Performance Evaluation Methods Widely Used to Assess Performance of Irrigation Scheme in Ethiopia

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Abstract
Irrigation is the application of water to agricultural crops by artificial means, designed to permit farming in arid and semi arid regions and helped to increase agricultural production in developing countries . Thus irrigation development particularly will be an important component of diversification and expansion strategy to strengthen food security in the future. Irrigation project development has both positive and negative impacts in the society and environment. Expanding efficient irrigation development on varies scales is one of the best alternative to provide reliable and sustainable food security. Irrigation scheme performance assessment is vital to evaluate the impacts of irrigation practices, to identify performance gaps and to improve system performances. However many irrigation schemes in developing countries in general and particularly in Ethiopia are performing below capacity. As a summary the selected minimum performance indicators which have employed for this paper were reviewed. Thus based on the selected performance indicators and their applications the selected internal and external performance evaluation indicators have been identified and benchmarked for the next study sections. The paper is prepared to understand irrigation performance evaluation indicators widely used to determined system performance and understand chance of comparing the system with another system that has different environment, infrastructure and climate in the region.
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1. INTRODUCTION

Together with ever increasing world population, food demands are also increasing. To meet these increasing demands, agricultural sector spends great efforts to increase productions and yields in irrigated lands. Therefore, soil and water resources development is a significant issue to achieve this goal in agricultural sector. (Seda, et al. 2017)

Agricultural sector plays a vital role in eradicating poverty plummeting in many regions of the world. The performance of irrigation systems has a major role in producing more food and making irrigated agriculture cost-effective. The superior irrigation management can improve the performance of irrigation system. (Chouhan, et al. 2017)

Irrigation is practiced in Ethiopia since ancient times producing subsistence food crops. However, modern irrigation systems were started in the 1960s with the objective of producing industrial crops in the Awash Valley. Private concessionaires who operated farms for growing commercial crops such as cotton, sugarcane and horticultural crops started the first formal irrigation schemes in the late 1950s in the upper and lower Awash Valley. In the 1960s, irrigated agriculture was expanded in all parts of the Awash Valley and in the Lower Rift Valley. (MCE 2004)

Irrigation in Ethiopia is considered as a basic strategy to alleviate poverty and hence food security. It is helpful to remodel the rain-fed agricultural system that depends on precipitation into the combined rain-fed and irrigation agricultural system. This is believed to be the most outstanding way of sustainable development in the country (Gebremedhin, 2015). However, in many parts of the country; the farmers are practicing irrigation without essential know-how on crop water need, water application method and irrigation interval. Lack of knowledge of irrigation water management aspects has resulted in wastage of irrigation water, deterioration of some structures and water logging problems on some farms (Berhanu, 2006).

The efficiency of irrigation water use varies from scheme to scheme. In schemes where water is limited, available water is used more carefully. Whereas, in areas of abundant water, the value put on conserving water is less and the tendency to over irrigate exists. Efficient use of water is also influenced by cost of labor, ease of controlling water, crops being irrigated, type of irrigation system, and soil characteristics. Various terms are used to describe how efficiently irrigation water is applied and used by crop. (Adam, 2013)

Performance of irrigated agriculture must improve to provide additional food to a growing and more affluent population, but it is constrained by water scarcity and the resulting competition for scarce water resources. (M.G. Bos *et al*. 2005). Beside that Performance evaluation of irrigation projects is not common in the country. Lack of knowledge and tools used to assess the performance of projects adds to the problem (Mintesinot *et al*., 2005).

The aim of this paper was to understand irrigation performance evaluation indicators widely used to determined system performance and understand chance of comparing the system with another system that has different environment, infrastructure and climate in the region.

2. Irrigation potential in Ethiopia

Ethiopia comprises 112 million hectares (Mha) of land. Cultivable land area estimates vary between 30 to 70 Mha. Currently, high estimates show that only 15 Mha of land is under cultivation. For the existing cultivated area, our estimate is that only about 4 to 5 percent is irrigated, with existing equipped irrigation schemes covering about 640,000 hectares. This means that a significant portion of cultivated land in Ethiopia is currently not irrigated. (Awulachew, 2010)

The irrigation potential was taken as one of the most underutilized opportunities in Ethiopia. At the end of the 1990s, the area under small-scale irrigation was estimated at around 64 thousand hectares while that of medium and large-scale were appraised at 112 thousand hectares, of which 22 thousand hectares were new small-scale irrigation schemes implemented since 1992. The nation has a National Irrigation Development Strategy, which has the goal of utilizing the country's natural potential to achieve food self-sufficiency at the national level, generate export earnings, and provide raw materials for industry on a sustainable basis. (Kamara and McCornic, 2012)

