Indicators for evaluating the performance of small scale irrigation schemes.

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Abstract

Evaluating the performance of irrigation scheme is essential to improve management and control. To carry out performance evaluation of irrigation schemes, a set of recognized and accepted parameters are required. The indicator is generally expressed as the ratio of actual performance to target performance. Depending on the purpose of performance assessment; the types of performance indicators are. The indicator should be based on an empirically quantified, statistically tested causal model of that part of the irrigation process it describes. The data needed to quantify the indicator must be available or obtainable with available technology. Many internal process indicators relate performance to management targets such as timing, duration, and flow rate of water; area irrigated; and cropping patterns. Some of internal indicators are like application efficiency, storage efficiency, distribution efficiency, project efficiency and deep percolation ratio. The external indicators may classify as water delivery indicators like conveyance efficiency, relative water supply, relative irrigation supply and etc.; agricultural output indicators like output per unit command area, output per unit irrigation area, output per unit water supply and output per unit irrigation supply; physical indicators like irrigation ratio and sustainability of irrigated area; financial indicators like gross return on investment; organizational indicators. Generally, we have to focus on evaluating the performance of the irrigation schemes and taking maintenance and operation measures not only focus on irrigation scheme development because it leads sustainability problem of irrigation systems.

Keywords: Efficiency, External, Indicators, Internal, Irrigation scheme, Performance evaluation.

Introduction

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 [1].

Evaluations are useful in a number of analyses and operations, particularly those that are essential to improve management and control. Evaluation data can be collected periodically from the system to refine management practices and identify the changes in the field that occur over the irrigation season or from year to year [2]. As many farmer managed irrigation scheme do not perform as well as they should, there is a need to identify the areas in which they fall short of their potential. It is therefore important to measure and evaluate their success or failure objectively and identifies specific areas in need of improvement [3].

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 [4]. 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.

General Features of Performance Indicators

To carry out performance evaluation of irrigation schemes, a set of recognized and accepted parameters are required [5]. Stated that, performance indicators measure the value of a particular item such as field canal discharge and have to include a measure of quality as well as of quantity, and

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be accompanied by appropriate standards or permissible tolerances. In connection with main system performance, the authors concluded that the services provided by the system and the appropriate performance standards are greatly influenced by the design of that system. Efforts have been made over the years to develop appropriate evaluation models that could use the irrigation parameters and variables to evaluate irrigation performance. Among these, the volume balance model is the basis for most design and field evaluation procedures. This has been proven with field and laboratory data. It allows quick and reliable definition of infiltration rates over the length of the field and it is easily extended to indications of uniformity and efficiency parameters [6].

According to [7] the performance of a farm irrigation system is determined by the efficiency with which water is diverted, conveyed, and applied, and by the adequacy and uniformity of application in each field on the farm. In response to the insufficient performance of existing irrigation system, focus was made on the performance evaluation of the schemes. However, in conducting performance of irrigation, more than one view point exists. In addition, few of these criteria reflect the view of the farmer [8]. It is therefore essential that evaluation of the performance of surface irrigation system be continued with a view to improve the performance of the systems.

According to [9], performance indicator is the response to the question, "How is it now?" The indicator is generally expressed as the ratio of actual performance to target performance. Using this indicator, irrigation managers will evaluate the performance achievement of their management at the initiation of performance assessment. As [5,10] described the framework of using performance indicators, and noted two approaches to the use of performance indicators in the field of irrigation:

1. Attempts to develop indictors which allow the performance of one system to be compared to similar systems elsewhere
2. The use of indicator to compare actual results with what was planned.

Mentioned that dividing the system into several sub-systems, and assessing the performance at those lower levels, helps describe system performance more effectively [11]. A true performance indicator includes both an actual value and an intended value that enables the assessment of the amount of deviation. It is therefore desirable wherever possible to express indictors in the form of a ratio of the actually measured versus the intended situation [12].The well-known head-tail dimension of many irrigation systems represents a spatial analysis of a single variable: depending on the magnitude of the variation, a manager may have to decide what action to take next.

Almost all operational performance indictors can, and should, be used in a spatial context whenever equity is included in the objective set. Confirmed that using performance indicators in a spatial dimension also enables managers to identify precise locations at which problems are arising, and where to take remedial action [11]. Dividing the system into several sub-systems, and assessing the performance at these lower levels, helps describe system performance more effectively. The common efficiency terms used for on-farm irrigation system evaluation include application efficiency, uniformity and storage efficiency, recently complementary terms such as runoff ratio and deep percolation ratio are being applied [13].

