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Conveyance Efficiency and Maintenance Performance Evaluation of Canals at Serenta Irrigation Scheme, Northern Ethiopia

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Abstract: Evaluation of conveyance efficiency and maintenance performance of canals in irrigation schemes is very important to improve the productivity of the irrigation scheme as whole. Thus, results help to improve the canals problem and the water loss. However, canals conveyance efficiency of Serenta irrigation scheme is not yet evaluated. Therefore, this study was conducted to evaluate the canals conveyance efficiency and maintenance performance of the Serenta Irrigation Scheme. To evaluate the canals conveyance efficiency, canals flow were measured using Parshall flumes (for secondary and tertiary canals) and Floating method (for main canal). The results from the field measurement revealed that, the average conveyance efficiency of the main canal measured from five observations was 96.2%. The average discharge of this canal was $0.104m^3/s$ at upper measuring point and $0.1m^3/s$ at lower position. Thus, the amount of water lost was estimated to be 4 l/s or 0.0076 l/s/m. The source of loss was observed during the field visiting and measurement, which was due to seepage loss. From the 4 (four) secondary canals of the irrigation scheme, the average conveyance efficiency ranged from 75.86% to 91.9% with an overall mean efficiency of 86.3%. The lowest conveyance efficiency (75.86%) was observed in secondary canal 3 (SC-3). This reflected that the high amount of water loss, due to broken and cracked condition of the structure at this particular canal, which contributed for deep and off farm loss. And, the average conveyance efficiencies of the tertiary canals ranged from 63.5% to 91.3%, with the overall mean value of 76.6%. The low conveyance efficiency observed in tertiary canal 6 (TC-6), implied for high mount of loss, due to the weak earth work canal (small width), a lot of water was flowing over the canal. Unlike the main canal the secondary and tertiary canals were under performance. So to reduce water loss and improve the performance the irrigation scheme, the conveyance efficiency of the irrigation scheme should be improved through regular canal cleaning and maintenance of the broken structures by mobilizing farmers to participate on the activities.

Keywords: Conveyance Efficiency, Performance Evaluation, Ethiopia

1. Introduction

Conveyance efficiency and maintenance performance viewed as the evaluation of the water balance of the main, lateral and sub-lateral canals and associated social organizations of the irrigation system [1]. It is the proportion of the outflow rate to the inflow rate of a system [2]. Water delivered to the farm or sphere is usually less than the water diverted from the root due to loss [3, 13]. The conveyance efficiency mainly depends on the length of the canals, the soil type or the permeability of the canal banks and the condition of the canals [3].

In large irrigation schemes more water is lost than in small systems, due to a longer canal system [13]. From the canals in sandy soils more water is lost than from canals in heavy clay soils [4]. Some water losses in canals may due to deep percolation to soil layers underneath the channels, seepage through the bounds of the canals, rat holes in the canal bonds and overstepping the bounds be [4]. Canal conveyance efficiency indicator is important to identify the canal sections that need maintenance [13]. Conveyance efficiency value equal to 100% indicates that there is no water loss over the section under consideration. While a value < 100% indicates that there is water loss in the section, and the loss determines the need for maintenance [5]. Conveyance loss consist operation losses, evaporation and seepage into the soil [3].

According to Baden *et al*. [6], the seepage loss in the irrigation canals accounts for the major portion of water conveyance loss (98.37%) while approximately (0.3%) is due to evaporation. However, evaporation loss in irrigation networks is generally not taken into consideration.

Evaluation of conveyance efficiency and maintenance performance of canals in irrigation schemes is very important to improve the productivity of the irrigation scheme as whole [14, 15]. Thus, results help to improve the canals problem and the water loss [5]. However, canals conveyance efficiency of Serenta irrigation scheme is not yet evaluated. Therefore, this study was attempted to fill this gap, conveyance efficiency of the main canal, secondary canals and tertiary canals of the irrigation scheme were evaluated. And, it is believed that this study will help the farmers, local and regional decision makers in developing appropriate strategies to enhance water use in the irrigation scheme.

