth.

$$A = w1 * h1 \quad \ldots(10)$$

where: A: area of wetted cross-section (m^2)

w1: surface water width (m)

h1: water depth (m)

The area of the cross-section was measured three times to get the average area.

To determine the amount of water applied by the irrigators to the field, during an irrigation event, three inch partial flume was installed at the entrance of test field. According to Walker [14], discharge was computed as:

$$Qf = Cf * W * hu^{nf} \quad \ldots(11)$$

Where: Qf: discharge for free flow condition

W: throat width , Cf: free flow coefficient, nf: exponents for free condition and hu: upstream heads of parshall flume (m).

The water conveyance efficiency and water losses main and tertiary canals were estimated by measuring inflow and outflow for the selected canal reaches. The average values of inflow and out flows for all measurements for each of the selected canals were used for the estimation of water conveyance losses and water conveyance efficiency using ([10].

$$Ec = \frac{Qinflow}{Qoutflow} * 100 \quad \ldots(12)$$

The average soil moistures in the effective root zone on selected points were taken. According to [9], application efficiency was calculated as:

$$Ea = \frac{\text{Average depth of water stored in the root zone(Ws)}}{\text{Average depth of water applied(Wf)}} * 100 \quad \ldots(13)$$

<u>Water storage efficiency</u>**.** It was calculated according to [10]: equation.

$$Es = \frac{\text{water stored in the root zone of the crop(Ws)}}{\text{Water needed in the root zone prior to irrigation(Wn)}} * 100 \quad \ldots(14)$$

The water needed in the root zone prior to irrigation was computed using [10] equation as:

$$Wn = \sum_{i=1}^{n} \left(\frac{M_{fci} - M_{bi}}{100}\right) * A_i * D_i \quad \ldots(15)$$

Where: Mfci: field capacity moisture content in the i^{th} layer of the soil (%)

Mbi: moisture content before irrigation in the i^{th} layer of soil (%)

Ai: bulk density of the soil in the ith layer
Di: depth of the soil layer within the root zone cm, and
n: number of soil layers in the root zone D

This is important to evaluate the distribution of water uniformally on field. [9], distribution uniformity was calculated as:

$$DU = \frac{\text{Average low quarter depth of water infiltrate}}{\text{Average depth of water infiltrated}} \quad \ldots(16)$$

The depth of stored water at particular soil layer was calculated using the equation below:

$$Z = \left(\frac{M_{ai} - M_{bi}}{100}\right) A_i * D_i \quad \ldots(17)$$

Where:
Mai: moisture content of the ith layer of the soil after irrigation weight basis, %
Mbi: moisture content of the ith layer of soil before irrigation weight basis, % .
Deep percolation ratio could be calculated indirectly from values of application efficiency and runoff ratio as given by [6].

$$DPR = 100 - Ea - RR \quad \ldots(18)$$

Where: RR: runoff ratio

According to [4] the project or overall efficiency of the scheme was calculated as the product of conveyance and application efficiency.

$$Ep = Ec \times Ea \quad \ldots(19)$$

3.0 Results and Discussion

3.1 Soil data analysis results

3.1.1 Soil textural class, bulk density, pH, nutrient contents and total available water

The textural class for Golda irrigation scheme for all the selected canal reaches was found to be clay soil. In the tail reach of the canal higher values of bulk density was recorded which indicates the soil was highly compacted than the head and middle canal reaches of the irrigation scheme (Table 1).

Average soil pH were 5.5 to 5.6 for the three canal reaches of the irrigation scheme which was medium acid. Average OM at head and middle reaches of the canal were 0.27 and 0.16 which were very low and at tail reach of the canal was 2.54 which was low respectively. There for, the fertility status of the area should be improved by adding crop residues and compost which can be increase the organic matter content of the soil. Average N at head and middle canal reaches were 2 and 1.2 which were very high and at tail reach 0.12 which was medium respectively. Average available P at head and tail canal reaches were 3.45 and 3.15 which were very low and at middle 6.8 which was low (Table 1).This deficiency of P indicates that the area has a response for phosphorous fertilizer so that framers should be apply P fertilizer in the recommended rate.

The average calculated value of total available water of the irrigation scheme was 150.4mm/m within the acceptable range which was [1] recommended TAM values for clay soil ranges from 120-200 mm/m. This average value of TAW was used as input for determination of the crop water requirement in the CROPWAT 8.0 model.

