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# Water Delivery Performance and Dependability of Irrigation Interval in Tendaho Sugar Estate, Ethiopia

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## Abstract

Extensive effort and huge investment towards irrigation development is being made in Ethiopia. However, little or no attention is given to the monitoring and evaluation of the performance of already established irrigation systems. Consequently, many of the existing irrigation systems are deteriorating in their physical structures, operation and management. Hence, this study attempted to evaluate the performance of water delivery performance and dependability of irrigation interval in Tendaho sugar estate irrigation system in the lower Awash River Valley. Water delivered to canals was measured using flow measuring structure and duration of water delivery while actual irrigation interval was monitored for selected fields. The average values of Delivery Performance Ratio were resulted in 0.36, 0.53, 0.54 and 0.38 for main, primary, secondary and tertiary canals, respectively, and the average value of dependability of irrigation interval was resulted in 1.6 for selected fields. These results of both delivery performance ratios and dependability of irrigation interval reveal that reliability of water delivery during study time was rated under very poor, and the fields waited for long time to get irrigation water. To alleviate the problem and avoid water shortage during dry period, Gate of the Dam should be installed; off-taking canals head and cross regulators must be installed for all canals; regularly repair and calibration should be done for all existing regulators in the Sugar Estate.

**Keywords:** Water measuring structure • Delivery performance ratio • Dependability of irrigation interval • Tendaho sugar Estate

## Introduction

Irrigation is expected to play a major role in the realization of Ethiopian food security and poverty alleviation effort. Irrigation enhances agricultural production and improves the food supply, income of rural population, opening employment opportunities for the poor, supports national economy by producing industrial crops that are used as raw materials for value adding industries and exportable crops [1]. From this important viewpoint, irrigation projects are widely studied, planed and implemented throughout the country.

However, little or no attention is given to the monitoring and evaluation of the performance of already established irrigation schemes [2]. Whether traditional or modern, public agency or community managed many of the existing irrigation systems are deteriorating in their physical structures, operation and management. Performance evaluation is used to identify the present status of the scheme with respect to the selected indicators and will help to identify 'why the scheme is performing so', which in turn imply means of improvement.

The simplest, and yet probably the most important, operational performance indicator is the Delivery Performance Ratio (DPR). The delivery performance ratio enables a manager to determine the extent to which water is actually delivered as intended during a selected period and at any location in the system [3]. The primary indicator proposed for use in measuring dependability of water delivery is concerned with the time between deliveries compared with the plan or subscription. To be good or fair performance, the deliveries to canals could be adjusted to keep Delivery Performance Ratio (DPR) values between 70% and 130%. The study conducted on performance evaluation of a Kalwande Minor Irrigation System in India shows that Delivery Performance Ratio of 1.27, indicating the condition of water abundance [4]. The other study conducted at the heads of secondary canals in the study area shows only 33% were rated as reliable supplies released to distributaries and minors. In addition, maximum dependability of irrigation interval of 1.15 was found between water applications in Chivilcoy canal in Argentina, where the government controlled the water distribution. Currently, there is ongoing large-scale irrigation development in the downstream reach Awash River basin, called 'Tendaho Sugar Estate'. The cane cultivation field is getting its water supply from

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as 72 km length and 78 m3/s full supply discharge capacity whereas the discharge capacity and length of primary and secondary canals depend on the irrigation areas.

However, poor operation and damage of irrigation canal system have been observed in the Tandaho Sugar Estate. Hence, water logging in nearby the canal and water shortage for downstream field is commonly observed problems due to poor construction, operation and management of irrigation system [5]. In addition, the magnitude and severity of the problem has not been quantified through a systematically investigation of water delivery service for all canal levels in the system. Therefore, this study was carried out to quantify water delivery service and dependability of irrigation interval of the Sugar Estate.

### Specific objectives

- To investigate the level of water delivery service declared and provided at selected canal levels in the system.
- To evaluate the dependability of irrigation interval for selected sugarcane fields in Tendaho Sugar Estate.

## Materials and Methods

### Description of the study area

The study was conducted in Tendaho Sugar Estate which is located between 11°30' to 11°50' North Latitude and 40°45' to 41°03' East Longitude, at about 610 km East of Addis Ababa with an altitude of 350 m a.s.l. The entire command area lies in deltaic alluvial plains with gentle slope ranging from 0.05 to 0.5 m per kilometer. The elevation of command area varies from 365m at dam site to 340 m at tail.

