Potential Assessment of Small-Scale Irrigation Scheme by Using Internal and External Indicators: Case Study on Kokono Small Scale Irrigation Scheme, North Wollo Zone, Amhara Region, Ethiopia

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Abstract

The study was conducted to evaluate the potential of Kokono irrigation scheme at north Wollo zone, Amhara region using indicators. Primary data collection includes measuring discharge, soil moisture and depth of water applied. The secondary data collection includes determination of crop types, total yields, farm gate prices of irrigated crops, area irrigated per crop per season, and cost of production. The internal indicators (conveyance, application and storage) were used to check the potential of the scheme. From analyses of internal indicators, the conveyance, application, storage and overall efficiencies were found to be 38.02%, 65.93%, 44.89% and 25.07%. From the analysis of external indicators, the outputs per cropped area were found as 753.38 us$ ha^{-1}, the value of the outputs per command area of scheme was 768.44 us$ ha^{-1}, the output per unit irrigation supply of 0.1us$$m^{-3}$, output per water consumed was 0.18 us$ m^{-3}. The relative water supply and relative irrigation supply were found to be 1 and 1.7 respectively. The irrigation ratio of the scheme was found to be 0.51. In general, based on the assessment carried out, the potential of Kokono irrigation scheme is low.

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1. Introduction

Agriculture is considered the backbone of Ethiopia's economy and a key driver of its long-term food security and development. It directly serves 85% of the population, representing 45% of the gross domestic product and 85% of the export value [27].

For their livelihoods, most of Ethiopia's population relies on rain-fed agricultural production. However, estimated crop production is not close to meeting the country's food requirements. Therefore, expanding the production of irrigation on various scales is one of the best alternatives to consider for effective and sustainable food security development [16].

The irrigation development is increased when the construction and the function of irrigation scheme increased. However, despite water resources and irrigation potential in Ethiopia best owed, the area developed under irrigation is less than its potential. Even those developed irrigation schemes do not perform well as planned and expected because of several inter related factors. One of the factors of the irrigation potential is the performance of conveyance structure is not well functional. Therefore, improving the performance of the irrigation scheme is one of the issues of development of irrigation in developing countries and also crucial due to relatively low performances [3].

One problem to be addressed in order to ensure the sustainability of the schemes is to increase the water utilization of the system, which includes enhancing the management skills of users.The production of water for agriculture is a priority in the region, but poorly built and planned irrigation undermines efforts to improve livelihoods and puts people and the environment at risk. Recent estimates say that Ethiopia's total irrigated area is 640,000 ha, about 4 to 5% of the current cultivated area and 12% of its irrigation capacity [4].

One of the key reasons for the low productivity of water usage in irrigation is inadequate irrigation water management. As available water supplies are becoming scarce, greater focus is put on the effective use of irrigation water for maximum economic return and the sustainability of water resources. This involves calculating how effectively water is collected and used to produce crop yield from a water supply.The insufficient and often unreliable supply of water in the main system causes farmers to face frequent shortages in the supply of water, resulting in lower yields and revenues, as well as irrigation in far smaller areas than originally expected. Inappropriate field layout and mismanagement often result in more water losses and decreased yields at field level. Research and capacity building is required to understand the complex issues of water use and water management in order to increase national and local capacity to address issues of water and land management in order to boost food security, reduce poverty and accelerate national economic growth.

2. Materials And Methods

Description of Study Area

Kokono small scale Irrigation Scheme is found in Eastern Amhara Regional state under North Wollo administrative zone, Habru district, 033 and 034 kebeles. It is located 5 km far from district town and 30 km from zone town. Geographically, the scheme lies at $\mathbf{11^{\circ}39'40''}$ N to $\mathbf{11^{\circ}40'40''}$ N latitude and $\mathbf{39^{\circ}39'40''}$ E to $\mathbf{39^{\circ}40'50''}$ E longitude and it covers the area of 80 ha.

The diversion weir were constructed on Kokono River in 1991 E.C by Commission for Sustainable Agriculture and Environmental Rehabilitation in Amhara Region (Co- SAERAR) having a design area of 80 ha. According to the report of Habru District, the Kokono weir was damaged and re-constructed by Amhara water works construction enterprise (AWWCE) in 2005 E.C.