As Awulachew et al (2007) tried to survey on experiences and opportunities for promoting Small-scale /Micro-Irrigation and Rainwater Harvesting for food security in Ethiopia, Irrigation is one means by which agricultural production can be increased to meet the growing food demands in Ethiopia. In addition, according to these researchers, increased food demand can be met in one or a combination of three ways: increasing agricultural yield, increasing the area of arable land, and increasing cropping intensity (number of crops per year). Expansion of the area under cultivation is a finite option, especially in view of the marginal and vulnerable characteristic of large parts of the country's land. Increasing yields in both rains fed and irrigated agriculture and cropping intensity in irrigated areas through various methods and technologies are the most viable options for achieving food security in Ethiopia. If the problem is failure of production as a result of natural causes, such as dry-spells and drought, agricultural production can be stabilized and increased by providing irrigation and retaining more rainwater for in situ utilization by plants.

Furthermore Awulachew et al (2007) specified the challenge that Ethiopia faces in terms of food insecurity as it is associated with both in adequate food production even during good rain years (a problem related to inability to cope with growth of population) and natural failures due to erratic rainfall. Therefore, increasing arable land or attempting to increase agricultural yield by, for instance, growing higher yielding varieties of crops offers limited scope to provide food security in Ethiopia. The solution for food security will be provided by a combination of these factors, enhancing water availability for production and expansion of irrigation that can lead to security by reducing variation in harvest, as well as intensification of cropping by producing more than one crop per year. This should be combined with improved portioning, storage and soil water-retention capacity to increase plant water availability, and use of highland Ethiopia.

Ethiopia in deed has significant irrigation potential assessed from both available land and water resources potential, irrespective of the lack of accurate estimates of potentially irrigable land and developed area under irrigation. Despite efforts of the government to expand irrigation, the country has not achieved sufficient irrigated agriculture to overcome the problems of food security and extreme rural poverty, as well as to create economic dynamism in the country (Awulachew et al., 2007).

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In Ethiopia, about 90% of the irrigation potential in terms of land and water resources has not been developed so far. However, there have been many ongoing medium and large-scale irrigation developments in recent years. While about 47% of the developed area is under large-scale public irrigation schemes, mainly industrial crops such as Cotton, Sugarcane and various fruits are grown. About 65% of the irrigated area is under small-scale irrigation schemes, either modern or traditional. Traditional irrigation schemes are those developed by farmers themselves and are without permanent water diversion, conveyance, and control and distribution facilities. Modern schemes are those equipped with basic irrigation infrastructure such as water diversion and flow control structures and conveyance and distribution systems. Modern small-scale schemes account for about 18% of irrigated area to date. Small-scale schemes are operated and managed by the water users themselves with little involvement of government agencies in some cases. Ministry of Water Resources emphasizes that in Ethiopia, these schemes have been playing a significant role in ensuring food security at household level and in improving the livelihood of the rural poor. (Dejen et al, 2012)

The country's agricultural sector has shown no significant structural transformation and is dominated by smallholder producers. Large-scale commercial productions run by the state were not given attention any more following the economic liberalization policy and programs of public enterprise privatization. Private commercial farms are still very limited although their role is growing (Adenew, 2006).

Currently, the government is giving more emphasis to irrigation sector by way of enhancing the food security situation in the country. Efforts are being made to involve farmers progressively in various aspects of management of small-scale irrigation systems, starting from planning, implementation and management aspects, particularly, in water distribution and operation and maintenance to improve the performance of irrigated agriculture.

4. Performance evaluation of irrigation scheme

The evaluation of surface irrigation at field level is an important aspect of both management and design of the system. Field measurements are necessary to characterize the irrigation system in terms of its most important parameters, to identify problems in its function, and to develop alternative means for improving the system (FAO, 1989).

Public agencies in many developing countries want to assist farmer-managed irrigation systems improve their performance through better management. And, better management is dependent upon appropriate methods and measures by which system performance can be evaluated relative to the management objectives (Oad and Sampath, 1995). Hence, reliable measures of system performance are extremely important for improving irrigation policy making and management decisions.

