Global Advanced Research Journal of Physical and Applied Sciences Vol. 4 (1) pp. 057-063, September, 2015
Available online http://www.garj.org/garjpas/index.htm


*Full Length Research Paper*

# Evaluation of Water Management in Irrigated Sugarcane Production: Case Study of Wondogenet, Snnpr, Ethiopia.

**Yewendwosen Mamo[1] and Zinabu Wolde[2]**

[1]Graduate student of Hawassa University, Department of Irrigation and water resource Engineering, P.O.Box05
[2] Ethiopian Sugar Corporation Research and Training, Wonji Ethiopia. P.O.Box 15

Accepted 10 September, 2015

**The study was initiated to evaluate how the irrigation water is being managed starting from the point of diversion of water from the source till field application. Internal indicators such as conveyance efficiency, water application efficiency, water storage and distribution efficiency and others related parameters were considered. Measurement of inflow and out flow water, determination of soil moisture before and after irrigation, field observation and collection of secondary data was done. The evaluation result showed that the conveyance efficiency in 5km long canal was 64.25% while Field application efficiency of the fields was very low 52.85%. The irrigation scheduling was irregular that it was in about 30-35 days whereas the normal should be in 20 days interval. The water storage efficiency of the soil was good (94.96%). The deep percolation fraction was high, and reaches up to 47%.This show that high amount of water is lost through deep percolation during field application and water conveyance. High deep percolation and poor water management practices such as irregular irrigation schedule, over application, etc were then observed to be contributing factors to low water use efficiency.**

**Keywords:** application efficiency, Conveyance efficiency, Sugarcane, Irrigation.

## INTRODUCTION

A reliable and suitable irrigation water supply can result in vast improvements in agricultural production and assure the economic vitality. The availability of water varies tremendously by region, and in some areas, it is very scarce. Nevertheless, even with limited water supplies, irrigation can vastly increase agricultural productivity and is crucial to improving food security.

According to Rockstrom et al. (2003), irrigation accounts for about 72% of global and 90% of developing countries water withdrawals. Hence, due to growing irrigation water demand to meet the increasing food security and increasing competition across water using sectors, the world faces a challenge to produce more food with less water. This goal will be realistic only if appropriate strategies towards saving water are created and followed.

FAO (1989) states that irrigated agriculture face a

*Corresponding author Email: sos.zine04@gmail.com

number of difficult problems in the future. One of the major concerns is the generally poor efficiency with which water resources have been used for irrigation. A relatively safe estimate is that 40 percent or more of the water diverted for irrigation is wasted at the farm level through either deep percolation or surface runoff. However, these losses often represent foregone opportunities for water because they delay the arrival of water at downstream diversions and because they almost universally produce poor quality water. One of the more evident problems in the future is the growth of alternative demands for water such as urban and industrial needs. These uses place a higher value on water resources and therefore tend to focus attention on wasteful practices.

Sustainability of irrigated agriculture depends primarily on efficient management of irrigation water; hence, it is imperative to raise the performance of less productive irrigation systems while sustaining the performance of more productive ones. With these the paper evaluates the existing water management practice in irrigated sugarcane production at Wondogenet Woreda, Southern Ethiopia with the help of selected indicators.

## MATERIALS AND METHODS

### Description of Study Area

Wondogenet is located in Sidama zone of the Southern Nations, Nationalities and Peoples' Region, with a latitude and longitude of 7°1′N38°35′E7.017°N 38.583°E and an elevation of 1723 meters. The Wesha small-scale irrigation scheme lies in Wendo Genet Woreda, Wesha town, Shesha Kekele. It is located at about 18 km from Shashemene, 1 km from Wesha town and 260 km from Addis Ababa.

## METODOLOGY AND DATA ANALYSIS

The climate data required for estimation of consumptive water use of the crops was taken from National Meteorology Agency, Hawassa regional station. Soil samples from a depth of 0-30, 30-60 and 60-90 were taken from selected farmers fields to study the physical property of the soil. Soil augers were used to take disturbed soil samples for texture analysis and core-samplers were used to collect undisturbed soil samples for soil moisture test. Soil infiltration characteristic was measured by double ring infiltrometer installed in the test fields. Finally, data collected were analyzed by using CROPWAT software and Descriptive statistics were used.

## RESULT AND DISCUSSION

### Measurement of soil physical properties

Physical properties of soils show that the soil textural class for sand, silt and clay of the soil are 55.9%, 25.76% and 17.66% respectively (Table1). With these soil's textural class is dominated and sand. Percent sand takes the highest proportion of the soil's textural class followed by silt and clay.

The soil bulk density for each depth was 1.26, 1.37 and 1.45 for field one, and 1.25, 1.32, and 1.53 for field two respectively. The result agreed with bulk density increase with soil depth.

The field capacity and permanent wilting point showed variation with depth (Table1). The top layer of the soil has higher value of field capacity and permanent wilting point than its immediate layer. Therefore, to manage irrigation water for sugarcane crop knowing rooting depth has a significant role.

Total available water of the test fields was calculated by using the method stated in equation 7. The calculated TAW for field one and field two was 84 and 83mm depth soil. This is the amount of moisture stored in the soil after 24hrs of irrigation (Table 2).

### The application depth of irrigation water in the area

The application depth in the two test fields was estimated after observing three irrigation events in each farm. In field one, the farmer applied 86.1mm, 73.54mm and 79.54 mm of water at $1^{st}$, $2^{nd}$, and $3^{rd}$ irrigation periods respectively. This indicates that the farmer lacks knowledge of water application depth and requires skill of irrigation scheduling.