Properties of Performance Indicators

Some of the desirable attributes of performance indicators suggested by [12] are: Scientific basis: the indicator should be based on an empirically quantified, statistically tested causal model of that part of the irrigation process it describes. The indicators must be quantifiable: the data needed to quantify the indicator must be available or obtainable (measurable) with available technology. The measurement must be reproducible. Reference to a target value: this is, of course, obvious from the definition of a performance indicator. It implies that relevance and appropriateness of the target values and tolerances can be established for the indicator.

These target values and their margin of deviation should be related to the level of technology and management [14]. Provide information without bias: ideally, performance indicators should not be formulated from a narrow ethical perspective. This is, in reality, extremely difficult as even technical measures contain value judgments. Ease of use and cost effectiveness: particularly for routine management, performance indicators should be technically feasible, and easily used by agency staff given their level of skill and motivation. Further, the cost of using indicators in terms of finances, equipment, and commitment of human resources, should be well within the agency's resources.

Types of Performance Indicators

Internal performance indicators

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?" [5].We could conclude, although it would be premature, that these internal indicators do not lend themselves well to cross-system comparison. This is due to several reasons:

1. Internal processes of irrigation systems vary widely from system to system, so that performance indicators are tailored to meet system-specific needs.
2. Indicators related to irrigation processes tend to be data intensive and it is often difficult, time consuming, and expensive to obtain complete data sets.

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3. 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.

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 [15].

Irrigation Efficiency

The Loss of irrigation water occurs in the conveyance and distribution system, non-uniform distribution of water over the field, percolation below crop root zone. Loss by runoff at the end of irrigation borders furrows and field channels may also occur some times. The losses can be held to a minimum by adequate planning of the irrigation system, proper design of the irrigation method, and efficient operation of the system. The common efficiency terms used for on-field irrigation system evaluation include application efficiency, uniformity, storage efficiency, and adequacy, and recently complementary terms such as runoff ratio, deep percolation ratio, etc. are being applied also put as a remark that the primary performance indicators are: storage efficiency, application efficiency and distribution efficiency [13,16].

Water Application Efficiency (Ea)

After the water reaches the field supply Channel, it is important to apply the water as efficiently as possible. A measure of how efficiently this is done is the water application efficiency. Water application efficiency below 100 percent are due to seepage losses from the field distribution channels, deep percolation below the crop root zone and runoff loses from the tail end of borders and furrows (in very long fields). Losses from the field occur as deep percolation beyond the root zone and as field tail water or runoff.

To compute application efficiency (Ea) it is necessary to identify at least one of these losses as well as the amount of water stored in the root zone [2]. This implies that the difference between the total amount of root zone storage capacity available at the time of irrigation and the actual water stored due to irrigation be separated, that is, the amount of under-irrigation in the soil profile must be determined as well as the losses. Application efficiency (Ea) does not include losses from the conveyance networks [17]. Indicated that attainable water application efficiencies vary greatly with irrigation system, type and management, and suggested that the attainable application efficiency for surface irrigation are 80-90%, 70-85% and 60-75% under basin, Border and furrow type of system respectively. [18] Said that a minimum value of the ratio of crop water demand to the actual amount of water supplied to the field of 0.6 (or irrigation efficiency of 60%) is included in the design of most surface irrigation systems to accommodate crop water needs and anticipated losses. Value below this limit would normally be considered unacceptable.

In general, water application efficiency decreases as the amount of water applied during each irrigation increases [16].

Water Storage Efficiency (Es)

Small irrigation may lead to high water application efficiencies, yet the irrigation practice may be poor. The concept of water storage efficiency is useful in evaluating this problem. This concept relates how completely the water needed prior to irrigation has been stored in the root zone during irrigation. Water storage efficiency becomes important when water supplies are limited or when excessive time is required to secure adequate penetration of water in to the soil. Also, when salt problems exist, the water storage efficiency should be kept high to maintain favorable salt balance.

The storage efficiency (Es) is an indicator of how well the irrigation meets its objective of refilling the root zone. The value of Es 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 reflects 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.

Water Distribution Efficiency (DU/Ed)

This shows how uniformly water is applied to the field along the irrigation run. In sandy soils there is generally over irrigation at upper reaches of the run when as in clayey soils, there is over- irrigation at the lower reaches of the run. Uniformity is related to crop yields through the agronomic effects of under and over-watering. Insufficient water leads to high soil moisture tension, plant stress and reduced crop yields. Excess water may also reduce crop yields below potential levels through mechanisms such as leaching of plant nutrients, increased disease incidence or failure to stimulate growth of commercially valuable parts of the plant. Suggested that having average distribution efficiency of 65% is sufficient for furrow irrigation.

