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Technical Performance Evaluation of Selected Small Scale Irrigation Schemes in North Shoa Zone, Oromia Region, Ethiopia

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ABSTRACT

In order to evaluate the technical performance and status of irrigation water management of Mummiti, Laga-Warke, Taltale, Alaltu-Tiko, and Alaltu-Dubana small scale irrigation schemes in North Shoa Zone, data on both internal and external indicators and status of irrigation water management like soil data, flow data, crop yield data, farm gate prices of each crops and other important data were collected and analyzed by using appropriate tools. From the internal performance indicators, values for conveyance efficiency for the considered irrigation schemes range from 39%-67%, while that of application and overall efficiencies range from 32%-41% and 14.4%-27.5%, respectively. This indicated that for most irrigation schemes, application and overall efficiencies were poor implying the management was poor. The results for external performance indicators like output per crop area, output per command area, output per irrigation supply, and irrigation ratio also showed mostly low output from the respective command areas as compared with outputs intended from the concerned schemes under normal condition. Further, the status of irrigation water management was found to be from low to medium range for most activities under irrigation water management. Hence, the study indicated that the issue of improving irrigation performances and irrigation water management in the study area should be prioritized.

Keywords: Efficiency, Irrigation schemes, Water management.

INTRODUCTION

In low income countries like Ethiopia, water resource development and management is increasingly recognized as a major component of economic development and poverty reduction. Lack of water infrastructure development is believed to be the major cause of famine and undernourishment, particularly in food insecure rural areas where people depend on subsistence agriculture both for food and income (Natea & Habtamu, 2006). Despite the availability of abundant surface and ground water resources, agriculture in Ethiopia is still largely subsistence rain-fed farming. Moreover, the spatial and temporal variability of rainfall is very high resulting in incidence of drought every 4 to 5 years which affects crop and livestock production and contributes to structural food deficit and food price volatility in the country (Adela et al., 2019).

To feed Ethiopia's rapidly increasing population and to boost the economic development of the country, there has been a growing focus on irrigation but still it is under-developed and under-performing (MoWE, 2013). There has been a concern in development of small-scale irrigation schemes as it plays an important role in adapting to climate change, achieving food security, and improving household incomes. The Ethiopian government considers irrigated agriculture as a primary engine of economic growth and plans to increase the current level of irrigation infrastructure three-fold by the end of 2025. Yadeta et al. (2018) indicated that the average crop yield per hectare from irrigated land has increased to be 2.3 times higher than the yield produced by rain-fed agriculture. However, irrigated agriculture currently produces less than 3% of the total food production of the country and Danante & Alemu (2014) indicated that there has been concern regarding the performance and management of existing small-scale irrigation.

According to FAO (2002), inefficient irrigated agriculture is the most water-consuming sector, accounting for over 90% of water withdrawal from

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various sources such as aquifers, streams, and lakes. Without improved efficiency measures, agricultural water consumption is expected to increase by about 20% by the end of 2050. The comparative estimate is 40% or more of the water diverted for irrigation is wasted at the farm level through either deep percolation or surface runoff. As a result, the performance evaluation of irrigation schemes plays a fundamental role in improving the productivity of irrigation schemes by identifying where the critical problem occurs. Adela et al. (2019) suggested that though small-scale irrigation is playing an important role in adapting to climate change, achieving food security, and improving household incomes, not enough attention has been paid to the performance and management of such schemes.

North Shoa Zone has ample water and irrigable land potential, but many farmers there have failed to produce more annual crops using the existing potential effectively (Habtamu et al., 2022). About 297,392 people in North Shoa are supported under regular food aid program (NSZAO, 2022).

To tackle the food crisis faced by this large number of people, the government has implemented a large number of small-scale irrigation schemes across almost all of the zone's 13 districts. So far, the interventions mainly have focused on the development of new irrigation schemes and upgrading the physical infrastructure of existing traditional irrigation practices, but very limited concern has been given to measuring the performance of the schemes including the irrigation water management in general. Therefore, this research has focused on filling these gaps through evaluation of technical performance of the selected schemes using internal and external irrigation performance indicators and through assessing the state of their irrigation water management.

