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EVALUATION OF SEEPAGE LOSS IN GOREZEN IRRIGATION CANALS, DABAT WOREDA, NORTH GONDAR, ETHIOPIA

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Abstract- **Evaluations are useful in a number of analyzes and operations, particularly for improving management practices and control. Therefore, the study was focus mainly on the evaluation of seepage loss through irrigation canals, which represented the basic problems as a reason for a lower performance of irrigation water on the Gorezen irrigation system. The flow data were collected from the selected canal. Descriptive statistics were used to analyze the major data collected from the laboratory and field measurements.**

Five canal reach 100 of each were selected to estimate the seepage rate of flow and inflow outflow and ponding method were applied to estimate this. From the five selected canal section, reach 1 and reach 5 accounts the highest average seepage rate (1.72 m^3/d for both reach) by inflow outflow method and (1.8 and 1.2 $m^{3/}$d respectively) by ponding method. The result also showed that the relation of soil texture and seepage loss rate. Highest seepage rate was observed in clay loam and the lowest was observed in clay dominant soil. Seepage loss rate in canal reach one (1) greater by 58.3 % than canal reached two and also high seepage rate that canal reach three by 51.11%. The study also compared estimated seepage losses from inflow outflow and ponding method. Seepage losses were presented in both types of methods. However the amount of loss evaluated within one day measurement is different average loss of water through seepage with inflow outflow and ponding method is 0.96 and 1.12 m^3/d respectively.

Keywords: seepage; Gorezen; inflow-outflow; ponding

I. INTRODUCTION

It has been recognized that rain-fed agriculture alone is not able to support the required amount of food production to feed the growing population in Ethiopia. Most parts of the country are arid and semiarid which suffer from the shortage and erratic nature of rainfall [1]. Reports show that the dependency on rain fed system has put more than 80% of the society at the mercy of meteorological variability [2]. Consequently, agricultural production is low while the food demand is growing at an alarming rate [3]. In order to meet the growing demand for food and to alleviate poverty, it is necessary to focus on agricultural development. One of the different ways to achieve agricultural development is through irrigation development. Consequently, there is a need to invest on irrigation, particularly small scale irrigation (SSI) schemes. The country has a significant potential for irrigation with an irrigable area of around 3.7 million ha, 122 billion m^3 of surface water resource and an estimated 2.6 - 6.5 billion m^3 of ground water [3, 4]. For this purpose, irrigation is being extended across the country to improve the productivity of the available land, thus improving the livelihoods of rural communities. Particularly, SSI schemes have been promoted by the current government and NGOs as a strategic intervention to address food security problem in the country.

Regardless of the aforementioned facts, inappropriate water management in irrigation development, high seepage and operational losses of the canal could have profound impacts on the irrigation activities and the environment.

The effective management of water in an irrigation system requires knowledge of the amount of water flowing in the channel to send the right amount of water to each user at the right time, avoid unnecessary losses, and avoid physical and environmental damage. The seepage out from the canals affects the efficient operation of the canal system as this water leaves the canal, moves downhill and through the soil layers and is no longer available directly to the water users. There are many factors that affect seepage from channels [4]: siltation conditions, microbiological activity, and texture of the soil in the canal bed and banks, water velocity, bank storage changes, irrigation of adjacent fields, and water table fluctuations and soil chemicals. Seepage losses affect the operation and maintenance of the channels in the sense that some of the water that is diverted to the user is lost from the conveyance system, erode the bank of the canals whether they are lined or not, produce excessive saturation, and at the same time this water might produce piping, which might produce failures of the canal and other structures, uplift pressure [5]. The main issue of evaluating the traditional irrigation water management is to identify management practices and systems that can be effectively implemented to improve the irrigation water management. Evaluations are useful for a number of analyzes and operations, particularly for improving management practices and controls. Evaluation data can be collected periodically from the system to refine management practices and identify the changes in the area that occur during the irrigation season or from year to year [6].