The development potential for small-scale irrigation seems attractive in view of cost effectiveness, well-focused target group and its sustainability through empowerment of the beneficiaries. However, experience has shown that there are still considerable constraints and setbacks that hinder the introduction of small-scale irrigation.

Performance is assessed for a variety of reasons: to improve system operations; to assess progress against strategic goals; as an integral part of performance-oriented management, to assess the general health of a system; to assess impacts of interventions; to diagnose constraints; to better understand determinants of performance; and to compare the performance of a system with others or with the same system over time. The type of performance measures chosen depends on the purpose of the performance assessment activity. (Molden et al., 1998)

5. Performance Indicators

Performance indicators measure the value of a particular item such as yield or canal discharge and have to include a measure of quality as well as of quantity, and be accompanied by appropriate standards or permissible tolerances (Rust and Snellen, 1993). Performance indicators can be broadly categorized into internal and external indicators.

Internal indicators, which relate performance to internal management targets, external indicators enable comparison between different regions, different infrastructure and management types, and different environments. Moreover, the trend in performance of a specific scheme can be compared over time. Internal irrigation performance is also linked to farmers' level of satisfaction by some authors (Ghosh *et al*., 2005; Kuscu *et al*., 2008). Much of the work to date in irrigation performance assessment has been focused on internal processes of irrigation systems. Many internal process indicators relate performance to management targets such as timing, duration, and flow rate of water; area irrigated and cropping patterns.

A major purpose of this type of assessment is to assist irrigation managers to improve water delivery service to users. Targets are set relative to objectives of system management, and performance measures tell how well the system is performing relative to these targets (Molden *et al*., 1998). Internal indicators do not lend themselves well to cross-system comparison. This is due to several reasons. First, internal processes of irrigation systems vary widely from system to system, so that performance indicators are tailored to meet system-specific needs. Second, indicators related to irrigation processes tend to be data intensive and it is often difficult, time-consuming, and expensive to obtain complete data sets. Third, assumptions about relations between internal processes and outputs may not be valid. It is often assumed that meeting a target will improve output in terms of agricultural production or net benefit to farmers.

5.1. Internal Performance Indicators

Internal performance describes the effectiveness of the physical system and operating decisions to deliver irrigation water from a water source to the crop. Several efficiency terms are used to evaluate irrigation system performance. These include water conveyance efficiency, water application efficiency, soil water storage efficiency, irrigation efficiency, overall irrigation efficiency, and effective irrigation efficiency (Irmark*et al.*, 2011). Generally, internal indicators enable a comprehensive understanding of the processes that influence water delivery service and the overall performance of a system (Renault and Wahaj, 2007).

Many internal process indicators relate performance to management targets such as timing, duration, and flow rate of water; area irrigated and cropping patterns. A major purpose of this type of assessment is to assist irrigation managers to improve water delivery service to users. Targets are set relative to objectives of system management, and performance measures tell how well the system is performing relative to these targets. When the performance is not adequate, either the process must be changed to reach the target, or the target itself must be changed. These "internal" indicators aid irrigation system managers to answer the question "Am I doing things right?" (Murray-Rust and Snellen, 1993).

5.1.1. Application Efficiency (Ea)

Application efficiency is a measure of the fraction of the total volume of water delivered to the farm or field to that which is stored in the root zone to meet the crop evapotranspiration (ET) needs. Water application efficiency (Ea.) provides a general indication of how well an irrigation system performs its primary task of delivering water from the conveyance system to the crop. The objective is to apply the water and store it in the crop root zone to meet the crop water requirement (Irmark *et al*., 2011).

Application efficiency is the most important in terms of design and management since it reflects the overall beneficial use of irrigation water. Design and management strategy will be proposed in which the value application efficiency is maximized subject to the value of requirement efficiency being maintained at 95 to100 percent. This approach thereby eliminates storage efficiency from an active role in the surface irrigation design or management and simultaneously maximizes application efficiency (FAO, 1989).

Increase the application efficiency, and poor irrigation management can result in inefficient use of water and reduce application efficiency. Over-irrigation may result in leaching chemicals below the crop root zone, cause yield reduction, and result in wasting water resources. Improper timing and inadequate irrigation applications that do not meet the crop water requirement may impose stress on the crop and reduce grain yield and yield quality (Irmark et al.,2011).

$$\mathrm{Ea} = \frac{\text{Depth of water added to the root zone}}{\text{Depth of water applied to the field}} \tag{1}$$

5.1.2. Storage Efficiency (Es)

The requirement efficiency is an indicator of how well the irrigation meets its objective of refilling the root zone. The value of Esis important when either the irrigations tend to leave major portions of the field under-irrigated or where under-irrigation is purposely practiced using precipitation as it occurs, and storage efficiency become important when water supplies are limited (FAO, 1989). The water storage efficiency refers how completely the water needed prior to irrigation has been stored in the root zone during irrigation (Roger *et al*., 1997).