MATERIALS AND METHODS

Description of the study area:

The study was carried out in North Shoa Zone of Oromia Region, Ethiopia (Fig. 1). The zone, has a total area of approximately 8,989.70 km2 and thirteen districts. Five districts in which irrigation schemes were widely implemented were chosen to be included in the study. Cultivable land in those districts totaled about 986,254 ha while irrigable land totaled about 78,366 ha. According to the information from NMA (2019), the altitude of the study area ranges from 980 to 3453 meters while the average annual rainfall is about 384 mm and the mean annual temperature ranges from 9°C to 28°o C.

Data Collection:

All necessary primary and secondary data were

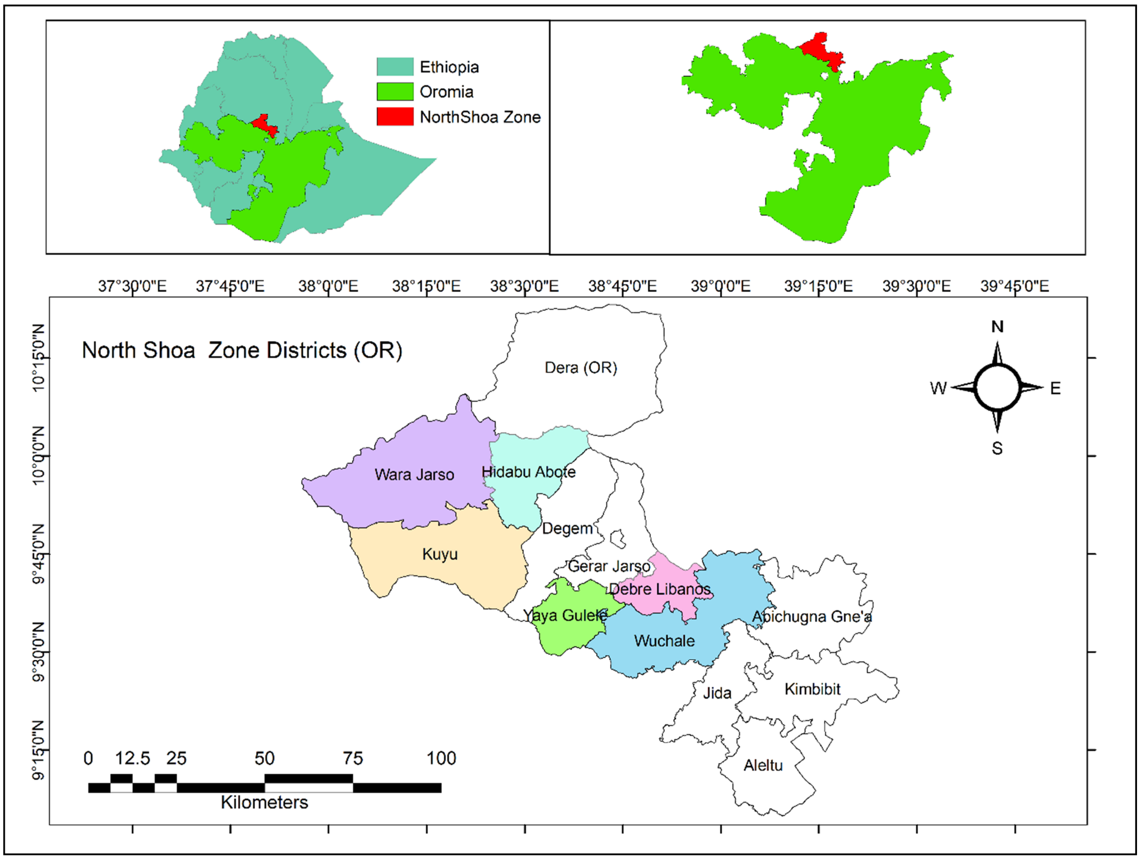

Fig.1: Map of the study area

collected during the 2020/2021 crop growing season under irrigation. Based on the status of their functionality, five small-scale irrigation schemes were selected. The schemes were Aleltu-Dubana, Laga-Warke, Mummit, Aleltu-Tiko, and Teltelle from Kuyu, Yaya-Gulalle, Wachale, Hidabu-Abote, and Dabra-Libanose districts, respectively. These small-scale irrigation schemes have command areas of 76, 31, 44, 54, and 102 hectares, respectively. All these schemes had a service year of two to five years except Taltale scheme which was constructed in 1987. Soil data, flow data, crop yield, and their respective market price data were collected.