The evaluation of traditional irrigation water management at field level is an important aspect of the management and design practice. Field measurements are necessary to characterize the irrigation practice in terms of its most parameters, (i.e seepage loose) to identify problems in its function, and to develop alternative means for improving the practice [6.] Thus, the study focuses on evaluating the seepage losses of irrigation canals in Gorezen irrigation schemes of Dabat woreda and to propose the practical ways of improving the performance of irrigation schemes from seepage losses.

II. DESCRIPTION OF THE STUDY AREA

The study has been conducted at Dabat woreda of North Gondar Administrative Zone. Dabat woreda is located 814 km and 75km north of Addis Ababa and Gondar city, respectively. Dabat town is the main town of the Woreda. The woreda has a total of 28,293ha of cultivated land and a population of 176,795. The total irrigable land in the Gorezen irrigation scheme is 70 ha. The altitude of the woreda ranges from 1500 to 3200 m.a.s.l Mean annual rainfall in the woreda ranges from 800 to 1400 mm. The main rainy season starts at the beginning of June and continues up to the end of September. The minimum and maximum temperature of the woreda is 18 and 35^{O}C respectively [10].

III. MATERIALS AND METHODS

A. Methods to Measure Canal Seepage

Methods for measuring the rate of seepage from canals include: inflow outflow methods (seasonal estimates based on diversion and delivery volumes for the district or actual measurements on specified reaches), the seepage meter method, the ponding method, and laboratory permeability [4].

B. FIELD DATA MEASUREMENTS

Seepage Measurement Method: The seepage measurements were done using the inflow-outflow method in selected reaches of the canals. Discharge measurements were estimate using a floating method. The estimation of the mean velocity in each vertical and in the cross section (i.e. width and depth measurements were made by the cross-section survey) obtained using the mid section method.

INFLOW-OUTFLOW METHOD

The inflow-outflow method is a water balance approach that consists in the direct measurement of the flow rate flowing into and out of a reach of canal. Thus, from Eq-1 it is possible to estimate the flow that goes into the soil through the wetted perimeter. Figure-1 shows the scheme of this method.

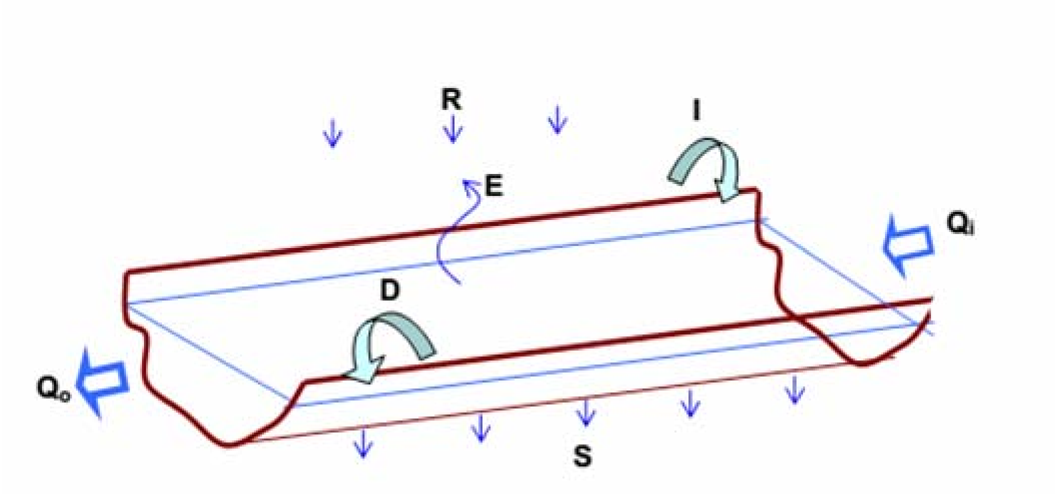

Figure-1: mass balance for the inflow outflow method

$S=Q_i+R-Q_o-D+I-E$……………1

Where,

S is the seepage rate; Q_i is the upstream inflow; R is the rainfall; Q_o is the downstream outflow;

D is the flow diverted along the reach; I is the inflow along the reach; and, E is Evaporation.

To be used this method, it is necessary assume steady flow conditions and take long canal reaches to obtain a measurable loss.