The main goal in most irrigation applications is to maximize water storage in the soil root zone to satisfy crop ET while minimizing deep percolation and surface runoff. The soil water storage efficiency indicates how well the system uses the available root zone storage capacity to store water to meet crop needs. Thus, in most cases, maximizing water storage from irrigation is beneficial. The maximum amount of water that should be applied to achieve high Es for a given irrigation event is the difference between the field capacity and average water content in the soil root zone prior to the irrigation event. A high Es means that the irrigation brings the soil root zone to field capacity, but does not lead to deep percolation. In most cases, it is suggested not to refill the soil profile to the field capacity, but rather to leave some storage capacity for a potential rainfall event. Thus, refilling the soil profile to about 90 percent of the field capacity can be a good strategy (Irmark*et al*., 2011).

Adequacy of irrigation turn in terms of storage efficiency and the purpose of an irrigation turn is to meet at least the required water depth over the entire length of the field. Conceptually, the adequacy of irrigation depends on how much water is stored within the crop root zone, losses percolating below the root zone, losses occurring as surface runoff or tailwater the uniformity of the applied water, and the remaining deficit or under irrigation within the soil profile following irrigation (Jurriens *et al.* 2001).

$$\mathrm{Es} = \frac{\text{Volume of water added to the root zone storage}}{\text{potential soil moisture storage volume}} \tag{2}$$

5.1.3. Distribution Uniformity

Distribution uniformity is one indicator used to represent the pattern of the infiltrated depths along the field length which is defined as the minimum infiltrated depth divided by the average infiltrated depth (Jurriens *et al.*, 2001).

When a field with a uniform slope, soil and crop density receives steady flow at its upper end, a waterfront will advance at a monotonically decreasing rate until it reaches the end of the field (FAO, 1989). According to (Roger *et al.,* 1997) water lost to percolation below the root zone due to the non-uniform application or over-application of water as run-off from the field, all reduce irrigation efficiencies.

The distribution uniformity of application can be evaluated using the Christiansen Uniformity coefficient (Michael, 1997; Jurriens *et al*, 2001). This is intended to be measured in the field and should be in the limit of FAO (1992) recommended that, distribution efficiency of 65 and 30% as sufficient and poor, respectively.

$$cu = 100 \times \left(1.00 - \frac{\sum|d|}{nx}\right), \qquad d = x_i - \bar{x} \tag{3}$$

Where:

Cu = Christiansen Uniformity Coefficient;
d =deviation of observation from the mean;
n = number of observations;
$\bar{x}$= Average depth infiltrated;
x= Depth infiltrated at observation point

5.1.4. Conveyance Efficiency (Ec)

Conveyance efficiency is an indicator which measures irrigation water is normally conveyed from a water source to the farm or field through natural drainage ways, constructed earthen or lined canals, or pipelines. Many conveyance systems have transmission losses, meaning that water delivered to the farm or field is usually less than the water diverted from the source. Water losses in the conveyance system include canal seepage, canal spills, evaporation losses from canals, and leaks in pipelines. The water conveyance efficiency is the ratio of the irrigation water that reaches a farm or field to that diverted from the water source (Irmark *et al*., 2011).

$$Ec = \frac{\text{volume of irrigation water that reaches the farm or field}}{\text{volume of irrigation water diverted from the water source}} \times 100 \tag{4}$$

The conveyance efficiency of the scheme will compute as:

$$Ec = Em * Es * Et * Ef \tag{5}$$

Where Ec =conveyance efficiency (%),
Em= conveyance efficiency of the main canal (%),
Es= conveyance efficiency of secondary canal (%),
Et=conveyance efficiency of tertiary canal (%),
Ef= conveyance efficiency of field canal (%)

5.2. External Performance Indicators

External indicators are used to relate outputs from a system derived from the inputs into an irrigated agricultural system (Molden *et al*., 1998). Many indicators of external performance are computed by using secondary data rather than primary data. The indicators tell general concept about the relative health of the irrigation system, yet they are not too data-intensive to discourage widespread and regular application.