Soil data:

The dominant soil types in the study area were categorized as Vertisols, Leptosols, and Cambisols. For a given scheme, a representative irrigable land was identified from upper, middle, and lower end and soil samples were collected from the top 20 cm (plough layer) by using core-sampler from head, middle, and tail end of the respective irrigated lands in the scheme, as done by Manirakiza et al. (2022). Accordingly, there were 9 (3*3) soil samples for a scheme and in total there were 45 (9*5 schemes) soil samples. For determination of soil textural classes, a composite soil sample was collected from top soil of each position of all irrigation schemes by using an auger. As the irrigation techniques in each schemes is furrow irrigation, the soil samples were collected from the field after 24 hours of irrigation.

Flow data:

Floating method was used to measure flow of discharge at diversion, primary canal, secondary canal, and farm gates of schemes canal. Canal depth, canal width, and flow depth were measured by using tape meter. The flow distance was considered constant value (10 m) for the whole schemes. During the flow measurement, at each point 4 trials were conducted to get average velocity (FAO, 2002; Manirakiza et al., 2022). The design discharge of each scheme was obtained from zonal office of irrigation.

Other data:

Crop yield, farm gate prices of each irrigated crops, area irrigated per crop, command area, and other important data were obtained from respective districts office of agriculture. In addition, a preliminary survey was conducted to further cross-check the reliability of some data like total yield and prices of each crop.

Status of irrigation water management:

As the mandate of irrigation water management was given for different actors in the scheme, focus group discussions with members of irrigation water users association, model farmers, and development agents were carried out to get information on the status of irrigation water management.

Data Analysis:

In this study, internal performance indicators include efficiencies while for the external performance, indicators developed by the international water management institute (IWMI) like output per crop area, output per command area, output per irrigation supply, and irrigation ratio were used to undertake the comparative performance assessment.

Soil data analysis:

For each collected soil sample, fresh weight was taken and put into oven for 24 hours at 105° C and dry weight was measured after cooling in open air. In the laboratory, soil textural classes, wet/fresh weight, dry weight, and volume of the soil were measured by using standardized procedures for respective parameters from which soil moisture content, bulk density, field capacity, permanent wilting point (PWP), and total available water (TAW) were computed using recommended formula as suggested by Renault et al. (2007).

$$\theta_w(\%) = \frac{W_w * W_d}{W_w} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

θw: water content on mass (g) basis,
ww: the mass of the wet soil (g) and
wd: weight of the dry soil (g).

The bulk density of the soil was computed using equation 2.

$$\rho_b = \frac{W_d}{V_s} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

ρ_b: the bulk density (g/m^3)
Wd: the weight of dry soil (g)
Vs: volume of soil in cm3

The moisture content at field capacity (FC) and wilting point (WP) were determined using pressure plate apparatus at 1/3 bar and 15 bar, respectively. The total available water (TAW) was estimated by using equation 3.

$$TAW = 1000 \times \left(\sum_{k=0}^{n} \left(\theta_{FCi} - \theta_{wpi}\right) \times Z_{ri}\right) \ldots\ldots 3$$

TAW: total available water in the soil (mm)
θ Fc: volumetric moisture content at field capacity (m3/m3)
θ Wp: volumetric moisture content at wilting point (m3/m3)
n: number of observations
Zr: root depth (m)

Flow measurement:

Flow velocity at each considered position of the schemes was computed as suggested on United

States Bureau of Reclamation of Water Management Manual (USBRWM, 1997):-

$$V = \frac{S}{t} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..4$$

V: flow velocity (m/s)
S: flow distance (m)
t: flow time over S (s)

Finally, the result was multiplied by a correction factor of 0.85 to convert surface velocity into average value as described by Muluken & Bimerew (2020). Discharge of the flow was determined by velocity area method as:-

$$Q = A * V \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..5$$

Q: Discharge of the flow (m3/s)
A: Cross-sectional area of canal (m2)
V: Velocity of the flow (m/s)

Performance evaluation using internal comparative indicators:

Conveyance Efficiency (EC): The conveyance efficiency of the schemes was computed by taking discharge measurement at different points. The measurements were taken at a point of diversion and the final points of secondary, tertiary and field canals and computed as suggested by Ramulu (1998).