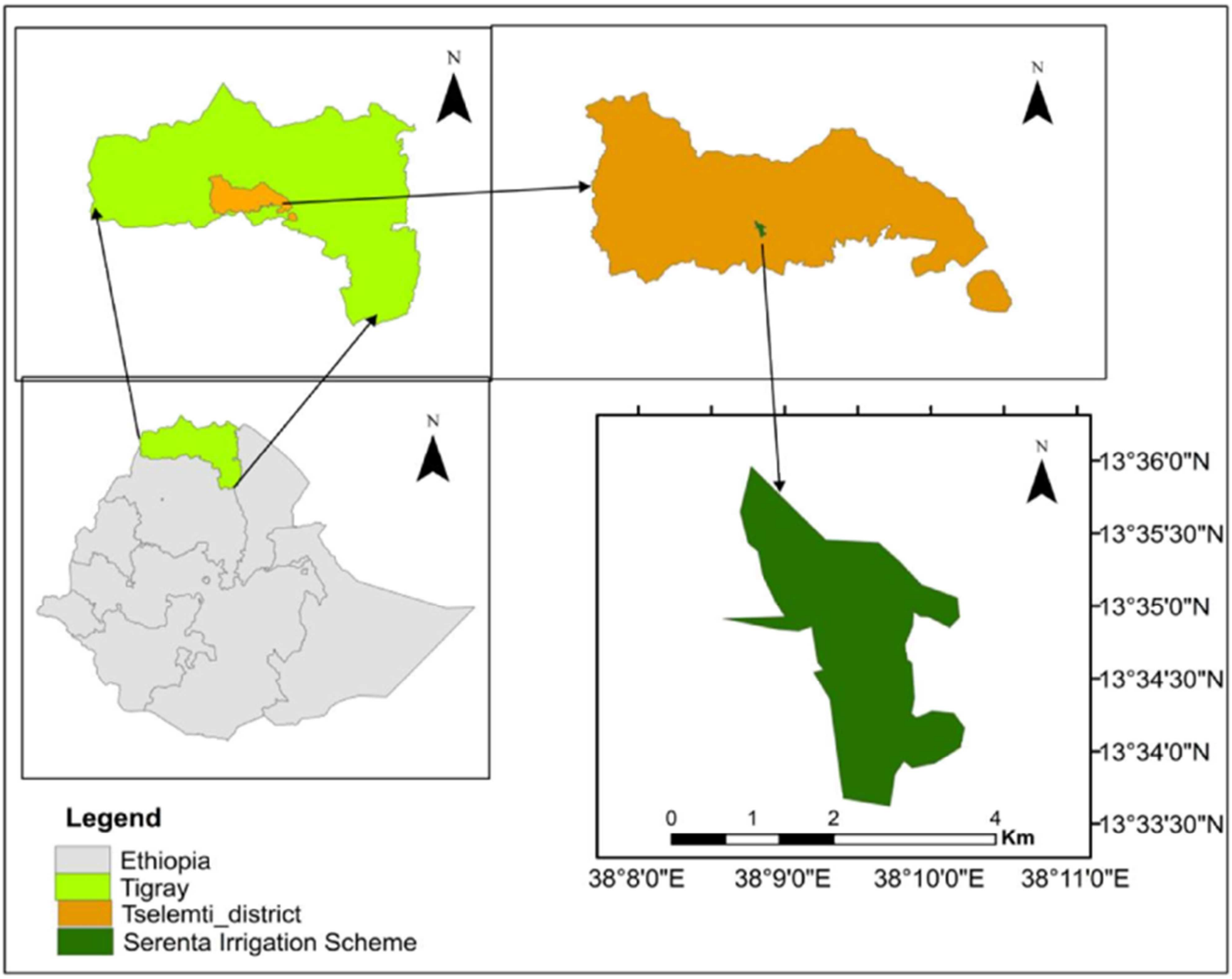


Figure 1. *Location of the study area.*

2. Materials and Methods

2.1. Description of the Study Area

2.1.1. Location

Serenta irrigation scheme is found in Tselemti district, North Western zone of Tigray regional State, Ethiopia. It lies between latitude of 13°36'29" - 13°34'18" N and 38°09'45"-38°10'44" E longitude. The elevation of the area ranges from 1315 m (downstream end of the command) to 1388 m (highest point in the catchment) above sea level (Figure 1).