Currently, water becomes a limiting resource; an important question that arises is "what is the value of irrigated agricultural production per unit of water consumed from the hydrological cycle?" In order to answer this question requires an indicator that measures the contribution of the irrigation activity to the economy in relation to consumption of the increasingly scarce resource, water (Molden et al., 1998).

The International Water Management Institute proposed a minimum number of external (comparative) indicators of four, two, one and two for agricultural outputs, water supply, delivery capacity and financial cases, respectively (Molden*et al*., 1998).

5.2.1. Agricultural Output Indicators

A number of indicators are developed regard to irrigated agricultural systems. Water, land and finance are the main inputs for output of crop production. Five of them are relating to output to land and water were selected, i.e., two from land productivity and three from water productivity. These external indicators provide the basis for the comparison of irrigated agricultural performances. Where water is a constraining resource, output per unit water may be more important, whereas if land is a constraint relative to water, output per unit land may be more important.

5.2.1.1. Output per unit irrigated cropped area ($/ha)

It is computed as the total value of production per harvested area in the irrigation seasons. The harvested /Irrigated / area includes the areas that were irrigated in the irrigation seasons.

$$OPUIA = \frac{Valueof\ production}{Harvested\ area}, \frac{\$}{ha} \tag{6}$$

5.2.1.2. Output per unit command area ($/ha)

This indicator quantifies the value of production that obtained per unit command irrigable area. The computed value indicates the level of utilization or number of cropping frequency of the given command area in the production year and the productivity of the command area. High value result shows there is good intensive irrigation. Meanwhile small values are not pertinent from land productivity point of view; less intensity of irrigation could not increase the production amount per unit of land. Furthermore this is more relevant for land is the major constraint factor for production. Command area is the nominal or design area to be irrigated.

$$OPUCA = \frac{Vlue\ of\ production}{Productioncommand\ area}, \frac{\$}{ha} \tag{7}$$

5.2.1.3. Output per unit irrigation water diverted ($/m^3)

This is one of the water productivity indicators and calculated as the total value of production per unit water diverted from the headwork to the command area throughout the irrigation seasons; it includes the conveyance losses in the irrigation systems. It illustrates the productivity of diverted water from the source. It is an important parameter where water is a scarce resource. Diverted/supplied irrigation water is the volume of surface irrigation water diverted to the command area.

$$OPUIS = \frac{Value\ of\ production}{Diverted\ Irrigation\ Water}, \frac{\$}{m^3} \tag{8}$$

5.2.1.4. Output per unit irrigation water delivered ($/m^3)

It quantifies the value of production per unit delivered irrigation water to the head of farm inlets in the irrigation seasons. It is the net irrigation water delivered to the farm and it does not include losses in conveyance systems. It is a useful comparative indicator because it addresses output per drop of irrigation water actually delivered to the user. A lower value of this indicator indicates there is inefficient water use in the irrigation system or specifically at farm level.

$$OPUID = \frac{Value\ of\ \ Production}{Delivered\ Irrigation\ water}, \frac{\$}{m^3} \tag{9}$$

5.2.1.5. Output per unit consumed water ($/m^3)

This indicator derived from the general water accounting frame work (Molden, 1998). Consumed water is the actual evapotranspiration or process consumption from only irrigated crops (ET); it excludes other losses and water depletion from the hydrological cycle. The computed value does not affected by water losses through the system but only affected by the climatic feature of the area. It used to observe water consumption of crops at scheme level through evapotranspiration relative to the diverted and delivered amount of irrigation water. It has a contribution for irrigation managementaspects; to take measurements those minimize evapotranspiration losses.

$$OPUWC = \frac{Value\ of\ production}{Volume\ of\ water\ consumed\ by\ ET}, \frac{\$}{m^3} \tag{10}$$

Value of Production is the output of the irrigated area in terms of gross or net value of production measured at local or world prices. 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 Wheat and Potato, as 1kg of wheat is not readily comparable with 1kg of potato. When only one irrigation system is considered, or irrigation systems in a region where prices are similar, production can be measured as 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 it was converted to US$; to standardize and to compare the results relative to other research findings in the world.

5.2.2. Water Supply Indicators

Water supply indicator includes as (Molden*et al.*,1998) cited, relative water supply as presented by(Levine,1982) and relative irrigation supply as developed for this indicator set (Perry,1996) are used as the basic water supply indicators.