$$(EC)\% = \frac{Q_{outflow}}{Q_{inflow}} * 100\% \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..6$$

Ec: conveyance efficiency (%)
Qout flow: Discharge at the inlet (m3/s)
Qout flow: Discharge at the outlet (m3/s)

Application Efficiency (Ea): This was computed as the ratio of depth of water beneficially used by the crop (mm), i.e., depth of water added to the root zone to the depth of water delivered to the area using equation 7.

$$(Ea) = \frac{D_s}{D_a} * 100\% \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 7$$

Ds: water stored in the root zone (mm)-computed from soil sample analysis
Da: water applied to the field (mm) - measured in field

The water delivery performance indicator (WDPI): It was computed as the ratio of actual water delivered to the field (Qa, m3) to amount intended to be delivered (Qi, m3). This was calculated by measuring the actually delivered volume of water to the intended (design) volume water to be delivered using equation 8 as recommended by Efrem & Mekonnen (2017).

$$WDPI(\%) = \frac{Q_a}{Q_i} * 100\% \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 8$$

Qa: volume of water actually delivered (m3) - volume measured
Qi: intended water to be delivered (m3) - obtained from Zonal Offices of irrigation development.

Project Irrigation Efficiency (Eo): It represents the efficiency of the entire physical system and operating decisions in delivering irrigation water from a water supply source to the target irrigable lands. It was calculated by multiplying the efficiencies of water conveyance and water application (Brouwer et al., 1998).

$$Eo = (Ec * Ea) * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..9$$

Eo: over all irrigation efficiency (%)
Ec: water conveyance efficiency (decimal)
Ea: water application efficiency (decimal)

Deep Percolation Ratio: As the furrow practiced in the schemes was close-ended, therefore runoff ratio could be neglected, and also evaporation from the soil was too small because it is only a short period after irrigation that the water remains in the furrow. The loss of irrigation water beyond the root zone is mainly through deep percolation. Therefore, deep percolation ratio was calculated by using the following equation as suggested by Muluken & Bimrew (2020).

$DPR = 100 - E_a - RR$ As RR was neglected,

$$DPR = 100 - E_a \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..10$$

DPR: Deep percolation ratio (%)
Ea: application efficiency (%)
RR: runoff ratio

External comparative Performance Indicators:

The basic comparative performance indicators relate output to unit land and water. These external indicators provide the basis for comparison of irrigated agriculture performance. The following four basic external indicators developed by international water management institute (IWMI) were used to undertake the comparative performance assessment as described by Molden et al. (1998).

Basically, as computation of most external performance indicators depends on standardized growth value of production (SGVP), it was computed as:-

$$SGVP_{crop\ 1} = Yieldofcrop\ 1 * \frac{priceofcrop\ 1}{priceofbasecrop} * areaofcrop\ 1 \ldots\ldots\ldots\ldots\ldots\ldots..11$$

SGVP: Standardized Gross Value of Production (birr)

Here, potato was considered as base crop as it was one of the common crops that have been grown under irrigation almost in all considered irrigation schemes.

Output per cropped area $\left(\frac{birr}{ha}\right) = \frac{SGVP}{IA}$ ………12

IA: irrigable area in (ha)

Output per unit command area $\left(\frac{birr}{ha}\right) = \frac{SGVP}{CA}$ ..13

CA: command area (ha)

Output per unit irrigation supply $\left(\frac{birr}{m^3}\right) = \frac{SGVP}{DIS}$ ………………………………………..…….14

DIS: diverted irrigation supply (m3)

Irrigationratio $= \frac{ICA}{CA}$………………….………15

ICA: irrigated cropping area
CA: command area (ha)

Status of irrigation water management:

At each irrigation scheme, a focus group discussion was held with 9 group members organized from 4 irrigation water users, 3 water users associations members, and 2 development agents and detail discussions were held on maintenance, irrigation scheduling, water utilization, and irrigation canals management issues

RESULTS

Physical Properties of the Soil:

In irrigation performance assessment, understanding the bulk density and moisture holding capacity (gravimetric or volumetric) is very important as these soil properties affects water availability for crops in irrigation system. In this study, most irrigation schemes experience average values of bulk density and soil moisture contents (Table 1).