DISCHARGE MEASUREMENTS

The flow rate in a cross section perpendicular to a canal is estimated using:

$Q = V*A$……………….3

Where Q is the discharge (in volume per unit of time);
V is the mean velocity of the flow; and,
A is the area of the cross section.
The method is used to measures surface velocity. Mean velocity is obtained using a correction factor. The basic idea is to measure the time that it takes the object to float a specified distance downstream.

Units to Express the Seepage Rate

According to [7], the seepage rate were evaluated in the canal is expressed the following equation

Seepage loss rate in mm/day:

$$Qi=8.64*10^{7}*\frac{Qu-Qd}{WPav*L} \quad \text{……………………..2}$$

Where Ql= seepage loss; Qu= inflow rate (m3/s); Qd= outflow rate (m3/s); L = reach length (m); and, Wpavg= average wetted perimeter (m).

S_{urface} = travel distance/ travel time = L/t …4

Because surface velocities are typically higher than mean or average velocities $V_{mean} = k\,S_{urface}$ where k is a coefficient that generally ranges from 0.8 for rough beds to 0.9 for smooth beds (0.85 is a commonly used value). Material required: Tape measure, Stop-watch, Rod, yard or meter stick to measure depth, At least three highly visible buoyant objects such as a drifting branches or logs, pine cone, coffee stir sticks, half filled bottles, or oranges (objects buoyant enough not to be effected by the wind), Stakes for anchoring tape measure to stream banks, Waders.

PONDING LOSS MEASUREMENT

The losses from the test sections were measured by the pond method (Fig-2). For most of these measurements, approximately 30 m long channel sections were chosen. In order to separate the test sections from each other, a compacted earthen bund was formed at each end of the test section. Initially, the test sections were filled to soak and stabilize the sections. In general, it took about 6 hours to perform the infiltration tests. After the section was filled with water to slightly above the normal operating level, a ruler was attached vertically in the bottom of each channel section. The water loss measurements were continued until all of the water in the test section was infiltrated. The rate at which the water was withdrawn in the test section was recorded. This recession rate was combined with the TW (Top Width in Fig. 2) of the channel at the time of measurement to calculate the water loss rate.