Project Efficiency (Ep)

This shows how efficiently the water source used in crop production. It shows the percentage of the total water that is stored in the soil and available for consumptive requirements of the crop. It indicates the overall efficiency of the systems from the head work to the final use by plants for Consumptive use. The overall project efficiency must be considered in order to fix the amount of water required at the diversion head work.

Deep Percolation Ratio (DPR)

Depending on the chemical nature of the groundwater, deep percolation can cause a major water quality problem of a regional nature. The loss of water through drainage beyond the root zone is reflected in the deep percolation ratio.

External Performance Indicators

An approach to cross-system comparison is to compare outputs and impacts of irrigated agriculture. “External” indicators are used to relate outputs from a system derived from the inputs into that system. They provide little or no detail on internal processes that lead to the output. For example, the

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critical output of an irrigation system is the supply of water to crops. This output in turn is an input to a broader irrigated agricultural system where water combined with other inputs, leads to agricultural production. As irrigated agriculture always deals with water and agricultural production it should be possible to develop a set of external indicators for cross-system comparison.

Water Delivery Indicators

Conveyance efficiency (Ec), relative water supply (RWS) and relative irrigation supply (RIS) could be used for evaluation of water delivery performance. RWS and RIS relate supply to demand, and give some indication as the condition of water abundance or scarcity, and how tightly supply and demand are matched. Care must be taken in the interpretation of results: 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 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 [1]. suggested that these two indicators provide a general sense of whether there is an adequate amount of water or whether the amount of irrigation water supplied is excessive [19].

Conveyance Efficiency (Ec)

Water conveyance efficiency (Ec) is the ratio in percent of the amount of water delivered by a channel to the amount of water delivered to the conveyance system. This term is used to measure the efficiency of water conveyance system associated with the canal network, water courses and field channels. It is also applicable where the water is conveyed in channels from the well to the individual fields. 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 [12]. 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 of water lost depends on quality of operation, maintenance and the nature of the soil that affects the seepage rate. In Tanzania, a survey of the efficiency of improved and unimproved small-scale irrigation schemes indicated that the conveyance efficiency for the main canals and the field canals (unlined) were 84 and 65% during the dry season and 85 and 74% during the wet season respectively. However, typical conveyance efficiency values generally reported are 70 and 50% for unlined poorly managed main and field canals respectively, while for the well managed canals the figures are 85 and 80% respectively.

Relative Water Supply (RWS)

One of the primary indicators used to determine the suitability of the water supply for agricultural production is the annual relative water supply [19].

Relative Irrigation Supply (RIS)

RWS and RIS values indicate whether there is an adequate supply done or not to cover the demand. RWS and RIS values of one or higher indicates adequate while the values smaller than one indicate inadequate supply of irrigation.

On Field Water Management Indicators

Effective irrigation management requires reliable performance assessment. Good farm irrigation management assures correct frequency of irrigations, correct application depth [17], uniform irrigation, minimum runoff and minimum deep percolation except for that required for salt management, minimum erosion and optimal return on irrigation investment.

Agricultural Output Indicators/Land and Water Productivity

It expresses output of irrigated area in terms of 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 [1]. The four basic external performance indicators relate output to unit land and water are listed below. These "*external*" indicators provide the basis for comparison of irrigated agriculture performance. 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 [1].

Output per Unit Irrigated Area

[1] Stated that it is land productivity indicator and important when land is a constraint. It can be calculated as the total value of production per harvested area in the irrigation season. The harvested /Irrigated / area includes the areas that were irrigated in the irrigation seasons. The annual harvested area depends on the cropping intensity. The area is the sum of all the areas under crops during the year in this case. This indicator is not affected by the intensity of cropping/ irrigation [1].

Output per Unit Command Area

This is more relevant for land is the major constraint factor for production. It is the value of agricultural production per unit of nominal area, which can be irrigated. 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. Smaller values of this indicator can also imply, less intensive irrigation and high value result shows there is good intensive irrigation [1].

Output per Unit Irrigation Supply

It is one of water productivity indicator which indicates how well the total annual diverted irrigation water from a source is productive. This is important parameter when water is scarce and calculated as the total value of production per unit water diverted from the headwork to the command area throughout the irrigation seasons [1].