The area is characterized by arid climate. The mean annual rainfall is about 204 mm. Mean monthly maximum and minimum temperature is 37.9°C and 22.9°C respectively. The average duration of sunshine per day is about 8.9 hours. The mean relative humidity is about 57%. Soil of the Sugar Estate is classified into four major soil types (fluvisols, vertisols, solonetz and regosols) of which fluvisols and vertisols cover about 47 and 39% of the gross surveyed area respectively. In general, most of the soil are slightly too moderately alkaline with PH value ranging from 7.0 to 8.5.

As per the design document of Tendaho Sugar Estate irrigation canals system, the layout consists of main canal and distribution system. The components of distribution system includes: Primary canal (Distributor), Secondary canal (Minor), Tertiary canal (Watercourse) and Quaternary canal (Field channel).

The Main Canal has Head Regulator located at the downstream end of the irrigation outlet in the dam in which the head is considered adequate to provide gravity flow irrigation in the entire command after taking into consideration head losses in different structures. In the structured system gate is provided at the head of primary and secondary canals. No gate is provided at off taking points of Tertiary canals [6]. The head regulators of Tertiary canals are designed in such a way that when the primary and the main canal are running with full discharge with water level at Full Supply Level (FSL), all the off-taking channels are able to draw required discharge for peak period and special precaution is taken to ensure full discharge and maintaining Full Supply Level (FSL). In the distributaries and other parent channels the system (the primary along with all off taking channels up to Tertiary) is required to run for a shorter duration only and for the rest of the time, the system is remain closed [7]. Thus the hardware in the form of structured system and software in the form of rotational water supply at primary level minimize the deficiencies and improve the efficiency of the system and help to achieve desirable characteristics like equitable distribution, adequacy and timely supply of irrigation (Figure 1).

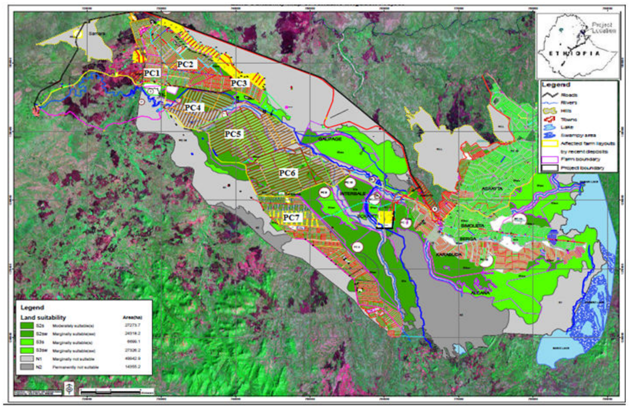


**Figure 1:** Irrigation canal lay out and land suitablility map of Tendaho Sugar Estate.

### Measurement of actual water delivery

Actual delivery discharge and duration data were collected using flow measuring structure at intakes of main, and selected primary and secondary canals, and for selected tertiary canals by measuring actual length of the water delivery period (days per month). For operational purposes it was then assumed that the flow rate was constant during a relatively long period. To determine the daily irrigation supplies equation (1) was used:

Where Q is Discharge of flow measuring structure ($m^3/s$), B is gate width (m), g is acceleration due to gravity (9.81 $m/s^2$), Co is discharge coefficient (0.73-0.83), Go is gate opening (m) and h is depth of water above the crest of open gate (m).

This discharge was used to calculate the Delivery Performance Ratio (DPR) by using equation (2):

Where Qa is actual discharges based on daily water level measurement (lit/s), Qi is intended daily water delivery, Ta is actual days of water delivered per month and Ti is intended day of water delivery per month (Figures 2 and 3).

**Figure 2:** Head and cross regulators of typical monitored secondary canal-1 of primary canal-1.

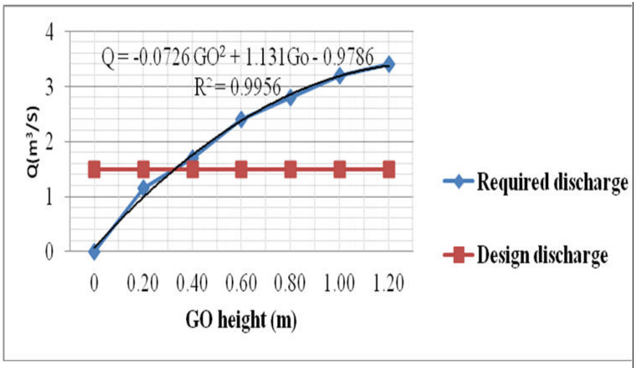


**Figure 3:** Relationship between discharge (Q) and gate opening (GO) of typical monitored primary canal-1.

### Monitoring actual irrigation interval

The actual irrigation interval ($A_{int}$) was measured as the time between the beginnings of two successive water applications for selected fields during the study period. Dependability of irrigation interval ($D_{int}$) was determined by using equation (3).