2.1.2. Climate

According to the ten years (2008 – 2017) climatic data from May-tsebri station (meteorological station nearest to the irrigation scheme), the study area is mainly hot semi-arid, with mean maximum 33.3°C and minimum 18.4°C temperature, and the annual average rainfall is 811.81 mm. Summer is the longest rainy season which starts early of May and ends in October. Rainy pattern is a monsoon model with a distinct peak in the period of June- September (Figure 2).

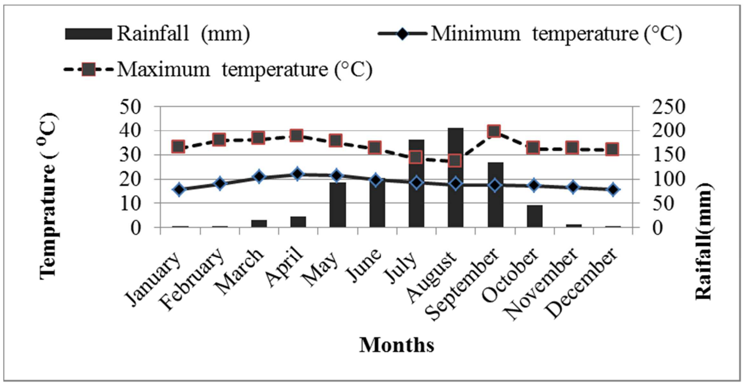


Figure 2. *Climate of the study area.*

2.1.3. Geology and Soils

The main rock units found in the watershed area are basaltic, and the predominant soil in the watershed is clay on a flat area. Grazing hilly and undulating lands are with significant stone with very shallow to shallow soil in depth. Regosol and Lithosol are common starting from the foot slopes of mountains [7].

2.1.4. Water Source and Canals Networking System

Serenta dam is earthen embankment type, which has 32.82 m height, 814.15 m length, two manually controlled gates and 8,435, 983.81 m^3 reservoir volume capacities [7]. The irrigation scheme has one main canal (lined), at the end of the main canal two secondary canals (lined) are branched to the left and right side naming Sc-1 (Secondary canal-1) and Sc-2 (Secondary canal-2) respectively. Secondary canal- 2 is branched to Sc-3 (Secondary canal-3) and Sc-4 (Secondary canal-4). The tertiary canals (unlined type) further branches from the secondary canals. Water reaches to the command area through the turnouts provided in the secondary and tertiary canals.

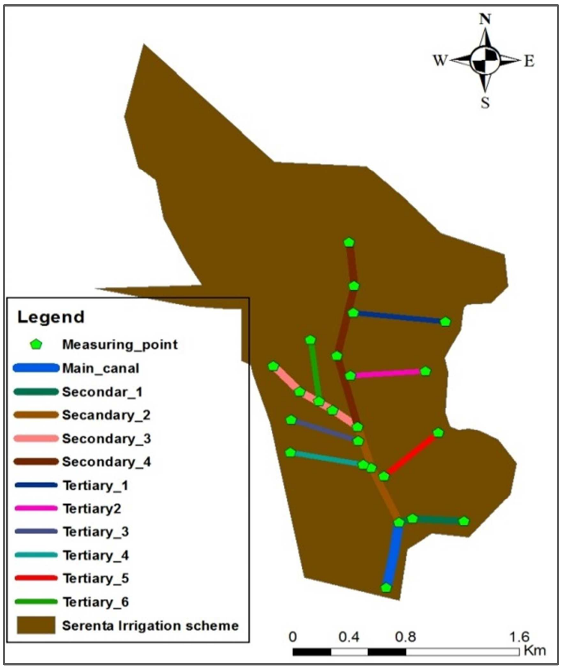


Figure 3. *Map of the canals water flow measuring points.*

2.2. Data Collection Methods

To evaluate the canals conveyance efficiency performance of the scheme; the amount of irrigation water inflows and outflows at one main, four secondary, and six tertiary canals were measured (Figure 3). In line with canals water inflow and outflow measurement at field, interview with 73 household irrigators on the current maintenance performance of the canals was conducted.