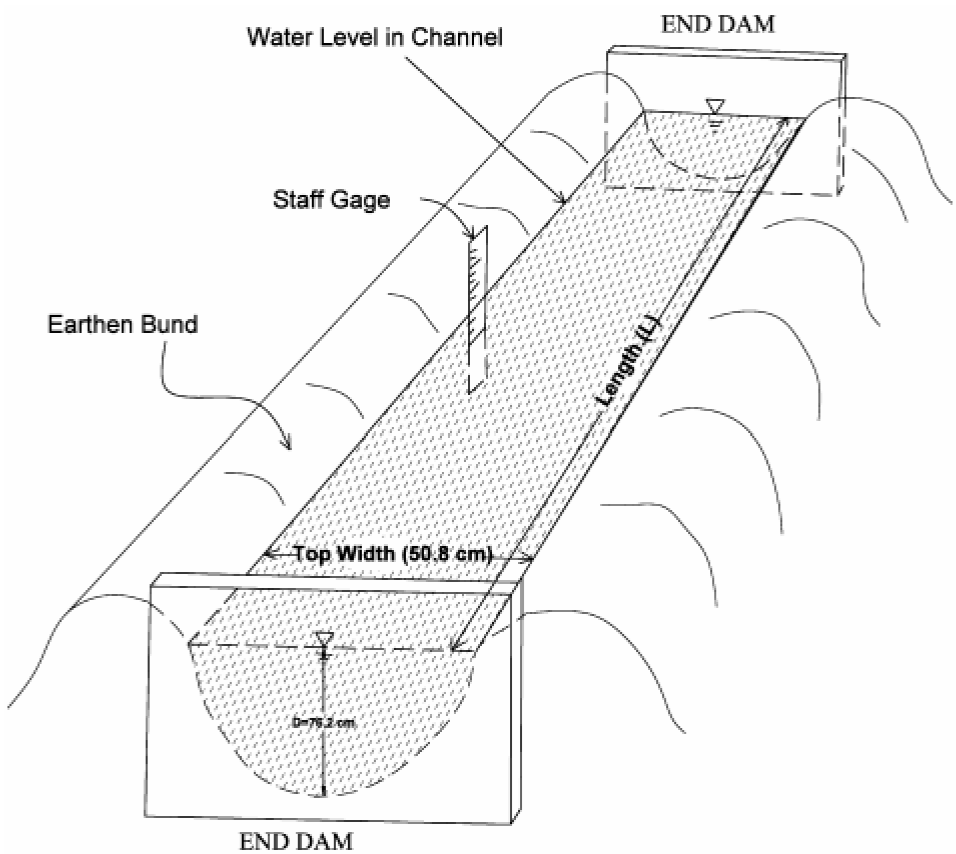

Fig-2 ponding loss measurements

IV. RESULT AND DISCUSSION

Estimation of seepage

The study on water losses by different methods has been carried out on an earthen water course (IR) of Gorezen irrigation schemes . To estimate the seepage, measurement was done in five (5) selected reaches with 100m of each along one long irrigation canal.

The watercourse was not clean and fairly maintained. there was some vegetation and grasses, there was no visible leakage. For conducting the inflow-outflow test a straight reach was selected at a distance of 500 m (Table 2).

The seepage measurements were done using the inflow-outflow and ponding method in the selected canal reaches, and evaporation was estimated to be negligible. Discharge measurements were estimated using a floating method, the estimation of the mean velocity in each station and in the cross section was obtained using the area velocity method. The area was obtained from the measurement of water depth at every station along the cross section; for a more accurate estimation of the area at the edges, the velocities at the edges of the canal were measure in order to determine the boundary between the flowing water and dead water, factors. The computation of the discharge was done using the midsection method, and the measurement of low-flow pipe discharges.

Before starting the measurement, operating surface water level, the bed slope, the conditions of water course and soil texture were determined. The measurement of seepage losses by inflow- outflow and ponding method was used. The reach was divided in to five test sections, and the length of each section was 100 m.

Inflow-Outflow Loss Measurement Method

The inflow-outflow method involves measuring the amount of water flows into a channel at inlet of the section and amount which flows out at the tail of the selected section. The loss is the difference between these two measured points. The measurement can be either of total volumes of water or within the selected section separately.

To measure the amount of water flow among the total canal or the selection reach, floating method was used. Measurement of velocities: Upstream inflow, downstream outflow, flow diverted and inflows were measured. The number of verticals per section was determined in the field, taking into account the canal width, the uniformity of the canal bottom, eddies, the available time to develop the measurement. Also, some parameters were monitored during the velocity measurement, in order to observe if debris, eddies, lack of perpendicularity, or lack of particles in the water affected the velocity measurements.

The loss is calculated in per unit length of canal and percentage loss as the following

A rate of decrease flow rate per unit length of channels $Q_L = \frac{Q1 - Q2}{L}$ ………………...5

Where Q_L=loss rate $m^3/100$

Q_1=flow rate in the upstream

Q_2=flow rate in the down stream

L=length of the channel between the measured 100 m

Accordingly, measurements were taken repeatedly on starting February 10, 2014 up to March 10 /2014 during non rainy season, in five reaches along this canal, and the data and calculations are shown in Tables on the following. Hence, measurements of rainfall as one of the inflow to canal were not taken. The measured reaches were earthen canals with non-prismatic sections, the measured top width varied from 0.9 to 0.4 m, the mean water depth varied from 0.498 to 0.276 m, and the average velocity varied from 0.51 to 0.64 m/s (show in table 2)

Table 1: Inflow outflow test of seepage

SR no.	distance	Section length (m)	Q1(m^3/s)	Q2(m^3/s)	QL= $\frac{Q1-Q2}{L}$ (m^3/100m)/s
1	0-100	100	0.021	0.019	0.00002
2	100-200	100	0.015	0.0138	0.0000012
3	200-300	100	0.0145	0.014	0.000005
4	300-400	100	0.014	0.013	0.00001
5	400-500	100	0.02	0.018	0.00002
Average					0.000012

Source: own measurement

According to the result, the average quantity of water loss through inflow outflow method is 0.000012 m3/100m/s. The first section presented the highest seepage losses in comparison with the other sections, and reach 2 presented the lowest losses. Also, seepage losses were observed in reach 5.Hence that the result indicates, the amount of water loss with in similar reach length is different. The average top width of the canal is one of the factor influences the seepage lose rate of canal (Table 2) Similar results were found by [8], reported that the influencing factors of canal width on seepage rate is directly related.