The main canal of Kokono small scale irrigation scheme is unlined and has a total length of 1.14 km; sediment and seepage are the big problem of this scheme. For operation and management purpose the command area was classified in to 3 water user groups.

2.1. Data Collection Methods

This research was carried out starting from November 2017 to June, 2018 of the two irrigation seasons. Primary and secondary data have been gathered and engaged for the study purpose. For field data collection and measurement purposes, Current Meter, Double ring Infiltrometer, Auger, measuring Tape, Parshall Flume, GPS and Sensitive Balance were used during the study period.

2.1.1. Primary data collection

The primary data were collected through field observations, measurements and laboratory analyses. Field topography and configurations, water applications and practices related to water management techniques made by the farmers, measurements of discharge at diversion (intake) points of each irrigation scheme and also at the initial and final points of main, secondary, tertiary and field canals, soil samples (for the determination of different soil parameters) and soil infiltration rate test were recorded for both irrigation schemes.

Additionally GPS data were also recorded to locate the boundary of the command area, actual canals network and location of canal structures. This was done by walking around the boundary of the command area and along canals and taking point data. These point data were transferred to map source then downloaded to GIS software, and then digitized to locate the command area with irrigation canal network and layout within the boundary on ArcGIS.

2.1.2. Secondary data collection

For each of the selected irrigation schemes, secondary data were collected from Agricultural and Rural Development Office, Water Resource Offices and irrigation offices at regional, zonal, district levels. The secondary data included total yields, farm gate prices of irrigated crops, area irrigated per crop per season, production cost per season, incomes generated by the irrigation associations and cropping pattern. Climatic data of Kokono irrigation scheme were collected from the nearby meteorological station. Total command area, irrigable area, irrigated area, crop yield and price, were collected from Habru district and Woldiya Zone agricultural experts, DA's reports of kebele 033 and 034. Key informant interviews with respective stakeholders and group discussions were carried out for verification of information gathered. A comprehensive field survey has been carried out starting from November 2017.

2.2. Methods used to measure performance indicators

There are large numbers of indicators proposed by different researchers to evaluate the performance of irrigation systems [6]. All performance indicators can however be broadly classified into internal or process indicators and external or comparative indicators [24]. The purpose of comparative indicators is to evaluate outputs and impacts of activities related to irrigation management and interventions across different systems or within the same system over time, while process indicators are used to assess the actual irrigation performance in relation to system-specific management goals.

2.2.1. Internal performance indicators

These indicators examine the technical or field performance of a project by measuring how close an irrigation event is to an ideal one. An ideal or reference irrigation is one that can apply the right amount of water over the entire region of interest (i.e. depth of root zone) uniformly and without losses. Analysis of the field data allows quantitative definition of the irrigation system performance. The performance of irrigation practice is determined by the efficiency with which the water is conveyed through the canal, how irrigation is applied to the field, how adequate the amount is and how the application is uniformly applied to the field [12].

a. Conveyance efficiency

Significant volume of water is lost by the networks of the conveyance canals due to seepage and evaporation depending on the nature of the soil and agro-climatic zone in which the canals are located. Conveyance efficiency is defined as the ratio of the amount of water that reaches the field to the total amount of water diverted into the irrigation system and can be expressed as:

$$E_c = 100\left(\frac{Q_{out}}{Q_{in}}\right)\% \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where: Ec is conveyance efficiency (%), Q_{in} and Q_{out} are the inflow and outflow discharge in specified canal reach.

The concept can also be viewed as the evaluation of the water balance of the main, secondary and tertiary canals and related structures of the irrigation system [21]. It is one of the several closely related and commonly used output measures of performance that focus on the physical efficiency of water conveyance by the irrigation system [5]. Losses of irrigation water in the conveyance system can be a major component of the overall water losses particularly for farms located at significant distances from water sources where the main canals are long and unlined. The amount lost depends on quality of operation, maintenance and the nature of the soil that affects the seepage rate.

b. Application efficiency

Depending on the type of the source, water is diverted, or pumped to a canal or pipe for conveyance to the farm for distribution and finally for application to the crops in the field. When water is diverted into any water application system such as furrows, part of the water infiltrates into the soil for consumptive use by the crop, while the rest is lost as deep percolation and as runoff. The efficiency terms determine these components and compare them with the volume of water actually applied to the field is regarded as application efficiency. The term is an indication of the effectiveness of the system in reducing losses during an irrigation event.