The irrigation water amount (depth) at selected points of the secondary and tertiary canals was measured using Parshalflum. Then the discharges were taken from tables for corresponding depths of a specific size of Parshalflum. While the flow at the main canal was measured using floating method in which the velocity of the water flowing in the canal was estimated by timing the passage over a predetermined distance (5 m) of the canal of the material (dried cow dung) floating on the water surface. The estimated velocity was multiplied by the cross sectional area of the particular section of the canal to obtain the discharge.

2.3. Data Analysis Technique

After measuring the water inflows and outflows at selected points, the conveyance efficiency (Ec) of the main, secondary and tertiary canals were calculated using equation 1 [2]:

$$Ec\ (\%) = \frac{Q\ out}{Q\ in} * 100 \qquad (1)$$

Where, Q out- discharge out flow from the given canal

Qin- discharge inflow to the given canal

And, the conveyance efficiency of the scheme as whole was calculated using equation 2 [2]:

$$Ec\ (\%) = Em * Es * Et \qquad (2)$$

Where, Em is the conveyance efficiency of main canal (%), Es is the conveyance efficiency of secondary canal (%), Et is the conveyance efficiency of tertiary canal (%).

The data generated through the household interview was analyzed by employing the computer Software known as Statistical Package for Social Science (SPSS vs. 20.0). Then, the descriptive statistical methods such as frequency and percentage were used. And, the data collected from keyinformant interviews and observations were assessed qualitatively.

3. Results and Discussion

3.1. Main Canal Conveyance Efficiency Performance

The main canal of Serenta irrigation scheme is lined with 521 m total length. As indicated in Table 1, the average conveyance efficiency measured from five observations was 96.2%. The average discharge of this canal was 0.104 m^3s in upper measuring point and 0.1 m^3s in lower position. Thus, the amount of water lost was estimated to be 4 l/s or 0.0076 l/s/m. The source of loss was observed during the field visiting and measurement, which was due to seepage loss.

However, the average conveyance efficiency value obtained for the main canal was in agreement with the value reported by Brouwer *et al.* [8], that the recommended value of conveyance efficiency for the lined canals is 95%. Similarly Alordzinu *et al.* [5], obtained similar value of 97% conveyance efficiency in lined canals. So, the main canal in the study area can be regarded as in good condition.

Table 1. *Average conveyance efficiency and loss rate of the main canal.*

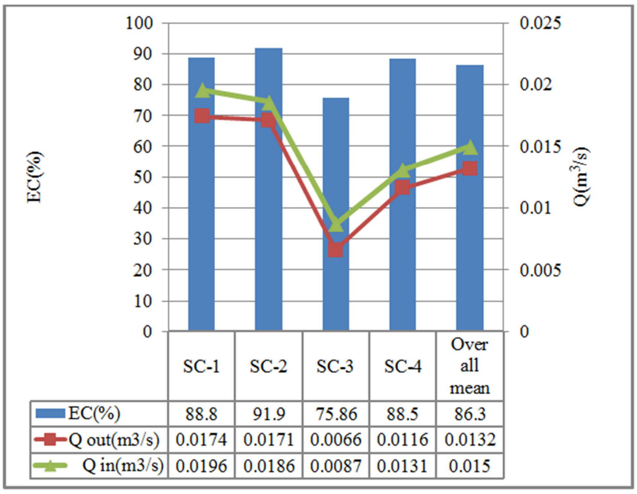
Canal flows	Average water Depth (m)	Average Width (m)	Area (m^2)	Distance (m)	Average Elapsed Time (sec.)	Velocity (m/s)	Q (m^3/s)	Conveyance loss l/s	Conveyance loss l/s/m	Ec (%)
Inflow	0.25	1.1	0.275	5	13.2	0.38	0.104	4	0.0076	96.2
Outflow	0.21	1.05	0.221	5	11	0.455	0.1			

Ec – conveyance efficiency, Q – discharge.