Internal technical performance indicator analysis:

In order to understand the overall physical internal performance of the schemes, important flow parameters were computed at upper, middle, and lower positions of the considered irrigation schemes as indicated in Table 2. The comparison of gravimetric and volumetric moisture content indicated that, overall volumetric moisture content was higher than gravimetric moisture content for all considered irrigation schemes.

Of all considered irrigation schemes, Alaltu-Tiko has shown the lowest average TAW (Table 3). This leads to short irrigation interval and smaller coverage of the command area with the available low discharge which further could be accounted to the nature of dominant soil type in the scheme (Leptosol) which is characterized by low water holding capacity.

The trend for total available water of the whole irrigation schemes indicated that Mummiti and Taltale irrigation schemes had relatively higher total available water while the lower part of Alaltu-Tiko and Alaltu-Dubana schemes experienced low total available water. As the soil type in the former schemes was dominated by vertisols, it experiences high total available water. While in the later schemes, the soil in the schemes was dominated by sandy soil resulting in relatively low total available water which might leads to moisture limitation for normal crop growth.

Efficiencies: Some of the common performance indicators of irrigation scheme are application, conveyance and project efficiencies and the results for this study were as indicated in Table 4. The study also indicated that at each scheme there was

Table 1: Soil physical characteristics

Irrigation scheme	Sampling position	Bulk density (g/cm^3)	Moisture content (%)	
			Gravimetric	Volumetric
Mummiti	Upper	1.40	49.9	69.9
	Middle	1.40	42.3	59.2
	Lower	1.41	44.2	62.3
Taltalle	Upper	1.45	38.7	56.1
	Middle	1.36	48.5	66.0
	Lower	1.36	48.1	65.4
Alaltu-Tiko	Upper	1.69	27.7	46.8
	Middle	1.74	24.1	41.9
	Lower	1.66	19.9	33.0
Laga-Warke	Upper	1.47	37.0	54.4
	Middle	1.07	35.0	37.5
	Lower	1.09	19.9	21.7
Alaltu-Dubana	Upper	1.33	27.0	35.9
	Middle	1.27	23.0	35.9
	Lower	1.21	24.0	29.0

Table 2: Nature of flow in each scheme at different stations

Scheme	Station	Width canal (m)	Depth canal (m)	Depth flow (m)	Velocity (m/s)	Area (ha)	Measured Q* (m^{3}/s)		Design q* (m^3/s)	Change (q-Q) m^3/s
Mummit	Upper	0.40	0.40	0.12	0.25	18.8	0.012	0.0288	0.039	0.0102
	Middle	0.40	0.40	0.10	0.20		0.008			
	Lower	0.35	0.45	0.80	0.24		0.067			
Taltalle	Upper	0.40	0.30	0.14	0.25	36.4	0.014	0.0114	0.015	0.0036
	Middle	0.45	0.45	0.20	0.10		0.009			
	Lower	0.50	0.50	0.20	0.11		0.011			
Alaltu-Tiko	Upper	0.30	0.25	0.15	0.25	46.3	0.011	0.0078	0.033	0.0252
	Middle	0.25	0.20	0.10	0.31		0.008			
	Lower	0.25	0.20	0.06	0.29		0.004			
Laga-Warke	Upper	0.35	0.40	0.09	0.44	24.9	0.014	0.0129	0.043	0.0301
	Middle	0.30	0.40	0.15	0.35		0.016			
	Lower	0.35	0.45	0.08	0.33		0.009			
Alaltu-Dubana	Upper	0.45	0.30	0.25	0.73	41.5	0.082	0.0410	0.063	0.0220
	Middle	0.45	0.45	0.15	0.49		0.033			
	Lower	0.30	0.30	0.10	0.29		0.009			