Both RWS and RIS relate supply to demand, and give some indication as for the condition of water abundance or scarcity, and how tight supply and demand are matched. An irrigated area upstream in a river basin may divert much water to give adequate supply and ease management, with the excess water providing a source for downstream users. In such circumstances, a higher RWS in the upstream project may indicate the appropriate use of available water, and a lower RWS would actually be less desirable. Likewise, a value of 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 (Molden*et al.,* 1998).

Water supply indicators is consisting of two indicators as below

$$1.\ \text{Relative water supply}$$

$$= \frac{\text{Total water supply}}{\text{Crop demand}} \qquad (11)$$

$$2.\ \text{Relative irriagtion supply} = \frac{\text{Irrigtion water supply}}{\text{Irrigation demand}} \qquad (12)$$

Where,

- Total water supply = Surface diversions plus net groundwater draft plus rainfall.
- Crop demand = Potential crop ET or the ET under well-watered conditions. When rice is considered, deep percolation and seepage losses are added to crop demand.
- Irrigation supply = only the surface diversions and net groundwater draft for irrigation.
- Irrigation demand = the crop ET less effective rainfall.

5.2.3. Water Delivery Capacity Indicator

Water delivery capacity is meant to give an indication of the degree to which irrigation infrastructure is constraining cropping intensities by comparing the canal conveyance capacity to peak consumptive demands. Again, a lower or higher value may not be better but needs to be interpreted in the context of the irrigation system, and in conjunction with the other indicators. Expressed as below

$$1.\ \text{Water delivery capacity}(\%)$$

$$= \frac{\text{Canal capacity todeliver water atsystem head}}{\text{Peak cosumptive demand}} \qquad (13)$$

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.

5.2.4. Financial Indicators

Financial indicators are interested in Policymakers in the returns to investments made. Similarly, researchers would like to be able to recommend systems that yield acceptable returns within a given environment. The cost of the distribution system can either be estimated from original costs, or estimated by using present costs of similar types of infrastructure development.

Financial self-sufficiency tells us what percent of expenditures on operation and maintenance is generated locally. If the government subsidizes O&M heavily, financial self-sufficiency would be low, whereas if local farmers through their fees pay for most of the O&M expenditures, financial self-sufficiency would be high. Financial self-sufficiency does not tell us the O&M requirement, only the expenditures. A high value of financial self-sufficiency does not automatically indicate a sustainable system as the O&M expenditures might be too low to meet the actual maintenance needs. A financial indicator includes two indicators gross return on investment and financial self-sufficiency.

$$\text{GRI} = \frac{Gross\ value\ of\ production}{Cost\ of\ irrigation\ infrustuctio} \quad (14)$$

Where:
Gross value of production is the output production value of the irrigation projects (ETB/ha)
Cost of irrigation infrastructure considers the cost of the irrigation water delivery system referenced to the same year as the production (ETB/ha)
For computation purpose, the cost of irrigation infrastructure was estimated as present net worth (PNW), through the average interest rate of the service years.

$$PNW = P * (1 + i)^{\ 2} \quad (15)$$

Where, P= initial investment cost (ETB)
i= Average interest rate in the service years (%)
n= Number of service years

5.2.4. Physical performance indicators
Under this, two important physical performance indicators were selected to measure the sustainability and irrigation intensities of the systems.
5.2.4.1. Irrigation ratio
Sener et al. (2007) 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 would be existed 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 water logging) etc. Furthermore cropping intensity is an illustrative for land utilization capacities. The cropping intensities from 100 to 200% are considered good, while lower ratio indicates poor intensities (Burton et al., 2000).

To compute the indicator information's of irrigated areas in the irrigation season and designed irrigable areas of both schemes were collected from Agricultural and Rural development Offices.

$$IR = \frac{Irrigated\ Area}{Command(nominal)irrigablearea} \quad (16)$$

Where,
Irrigated area = irrigated area in the irrigation season (ha)
Command area= the design (nominal) irrigable area (ha)
5.2.4.2. Sustainability of irrigated area
According to Bos (1997) sustainability of irrigated area is the ratio of currently irrigable area to initially irrigated area. This important indicator mainly used to observe the status of the irrigation systems either contracted or expanded. If the computed value is small or less than 1 it shows the irrigable area is contracted and if it is large i.e. greater than one, it shows the irrigable area is expanded from the designed irrigable area, through including nearby farm areas. The contraction of irrigable land may be appeared due to different reasons, i.e. water shortage, water logging, flooding problems etc. On the other hand expansion might be occurred due to interests coming from neighboring farmers to irrigate extra land addition to designed one. This expansion of irrigable area indicates there is more sustainable of irrigation.