Where $D_{int}$ is dependability of irrigation interval, $A_{int}$ is actual irrigation interval (days), and Iint is intended irrigation interval (days)(Figure 4).

**Figure 4:** Actual irrigation interval typical monitored of sugar cane field number 1163.

## Results and Discussion

### Water delivery performance

Delivery performance of main canal and selected primary, secondary and tertiary canals are presented respectively. Comparison of the DPR for main canal reveals that DPR has maximum value as about 66%, and minimum value as about 21% with the average value of 36%. For selected primary canals, the maximum DPR was about 0.94 for PC4 and the minimum was about 0.10 for PC1 with average DPR of 0.53. The result of DPR for secondary canals show that the maximum DPR was about 1.02 for SC42 and minimum was about 0.17 for SC11 and SC13, with the average DPR of 0.54. In the tertiary canals, lowest DPR was about 0.16 for TC111 and the highest DPR was about 0.51 for TC422, TC423, TC427, TC611 and TC624 with average DPR of 0.38 (Figure 5).

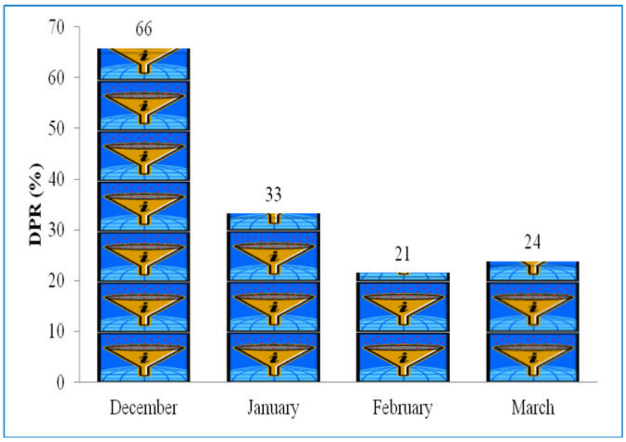


**Figure 5:** Delivery performance ratio (DPR) at main irrigation canal inlet.

The reliability of water supply found in this study is comparable to other results found in the other studies. The study conducted on performance evaluation of a Kalwande Minor Irrigation System in India shows that Delivery Performance Ratio of 1.27, indicating the condition of water abundance [8]. Another study conducted at the heads of secondary canals in other area was found only 33% of supplies released to distributaries and minors [9]. The average reliable supply for main and all selected primary, secondary and tertiary canals were regarded as very poor as indicated. To be good or fair performance, the deliveries to canals could be adjusted to keep DPR values between 70% and 130%). The values of DPR to canals were quite very low due to the effect of drought in Ethiopia and absence of gate on Tendaho Irrigation Dam causing high water shortage during the study time. However, after at later irrigation season, there is sufficient rainfall, and flow of Awash River to the Dam improved (Tables 1-3).

| Off take canal | Month | Intended flow rate (m³/s) | Intended days of supply per month | Actual flow rate (m³/s) | Actual day of delivered per month | DPR (%) |
|---|---|---|---|---|---|---|
| PC1 | Dec | 1.095 | 31 | 0.931 | 23 | 63 |
| | Jan | 1.073 | 31 | 0.931 | 15 | 42 |
| | Feb | 1.32 | 29 | 0.492 | 12 | 15 |
| | Mar | 1.133 | 31 | 0.492 | 7 | 10 |
| PC2 | Dec | 1.91 | 31 | 2.033 | 23 | 79 |
| | Jan | 1.869 | 31 | 2.033 | 15 | 53 |
| | Feb | 2.298 | 29 | 2.033 | 12 | 37 |
| | Mar | 2.007 | 31 | 2.033 | 7 | 23 |

| | | | | | | |
|---|---|---|---|---|---|---|
| PC4 | Dec | 1.08 | 31 | 1.361 | 23 | 94 |
| | Jan | 1.059 | 31 | 1.361 | 15 | 62 |
| | Feb | 1.311 | 29 | 1.361 | 12 | 43 |
| | Mar | 1.148 | 31 | 1.361 | 12 | 46 |
| Average | | | | | | 53 |