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Output per Unit Water Consumed

According [1] stated that 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 management aspects; to take measurements those minimize evapotranspiration losses.

Physical Indicators

Physical indicators are related with the changing or losing irrigated land in the command area by different reasons.

Irrigation Ratio (IR)

Irrigation ratio is the ratio of currently irrigated area to irrigable command area. As [20] suggested that a high irrigation ratio can be achieved by effective water delivery in the scheme. There is no irrigation water fee that promotes farmers to use the irrigation water efficiently so as to increase the irrigable land in the scheme [21]. At Golgota and Godana irrigation schemes respectively have found similar reasons for the greater irrigation ratio which could be explained by three factors; these are, generous water availability, absence of irrigation water fee and better land productivity encouraging farmers to invest on more areas.

In order to raise irrigation efficiency and the irrigation ratio, on-farm developments and practices should carefully be monitored and evaluated. Training and extension of farmers and irrigation managers in technical and economical considerations are also vital to the augmentation of the irrigation ratio [22].

Sustainability of Irrigated Area (SIA)

Sustainability of irrigated area is the ratio of currently irrigated area to initially irrigated area when designed [23]. It is a useful indicator for assessing the sustainability of irrigated agriculture. Lower values of this indicator would mean abandonment of lands which were initially irrigated; and hence, indicate contraction of irrigated area over time. On the other hand, values higher than unity indicate expansion of irrigated area and would imply more sustainable irrigation.

The degree to which the initially planned (irrigated) area of schemes is sustained years after the implementation of a scheme is an important issue for the success of an irrigation scheme; in principle, neither extension nor shrinkage is desired, particularly where schemes are well planned and command areas were defined based on land suitability and water availability. The major factors that can contribute to shrinkage of irrigated land would be: water shortage (unreliability), lack of proper maintenance of infrastructure for water conveyance and distribution, lack of interest in irrigation when it is not paying back (for example poor access to marketing system), etc.

Financial Indicator

Gross Return on Investment

Researchers would like to be able to recommend systems that yield acceptable returns within a given environment. Water delivery infrastructure to be able to analyze differences between various types of delivery systems such as structured, automated, lined, and unlined canal sections. Infrastructure related to river diversions, storage and drainage is not included, because of the desire to be able to compare different methods of water delivery. Also, diversion and storage works often serve other non-irrigation purposes so their costs cannot be entirely allocated to irrigation. 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 [1].

Organizational Indicator

A group based irrigation system implies an organization in charge of operation and management and organizational performance is an important factor of sustainability and productivity of irrigation systems.

Water users' associations (WUAs)

Water user association is a user-based organization that aims to manage the irrigation system for its members mostly on a nonprofit basis. A WUA is generally small in scale with a limited number of members (usually no more than several hundred members), so that self-management by users is possible. The actual size of a WUA often depends on the irrigation system. For example, a WUA may be responsible for one tertiary block that is subdivided into smaller units of Water User Groups (WUGs), or one WUA may be responsible for the entire system [24].

Function of WUAs

Its main tasks include [24].

1. The allocation of water within the irrigation system,
2. Operation and maintenance (O&M) of the system and
3. The cost recovery of O&M through the collection of irrigation fees from its members.

According to [25], developing, operating and maintaining an irrigation scheme almost always requires joint action by the water users. In traditional irrigation schemes, farmers would get together to build a diversion weir across a river or dig an access canal, because these were things they could not accomplish on their own. Without a capacity for organization and decision making among the users, it was simply not possible to complete a scheme. This capacity helped users to develop an organization capable of operating and maintaining the scheme.

In a modern scheme where most of the preparation and construction is done by a government agency, the water users have much less experience in organizing themselves. Yet the fact that in such schemes the water is usually delivered to a group of farmers requires a water users' association that is capable of assuming responsibility for water distribution among farmers. In many cases, the WUAs are also responsible for maintenance and for collecting irrigation fees from its users. WUAs could also play an important role in negotiating with the scheme operators on the service agreement [25].

Figure 1 shows many conflicts occur due to the problem of water theft or unauthorized canal breaching in the scheme. There is a conflict resolution mechanism and most WUAs develop their by-laws which is a system rules for controlling the conflict within the scheme. The WUAs committees have long existed to manage SSI schemes. They are generally well organized and effectively operated by farmers. The associations handle construction, allocation, operation and maintenance functions with government technical and material support [26].

Factors influencing WUA performance: Studies have identified the most important factors that shape WUA performance. Often a distinction is made between external and internal factors, in which external factors refer to the physical, socioeconomic and political environment, while internal factors describe the water management organization itself [24].