*Q = measured discharge, *q = design discharge

Table 3: Total available water within the root zone

Irrigation Scheme	Position	Soil textural	FC (m^3/m^3)	PWP (m^3/m^3)	TAW (mm)
Mummiti	Upper	Clay	0.44	0.18	52
	Middle	Silty clay	0.42	0.19	46
	Lower	Silty clay	0.41	0.20	42
	Average		**0.42**	**0.19**	**46.67**
Taltalle	Upper	Clay loam	0.39	0.20	38
	Middle	Clay loam	0.40	0.21	38
	Lower	Silty clay loam	0.41	0.18	46
	Average		**0.40**	**0.20**	**40.67**
Alaltu-Tiko	Upper	Silty loam	0.35	0.14	42
	Middle	Silty loam	0.34	0.16	36
	Lower	Sandy clay	0.29	0.16	26
	Average		**0.32**	**0.14**	**34.67**
Laga-Warke	Upper	Silty clay loam	0.39	0.16	46
	Middle	Silty clay loam	0.36	0.18	36
	Lower	Clay loam	0.34	0.17	34
	Averge		**0.36**	**0.17**	**38.67**
Alaltu-Dubana	Upper	Loam	0.34	0.13	42
	Middle	Sandy loam	0.32	0.13	38
	Lower	Sandy loam	0.30	0.14	32
	Average		**0.32**	**0.13**	**37.33**

PWP = permanent wilting point; FC = *field capacity*; TAW = total available water

excess deep percolation loss, which showed poor irrigation water management. Further, the result depicted that in each irrigation schemes, there was poor irrigation water management as indicated by maximum loss by deep percolation and poor application performance that was below the recommended range.

External technical performance indicator analysis:

As the price of irrigated crops varies, the choice of farmers to grow the crops also varies from scheme to scheme. This affected the limited market and has reduced the overall price of the crops produced. As indicated in Table 5, farmers' choice to grow crops was mainly limited to cash crop like potato, onion, garlic, and tomato rather than cereal crops.

From the crop related output of the schemes (Table 6), it was possible to demark that the output per cropped area is higher than output per command area for the irrigation schemes implying that there was some intended command area left un-produced. Besides, output per irrigation supply indicated relatively low values ranging from 156.01 to 718.85 birr per cubic meter of water applied. This resulted from poor water management on the irrigated area. As indicated in

Table 4: Irrigation efficiencies

Irrigation Scheme	E_c (%)	E_a (%)	WDPI (%)	E_o (%)	DPR
Laga-Warke	52	34	38	17.68	66
Alaltu-Tiko	56	39	45	21.84	61
Taltale	39	37	24	14.43	63
Mumiti	64	32	42	20.48	68
Alaltu-Dubana	67	41	49	27.47	59

E_o: over all irrigation efficiency; E_c: water conveyance efficiency; E_a: water application efficiency; WDPI = water delivery performance indicator; DPR = deep percolation ratio.

Table 5: Irrigation schemes average major crops and economic data for 2020/21

Irrigation scheme	Crop type	Irrigated area (ha)	Productivity and price					
			Command area (ha)	Yield per ha	Total Yield (Quintal)	Price per-quintal	Total price (Birr)	SGVP
Laga-Warke	Onion	11.1	31	75	832.5	600	499,500	6982.62
	Cabbage	3.6		60	216	400	86,400	101.64
	Potato	4.1		120	492	900	442,800	1351.24
	Average	18.8		255	1540.5	1,900	1,028,700	45069.61
Alaltu-Tiko	Potato	22.5	54	80	1800	600	1,080,000	66168.96
	Cabbage	3.9		65	253.5	500	126,750	189.57
	Maize	9.6		23	220.8	1,500	331,200	1062.03
	G/pepper	0.4		40	16	650	10,400	0.10
	Average	36.4		208	2290.3	3250	1,548,350	195271.31
Taltale	Carrot	17.3	102	50	865	750	648,750	14686.39
	Tomato	14		76	1064	600	638,400	14385.93
	Cabbage	2.5		45	112.5	430	48,375	20.58
	Potato	12.5		105	1312.5	800	1,050,000	26059.99
	Average	46.3		276	3354	2,580	2,385,525	560407.02
Mummiti	Onion	9.2	44	70	644	850	547,400	4906.30
	Wheat	11		25	275	2,000	550,000	2516.89
	Barely	2.9		20	58	1,500	87,000	22.14
	Garlic	1.8		39	70.2	3,500	245,700	46.97
	Average	24.9		154	1047.2	7,850	1,430,100	56411.93
Alaltu-Dubana	Greenpeper	10.1	76	55	555.5	600	333,300	2828.89
	Potato	9.3		105	976.5	750	732,375	10061.54
	Cabbage	3.5		85	297.5	650	193,375	304.60
	Maize	18.6		20	372	1,500	558,000	5840.71
	Average	41.5		265	2201.5	3,500	1,817,050	251136.14