Table 2: Measured average top width, water Depth and velocity

Sr no	distance	Section length (m)	Average top width(m)	Average water depth(m)	Average velocity
1	0-100	100	0.9	0.48	0.64
2	100-200	100	0.5	0.35	0.51
3	200-300	100	0.4	0.3	0.68
4	300-400	100	0.44	0.3	0.53
5	400-500	100	0.4	0.27	0.55

Source: own measurement

Ponding Loss Measurement Method

Measuring watercourse losses by the ponding method involves filling a section of Channel at both ends and determining the decrease in the volume of water in the section over time. This volume decrease is determined by measuring the area of the surface of the ponded water (Top width times the section length) and the rate of Recession of water surface. Table 2 the loss rate is taken per unit distance m3/s/100 meters.

The most dependable and reliable method for measuring the quantity of water loss through seepage from the existing canals in a particular reach is by the ponding method. It consists of constructions of a temporary water blockage across the canal with available local materials. The canal above the blockage is filled with water to a certain measured level. After allowing the water to stand for some time, the level of water in the canal is recorded. Any drop in the level is obviously due to seepage through the section of canal. The volume of water divided by the time determines the rate of seepage loss through the canal.

For conducting the ponding test, sections of 100 meters length was selected at every reach of 100 m. Staff gauges were inserted at the bottom of watercourse for measuring the water depth changes.

Width of each bank was measured at different places with tape and average values were taken. Formula used for this method is as under:

$$Q(m^3/s/100m) = \frac{DD}{Dt} * TWT * C \quad \ldots\ldots\ldots\ldots 6$$

Q=Loss rate

DD/Dt= rate of change of flow depth

TWT= Average top width

C=conversion factor (1/3600) hr/se*(1/1000) lit/cm^3*(100) m*100 cm/m = 0.0028

Therefore, five selected pond site were prepared to evaluate loss of water by pond for one day interval as indicated below in table 3.for the calculate the ponding loss of water, average width, wetted perimeter and average depth of the wetted part were determined in February 10/ 2014.

Table 2: Seepage lose rate by ponding test

Sr no	Length of section(m)L	Average width B	Average depth	Wetted (p) perimeter(B+ 2d)	Ponding area(m^2) P*L	Depth of water loss(m/ day)	Volume of water loss/day
1	100	0.9	0.48	1.36	136	0.02	1.8
2	100	0.5	0.35	1.2	120	0.015	0.75
3	100	0.4	0.3	1.5	150	0.022	0.88
4	100	0.44	0.3	1.04	104	0.023	1.012
5	100	0.4	0.27	0.94	94	0.03	1.2

Source: own measurement

Soil texture and seepage rate

To compare the effect of soil type with seepage lose of earthen canal, Soil data along irrigation canal were selected. five soil samples were collected from the side of water course at a depth of 10 cm each from a distance of 100 m apart. Based on the laboratory result, the soil type was identified presented in Table 1, in which the soil type varies from clay, silt clay and clay loam type.

Table 4: percent of soil texture

reach	% clay	%silt clay	% clay loam type.
1	35	-	65
2	60	27	13
3	70	-	30
4	35	15	50
5	38	20.6	42

Source: own survey

According to data, clay-textured soils are dominant in almost all reaches of the canal. About 47.6 % of the soils along the canal are clay -textured, 20.6 % are silt clay, and the rest 40 % are clay loam texture soil. Above 100 % of the average soil texture value is due to repeatedly existence of soil texture in different reaches.

