Irrigation & Drainage Systems Engineering

Research Article Open Access

Comparative Performance Evaluation of Irrigation Schemes in Southern Ethiopia

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Abstract

Performance evaluation of irrigation schemes plays a fundamental role in improving irrigation system by identifying where the critical problems occurred. This study was conducted to evaluate the performance of Wosha and Werka irrigation schemes found at Wondo Genet district southern Ethiopia using comparative indicators. Agricultural output, water supply and physical indicators were used as proposed by the International Water Management Institute. The study showed that Werka irrigation scheme has performed better with respect to all agricultural output indicators except output per unit command area. The crop water demands at both irrigation schemes were not satisfied due to the diverted water was inadequate. Physical indicators revealed that irrigation ratio of 0.89 and 0.78 were recorded at Wosha and Werka irrigation scheme, respectively. In addition, water delivery capacity of both irrigation schemes was sufficient. Moreover, the sustainability of irrigated area indicated that the irrigated area of both schemes was expanding beyond the designed command area. Therefore, both irrigation schemes would needs improvement on irrigation water management and expanding high value crops.

Keywords: Performance; Evaluation; Comparative indicators

Introduction

Nowadays the world's demand for food and fiber is increasing due to the highly growing of the population consequently per capita land and water resources become decreasing [1]. Water is the most limited resource, which is widely used by different sectors like agriculture, domestic and industrial. The competition for this scarce resource is increasing from time to time due to increasing demand from sectors that utilize, which makes less water available for agriculture crop production [2].

Because of the acceleration of population and changes in nutritional habits, food consumption is increasing in most regions of the world. It is expected that by 2050 an additional billion tons of cereals and 200 million tons of meat will need to be produced annually to satisfy growing food demand [3]. currently, irrigated agriculture contributes to producing 40% of world food and agricultural commodities within 16% of cultivated land [4]. In addition, the increasing stress on water resources could inhibit adaptation efforts that improve irrigation water management or a minimum of maintaining the current levels of irrigation system. Global Climate change, water scarceness, and variability have a direct impact on the key sector outputs and therefore ultimately on the overall economy of most African countries [5].

Performance assessment allows verification of the degree to those targets and objectives are being accomplished and additionally provide different stakeholders (system managers, farmers, and policymakers) with a far better understanding of how a system operates [6]. Performance evaluation practices are very much essential because of their central role in effective management [7].

Performance indicators can be broadly categorized into internal and external indicators. However commonly an efficiency term used for on-farm irrigation system evaluation is conducted using internal process indicators [8]. However, with the many variables that influence the performance of irrigated agriculture including infrastructure design, management, climatic conditions, price and availability of inputs, and socioeconomic settings, the task of comparing performance across systems is difficult [9]. The aim of applying comparative indicators is to evaluate outputs and impacts of irrigation management practices, interventions across different systems and system levels, as well as to compare various irrigation seasons and technologies with one another. These indicators are small, not data intensive and are cost-effective [10].

International Water Management Institute (IWMI) has proposed *a* minimum set of indicators for comparative performance studies in irrigation systems. It is mainly focused on water, land and crop production in different systems. Such evaluation using comparative indicators can give the response to which irrigation system utilizes limited water and land resources optimally [9]. With this regards the evaluation conducted in Wosha and Werka irrigation schemes having objective to identify the performance level in accordance with comparative indicators since in 2017/18 irrigation season.

Materials and Methods

Description of the study area

The study irrigation schemes are found in two different kebele of Wondo Genet district at Sidama zone, South Ethiopia, which is located at about 263 km south of Addis Ababa. Geographically lied from 6°54′0″ to 7°7′45″ N and 38°31′33″ to 38°41′20″ E and covers an area with an altitudinal range of 1600 to 1950 m. a.s.l. The schemes have designed to develop 180 and 200 ha of the irrigated area at Wosha and Werka irrigation schemes, respectively.

Long-term (1986-2015) climatic record of Wondo Genet College of forestry and natural resources meteorological station, average annual rainfall in the area is 1069.2 mm. The area receives more than 70% of the total annual rainfall between Aprils and September. The monthly

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Received April 15, 2019; **Accepted** May 13, 2019; **Published** May 20, 2019

Citation: Tesfaye HC, Dananto M, Woldemichael A (2019) Comparative Performance Evaluation of Irrigation Schemes in Southern Ethiopia. Irrigat Drainage Sys Eng 8: 232.

maximum and minimum rainfall values are 147.0 mm and 18.3 mm occurs in the month of August and December, respectively.