SGVP = Standardized Gross Value of Production

Table 6: Output from the schemes

Irrigation scheme	Output per crop area (Birr/ha)	Output per command area (Birr/ha)	Output per irrigation supply (Birr/m^3)	Irrigation ratio (ha/ha)
Laga-Warke	23973.20	14538.58	156.01	0.61
Alaltu-Tiko	53645.96	36161.35	171.28	0.67
Taltale	121038.23	54941.86	718.85	0.45
Mummiti	22655.39	12820.89	437.83	0.57
Alaltu-Dubana	60514.73	33044.23	512.71	0.55

Table 5, output for similar crop under different irrigation schemes has variable results implying that the total output from each scheme varies. Accordingly, output per crop was found better in Taltale irrigation project followed by Alaltu-Dubana irrigation scheme.

Status of irrigation water management in each scheme:

The result generally indicated that the status of irrigation water management varies as the perception of farmers varies from scheme to

Table 7: Focus group discussion results

Irrigation scheme	Role of irrigation water users	Status
Laga-warke	• Maintenance of irrigation canals • Irrigation scheduling • Controlling effective water utilization by irrigators • Regular cleaning of canals	Medium High Low Low
Alaltu-Tiko	• Maintenance of irrigation canals • Irrigation scheduling • Controlling effective water utilization by irrigators • Regular cleaning of canals	Low Medium Medium Low
Taltalle	• Maintenance of irrigation canals • Irrigation scheduling • Controlling effective water utilization by irrigators • Regular cleaning of canals	Low High Low Very low
Mummiti	• Maintenance of irrigation canals • Water scheduling • Controlling effective water utilization by irrigators • Regular cleaning of canals	Medium Medium Low Low
Alaltu-Dubana	• Maintenance of irrigation canals • Irrigation scheduling • Controlling effective water utilization by irrigators • Regular cleaning of canals	Medium Medium Medium Low

scheme. As indicated in Table 7, based on the criteria to evaluate the status of irrigation water management (like maintenance of irrigation canals, irrigation scheduling, controlling effective water utilization by irrigators, regular cleaning of canals), in well-managed irrigation schemes like Alaltu-Dubana and Taltale, there was better performance on irrigation water management.

DISCUSSION

Scholars have suggested that the average normal bulk density of most irrigable soils ranged from 1.1 g/cm3-1.9 g/cm3 (Greavs, 2007). Similarly, the result of this study revealed that for all considered irrigation schemes, the bulk density was in the recommended range implying that there would be no extreme effect of the recorded bulk density on the water availability for plants at each of the considered irrigation schemes. As indicated by Dananto & Alemu (2014), soils having moderate moisture-holding capacity are better for high irrigation performance. In this study, both gravimetric and volumetric water content also indicated average condition, implying the condition of the soil at each considered irrigation schemes were good at holding appropriate moisture for crops.

Variability in the moisture-holding capacity of the soil could be attributed to the great variability of the soil textural classes which strongly determine the water-holding capacity of the soils. In this study, this was shown in the Mummit, Taltale, and upper part of Laga-Warke irrigation schemes, which had relatively high moisture-holding capacity that would play a great role in advancing irrigation scheduling to improve proper water utilization. Similar research results conducted by Dessalew et al. (2016) showed that the soil textural classes critically affect water-holding capacity and further irrigation scheduling.

Though the schemes were constructed to irrigate the intended command area with the estimated design discharge, this study revealed that currently the available discharge is quite a bit lower than the design discharge for all considered irrigation schemes. Further, this reduction has brought stress on irrigation water scheduling and reduction in full utilization of the command area. The greatest change was observed in Laga-Warke followed by Alaltu-Dubana irrigation scheme. Even though these irrigation schemes were constructed recently, rapid reduction in their discharge would lead to reduction in command area and types of crops to be grown. This would also impact irrigation scheduling as the farmers are trying to share the limited discharge to irrigate much area by extending irrigation interval which leads to water shortages so that crops would be stressed and yield will be potentially reduced. This agrees with findings by Romulus & Schmitter (2016). The degree of variability of total available water (TAW) could be attributed to variability in their soil textural classes as indicated by Agmasie et al. (2022). Likely, in this study, the low TAW in most irrigation schemes could be accounted to variability in their soil textural classes as indicated in (Table 3). Further high TAW implies extended irrigation interval which could leads to maximum coverage of the irrigable area with the limited flow.