Three of the five canal reaches inflow outflow and ponding test were conducted in clay dominant textured soils, two of in clay loam textured soils. Hence the highest seepage rates have accounted in clay loam texture soil type and the lowest were observed only on pure clay texture soil in both methods of seepage rate measurements. Similar results were also found by [9], indicates that high seepage rate were exist in clay loam texture soil than clay and silt clay.

Table 3: soil texture and seepage rate in inflow outflow method

Reach	% clay	%silt clay	%clay loam type.	Seepage rate m^3/s $QL=\frac{Q1-Q2}{L}$ $(m^3/100m)/s$	Volume of water /day m3/d
1	35	-	65	0.00002	1.72
2	60	27	13	0.0000012	0.1036
3	70	-	30	0.000005	0.436
4	35	15	50	0.00001	0.86
5	38	20.6	42	0.00002	1.72

On the other hand soil texture and seepage rate were also analysis in ponding test. Hence that the amount of water seeped with respect to soil texture type have a similar result of inflow outflow method.

Table 4: soil texture and seepage rate in ponding method

Sr no	% clay	%silt clay	% clay loam type.	Volume of water loss/day
1	35	-	65	1.8
2	60	27	13	0.75
3	70	-	30	0.88
4	35	15	50	1.012
5	38	20.6	42	1.2

The result also indicates that the highest seepage rate was observed in clay loam and the lowest was observed in clay type soil. Seepage loss rate in canal reach one (1) greater by 58.3 % than canal reached two (2) and it also has highest seepage rate than canal reach three (3) by 51.11%. This indicates that the different soil texture has a different seepage rate with the same conditions.

Seepage loss through inflow out flow and ponding method

The study compared estimated seepage losses from inflow outflow and ponding method. Seepage losses were presented in both types of methods. However the amount of loss evaluated within one day measurement are different. The table above indicated that, average loss of water through seepage with inflow outflow and ponding method is 0.96 and 1.12 m^3/d respectively. The figure below shows the seepage variation between inflow, outflow and ponding method.