The Application Efficiency is a term initially formulated by Israelson (1950) and measures the ratio between the volumes (depth) of water stored in the root zone for use by the plant to the volume (depth) of water applied to the field. The term has been expressed in different ways over the years to include different parameters by different authorities. Field irrigation efficiencies are influenced by factors such as soil type, field application methods, depth of application and climate. Very high values are achieved in arid climates and where water shortages prevail. However, in the area where the water applied exceeds water required, indicating an over irrigation, emphases should be given to reduce the amount of irrigation water [13]. The water application efficiency is defined as:

$$E_a = 100\left(\frac{w_c}{w_f}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where: w_f the water delivered to the field and w_c is water available for use by the crop.

c. Storage efficiency

The water storage efficiency refers how completely the water needed prior to irrigation has been stored in the root zone during irrigation. It is the ratio of the quantity of water stored in the root zone during irrigation event to that intended to be stored in the root zone. The value is important either when the irrigations tend to leave major portions of the field under-irrigated or where under-irrigation is purposely practiced to use precipitation as it occurs. This parameter is most directly related to the crop yield since it will reflect the degree of soil moisture stress. Usually, under-irrigation in high probability rainfall areas is a good practice to conserve water but the degree of under-irrigation is a difficult question to answer at the farm level [13]. The total available water in the root zone is the difference between the water content at field capacity and wilting point [2].

$$TAW = 1000(FC - PWP)Z_r \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where: TAW the total available soil water in the root zone [mm], FC the water content at field capacity [m^3 m^{-3}], PWP the water content at permanent wilting point [m^3 m^{-3}], Z_r is the rooting depth [m]. TAW is the amount of water that a crop can extract from its root zone, and its magnitude depends on the type of soil and the rooting depth. The fraction of TAW that a crop can extract from the root zone without suffering water stress is the readily available soil water.

$$RAW = pTAW \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where RAW is the readily available soil water in the root zone [mm], and p is an average fraction of Total Available Soil Water (TAW) that can be depleted from the root zone before moisture stress (reduction in ET).

If there are plants growing on the soil, the moisture level continues to drop until it reaches the "permanent wilting point" (PWP). Soil moisture content near the wilting point is not readily available to the plant. Hence the term "readily available moisture" has been used to refer to that portion of the available moisture that is most easily extracted by the plants, approximately 75% of the available moisture. After that, the plants cannot absorb water from the soil quickly enough to replace water lost by transpiration [31]. Therefore, readily available moisture is:

$$W_n = 75\%TAW \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Then the storage efficiency is calculated as:

$$E_s = \frac{W_d}{W_n} \quad \ldots (6)$$

Where W_d water stored in the root zone during irrigation event (mm) and W_n is water desired to be stored in the root zone (mm).

d. Overall scheme efficiency

Irrigation efficiencies are evaluated at scheme or farm level for the purpose of identifying the losses that occur in the irrigation system starting at the water abstraction point, through the conveyance system down to water application in the field to determine the overall irrigation efficiency. In addition to design and other technical factors, the farm efficiency is much regulated by the operation of the main supply system to meet the actual field supply requirements and the skill of the system operators [8, 10]. defined the overall irrigation efficiency (or farm irrigation efficiency) as the product of the component terms (E_c, E_a), expressed as ratios.

$$E_o = E_c * E_a \quad \ldots (7)$$

2.2.2. External performance indicators

External performance indicators evaluate irrigation systems based on a relative comparison of absolute values rather than being referenced to standards or target. Many indicators used for external performance evaluation can be calculated from secondary data rather than primary data. These set of indicators are designed to show gross relationship and trends and are useful in indicating where more detailed study should take place, where a project has done extremely well, or where dramatic changes take place. According to [7], external performance indicators are grouped as:

a. Agriculture performance indicators

A number of indicators were developed with regard to irrigated agricultural systems. They are used for the evaluation of the project performance in terms of the production it results in. It expresses the output of irrigated area in terms of the gross or net value of production measured at local or world prices. This addresses the direct impact of operational inputs in terms of such aspects as area actually irrigated and crop production, over which an irrigation manager may have some but not full responsibility. Four indicators related to the output of different units were used for the evaluation of agricultural performance. These indicators were calculated as follows [18,20].