Data collection and analysis

For this study, primary and secondary data were collected from each scheme and Wondo Genet Agricultural Office, respectively. The secondary data included climate data, total yields, and farm gate prices of irrigated crops and irrigated area of 2017/18 irrigation season. The diverted irrigation water was recorded at the offtake canal of both irrigation schemes using area velocity method for three consecutive months from December to February. Crop water requirement and irrigation requirement were determined by crop wat 8 computer model. In absence of reports on some crop data of chat, the crop water and irrigation requirement computation made by taking the crop coefficient (Kc) and critical depletion fraction (p) values of the citrus plant, but for the rest of crops appropriate crop data used from FOA 56 [11]. Some data adjusted based on the local crop data and planting date also used from local data of the region (Table 1).

Comparative indicators

Three comparative performance indicators were used in this study to evaluate and compare the performance of the two irrigation schemes. These are agricultural output, water supply, and physical sustainability indicators, which are proposed by International Water Management Institute (IWMI) as a minimum number of comparative indicators grouped as the following [9].

Agricultural performance indicators: For this study, the following agricultural out-put indicators were used by Molden [9].

$$Output\ per\ cropped\ area\left(\frac{\$}{ha}\right)=\frac{Production}{Irrigated\ cropped\ area} \quad (1)$$

$$Output\ per\ unit\ command\left(\frac{\$}{ha}\right)=\frac{Production}{Command\ area} \quad (2)$$

$$Output\ per\ unit\ irrigation\ diverted\left(\frac{\$}{m^3}\right)=\frac{Production}{Irrigation\ diverted} \quad (3)$$

$$Output\ per\ unit\ water\ consumed\left(\frac{\$}{m^3}\right)=\frac{Production}{Volume\ of\ water consumed\ by\ ET} \quad (4)$$

Water supply indicators: Water supply indicators are used to check the water supply and demand for the scheme. According to Molden [9], two indicators are suggested as given below. Relative irrigation and relative water supply for both schemes evaluated for five consecutive months from November to March when the months are very sensitive for the additional water to fill the moisture deficit of the soil. Irrigation supply is the volume of irrigation water delivered from the river source, which is the flow of those five consecutive months measured at the offtake canal of both schemes. Relative water supply is the sum of delivered irrigation water and effective rainfall. Total crop water demand is the actual evapotranspiration demand of the crops, determined using CROPWAT computer model for a given cropping pattern [12].

The crop requirement was calculated for each month using the following equation.

$$CWR_{Dec=}CWR_{Sugar}\times\left(\frac{area_{sugar}}{area_{total}}\right)+CWR_{chat}\times\left(\frac{area_{chat}}{area_{total}}\right)+CWR_{Sugar}\times\left(\frac{area_{sugar}}{area_{total}}\right)+etc \quad (5)$$

The same fashion used to compute each months irrigation requirement for both irrigation schemes. More than 72 and 76% of the total irrigation demands of Wosha and Werka irrigation scheme respectively were demanded from months November to March out of irrigation demand over the irrigated year.

$$RIS=\frac{IWS\left(m^3\right)}{IWD\left(m^3\right)} \quad (6)$$

$$RWS=\frac{\left(IWS+RWS\right)\left(m^3\right)}{CWR\ (m^3)} \quad (7)$$

Where,

RWS: Relative water supply (m^3)

IWS: Irrigation water supply (m^3)

IWD: Irrigation water demand (m^3)

CRW: Crop water requirement (m^3)

Water delivery capacity indicator (WDC): The peak consumptive demand was computed by CROPWAT 8.0 computer model while the canal capacity of designed (intended) volume of water was taken from the design document. It was calculated using the following equation as recommended by Bos [13].

$$WDC(\%)=\frac{Canal\ capacity\ to\ deliver\ water\ at\ system\ head}{Peak\ cosumptive\ demand} \quad (8)$$

Where,

- Capacity to deliver water at the system head: The present discharge capacity of the canal at the system head, and
- Peak consumptive demand: The peak crop irrigation requirements for a monthly period expressed as a flow rate at the head of the irrigation system