**Table 1:** Delivery performance ratio (DPR) at primary irrigation canals inlet.

| Off take Canal | Month | Intended flow rate ($m^3/s$) | Intended days of water supply per month | Actual flow rate ($m^3/s$) | Actual day of delivered per month | DPR (%) |
|---|---|---|---|---|---|---|
| SC11 | Dec | 0.138 | 31 | 0.178 | 23 | 96 |
| | Jan | 0.134 | 31 | 0.178 | 15 | 64 |
| | Feb | 0.165 | 29 | 0.11 | 12 | 28 |
| | Mar | 0.143 | 31 | 0.11 | 7 | 17 |
| SC13 | Dec | 0.123 | 31 | 0.099 | 23 | 60 |
| | Jan | 0.12 | 31 | 0.099 | 15 | 40 |
| | Feb | 0.149 | 29 | 0.099 | 12 | 28 |
| | Mar | 0.13 | 31 | 0.099 | 7 | 17 |
| SC22 | Dec | 0.156 | 31 | 0.17 | 23 | 81 |
| | Jan | 0.153 | 31 | 0.17 | 15 | 54 |
| | Feb | 0.187 | 29 | 0.17 | 12 | 38 |
| | Mar | 0.162 | 31 | 0.17 | 9 | 30 |
| SC211 | Dec | 0.294 | 31 | 0.38 | 23 | 96 |
| | Jan | 0.264 | 31 | 0.38 | 15 | 70 |
| | Feb | 0.26 | 29 | 0.38 | 12 | 61 |
| | Mar | 0.321 | 31 | 0.38 | 9 | 34 |
| SC42 | Dec | 0.384 | 31 | 0.528 | 23 | 102 |
| | Jan | 0.378 | 31 | 0.528 | 15 | 68 |
| | Feb | 0.468 | 29 | 0.528 | 12 | 47 |
| | Mar | 0.409 | 31 | 0.528 | 12 | 50 |
| Average | | | | | | 54 |

**Table 2:** Delivery performance ratio (DPR) of TSE at secondary irrigation canals inlet.

| Off take Canal | Daily Intended flow rate ($m^3/s$) | Intended days of water required per month | Actual day of water delivered per month | DPR (%) |
|---|---|---|---|---|
| TC111 | 0.039 | 31 | 5 | 16 |
| TC114 | 0.029 | 31 | 11 | 36 |
| TC116 | 0.008 | 31 | 14 | 46 |
| TC132 | 0.027 | 31 | 9 | 29 |
| TC133 | 0.033 | 31 | 10 | 32 |
| TC221 | 0.024 | 31 | 8 | 26 |
| TC223 | 0.025 | 31 | 9 | 27 |
| TC291 | 0.021 | 31 | 8 | 26 |
| TC422 | 0.044 | 31 | 16 | 51 |
| TC423 | 0.041 | 31 | 16 | 51 |
| TC427 | 0.056 | 31 | 16 | 51 |
| TC611 | 0.045 | 31 | 16 | 51 |
| TC624 | 0.038 | 31 | 16 | 51 |
| Average | 0.034 | 31 | 12 | 38 |
| CV (%) | | | | 32 |

**Table 3:** Average DPR of tertiary canal based on length of delivery duration of four months.

## Dependability of irrigation interval

The intended irrigation interval as per the design document of Tendaho sugar estate was 12 days for initial and development growth stages and 14 days for mid and maturity growth stages of sugarcane [10]. However, due to water shortage during this study period, most of fields were irrigated after 22 days. The lowest value of dependability of irrigation interval ($D_{int}$) was 1.14 for field No 1162 and highest value of $D_{int}$ was 2.36 for field No 2112. The average calculated dependability of irrigation interval of 1.60 was obtained.

