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Performance Evaluation of Bedene Alemtena Small Scale Irrigation Scheme in Hallaba Special Woreda, Southern Ethiopia

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Abstract

The aim of study was to assess the overall performance of Bedene Alemtena small scale irrigation scheme using internal and external performance indicators. Primary data were collected from three farmers' field situated at the upper, middle, and downstream of the main canal. Discharge measurements and soil sample analysis were conducted, and secondary data were collected from Halaba Kullito Bureau of Agriculture. CROPWAT 8.0 computer model was used to calculate the crop water requirements. From the analysis of data, the indicative values of the output per unit command area for Bedene Alemetena were 65423.669 Br/ha, similarly the output per unit cultivated area for this scheme was 58940.242 Br/ha. The output per unit water consumed was 14.588 Br/m^3 and the results of application efficiency, distribution efficiencies and water productivity are 54.9%, 90.23% and 4.314 kg/m^3 respectively. According to these results, it can be concluded that expected results are best but to sustain the scheme more than this; it is recommended that all activities in the irrigation network should be monitored and checked, technical requirements should be met, training and extension should be enhanced, evaluations should be performed on a seasonal basis and the results should be delivered to the relevant individual and institutions with an efficient monitoring and evaluation system. Water users associations and cooperatives that undertake the operation and management of irrigation scheme should be empowered more than done in this time.

Keywords

Small Scale Irrigation, Performance Evaluation, Efficiency

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Subject Areas: **Agricultural Engineering, Environmental Sciences, Hydrology**

1. Introduction

Ethiopia has a surface area of 1.3 million square kilometres, of which 99.3 percent is a land area and the remaining 0.7 percent is covered with water bodies [1]. Using these water bodies, farmers change their living standard through irrigation. Irrigation is the supply of water to agricultural crops by artificial means, designed to permit farming in arid regions and to offset the effect of drought in semi-arid regions. Effectiveness of irrigation is a term that qualitatively describes the application efficiency, uniformity and adequacy of irrigation [2].

With increasing population and hence demand for food, sustainable production in irrigated agriculture could be achieved though development of new irrigation project and/or improvement of the performance of the existing schemes. But improving irrigation system performance is becoming important because the performance of many irrigation systems is significantly under their potential due to one of shortcomings such as poor planning, operation and maintenance, and over all poor water management practices [3].

Performance evaluation is a practical tool to assess the successes of irrigation management at the scheme to meet growing challenges; increasing demand for irrigation to meet the growing food demands of the population: the competition for water allocation from high priority non-agricultural sectors and technical infeasibility [4]. It is necessary to retrofit new techniques and approaches to existing management practices to improve the performance of the scheme. In recognition to both the promise and hazards associated with irrigation, evaluating irrigation performance has now become of paramount importance not only to point out where the problem exists but also helps to identify alternatives that may be both effective and feasible in improving system performance [5].

The purpose of the study is to assess and evaluate the performance of one community managed small scale irrigation scheme, *i.e*. Bedene Alemtena small scale irrigation scheme.

2. Materials and Methods

Study Area

Bedene Alemtena Small Scale Irrigation Project is located in South Nations Nationalities and Peoples administrative region in Halaba special District. The project area is lies between 7.33˚ - 7.42˚N latitude and 38.08˚ - 38.17˚E longitude. The project is located at 86 kilometres away from Hawassa and 12 kilometres from the District capital, Halaba Kullito town. The topography of the project area ranges from 1780 to1800 m above sea level. According to the 12 years meteorology data analysis of the area, the mean annual rain fall is 970 millimetres and the minimum rain fall occurs in months of October, November, December, and January and the maximum occur during months of April, May and August. The mean monthly minimum and maximum temperature vary between 18 degree Celsius and 20 degree Celsius occurring during the months of December and February respectively.

The diversion head work structures are constructed on Bilate River and the farmers practice furrow type of water application method .The planned command area and beneficiaries of the scheme are 200 hectares and 265 households, respectively [6].

Materials which were used to conduct the study: auger, weight balance, oven dry, tape meter, floating materials, and stop watch.

Auger—used to took soil sample in order to determine soil textural class.

Weight balance—used to measure weight of soil moisture (*i.e*. at wet and dry condition of soil).

Oven dry—oven was used by high-forced thermal convection (105˚C) to dry soil sample.

Discharge was determined by using velocity-area method, in order to perform the following materials were used on the study.

- Tape meter—was used to measure the length of the canal.
- Range poles—Two range poles were used to mark the length of canal in which discharge measurement has been taken.