$$SIA = \frac{Currently\ Irrigable\ area}{Innitially\ Irrigated\ area} \quad (17)$$

Where,
SIA = Sustainability of irrigated area
5.2.5. Fertilizer utilization efficiency (FUE) indicators
From a number of FUE performance measurements; due to data availability, level of interest and questions to be addressed; two indicators were selected for this study purposes. For computation purposes basic data; i.e. yields with and without fertilizer for selected crops, fertilizer rates (N and P) at each scheme were collected.
5.2.5.1. Partial factor of productivity (PFP)
Partial factor of productivity is a simple production efficiency expression, calculated in units of crop yield per

unit of nutrient applied.

$$PFP = \frac{Yield}{Fertilizer\ used} \tag{18}$$

5.2.5.2. Agronomic efficiency (AE)

Agronomic efficiency indicator was calculated in units of yield increase per unit of nutrient applied. It more closely reflects the direct production impact of an applied fertilizer and relates directly to economic return.

$$AE = \frac{Y - Y_0}{F} \tag{19}$$

Where, Y= yield with fertilizer (kg),
Y_0= yield without fertilizer (kg)
F= fertilizer amount used (kg)

5.2.6. Organizational indicators

Organizational objectives, functions and structures of Water user association's (WUAs were assessed. Under this organizational establishment, roles and functions, organizational structure and level of management starting from users to general assembly level were assessed. The responsibility at each level was identified. Finally the organizational structure and the level of management were indicated in map. Water use fee amounts for members and non members; way of estimation and collection; final utilization status were clarified. Beneficiary's degree of participations in operation and maintenance activities and number of rounds for canal cleaning in the production year also assessed. Functionality of bylaws and internal rules and regulations and legal enforcement status was identified. Water allocation at each organizational level, way of water allocation and gaps was clarified. Types of conflicts, causes of conflicts and conflict management experiences were assessed at each irrigation schemes.

6. Conclusion

In general irrigation systems are composed from several components that interact with one another; i.e. irrigation scheme, on-farm water management and organizations. For better achievements and sustainability of the system there should be a close association between the components at different levels. Land productivity, water productivity, selection of crops, irrigation intensity, on farm management practices, technology and input utilization /fertilizers, chemicals/ and organizational arrangements and functionality are highly affects the productivity and sustainability of the irrigation schemes. Due to poor linkages of the above factors recently many small scale irrigation schemes are under utilization and structurally under failure. As result to characterize the level of utilization of the given irrigation scheme field measurements and performance evaluation works are very relevant.

Process indicators help system managers to monitor the quality of water delivery services. While comparative indicators used to assess hydrological, agronomic, financial and environmental performances of irrigation systems and to evaluate outputs and impacts of irrigation management practices across systems. Water delivery, on farm water management, physical, financial and organizational performances are highly contributed for the productivity of the given irrigation schemes. Water delivery indicators include conveyance efficiency, relative water supply indicators and relative irrigation supply indicators. Properly conveying of water from diversion weir to farm inlet is the main factor for the productivity of the scheme. The output per unit irrigated and command area, water productivity per unit diverted and delivered amounts are also affects the value of total output production levels. Additionally the level of organizational setups and farmers participation in scheme management and maintenance works has a positive contribution for the productivity of the irrigation schemes. As a summary the selected minimum performance indicators which have employed for this paper were reviewed.

REFERENCE

Adam T. 2013. Hydraulic and Hydrologic Factors on Conveyance Efficiency: Case of Fantale and Tibila Irrigation Schemes M.Sc. Thesis, Addis Ababa University

Adenew B., 2006. Effective Aid for Small Farmers in Sub-Saharan Africa, Southern Civil Society Perspectives (case study).

Awulachew, S. B.; Yilma, A. D.; Loulseged, M.; Loiskandl, W., Ayana, M.; Alamirew, T. 2007. Water Resources and Irrigation Development in Ethiopia. Colombo, Sri Lanka: International Water Management Institute. 78p. (Working Paper 123)

Awulachew,S.B. 2010. Irrigation potential in Ethiopia; Constraints and opportunities for enhancing the system. International Water Management Institute.

Berhanu B. 2006. Performance Assessment and Benchmarking Irrigation Schemes in Ethiopia: A Case Study of Two Irrigation Schemes M.Sc. Thesis, UNESCO IHE.