Month	T max (°C)	T min (°C)	Relative humidity (%)	Wind speed (m/s)	Sunshine hour	Rainfall (mm)
January	24.2	12.6	47.4	3	8.7	28
February	25.7	13.8	42.0	3.2	8.4	54
March	26.2	15.1	46.4	3.3	7.9	95.6
April	24.6	14.9	60.5	3.0	7.3	128.5
May	23.1	14.5	71.4	2.4	7.4	115.0
June	20.9	13.8	78.8	2.9	6.7	110.9
July	19.5	13.1	81.6	3.3	4.7	143.5
August	19.8	13.0	81.5	3.1	5.1	147.1
September	21.0	13.1	77.9	2.3	5.5	125.2
October	22.0	12.3	70.6	2.4	9.2	77.2
November	23.0	11.8	58.0	3.0	9.0	26.0
December	23.2	11.9	52.1	3.1	7.2	18.3

Table 1: Long-term climatic data of the study area.

Physical indicators

Two physical performance indicators were used for the evaluation of irrigation schemes those are irrigation ratio and Sustainability of irrigated area. Irrigation ratio, being an indicator used to evaluate the degree of utilization, which the land available for irrigation is also a useful indicator of whether there are factors contributing for under irrigation of the command area. Sustainability of irrigated area tells us the command area under irrigation is contracting or expanding as compared to the area irrigated initially. Those are expressed as follows [9,14].

$$IR = \frac{Irrigated\ cropped\ area}{Command\ area} \tag{9}$$

$$SIA = \frac{Currently\ Irrigable\ area}{Innitially\ Irrigated\ area} \tag{10}$$

Where,

- Irrigated crop area (ha) is the portion of the actual irrigated land in any given irrigation season
- Command area (ha) is the potential scheme command area
- Current irrigable area is the area currently can be irrigated (ha)
- Initially irrigated area is the designed/nominal/irrigable area (ha).

Result and Discussion

Agricultural output indicators

The study revealed that the total production of Wosha irrigation scheme was 1571812 US$. The cropping pattern indicates that the major parts of the scheme covered by sugarcane and chat, it is about 354 ha but the rest of 19 ha of land covered with high-value horticultural crops. The irrigated crop area during the study year was 373 ha at Wosha irrigation scheme whereas the designed or nominal crop area was 180 ha (Table 2).

The total production value of the Werka irrigation scheme was 1706838.4 US$. As the result indicated that the total production of Werka was better than Wosha irrigation scheme, this is because of Werka scheme has covered more lands with high-value horticultural crops than Wosha irrigation scheme. The irrigated crop area during the study year was 292.25 ha in the irrigation scheme however the designed or nominal crop area was 200 ha (Table 3).

Output per unit irrigated area (OPUIA): As the result showed that the output per unit irrigated area of Wosha and Werka irrigation were 4213.97 US$/ha and 5840.34 US$/ha respectively (Table 4). As compared the output per unit irrigated area over both schemes, Werka irrigation scheme has better value than Wosha scheme this is due to its greater production (US$) value as a result of the scheme covered by high-value horticultural crop than Wosha scheme. Nearly similar study reported by Degirmenci [15] who found the output per irrigated area was varied between 308 and 5771 US$/ha for the 12 irrigation schemes found in the Southeastern Anatolia Project.

***Output per unit command area (*OPUCA):** The study revealed that the outputs per unit command of Wosha and Werka irrigation schemes were 8732.29 US$ US$/ha and 8534.19 US$/ha, respectively (Table 4). The OPUCA value of both schemes is greater than the value of OPUIA due to the expansion of irrigated land increased beyond the designed or nominal command area of the schemes. Hence, the output per unit command area of Wosha irrigation scheme is better than Werka irrigation scheme. Similar result found in Southeastern Anatolia Project, which was the output per unit-cropped area varies between 1223 and 9436 US$/ha for the period 1997-2001 overtime for the 12 irrigation schemes as reported by Degirmenci [15].

Output per unit irrigation delivered (*OPUID):*** The total amount of water delivered at Wosha and Werka irrigation schemes were 2093656 m^3 and 2001734 m^3, respectively for five consecutive months through irrigation diverted from Wosha and Werka rivers with an average flow of 102 l/s and 74 l/s, respectively. As the result indicates the output per unit irrigation delivered of Wosha and Werka irrigation scheme was 0.75 US$/m^3 and 0.85 US$/m^3, respectively (Table 4).