- Floating materials—this used to took time required to reach the length required to determine discharge passing on the canal.
- Stop watch—to know time taken by floating material to reach the second marked point.

3. Methods

3.1. Data Collection Techniques

Repeated field visits were made to investigate method of water applications and closely observe practices related to water management techniques used by irrigators.

Primary data at field level were collected from farmers field from irrigated (the head, middle, and downstream water user) of the study area. The interview of farmers irrigated field was that the head end users (farmers at the top) over irrigated their crop while the tail end users (farmers at the bottom) are in short supply of irrigation water ([7] [8]).

These primary data are important to determine the initial moisture content of bulk density, field capacity (FC), and soil textural classes and hence using sampling auger undisturbed soil samples was collected to determine the soil bulk densities and disturbed samples was taken to determine the soil textural class.

Field capacity is the water content of soil after free drainage has taken place for a sufficient period. The field capacity is expressed as the ratio of the weight of water contained in the soil to the weight of the soil retaining that water.

$$\text{FC} = \frac{\text{Weight of water retained in certain volume of soil}}{\text{Weight of the same volume of soil}}. \tag{1}$$

Measurement of canal water flow at the diversion of the irrigation scheme was done by velocity-area method. Initial moisture content of the soil and moisture content after irrigation was determined by taking soil sample at the same depth before and after irrigation.

Secondary data such as total yields, farm gate prices of irrigated crops, area irrigated per crop per season, crop types and yield per hectare are collected. Local prices of each cultivated crop were collected from the Agronomist Bureau of Agriculture and Rural Development. Climatic data were collected from BOAH.

FAO CROPWAT 8.0 computer model was used to determine the crop water requirements (CWR), and monthly ET of the irrigated crops at field levels during irrigation season (Nov. to Apr.). The calculation of reference crop ET was used done by [9].

3.2. Soil Sampling and Analysis

Soil samples were taken for the analysis of texture and bulk density. Bulk density of the soil was determined using undisturbed soil samples collected by using core cylinder of 98.125 cubic centimetres volume at 30 centimetre soil depth. Twenty samples were tasted to prove the reliability of the results. In order to determine it the undisturbed soil samples collected were measured and put it in to an oven dry at 105˚C. Then after oven dry soil was measured. The mass of water was calculated by subtracting the oven dry soil from the wet soil. Finlay the bulk density was determined by dividing the mass of soil or volume of water by the total volume of core sampler. Initial moisture content of the soil before irrigation and moisture content after irrigation was determined using gravimetric method. Therefore, for determining the soil moisture on a mass basis, the collected samples were oven dried, and then reported (in percent) as stated by [10]:

$$W_d = \frac{\text{Weight of moist soil} - \text{Weight of oven dry soil}}{\text{Weight of oven dry soil}} \times 100 \tag{2}$$

where: W_d soil moisture (soil water) content on dry weight basis %.

The amount of moisture stored in the root zone of the crop was determined by deducting the percentage of the initial moisture content from the moisture content after irrigation. The purpose of calculating the amount of moisture stored in the root zone of the crop is to determine the water application efficiency of the scheme.

The internal performance indicators used to evaluate were: application efficiency, Christensen's uniformity coefficient, and water productivity.

$$\text{Application efficiency } (\eta_a) = \frac{\text{depth of water stored in the root zone}}{\text{depth of water applied to the field}} \times 100 \quad (3)$$

$$\text{Water distribution efficiency } (\eta_d) = \left(1 - \frac{d}{D}\right) \times 100 \quad (4)$$

$$\text{Water Productivity } (\text{m}^3) = \frac{\text{Gross value of production}}{\text{Volume of supplied irrigation water}} \quad (5)$$

The external performance indicator types used were: Output per cropped area (Br/ha), Output per command area (Birr/ha), Output per unit of water consumed (Birr/m^3), irrigation ratio and sustainability of irrigated land.

$$\text{Output per cropped area (Br/ha)} = \frac{\text{SGVP}}{\text{Irrigated cropped land}} \quad (6)$$

$$\text{Output per command area (Birr/ha)} = \frac{\text{SGVP}}{\text{Command area}} \quad (7)$$

$$\text{Output per unit of water consumed (Birr/m}^3\text{)} = \frac{\text{SGVP}}{\text{Volume of water consumed by ET}}. \quad (8)$$

4. Results and Discussion

As shown in **Table 1**, soil textural class of the study area was almost similar from upstream to downstream. The field capacity of the soil in field 2 (Middle stream) was a slightly greater than field 3 and filed 2.