$$\text{Output per cropped area} = \frac{\text{Value of production(\$)}}{\text{Irrigated Cropped area(ha)}} \quad \ldots (8)$$

$$\text{Output per unit Command} = \frac{\text{Value of production(\$)}}{\text{command area(ha)}} \quad \ldots (9)$$

$$\text{Output per unit irrigated supply} = \frac{\text{Value of production(\$)}}{\text{Diverted Irrigation supply } (m^3)} \quad \ldots (10)$$

$$\text{Output per unit water consumed} = \frac{\text{Value of production(\$)}}{\text{volume of water consumed by ET } (m^3)} \quad \ldots (11)$$

Value of production: is the output of the irrigated area (US$) in terms of the gross or net value of production measured at local or world prices. Irrigated cropped area (ha) is the sum of areas under crops during the time period of analysis. Command area (ha) is the nominal or design area to be irrigated. Diverted irrigation supply (m^3) is the volume of surface irrigation water diverted to the command area. In this study production from irrigated agriculture is the principal issue to compare systems. However there are difficulties when comparing different crops across a system, say onion and tomato, as 1kg of onion is not readily comparable with 1kg of tomato. When only one irrigation system is considered, or irrigation systems in a region where prices are similar, production can be measured as the net value of production and gross value of production using local values. As a result, agricultural output production values were determined through local price and finally, they were converted to US$; to standardize and to compare the results relative to other research findings in the world.

b. Water supply indicators

[20], states that the water supply indicators (relative water supply and relative irrigation supply) are better suited to place the irrigation system in its physical and management context. Higher values of these indicators indicate a more generous supply of water. In this case, productivity to land may be more important. Where the water supply indicators show a lower value it indicates a situation of a more constrained water supply and values of productivity per unit of water are more important.

According to [7], these indicators deal with the primary task of irrigation managers in the capture, allocation, and conveyance of water from a source to field by management of irrigation facilities. Indicators address several aspects of this task: efficiency of conveying water from one location to another, the extent to which agencies maintain irrigation infrastructure to keep the system running efficiently, and the service aspects of water delivery which include such concepts as predictability and equity.

i. Relative water supply (RWS)

According to [17], Relative water supply indicates the adequacy of water applied to the amount of water demanded by the crop. It is the ratio of total water supplied by irrigation plus rainfall to total water demanded by crop i.e. actual crop evapotranspiration (*ETc*).

$$\text{Relative water supply} = \frac{\text{Total water supply}}{\text{Cropped water demand}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (12)$$

Where, Total water supply = diverted water for irrigation plus rainfall (m^3), Crop water demand = potential crop evapotranspiration, or the real evapotranspiration (ETc) when full crop water requirement is satisfied (m^3).

ii. Relative irrigation supply (RIS)

This is the second water supply indicator and described as the ratio of irrigation supply to irrigation demand. Irrigation water is a scarce resource in many irrigation schemes and it is a major constraint for production. This indicator is useful to assess the degree of irrigation water stress/abundance/ in relation to irrigation demand [20,22].

$$\text{Relative irrigation supply} = \frac{\text{irrigation supply}}{\text{irrigation demand}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (13)$$

Irrigation supply = only the surface diversion for irrigation (m^3), Irrigation demand = the crop ET minus effective rainfall (m^3).

RIS relates irrigation supply to irrigation demand of the irrigation schemes in the production season. The computed value shows some indication as to the condition of water abundance or scarcity, and how tightly supply and demand are matched. If the value greater than 1, it indicates irrigation supply was beyond the irrigation demand; if it is less than 1, the irrigation supply was below the irrigation demand. While if it is equal to 1, the supplied amount of irrigation was sufficient to demand, i.e. neither surplus nor deficit. Most of the time it is better to have a RIS near 1 than a higher value.