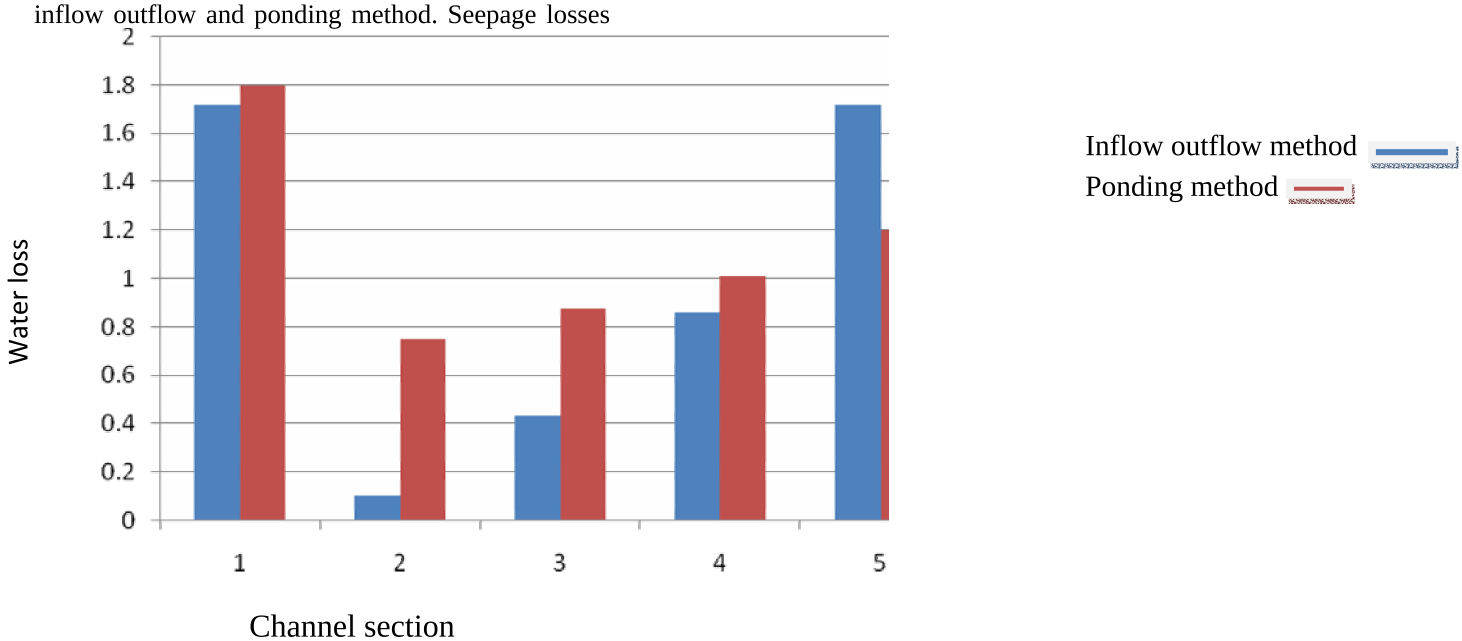

Figure-3: comparison of water loss by inflow outflow and comparison method

Hence, Seepage loss through inflow outflow method is less by 14.29 % than the ponding method. The main reason of highest rate of seepage in ponding method is that, water has the chance to seep vertically than flow in horizontally with velocity of an open channel.

V. CONCLUSION

Estimation of water loss through seepage was done in 5 selected reaches in the Gorezen irrigation channel. The experiment was conducted for one month in which one in a weak and repeatedly for three weak during the dry season at Dabat woreda of Gorezen irrigation canals in 2013/14. The method used was the inflow-outflow method and ponding, for which area and velocity were, measured under steady flow conditions. Due to high vegetation growth in reach 1 and 5 than the other reaches, comparatively high seepage rate was observed in both canal reaches with both of inflow outflow and ponding methods than the other reaches. The highest seepage rate was also observed in clay loam texture soil and the lowest was observed in clay type soil. The canal reached located in clay loam soil has more chance to seep more water than other texture in the study area this indicates that the different soil texture has a different seepage rate in the same conditions. Seepage measurement method comparison of seepage losses within the reaches did indicate higher seepage loss in ponding method than inflow outflow. Even though, the same soil texture with the two methods has different seepage loss rate. The comparison analysis indicated that, average loss of water through seepage with inflow outflow and ponding method is 0.96 and 1.12 m3 respectively. Thus, Seepage loss through inflow outflow method is less by 14.29 % than the ponding method.

REFERENCES

1. Hagos F, Makombe G, Namara RE, Awulachew SB (2009). Importance of irrigated agriculture to the Ethiopian economy: Capturing the direct net benefits of irrigation. Colombo, Sri Lanka: Int. Water Manage. Inst. p.37.
2. Awulachew,S.B.,Merry,D.J.,Kamara,A.B.,Van Koppen,B.,Penning deVries,F.,Boelee,E. and Makombe, G.2007. Experience and opportunities for promoting small scale irrigation and rain Water harvesting for food security in Ethiopia. IWMI working paper 98.colombo, international Water management institute
3. McCormick PG, Kamara AB, Girma T, editors.2003. Integrated water and land management research and capacity building priorities for Ethiopia. Proceedings international workshop at ILRI, Addis Ababa, Ethiopia, 2–4 December 2002. 2003.
4. Worstell, R.V. 1976. Estimating seepage losses from canal systems. Journal of the Irrigation and Drainage Division, American Society of Civil Engineers 102 (IR1):137-147.
5. Rushton, K. and Redshaw, S. 1979. Seepage and groundwater flow. Wiley Intersicencepublication. Norwich, Great Britain.339 pp.
6. FAO (Food and Agriculture Organization), 1989. Irrigation scheduling. Irrigation water Management. Training Manual no. 4, Rome, Italy: FAO.
7. Skogerboe, G., and Merkley, G. 1996. Irrigation Maintenance and operations learning Process. Water Resources Publications, Colorado, USA. 358 pp.
8. katerine N,2008. Seepage evaluations in cache valley irrigation canals
9. Bennet, Z. Iqbal, R.T. MacLean, B.D. Taylor, F.J. Hecker and D.R. t 2002. Seepage losses from irrigation canals in southern Alberta
10. Dabat Woreda Office of Agriculture and Rural Development, 2007