3.2. Secondary Canals Conveyance Efficiency Performance

The secondary canals of Serenta irrigation scheme are lined canals with different lengths. Since the canals are so long, each canal was classified to different segments to measure the discharge of each canal. Then, the average conveyance at the specific segment length was calculated. Finally, the overall average conveyance efficiency of the specific canal length was taken.

Even though the secondary canals are lined canals like that of the main canal, the water losses from those canals were high. This was due to improper management and illegal breaking of the canals. Similarly Awulachew & Ayana [9] reported that, water loss from the lined canals was observed in Tendaho Sugar Estate project (Ethiopia) due to broken structures of the canals.



Ec-conveyance efficiency, Qin –inflow discharge, Q out - outflow discharge.

Figure 4. *Average conveyance efficiency of secondary canals.*

As indicated in Figure 4 from the 4 (four) secondary canals of the irrigation scheme, the average conveyance efficiency ranged from 75.86% (SC-3) to 91.9% (SC-2) with an overall mean efficiency of 86.3%. The lowest conveyance efficiency (75.86%) was observed in secondary canal 3 (SC-3). This reflected that the high amount of water loss, due to broken and cracked condition of the structure at this particular canal (Figure 5), which contributed for deep and off farm loss.

This low performance of the canals was also confirmed by the respondents interviewed. Of the total respondents, 46.6% of them responded that the canals cleaning and maintenance performance were in poor condition. And also, at the time of water flow measurement and field visiting a lot of broken secondary canal structures were observed (Figure 5). This breaching canals problem was also confirmed by the respondents' interview. 50% of the respondents stated that, the major cause for the poor conditions of the canals was breaching of canals by illegal water users. The siltation, animals' damage (animal's movement) and improper management of weeds (Farmers were thronging weeds to the canals and poor cleaning weeds which grows in the canals) were the other problems in the secondary canals.

The high water losses in those canals lead to low performance of the canals. Similarly Jibril *et al.* [10], reported that the causes for the low conveyance efficiency in Badeggi irrigation scheme (Nigeria) were damaged structures, improper water management practices and lack of skills and carelessness of farmers.

Due the broken structures and improper management problems existing in the irrigation scheme, an average value (86.3% conveyance efficiency) obtained from all the secondary canals was less than the standard value (95%) reported by Brouwer and Prins (1989), for lined canals. And, below the result (88.7%) obtained by Tadesse, G. in Bilate irrigation scheme in Ethiopia [11].

Figure 5. *Broken secondary canals and water wastage (losses) in the irrigation scheme.*

3.3. Tertiary Canals Conveyance Efficiency Performance

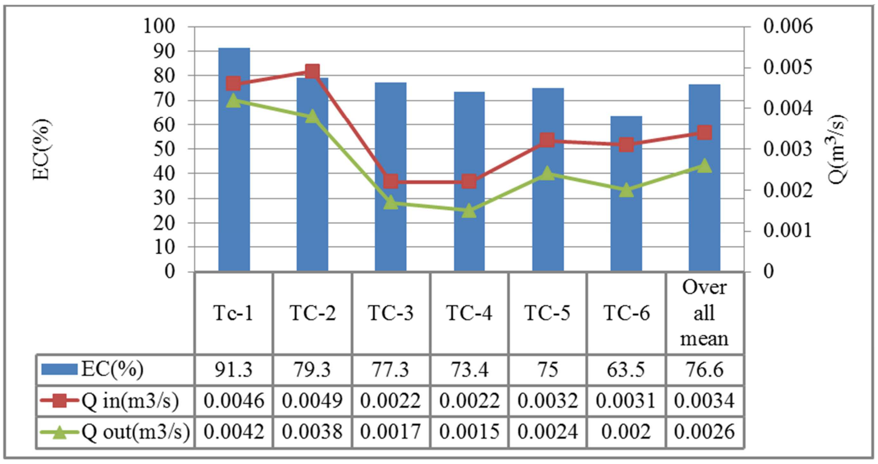
To evaluate the conveyance efficiency performance of the tertiary canals in Serenta irrigation scheme, six (6) canals were selected. The selection criteria of these canals were based on full functionality of the canals and representativeness of the remaining others. Those tertiary canals are unlined canals (earthen type canals) and not well properly constructed.