However, the indicator did not show the monthly relation between irrigation supply and irrigation demand. Additionally, care must be taken in the interpretation of results; the value 0.8 may not represent a problem; rather it may provide an indication that farmers are practicing deficit irrigation with a short water supply to maximize returns on water.

c. Physical performance indicators

Physical indicators are related to changing or losing irrigated land in the command area due to different reasons. Water scarcity and input availability are the main reasons why lands in command area are not fully under irrigation in a particular season. From physical performance, two important indicators were selected to measure the sustainability and irrigation intensities of the system.

i. Irrigation Ratio

[26] developed a relation between currently irrigated areas to the command (nominal) area to be irrigated to quantify the level of utilization of the potential irrigable area for irrigated agriculture for a particular production time period. Lower utilization of the given irrigable area may be due to different constraints; i.e. lack of irrigation infrastructure, shortage of irrigation water, lack of interest on irrigation due to less return and market problems, and reduced productivity due to (soil nutrient depletion, lack of improved technologies, lack of inputs and waterlogging) etc.

To compute the indicator information of irrigated areas in the irrigation season and designed irrigable areas of both schemes were collected from Agricultural and Rural development Offices. Irrigation ratio is determined as follows [20].

$$\text{Irrigation ratio} = \frac{\text{Irrigated area}}{\text{command (nominal) irrigable area}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots. (14)$$

Where, Irrigated area = irrigated area in the irrigation season (ha), Command area = the design (nominal) irrigable area (ha).

3. Results And Discussion

3.1. Soil Physical Properties

To investigate some of the physical properties of soil in the study area (moisture content at field capacity (FC) and permanent wilting point (PWP), moisture content before and after irrigation, texture and bulk density), for the purpose of understanding the general feature of the irrigated soil type, different field samples were taken and analyzed.

3.1.1. Particle size distribution (texture)

Based on the laboratory analysis of particle size distribution, the textural class of Golina Small scale irrigation scheme was found to be clay loam at upper and lower and clay at the middle while the particle size distribution of Kokono Small scale irrigation scheme was clay loam at upper and middle and clay at lower.

3.1.2. Bulk density, field capacity, PWP and total available water

Bulk density

The bulk density of the soil of the Kokono small scale irrigation scheme varied between 1.13 to 1.34 gcm^{-3} with average bulk density of 1.25 gcm^{-3} [9], recommended the soil bulk density below 1.4 gcm^{-3} for clays and 1.6 gcm^{-3} for sands in order to get better plant growth. The bulk density values of the soils at Kokono irrigation scheme were low as per the bulk density rating of [28] indicating that there was no compaction that could limit infiltration of water into and through the soil and root penetration.

Field capacity, permanent wilting point, and total available water

Volumetric moisture content retained at field capacity varied from 17-40% while the volumetric moisture content at permanent wilting point varied from 7-20% at Kokono irrigation scheme Furthermore, the total available water holding capacity of soils selected fields from Kokono scheme ranged from 100-240 mm m^{-1}. In general soil of the scheme is medium as per available water holding rating [14,19]. The results depict that the relevant soil physical properties measured are not different from a great deal from each other with depth and that the soil of the study area is homogeneous.

3.1.3. Soil Infiltration Rate

The infiltration rate was measured at the head, middle and tail end of three test plots to determine the infiltration characteristics of the soil using double ring infiltrometer. Infiltration rate is very rapid at the start of water application, but it decreases rapidly with the advance of time and eventually approaches a constant value. The almost constant infiltration rate that reaches from the beginning of irrigation after some elapsed time is called the basic infiltration rate.

From the result obtained the average basic infiltration rate Kokono Small scale irrigation scheme was measured as 5.4 mm/h. The infiltration rate of the scheme was between the ranges recommended by FAO. According to [15], the basic infiltration rate of soil in the range of 1-10 mm/hr, is classified as soil with low infiltration rate which is the typical characteristics of clay textured soil. The textural class and average infiltration rate is agreed on the textural class of the schemes.

3.2. Determination of Reference Evapotranspiration (ET_o)

The reference evapotranspiration value of the scheme have been calculated based on the procedure mentioned in the methodology part. The minimum and maximum daily ETo values of the scheme were 2.73 mm/day in the month of May and 4.88 mm/day in the month of October. The calculated average daily Reference Evapotranspiration value was 4 mm/day.

3.3. Water Flow Rate Measurement

Continuously calculating water flow rates from intake to farm inlets was very difficult because there was a fluctuation in flow; rotational scheduling systems are used by the farmer. Often, in the upstream/illegal water users/ there were water abstractions and the absence of effective and usable flow control systems at each division boxes. For the purposes of evaluating conveyance performance, application efficiency and total water demand for irrigation, the flow rate at intake, main canals and flow applied to the field was recorded five times. according to the primary field survey, the average discharge at the inlet of the intake gate was 34.325 l/s.