Similar finding with Werka irrigation scheme reported by Solomon [16] which is 0.89 US$/m^3 at Jari irrigation scheme. According to Cakmak [17], output per unit irrigation delivered of both schemes was lies on range from 0.03 $/m^3 to 2.21 $/m^3 where the study conducted in sixty irrigation schemes found in Kızılırmak Basin, Turkey. The

Crop	Area Coverage (ha)	Yield (ton/ha)	Total Yield (ton)	Price(US$/ton)	production (US$)
Sugar cane	205	13500 pcs/ha	2767500 pcs	0.33 US$/pcs	903427.6
Chat	149	4.5	670.5	763.64	512020.6
Carrot	5	28	140	199.49	27928.6
Potato	4	35	140	290.17	40623.8
Cabbage	7	36	252	154.15	38845.8
Tomato	3	45	135	362.71	48965.85
Total	373				1571812
One US$=27.57 ETH birr, pcs indicate single sugar cane ban					

Table 2: Crop type and production value of Wosha irrigation scheme.

Crop	Area Coverage (ha)	Yield (ton/ha)	Total Yield (ton)	Price(US$/ton)	production (US$)
Sugar cane	118.25	13500pcs/ha	1596375	0.33 US$/pcs	526803.8
Chat	78.5	4.5	353.25	763.64	269755.8
Carrot	3.5	28	98	199.49	19550.0
Potato	68.5	35	2397.5	290.17	695682.6
Cabbage	17.5	36	630	154.15	97114.5
Tomato	6	45	270	362.71	97931.7
Total	292.25				1706838.4
One US$=27.57 ETH birr, pcs indicate single sugar cane ban					

Table 3: Crop type and production value of Werka irrigation scheme.

greater value of output per unit irrigation delivered recorded in Werka irrigation scheme this is due to the greater production value gained and the lower irrigation volume of water supplied as compared to Wosha irrigation scheme.

***Output per unit water consumed (*OPUWC)**: The outputs per unit water consumed at Wosha irrigation scheme was 0.32 US$/m^3 and Werka irrigation scheme was 0.42 US$/m^3 water (Table 4). Both schemes of output per unit water consumed were in the range of 0.15-1.55 US$ m^3 as reported by Çakmak [17] where the study conducted in the Kızılırmak Basin irrigation schemes.

Water supply indicators

The study showed that the relative irrigation supply was 0.64 and 0.48 at Wosha and Werka irrigation scheme, respectively (Table 5). As the ratio indicated that both schemes revealed less than one this implies, the schemes currently diverted less than the irrigation requirement of the schemes. According to Molden [9] reports found in many schemes over the world was indicated there is a wide variation in the RIS values among the systems studied which is from 0.41 to 4.81. Both irrigation schemes revealed less relative irrigation supply due to the expansion of irrigated land over both schemes without considering or increasing the amount of water should divert. However, Wosha irrigation scheme has better RIS than Werka.

The relative water supply of both schemes was also less than one, which means the sum of irrigation water supply and effective rainfalls were not adequate for the crop water requirements of the schemes. The result indicated that the relative water supply was 0.71 and 0.55, respectively for Wosha and Werka irrigation schemes (Table 5). Still, Wosha scheme has greater than Werka irrigation scheme. Similar findings to Wosha irrigation scheme reported by Kuscu [18] where the study conducted at Karacabey irrigation scheme in Turkey was 0.75 during the period from 2002 to 2007.

Parameters	Wosha IS	Werka IS
Irrigated cropped area (ha)	373	292.25
Command cropped area (ha)	180	200
Irrigation supplied (m^3)	2093656	2001734
Water consumed ET (m3)	4855628.21	4036680.6
Production (US $)	1571812	1706838
OPUIA (US$/ha)	4213.97	5840.34
OPUCA (US$/ha)	8732.29	8534.19
OPUID (US$/m3)	0.75	0.85
OPUWC (US$/m3)	0.32	0.42

Table 4: Agricultural output indicators.