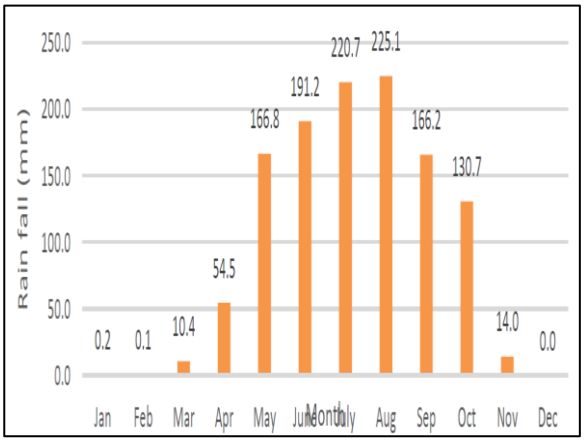
Table 1: Soil Textural Classes, Bulk Density, pH, Nutrient Contents and Total Available Water(TAW)

Canal reaches	Soil depth (cm)	Bulk density (gm/cm^3)	Texture	pH	OMC(%)	OMC (%)	P (ppm)	TAW(mm)
Head	0-120	1.11	Clay	5.6	0.27	2	3.45	133.1
Middle	0-120	1.12	Clay	5.5	0.16	1.2	6.8	120
Tail	0-120	1.25	Clay	5.5	2.54	0.12	3.14	198
Average		1.16		5.53	0.99	1.12	4.46	150.4

3.2 Rainfall data

Mean monthly rainfall profiles were generally uni-modal with peak in August as shown in (Fig.1). Rainfall is conditioned principally by migration of Inter-Tropical Convergence Zone which accounts for almost 100% of annual rainfall on average between March and November.

Figure 1: Mean Monthly Rain Fall Variations the Irrigation Scheme



3.3 Internal indicators

Even though, various authors have suggested many performance indicators, the types of indicators chosen depend on the purpose of performance assessment [2]. In this study, on field water management was assessed in terms of conveyance efficiency, application efficiency, storage efficiency, distribution uniformity and deep percolation ratio.

3.3.1 Conveyance efficiency and losses

The irrigation scheme had been only main canal and tertiary canals so that conveyance efficiency and losses were determined for main and tertiary canals. The calculated main and tertiary canal efficiencies were 78% and 68% respectively as indicated in (Table 2).The conveyance efficiency of the scheme would be the product of main and tertiary canals which was 53%.The value was below [3] recommended values which greater than 2000 meters canal length earthen canals in clay soil of conveyance efficiency should be 80%.

Table 2: Calculated Conveyance Efficiencies and Losses

Canals	**Conveyance efficiency (%)**	**Conveyance losses(l/s/m)**
Main canal	78	0.76
Territory canal	68	0.81
Average conveyance efficiency of the scheme	53	

3.3.2 Application efficiency

The calculated application efficiencies of the three canal reaches were in the range of 50 – 53 %, which was indicated that the farmers were applying excess water to their fields (Table 3). [8] was reported as, it could be in the range of 50-80% . But the result was disagreed with [3] reported that the maximum attainable application efficiency ranges from 55%-70%.

Table 3: Parameters and Calculated Application Efficiencies

Canal reaches	Applied depth (mm)	Stored depth (mm)	Application efficiency (Ea)%
Head	146	77.38	53.00
Middle	133	68.10	51.00
Tail	128	64.90	50.70
Average application efficiency of the scheme			51.60

3.3.3 Storage efficiency

The calculated value of storage efficiency at middle field was higher than head and tail fields as shown in (Table 4). The average storage efficiency of the scheme was 91.6%. Depending on weather, type of soil and time span considered, storage efficiency might be as high as 90% [1].

Table 4: Parameters and Calculated storage Efficiencies

Field	Stored water at root zone (mm)	Required water (mm)	Es (%)
Head	49.70	53.44	93
Middle	44.60	46.46	96
Tail	40.70	47.33	86
Average storage efficiency of the scheme			91.6

3.3.4 Water distribution uniformity

The distribution uniformity which describes how evenly irrigation is applied to the crop. There was high distribution uniformity at middle and tail field users than head irrigation fields which was 82% (Table 5).The average distribution uniformity was 80.76.

Table 5: Parameters and Calculated Water Distribution Uniformities

Field	Mean stored water (mm)	least quarter mean stored water (mm)	DU (%)
Head	50	40.14	80.28
Middle	44.7	36.66	82.00
Tail	40.7	33.38	82.00
Average distribution efficiency of the scheme			80.76

3.3.5 Deep percolation ratio

Since farmers were practicing closed end furrow, only deep percolation was considered. The deep percolation ratio or high loss due to deep percolation was 44% which was obtained at middle field of the irrigation scheme as indicated in (Table 6) because of excess application of water before water depleted from the root zone. The average scheme loss due to deep percolation was 40% that means from the total depth of water applied, 40% water was lost.