3.3.1. Water flow rate measurement at farm inlets

The total inflow that came via the main canal in the Kokono irrigation scheme was split into five field channels. The calculated observations showed that the farm inlets obtained a mean in-flow rate of 9.47 l/s. This mean inflow rates have been used in the irrigation scheme to assess the total water supplied to farm fields. Two irrigation seasons have been carried out by farmers in the scheme; the volume of diverted and supplied water was the combined number of the two irrigation seasons for the year 2017/18.

3.4. Crop Water Requirements and Irrigation Requirements

In order to evaluate crop water requirements and irrigation water requirements, the CROPWAT 8.0 model determined the requirements for crop water and includes climate data for ETo calculation, crop characteristics data and soil definition. The requirements of crop water are specified as the water depth required by evapotranspiration to meet the water loss. For the main crops grown in both irrigation systems, it was decided. For both schemes, the major crops grown during the study period have been established.

The values of crop coefficient (Kc), maximum root depth (m), crop height, yield reduction factor (Ky) were adopted from FAO Irrigation & Drainage Paper 24 and 56, based on the detailed growth phase values. In the growing period, the values of K-c are expressed by the crop coefficient curve, while the values differ throughout the growing period. The three coefficients of Kc (Kc of original, development and late stages) were required by the CROPWAT 8.0 model.

For the calculation of total water requirements for irrigation scheme in the growing seasons, the total crop water and irrigation water requirement have been computed using the above input data. The total crop water/demand/irrigation requirement for seasons I and II were provided in Table 1. The total irrigation requirement was multiplied by the total irrigated area to adjust the depth to CWR volume.

Table 1 CWR and IR per season for Golina and Kokono SSI schemes

Season	CWR		IR		Eff. Rainfall	
	mm/season	m^3	mm/season	m^3/season	mm/season	m^3/season
I	381.2	150204.7	209.8	82680.5	178.6	70370.2
II	465.7	194178.9	305.7	127465.8	191.4	79805.9

Where; CWR- crop water requirement, IR- irrigation requirement

3.5. Internal Performance Indicators

The main objective of water distribution systems is to convey the diverted water to the place of use, i.e. to the cropped area. There are numerous losses in the course of this transport that decrease the amount of water reaching the farm.

a. Conveyance efficiency

In Kokono SSI scheme the mean conveyance efficiency of the main canal was 38.02% with the mean conveyance loss of 0.027 (l/s/m). [11] recommended the value of conveyance efficiency for the unlined canal as 80% and the recommended value of conveyance loss in the earthen canal was from 0.0017 to 0.005 (l/s/m) for clay loam soil [29]. The conveyance loss of Kokono was higherthan the recommended value. This shows that more water was lost at the unlined main canal of Kokono small scale irrigation scheme.

In general, the efficiency of canal conveyance is influenced by various canal attributes, which are forms of canal and amounts of flow rate.

No working flow control gates, unauthorized water turnouts (breach of main channels leading to leakage) and illegal diverted water led to high water losses or poor conveyance efficiencies in Kokono irrigation scheme, despite common losses, seepage and evaporation. Water seepage and sediment issue at the head and non-functionality of water flow control gates were the major causes of low efficiencies in Kokono scheme as shown in figures 1 and 2. The equity of water delivery in the systems was impaired by this inefficient conveyance; in particular, the tail users did not get their fair share within the required period.

Figure 1 Sediment problem

Figure 2 water losses

b. Application efficiency

The quality of water application gives a general indicator of how well an irrigation system fulfills its primary task of supplying water to the crop from the conveyance system. It informs us whether the irrigation water is retained or lost as surface runoff or/and deep percolation in the intended soil profile.