Strengthen water user association: Policy makers and donor agencies have tried five main channels to strengthen conventional WUAs: i.WUA policy and legal instruments ii.WUA bylaws iii. Contracts and formal agreements with WUAs iv. Training of WUA members v. Introducing monitoring and evaluation [24].

WUA Policy and Legal Instruments

Donors and policy makers turned to the development of national-level legal instruments to regulate WUA operations to make them more effective. In some cases, donor agencies push national governments to put forward desirable WUA regulations that enforce the '*norms*' in conventional WUAs, including cost recovery and user participation based on principles of equity.

WUA by Laws

Bylaws are "*the constitutional rules of each WUA*" sometimes referred to as the '*internal code*' or '*constitution*' [27-29]. Important aspects included in bylaws are structure and mandate of the WUA board, rights and duties of WUA members, procedures for calling meetings and setting irrigation fees [30]. Generally, water users themselves are supposed to set WUA bylaws to ensure they are fit to purpose.

Contracts and Formal Agreements with WUAs

A more direct way to enforce requirements upon WUAs is the enactment of contracts or agreements with WUAs. These can be transfer agreements between the WUA and the government and/or donor agency defining the rights and duties of each party. The agreement may include cuts in financial support if requirements are not met [31].

Training of WUA members

Another approach to improve WUAs is through training. Here, the focus is not so much on formalizing institutions, but on building internal capacities with regard to the technical, financial and managerial skills considered necessary to manage a WUA and take over operation & maintenance tasks [32].

Monitoring and Evaluation

Development banks and agencies have sought to introduce or strengthen monitoring and evaluation within and on WUAs toward ensuring effectiveness. Monitoring and evaluation of a WUA income and expenditure, as well as water use and levels could contribute to the transparency of its financial governance and improved service delivery. However, monitoring data on the availability and distribution of water is often lacking at WUA level, which can undermine the ability of WUAs to control water use and impose sanctions when users do not respect irrigation turns or any other operational rule.

Conclusion

The performance of small scale irrigation schemes should be evaluated using performance indicators. Based on the purpose, we can use internal indicators, external indicators or both of

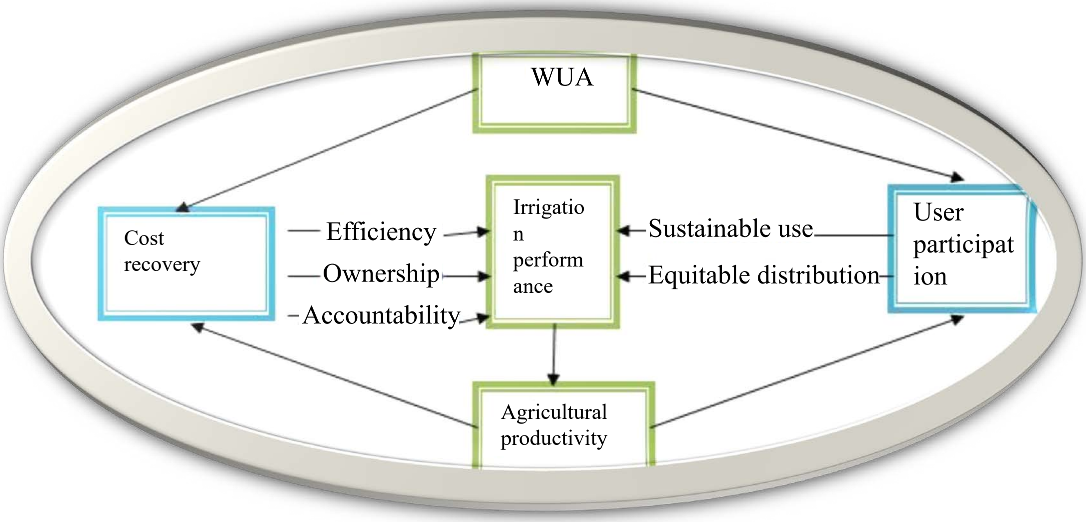

Figure 1. Theoretical framework of WUAs (Aarnoudse et al).

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them. Most of the time, we have missed the organizational indicators but this indicators are very essential because irrigation schemes implemented for the aim of the irrigator and the responsibility is; the user and the institution. Generally, we have to focus on evaluating the performance of the irrigation schemes and taking maintenance and operation measures not only focus on irrigation scheme development because it leads sustainability problem of irrigation systems.

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