Water delivery capacity indicator (WDC)

The study revealed that both schemes have a peak demand in January, which are 0.50 l/s/ha and 0.53 l/s/ha, respectively in Wosha and Werka irrigation scheme. As a result, show that in Table 6 the water delivery capacity was 2.1 and 1.64 at Wosha and Werka irrigation scheme, respectively. The indicator of water delivery capacity was greater than one for both schemes this implies that the canal capacity of the schemes has a capacity to deliver irrigation water at a season of peak demand. However, the schemes cannot supply the offtake canals to carry water at full capacity this might the canals were over-designed.

Physical indicator

Irrigation ratio: Irrigation ratio of Wosha irrigation scheme was 0.89, which implies about 89% of the irrigable command area is under irrigation in 2017/18 crop season. This found also nearly similar to Jari irrigation scheme which is 0.92 as reported by Solomon [16]. Whereas irrigation ratio of Werka irrigation scheme was 0.78, which means 78% of the irrigable land covered under irrigation in 2017/18 (Table 7). Similar findings reported by Solomon [16] which is 0.78 at Aloma irrigation scheme.

Wosha irrigation scheme has better irrigation ratio than the Werka one this is due to the scheme has an advantage of modernized infrastructures and the sloppy nature of the scheme enable the irrigation water to rich any parts of the scheme with low flow rate those reasons might lead greater irrigation ratio at Wosha Scheme. Lower irrigation ratio at Werka scheme is because of the whole conveyance system is unlined earth material which contributes loss through seepage and the slope is not favored the irrigation water to run a longer distance with minimum flow rate as compared with Wosha scheme consequently the expansion became less.

According to Awulachew [19], the most similar schemes in Ethiopia performed an average of about 40%, this implies these two schemes have greater irrigation ratio. The similar finding also reported by Zeleke [12] as the irrigation ratio of Golgota irrigation scheme and Godino and Gohaworki subsystems of Wedecha irrigation schemes ranges from 0.67 to 0.92.

Sustainability of irrigated area: As a result, shown in Table 7 that the sustainability of irrigated area of Wosha and Werka irrigation schemes were 2.07 and 1.46, respectively this implies the current area under irrigation was double and increased by 46% of initially irrigated command area, respectively [20,21]. Wosha scheme is more sustainable than that of Werka scheme but both have an advantage of market accesses and most area coverage is by commercial crops like

Irrigation scheme	Irrigation demand (m^3)	Crop water requirement (m^3)	Eff. Rainfall (m^3)	Irrigation supply (m^3)	RIS	RWS
Wosha	2093656	2341534	329359	1330664	0.64	0.71
Werka	2001734	2204676	258057	964142	0.48	0.55

Table 5: Water supply indicators.

Irrigation schemes	Peak demand (l/s/ha)	Peak demand (l/s)	Canal capacity (l/s)	WDC
Wosha	0.50	186.5	388.8	2.1
Werka	0.53	154.9	253.9	1.64

Table 6: Water delivery capacity.

Irrigation Scheme	Irrigable Land (ha)	Initial Irrigated Land (ha)	Currently Irrigated Land (ha)	Indicators	
				Irrigation Ratio	Sustainability of Irrigated Area
Wosha	420	180	373	0.89	2.07
Werka	375	200	292.25	0.78	1.46

Table 7: Physical performance indicator.

sugarcane and chat. Werka sustainability of irrigated area is nearly similar to Golgota irrigation scheme as reported by Agide et al. [12], which is 1.22.

Conclusions and Recommendations

As the study showed that, the agricultural output indicators were relatively better at Werka irrigation scheme. In contrary better water supply and water delivery capacity, indicators were obtained at Wosha Irrigation Scheme. However, both relative water and irrigation supply were not satisfied the crop water demands at both Wosha and Werka Irrigation Schemes. Both schemes were sustainable according to physical indicators. However, the irrigation command area at both schemes was expanding without considering water resource. This leads to the schemes inadequate irrigation water supply for crop production. Therefore, the study highly recommended that improving irrigation water management is critical to optimize limited water resource. To maximize agricultural production efficiency of both schemes selecting and expanding high-value horticultural crops is very significant especially for Wosha Irrigation Scheme.

Conflict of Interests

The authors declare that they have no competing interests.

Acknowledgments

The authors are grateful to Natural Resource Management Research Directorate, Ethiopian Institute of Agricultural Research, for providing financial support. They are also thankful to Wondo Genet District Agricultural Office for their support.

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