Table 6: Parameters and Calculated Deep Percolation Ratio

Field	Ea(%)	RR(%)	DPR(%)
Head	60	0	40
Middle	44	56	0
Tail	64	0	36
Average efficiency of the scheme	60		40

3.3.6 Overall efficiency

The calculated overall efficiency of the irrigation scheme was 27.35% as indicated in (Table 7).This result was implied that the scheme was performed with low efficiency.

Table 7: Calculated Over All Efficiencies

Indicators	Efficiency of the scheme (%)
Conveyance efficiency	53.0
Application efficiency	51.6
Storage efficiency	91.6
Distribution efficiency	80.76
Deep Percolation ratio	40.0
Overall efficiency of the scheme	27.35

4.0 Conclusions

The conveyance efficiency of the system was found to be poor. Thus, to increase the efficiency, the canals should be cleaned and soil and water conservation structures should be constructed to protect canal banks from erosion. Supporting by irrigation experts; the scheme requires proper irrigation water management like irrigation scheduling: applying the required amount of water at the right time that could increase application efficiency. The organic matter content and available phosphorous deficiency should be improved by mulching with crop residues, using compost and applying the recommended phosphorous fertilizer that could increase on field water management performance of the scheme. The Irrigation scheme users should be produced more than once per year to get high production that could increase gross return of the investment. Finally, the result of this study will have an input to take improvement measures for the sustainability Golda small scale irrigation scheme.

5.0 Acknowledgements

First, We thank Almighty God for always being with us in all our endeavors and giving us endurance to complete our study. Our special appreciation also goes to Ethiopian Institute of Agricultural Research for financial support for the research. Our especial thanks go to Mr. Lijalem Abebel for his valuable advices and facilitating laboratory works during our study. Also to Ahmed Mohammed for his assistance in field works.

References

[1] RG Allen, LS Pereira, D Raes, M Smith. Crop Evapotranspiration. Guidelines for Computing Crop Water Requirements. FAO Rome, Irrigation and Drainage Paper No.56, 1998.

[2] MG Bos, MA Burton, DJ Molden. Irrigation and Drainage Performance Assessment, Practical Guidelines. Wageningen, The Netherlands: International Institute for Land Reclamation and Improvement, 2005.

[3] FAO (Food and Agricultural Organization). Guidelines for Designing and Evaluating Surface Irrigation Systems: Irrigation and Drainage Paper. No. 45. FAO, Rome, 1989.

[4] FAO (Food and Agricultural Organization). Irrigation Manual: Planning, Development Monitoring and Evaluation of Irrigated Agriculture with Farmer Participation. 2(7), 2002.

[5] DH Foth, GB Ellis.Soil fertility. New York 1995.

[6] J Feyen, D Zerihun. Assessment of the performance of border and furrow irrigation systems and the relationship between performance indicators and system variables. Agricultural Water Management, 40(2), 1999, 353-362.

[7] CC Harrelson, CL Rawlins, JP Potyondy. Stream channel reference sites: an illustrated guide to field technique. Gen. Tech. Rep. RM-245. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 61 ILRI, The Netherlands, 1994.

[8] WLesley. Irrigation Efficiency. Irrigation Efficiency Enhancement Prepared for Land WISE Hawke's Bay. Lincoln Environment. USA Report No 4452/16a, March 2002.

[9] JL Merriam, MN Shearer, CM Burt. Evaluating Irrigation Systems and Practices. In: Design and Operation of Farm Irrigation Systems. An ASAE Monograph No.3, American Society of Agricultural Engineers Publisher, USA, 1983, 721-760.

[10] Michael, A. M. 2008. Irrigation theory and Practice, Second edition VIKAS Publishing house Pvt Ltd. India.

[11] Ministry of Agriculture, Natural Resources Management Directorates. Small-Scale Irrigation Situation Analysis and Capacity Needs Assessment, Addis Ababa, Ethiopia 2011a.

[12] RP Morgan. Soil Erosion and Conservation. DA Davidson (Ed) John Wiley & sons Inc. New York 1986.

[13] O Sadras, P Grassini, P Steduto. Undated. Status of water use efficiency of main crops. Solaw Background Thematic Report - TR07. FAO.

[14] WR Walker, V Gaylord, Skogerboe. Surface Irrigation, Theory and Practice, Prentice Hall, New Jersey 1987.

[15] Z Agid, A Haileslassie, H Sally, T Erkossa,P Schmitter, S Langan, D Hoekstra. Analysis of water delivery performance of small holder irrigation schemes in Ethiopia: Diversity and lessons across schemes, typologies and reaches. LIVES Working Paper 15. Nairobi, Kenya: International Livestock Research Institute (ILRI), 2016.