As indicated in Figure 6, the average conveyance efficiencies ranged from, 63.5% (TC-6) to 91.3% (TC-1), with the overall mean value of 76.6%. The low conveyance efficiency observed in tertiary canal 6 (TC-6), implied for high amount of loss, due to the weak earth work canal (small width), a lot of water was flowing over the canal, and improper management (it was covered by grasses).

Accordingly, the causes for the low performance of the tertiary conveyance efficiency were presented by the respondents. Of the, 46.6% of the respondents said that the canals cleaning and maintenance performance were in poor condition, 35.3% and 8.8% of theme responded as siltation problem and animals damage, respectively.

The average conveyance efficiency value (76.6%) obtained for all tertiary canals at 485 m canal length (clay earthen canal) did not agree with the value reported by [8]. which is 85% recommended conveyance efficiency value for medium canal length (200-2000 m) clay earthen canal type. It was only one tertiary canal-1 (TC-1) that had 91.3% conveyance efficiency (above the value recommended by [8] for the unlined canals (clay earthen canals) with medium length (200-2000 m). This highest conveyance efficiency was due to proper management of the canal by the users, who has farm plot near the canal.

Generally, from the field observation and key informant interview result with farmers revealed that some farmers in the scheme were interested to clean the canals near to their farm, while some are reluctances. Due to this variation in canals cleaning and management, the conveyance efficiency of the tertiary canals highly varied across the scheme.



	Tc-1	TC-2	TC-3	TC-4	TC-5	TC-6	Over all mean
EC(%)	91.3	79.3	77.3	73.4	75	63.5	76.6
Q in(m3/s)	0.0046	0.0049	0.0022	0.0022	0.0032	0.0031	0.0034
Q out(m3/s)	0.0042	0.0038	0.0017	0.0015	0.0024	0.002	0.0026

Ec-conveyance efficiency, Qin –inflow discharge, Q out - outflow discharge.

Figure 6. *Conveyance efficiency of tertiary canals.*

3.4. Overall Canals Conveyance Efficiency Performance

Smith, M. reported that, lower limit for overall conveyance efficiency of a scheme is supposed to be 65% [12]. The overall canal conveyance efficiency of the scheme was calculated and comparisons were made between the existing (actual) and expected (designed) conveyance efficiency of the scheme, extracted from the design documents of Serenta irrigation project**.** Then, the existing (actual) overall efficiency was found to be 63.7%, while the expected (designed) was 65% [7].

So, it is clear that, the existing conveyance efficiency is slightly less than the expectation (design) and the result reported by Smith [12]. This difference is due to the conveyance loss, which caused by the breaking of the canals, siltation and improper cleaning of the grasses in the canals. Similarly Mohammed [3] reported that, the difference between the existing conveyance efficiency and expectation (design) was due to improper operation and maintenance of the canals.

Generally, it can be considered that the main canal was in good condition, which put under the recommended value for lined canals. However, the secondary and tertiary canals were under poor performances.

4. Conclusion

The main canal conveyance efficiency in the irrigation scheme was with acceptable value. However, the majority of the secondary and tertiary canals were broken, cracked and silted by weeds and soils contributing to high water loss. As a result, the conveyance efficiencies were very low and under recommended values. So to reduce water loss and improve the performance the irrigation scheme, the conveyance efficiency of the irrigation scheme should be improved through regular canal cleaning and maintenance of the broken structures by mobilizing farmers to participate on the activities.

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