Table 2 shows that at the study area, the water application efficiency of the farmers were varied between 53.6% - 57.2%, at the field 2 the value were in acceptable range. This revealed that the filed 2 farmers were more efficient in applying water than the others.

As shown in **Table 3**, distribution efficiency obtained were more than 60% *i.e.* the water applied in the field is distributed evenly.

5. Discussion

5.1. Internal Process Indicators

In the irrigation project water was provided of any charge and it was observed that farmers were applying water without considering the crop water requirements. At Bedene Alemtena, it was observed from **Table 2** that field two was the most efficient, followed by field three and field one.

Similar research results conducted by [11] showed that the application efficiency could be in the range of 50% - 80%, however [12] stated that application efficiency vary widely but it is possible to have high application effi-

Table 1. Physical properties of selected field of Bedene Alemtena irrigation project.

Field	Soil depth(cm)	Bulk density (g/cm^3)	Textural class	Field capacity (%)
Field 1 (upper stream)	30	1.079	Silty clay loam	39.233
Field 2 (Middle stream)	30	1.072	Clay loam	39.77
Field 3 (Downstream)	30	1.091	Clay loam	39.26

Table 2. Calculated application efficiencies

Field	Depth applied (mm)	Depth stored (mm)	Application efficiency (%)
Field 1	11.3	6.053	53.6
Field 2	10.9	6.234	57.2
Field 3	10.54	5.677	53.9

Table 3. Calculated distribution efficiencies.

Field	Distribution efficiency (%)
Field 1	92.45
Field 2	95.74
Field 3	82.5

Table 4. Indicative values of the production performance indicators.

Site	Output per command area (Br/ha)	Output per cultivated area (Br/ha)	Output per water consumed (Br/m^3)
Bedene Alemtena Irrigation Project	65423.669	58940.242	14.588

ciency. [7] Reported that the attainable application efficiency according to the US (soil conservation science) ranges from 55% - 70%, value below this limit would normally be considered unacceptable while in ICID/ILRI this value is about 57%.

In general, according to [10] water application decreases as the amount of water applied during each irrigation increase.

As shown in **Table 2** at Bedene Alemtena Small Scale Irrigation Scheme, the water application efficiency of the farmers varied from 53.6% at the head and 53.9% at downstream to 57.2% at the middle stream with 54.9% as the average application efficiency, at the middle stream the value were within acceptable range. The result showed that the middle stream farmers were more efficient in applying water than the head and downstream ends.

The water distribution efficiency (η_d) was 95.74%, 92.45% and 82.5% in the middle stream, downstream and upstream of the irrigation project respectively. As the result shown, the water distribution was the most efficient in the field 2of the irrigation project. According to the study conducted by [13], distribution efficiency, η_d (≤60%) indicates that the irrigation water is unevenly distributed, while η_d (≥60%) indicates that the application is relatively uniform over the entire field. Therefore, according to this study the results of distribution efficiency obtained in Bedene Alemetena irrigation scheme indicates the application is uniform in the entire field.

5.2. Comparative/External Performance Indicators

At Bedene Alemtena irrigation scheme, the major crops grown were onion (red and white), tomato, potato, head cabbage, cabbage (habesha), carrot, haricot bean and reddish.

Among them, onion (red) was the dominant crop produced covering around 45.49% of the irrigable land.

From the analysis of data as shown in **Table 4**, the indicative values of the output per unit command area for Bedene Alemetena was 65423.669 Br/ha, similarly the output per unit cultivated area for this scheme was 58940.242 Br/ha and output per unit water consumed was 14.588 Br/m^3.

6. Conclusions

In conclusion, Ethiopia irrigation plays a vital role to ensure food security and remains a high priority consideration in development strategy and prevention of food shortage. The availability of water confers opportunities to individuals and communities to boost food production, both in quantity and diversity, to satisfy their own needs and to generate income from surpluses.

Improper irrigation management practices do not only waste scarce and precious water resources but also decrease marketable yield and economy [14].

Accordingly, it can be summarized from the results of the study that the water application efficiency at field two was efficient than the field one and field three. And also water distribution efficiency *i.e.* water penetrating to a uniform depth is better in field two followed by field three and field one.

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Notation

The following symbols are used in this paper

η_d = Water distribution efficiency

η_a =Application efficiency

W_d = soil moisture (soil water) content on dry weight basis %

SGVP = Standard Gross Value of Production

ICID = International Commission on Irrigation and Drainage