Bos, M.G. (1997). Performance indicators for irrigation and drainage. Irrigation and Drainage systems, 11:119-137.

Burton, M., Molden, D. and Skutsch, J. (2000). Bench marking Irrigation and Drainage System Performance: Working group on performance indicators and benchmarking. Rome, Italy: FAO.

Dejen, Z. A., Schultz, B. &Hayde, L. (2012).Comparative irrigation performance assessment in community-managed schemes in Ethiopia.*African Journal ofAgricultural Research* 7(35) 4956-4970.

D. Chouhan, R. K. Nema, and K. S. Kushwaha. 2017. Physical Performance in Irrigation Minors Area under Different WUAs. J. Agr. Sci. Tech. (2017) Vol. 19: 1197-1208

FAO (Food and Agriculture Organization of the United Nations). 1989.Guidelines for designing and evaluatingsurface irrigation systems. Irrigation and Drainage Paper 45. FAO, Rome.

FAO (Food and Agriculture Organization).1992.CropWat: A Computer Program for Irrigation Planning and Management: Irrigation and Drainage Paper. No. 46. FAO, Rome.

Irmak S., Lameck O, Odhiombo and William L. Kranz, 2011. Irrigation Efficiency and Uniformity, and Crop Use Efficiency.

Gebremedhin Gebremeskel Haile.2015.Irrigation in Ethiopia, a Review. Journal of Environment and Earth Science.Vol.5, No.15.

Jurriens M., Zerihun D., Boonstra J. and Feyen J2001, SURDEV: Surface Irrigation Software. Publication 59, ILRI, Wageningen.

M.G. Bos, M.A. Burton and D.J. Molden 2005.Irrigation and DrainagePerformance Assessment: Practical Guidelines

McCornick P.G., KamaraA.B., and GirmaTadesse. (eds). 2003. Integrated water and land management research and capacity building priorities for Ethiopia. Proceedings of a MoWR/EARO/IWMI/ILRI international workshop held at ILRI, Addis Ababa, Ethiopia, 2–4 December 2002. IWMI (International Water Management Institute), Colombo, Sri Lanka, and ILRI (International Livestock Research Institute), Nairobi, Kenya. 267 pp.

MCE (Metaferia Consulting Engineers). 2004. The World Bank. Assessment of experiences & opportunities on mediumand large-scale irrigation in Ethiopia. Draft Report, Addis Ababa: Ethiopia.

Michael A. M. 1997. Irrigation Theory and Practice. Evaluating Land for Irrigation Commands. Reprinted Edition, Vikas Publishing House Pvt Ltd, New Delhi, India.

Mintesinot B, Mohammed A, Atinkut M, and MustefaY, 2005. REPORT ON Community Based IrrigationManagement in the Tekeze Basin: Performance Evaluation A case study on three small-scale irrigation schemes (micro dams). A Collaborative projectbetween Mekelle University, ILRI & EARO Funded through the IWMI-Comprehensive Assessment of Water for Agricultural Programme.Ethiopia.

Molden, David J., R. Sakthivadivel, Christopher J. Perry, Charlotte de Fraiture, and WimH.Kloezen. 1998. Indicators for comparing theperformance of irrigated agricultural systems. Research Report 20. Colombo, Sri Lanka: International Water Management Institute.

Oad R. and Sampath R. K. 1995.Performance measure for improving irrigation management. Irrigation and Drainage Systems, 9:357-370.

Perry, C. J. 1996.Quantification and measurement of a minimum set of indicators of the performance of irrigation systems. Colombo, Sri Lanka: International Irrigation Management Institute. Duplicated.

Renault, D. and Wahaj, R. 2007. Performance Indicators of Irrigation Service. Rome, Italy: FAO NRLW.

Roger, E. Smith, and Arthur, W. Warrick, 1997. Efficiencies and Water Losses of Irrigation System. Irrigation Management Series, Kansas.

Rust, H. and W. Snellen, 1993. Irrigation system performance assessment and diagnosis, IIMI, ILRI, the Netherlands.

Seda CIN, Belgin, ÇAKMAK. 2017. Assessment of Irrigation Performance in Basören Irrigation Cooperative Area of Beypazari, Ankara.

Şener,M., Yüksel, AN and Konukcu, F. (2007). Evaluation of Hayrabolu Irrigation Scheme in Turkey Using Comparetive Performance Indicators. J. Tekirdag Agric. Fac. pp. 14.