In the Kokono irrigation system, the average application performance of selected fields was found to be 76.13%, 58.35% and 63.31% for upper users, middle users and lower users, with an average of 65.93%. At Kokono scheme some farmers prepare their fields in a special way. As a result of this, the application efficiency of selected fields was very good and no water lost by runoff. Generally, the obtained application efficiency was between the recommended value reported by [25] which is recommended as 50-70% for properly designed furrow irrigation.

c. Storage efficiency

Storage efficiency refers to how absolutely the water needed prior to irrigation was stored in the root region during the irrigation water application. Based on the FC, PWP, Bd of the soils of the chosen irrigation fields and the root depth of the crop irrigated, the depth of irrigation water required by the crop was determined at 75 percent humidity depletion level [2]. It was calculated as defined under the methodology portion after determining the storage and the appropriate depths.

The result obtained from the Kokono irrigation system for the storage efficiency of selected fields was 48.49%, 47.25% and 38.91% for upper, middle and lower users, with an average storage efficiency of 44.89%. The storage efficiency of the scheme was generally very poor compared to the 63% storage efficiency typically found in typical furrow irrigation systems [23]. This usually demonstrates over field irrigation and this may be associated with the farmers 'intention of high return from high irrigation depth.

d. Overall scheme efficiency

The ratio of water made available to the crop to the amount released on the headwork is the overall efficiency of the method. In other words, it is the product of efficiency of conveyance and efficiency of application. The overall efficiencies of the Kokono irrigation scheme was found to 25.07% in the present analysis. The overall effectiveness of the Kokono irrigation system was lessthan the range values of generally found in other comparable African irrigation systems 40-50% [25].

3.6. External Performance Indicators

a. Irrigated agriculture performance indicators

The degree of productivity of land and water and major constraints were examined in this comparison. This includes performance metrics related to manufacturing. Four comparative indicators (output per cropped area; output per unit command area; output per unit irrigation supply and output per unit water consumption) were used to compare the two selected irrigation schemes with regard to their output per area and water supply.

As shown in Table 2, the crop production for the year 2017/2018 of Kokono scheme was about 2,904 quintals. The cropped area was 81.6 ha with a gross income of 61,475.4 US$. The cropped areas of the irrigation scheme was greater than the command area because some areas were irrigated more than once in the same year.

The total volume of water diverted to Kokono irrigation scheme for 81.6 ha of land during the season (Nov. - Jun, with an average discharge of 34.325 l/s was 717,695 m^3.

Table 2 Crop yields and output production values for Kokono SSI scheme in the year 2017/2018

	Season I						**Season II**					
Crop	Area (ha)	Yield (ku/ha)	Yield (ku)	Ave. price birr/ku	Total income (birr)	Total income (US$)	Area (ha)	Yield (ku/ha)	Yield (ku)	Ave. price birr/ku	Total income (birr)	Total income (US$)
	(1)	(2)	(3)=(1)*(2)	(4)	(5)=(3)*(4)	(6)=(5)/(27ETB)	(7)	(8)	(9)=(7)*(8)	(10)	(11)=(9)*(10)	(12)=(11)/(27ETB)
maize	8.3	13	107.9	1000	107900	3996.2963	22.6	12	271.2	1100	298320	11048.9
Chickpea	2.5	20	50	1000	50000	1851.8519	-	-	-	-	-	-
Pepper	1.3	9	11.7	700	8190	303.33333	1.1	10	11	800	8800	325.9
Tomato	4.6	55	253	600	151800	5622.2222	2.6	60	156	900	140400	5200.0
Onion	19.5	58	1131	400	452400	16755.556	14.2	55	781	450	351450	13016.7
Cabbage	1.2	65	78	300	23400	866.66667	0.1	60	6	350	2100	77.8
Teff	1.5	11	16.5	1450	23925	886.11111	1.1	12	13.2	1500	19800	733.3
mango	0.3	-	-	-	-	-	0.3	35	10.5	1200	12600	466.7
banana	0.2	-	-	-	-	-	0.2	35	7	1250	8750	324.1
Total	**39.4**				**817615**	**30282.037**	**42.2**				**842220**	**31193.3**
										Grand Total=Season I+Season II	**1659835**	**61475.4**

Qu: represents quintal, 1US$=27ETH birr, average currency exchange rate for 2017/18 production year

i. Output per unit cropped area

The production per unit cropped area indicates the reaction of each cropped area to the gross return generation. In any system, this parameter gives a hint about the management activity. The outputs per unit cropped area was753.38 US$ ha^{-1} for Kokono scheme, based on the data obtained.

ii. Output per unit Command area

The average return per design cropped area is expressed by this indicator. It is an indication of whether or not all the cropped areas yield returns. The Kokono irrigation scheme output per unit command area was US$ 768.44 ha^{-1}.