For all fields dependability of irrigation interval is more than one showing that it requires more time than anticipated to irrigate the fields [11]. The dependability of intervals ($D_{int}$) between water deliveries was very low during this study period [12]. As indicated in Table 8 that the average waiting period between two consecutive water applications was 22 days. This is more than the intended interval of 14 days between water applications (Table 4).

| S/N | Field code | Average actual irrigation interval (day) | Intended irrigation interval (day) | Dependability of irrigation Interval or Dint |
|---|---|---|---|---|
| 1 | 1162 | 14 | 12 | 1.14 |
| 2 | 1163 | 14 | 12 | 1.16 |
| 3 | 2112 | 33 | 14 | 2.36 |
| 4 | 2113 | 30 | 14 | 2.16 |
| 5 | 2114 | 24 | 14 | 1.71 |
| 6 | 2115 | 17 | 14 | 1.23 |
| 7 | 2116 | 24 | 14 | 1.71 |
| 8 | 2122 | 21 | 14 | 1.48 |
| 9 | 2123 | 19 | 14 | 1.38 |
| 10 | 2124 | 19 | 14 | 1.37 |
| 11 | 2125 | 28 | 14 | 2 |

| | | | | |
|---|---|---|---|---|
| 12 | 2126 | 17 | 14 | 1.2 |
| 13 | 2127 | 30 | 14 | 2.14 |
| 14 | 2231 | 20 | 14 | 1.43 |
| 15 | 2322 | 19 | 14 | 1.33 |
| Average | | 22 | 14 | 1.6 |
| CV (%) | | | | 25.5 |

**Table 4:** Dependability of irrigation interval of sugarcane fields in Tendaho Sugar Estate.

The results found in this study are comparable to those found in other studies. A maximum dependability of irrigation interval of 1.15 was found between water applications in Chivilcoy canal in Argentina, where the government controlled the water distribution while the research result from this study shows average dependability of irrigation interval between water applications of 1.6.

## Conclusion

Water delivery Performance and dependability of irrigation interval in Tendaho Sugar Estate open canal irrigation system were evaluated using internal performance indicators. The results obtained show that inability of the system to deliver according to the crop water requirement due to drought during study period in which only average of 36% of required delivery was supplied from the Dam to main canal for irrigation and other uses of the Sugar Estate. This reliability of water supply fall under very poor, since values of DPR 70%. In terms of dependability of irrigation interval between water applications, the scheme is performed below expectations due to shortage of water from the source, and the result reveals that the fields waited for long time to get irrigation water. To store required irrigation water and avoid water shortage during dry period, Gate of the Dam should be installed; off-taking canals head and cross regulators must be installed for all canals, regularly repair and calibration should be done for all existing regulators. Generally, from the indicators monitored in this study, the performance of irrigation water delivery system was very poor and it requires taking urgent measures in the Sugar Estate.

## References


1. Eshetu BD and Alamirew T (2018) Estimation of seepage loss in irrigation canals of tendaho sugar estate, Ethiopia. Irrigat Drainage Sys Eng. 7: 220.
2. Ayana M and Awulachew SB (2007) Comparison of irrigation performance based on management and cropping types. Inte Water Managemen Institute for Nile Basin and East Africa.
3. Awulachew SB, Merrey DJ, Kamara AB, Van Koppen B and Penning de Vries F, et al (2005) Experiences and opportunities for promoting small-scale/micro irrigation and rainwater harvesting for food security in Ethiopia. IWMI working paper 98. Colombo, Sri Lanka.
4. Molden DJ and Gates TK (1990) Performance measures for evaluation of irrigation water delivery systems. J Irrigat Drainage Eng. 116: 804-823.
5. Bos MG, Burton MA and Molden DJ (2005) Irrigation and drainage performance assessment. Practical guidelines. CABI Publishing, CAB International, Wallingford, UK.
6. Murray-Rust H, Lashari B and Memon Y (2000) Water distribution equity in Sindh Province, Pakistan: International Water Management Institute (IWMI). Colombo, Sri Lanka.
7. PM Ingle, SE Shinde, MS Mane, RT Thokal and Ayare BL (2015) Performance evaluation of a minor irrigation system. Res J Recent Sci. 4: 19-24.
8. Bos MG, Salatino SE and Billoud CG (2001) The water delivery performance within 47 the Chivilcoy tertiary unit, Mendoza, Argentina. *Irrigation Drainage Syst*. 15: 311-325.
9. Mangrio MA, Mirjat MS, Li J and Chandio AS (2014) Performance Evaluation of irrigation System. *Pak J Agri Agril Engg Vet Sci*. 30: 216-228.
10. Burton MA (2010) Irrigation management, principles and practices. CABI Cambridge. 375.
11. Tariq JA and Kakar MJ (2010) Effect of variability of discharges on equity of water distribution among outlets. *Sarhad J Agri*. 26: 51-59.
12. Korkmaz N, Avci M, Unal HB, Asik S and Gunduz M (2009) Evaluation of the water delivery performance of the Menemen left bank irrigation System using variables measured on-site. J Irrigat Drain Eng. 135: 633-642.


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