The soil textural classes of most schemes were characterized by good moisture-holding capacity as they are clay dominated soil except for the middle and lower parts of Alaltu-Dubana irrigation scheme in which sandy soil dominates. According to Efirem & Mekonnen (2017), soils having available soil moisture in the range of 35 to 95 mm depth are categorized under good moisture-holding soil. The result of this study indicated the values within this range except the lower part of Alaltu-Tiko, Laga-Warke and Alaltu-Dubana indicating the minimum value below the recommended ranges.

As described by Dessalew et al. (2016), performance evaluation for any irrigation system is important for assessing how well goals are being achieved. Formulating a set of objectives at the time an irrigation project is conceived forms the basis for such evaluation as a tool to provide feedback for improving the systems management by initiating remedial measures when needed.

As far as project irrigation efficiency was considered, Brouwer et al. (1998) suggested that irrigation project efficiency of 50%-60% is good; 40% is reasonable, while 20%-30% is poor. In the areas of this study, the results obtained were mainly in the range of 15% to 30% indicating that overall project performance for all schemes was poor. The result obtained for comparison of each irrigation scheme showed that the Taltale irrigation project has relatively lower conveyance efficiency. As suggested by Tesfaye et al. (2019), in order to expand the irrigated command area beyond the design capacity without modifying the amount of water diverted, in this regard, more efficient irrigation water management options should be introduced.

A study by Haileslassie et al. (2016) suggested that in deciding performance of an irrigation scheme, common external indicators focusing on the output from the irrigation system should be considered. In this study, the extent of the intended command area and the currently irrigated area showed great variability as the amount irrigated is quite a bit lower than the command area in all schemes. This resulted in low intended output from the schemes. Further, the price from the scheme showed variability for the same type of crop, which could be attributed to a lack of uniform access to market for the considered schemes.

The output per crop found maximum in Taltale and Alaltu-Dubana irrigation schemes was due to the fact that farmers under those schemes were able to penetrate local and even national market so that what they produces have been sold properly especially in local markets. In irrigation schemes like Taltale, there was better irrigation water management by the farmers as they have adopted to produce vegetables and provide to local and national market to some extent. This result agrees with the finding of Zeleke et al. (2021).

To understand the current status of irrigation water management in each scheme, focus group discussion was conducted with irrigation water users. This was done due to the reason that the mandate of managing irrigation schemes and irrigation water was legally given to each irrigation water users association which was established from irrigation water users. During focus group discussion, the researchers have used constant irrigation water management factors like maintenance of irrigation schemes, irrigation scheduling, controlling effective water utilization by irrigators, and regular cleaning of canals. On these factors respective members of the groups have detail discussion and reached on common agreement about status of irrigation water management at each scheme. The same concept was suggested by Yadeta et al. (2018).

In all schemes regular cleaning of canals and controlling effective water utilization by irrigators were found to be quite poor, while in most schemes, the maintenance of irrigation canals and irrigation scheduling were found to be in a moderate state. This finding agrees with the concept suggested by Sileshi & Mekonnin (2014), implying that improved supervision can save water that could be used for either extension of irrigable land or advancing irrigation water management.

In conclusion, in order to evaluate the technical performance of selected irrigation schemes in the districts, an assessment was done by using internal and external performance indicators. The result indicated that the physical property of soil was good for irrigation. TAW was also found better except at the lower part of Alaltu-Tiko and Alaltu-Duban irrigation schemes. The trend of available irrigation water also indicated that there is a decreasing discharge from that of the design, implying that great stress would be created on producing on the intended command area. Further, application and project efficiencies at the schemes were found to be low, indicating that there was poor irrigation water management. The output related to crops produced in the schemes, output per irrigation supply, and output per command area indicated low values, which could be attributed to the main problems prevailing in the management and operations of the schemes such as malfunctioning of water control structures, poor conveyance system, poor methods of irrigation practice (uncontrolled flooding) at a certain blocks, and poor irrigation schedules. Farmers utilize water above the crop demand and irrigate based on their willingness rather than crop water demand. This further leads to poor state of irrigation water management in the schemes.

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