The kokono irrigation area was 39.4 ha during the first season and 42.2 ha during the second season. Which means that 49.25% and 52.75% of the control area is irrigated during the first and second seasons when these areas are compared to the designed command area. Land productivity indicators were called output per unit irrigated area and output per unit command area performance indicators.

iii. Output per unit irrigation supply

The output per unit irrigation supply shows the revenue from the agricultural output for each meter cube of irrigation water supplied. The output per unit irrigation water supply for Kokono was found to be 0.1 US$ m^{-3}.

iv. Output per unit of water consumed

To define the return on the water actually consumed by the crop, the production per unit of water consumed is used. This indicator gives due consideration to the water used by each system and informs us how, from an economic point of view, water is used effectively by the system. For the Kokono irrigation scheme, the production per water consumed was 0.18 US$ m^{-3} of water.

Water productivity performance was assessed by using two indicators; output per unit of irrigation water supplied/diverted/and output per unit of water consumed. The output per unit of water consumed was greater than the output per unit of water supplied. This means that the quantity of irrigation water consumed was more productive than the irrigation water diverted.

b. Water Supply indicators

i. Relative water supply

Relative Water Supply (RWS) showed the availability of water in relation to the demand for crop water, which means that the relative supply of water indicates whether sufficient irrigation water is supplied or not. Both the relative supply of water and the relative supply of irrigation relate supply to demand and give some indication as to the state of abundance or scarcity of water and how closely supply and demand are matched. Normally, the relative water supply value below one indicates that the water applied is lower than the demands of the crops. A RWS value of less than one may not be a problem; rather, it may provide an indication that farmers are practicing short water supply deficit irrigation to maximize water returns. And a RWS value above one indicates that, beyond plant requirements, additional water is added to the root zone, which means that the total water applied satisfies the needs of the crop.

Based on equation 12, the indicator was calculated for the scheme. Total demand for crop water, successful rainfall and demand for crop irrigation were calculated by the CROPWAT model for a given cropping pattern and irrigation season, in addition to the amount of irrigation provided. The relative water supply values in Kokono irrigation scheme was 1, indicating that the water supply was sufficient, i.e. neither surplus nor deficit, for the demand for crop water. This means that the water supplied was sufficient to demand crop water for the irrigated soil. However, it could not irrigate additional rainfall with this distribution quantity and usable productive rainfall.

ii. Relative irrigation supply

The relative supply of irrigation shows whether or not the demand for irrigation is satisfied. The calculated value interpretation is similar to RWS. The computed RIS value for Kokono irrigation scheme was 1.7. This value indicated that a generous supply of water existed and irrigation was the sole water supplier. Having RIS close to 1 is better than having a higher or lower value than [20].

c. Physical performance indicators

For various reasons, physical indicators are linked to changing or losing irrigated land in the command area. The irrigation ratio for kokono irrigation scheme was 0.51, meaning that 49% of the scheme's control area was irrigated during the study period. The main reasons for this were the decrease in the discharge of the scheme due to the construction of the new diversion structure on the upper Kokono River, which is the source of the Kokono irrigation system.

4. Conclusions

In this study, an attempt was made to assessing the potential of Kokono small scale irrigation scheme by using the internal and external indicators. The internal indicators computed were conveyance efficiency, application efficiency, storage efficiency, and overall efficiency. The standardized performance indicators established by the international irrigation management institute (IIMI) were taken as external indicators. The external indicators included in this study were agriculture, water use, and physical performance. Because of data limitation, economic performance was not included.

The conveyance efficiency of Kokono scheme at the main canal showed low value because the canals are unlined and due to leakage and lack of management. The application efficiency of the scheme was, found to be good compared to the application efficiency of 50-70% for furrow irrigation observed in other African countries. The output per unit command area was also observed to be relatively low in Kokono. This implies that a large amount of command area was not under irrigation during the study season in Kokono due to a shortage of water. In general, it can be concluded that Kokono irrigation scheme. In general, based on the assessment carried out, the potential of Kokono irrigation scheme is low.

Data Availability Statement

All data, models, and code generated or used during the study appear in the submitted article.

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