Application depth is one of important indicators in evaluation of water management in every irrigation systems. It is dependent on the physical characteristics of the soil under irrigation. The depth of application per irrigation is the amount of water added to the root zone in one irrigation event. To determine the depth of application, the soil's moisture content after 24hrs of irrigation was tested by gravimetric method. The soil moisture content in the soil is commonly expressed as the amount of water (in mm of water depth) present in a depth of one meter of soil. In this evaluation soil moisture content to a depth of 90cm was tested. The soil moisture content at the depths of 30, 60 and 90cm was tested.

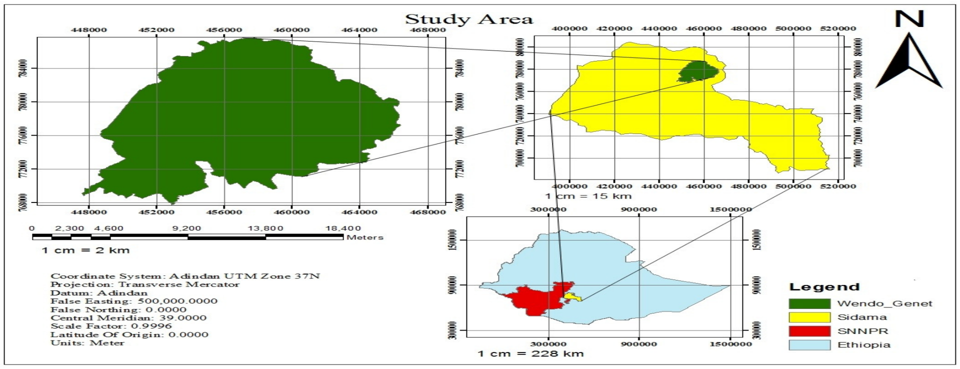


**Figure 1** Map of the study area.

**Table 1** Results of physical measurement of the soil

| | Field 1 | | | Field 2 | | |
|---|---|---|---|---|---|---|
| Soil depth (cm) | 0-30 | 30-60 | 60-90 | 0-30 | 30-60 | 60-90 |
| Percent Sand | 58.5 | 57 | 54.2 | 58 | 48.7 | 53.9 |
| Percent Silt | 29.2 | 23.4 | 24.7 | 27.66 | 38 | 30.1 |
| Percent Clay | 12.3 | 19.6 | 21.1 | 14.34 | 13.3 | 19 |
| Textural Class | Sandy Loam | Sandy Loam | Sandy Loam | Sandy Loam | Sandy Loam | Sandy Loam |
| Average Bulk Density (g/cc) | 1.26 | 1.37 | 1.45 | 1.25 | 1.32 | 1.43 |
| Field Capacity (Volume %) | 23.1 | 19.2 | 25.7 | 23.45 | 18.55 | 25.56 |
| Permanent Wilting Point (Volume %) | 14.6 | 15.7 | 16.9 | 14.85 | 15.56 | 16.34 |
| Total Available Water (TAW) | 84mm | | | 83mm | | |
| Readily Available Water (RAW) | 54mm | | | 53mm | | |

## The application efficiency of irrigation water in the area

### Canal conveyance efficiency

The main canal is 2km long from the water source and only 280m of the canal is lined with concrete. Secondary and tertiary canals are also unlined (earthen canals). The secondary canal is 1.25Km long and tertiary canal is 0.75Km long. The conveyance efficiency of the main canal was found to be 73.79%, while conveyance efficiencies of secondary and tertiary canals were 51.78% and 41.66 respectively (Table 3). The lower conveyance efficiency of secondary and tertiary canals could be due to high infiltration rate of the soil. This also shows there is high water loss in the scheme due to excessive percolation. The field channels had relatively high conveyance efficiency (89%) and this could possibly be

**Table 2** Table showing volume and depth of water applied

| Test field | Size of the field ($m^2$) | Irrigation event | Volume of water applied ($m^3$) | Depth of applied water (mm) Da | Mean depth of water stored in the RZ (Rs) mm |
|---|---|---|---|---|---|
| Field 1 | 1200 | 1st<br>2nd<br>3rd | 79.33<br>62.25<br>47.6 | 66.683<br>51.875<br>39.66 | 31.4<br>32.24<br>30.21 |
| | | Average | 63.06 | 54.74 | 31.28 |
| Field 2 | 900 | 1st<br>2nd<br>3rd | 63.16<br>46.5<br>39.9 | 70.177<br>51.66<br>44.333 | 24<br>23.25<br>32 |
| | | Average | 49.8 | 55.39 | 26.41 |

**Table 3** Evaluation of the water conveyance efficiencies of different canals

| Canal type | General soil type | Canal length category (m) | Average canal inflow (l/s) | Average canal outflow (l/s) | Conveyance efficiency (%) |
|---|---|---|---|---|---|
| Main canal | Sandy Loam | 2000 | 22.4 | 16.53 | 73.79 |
| Secondary canal | Sandy Loam | 1250 | 16.8 | 8.7 | 51.78 |
| Tertiary canal | Sandy Loam | 750 | 15 | 6.25 | 41.66 |
| Field channel | Sandy Loam | 1000 | Flo<br>22w (l/s) | C119.75anal | 89.77 |
| Average | | | | | 64.25 |

**Table 4** Depths of water applied (Da) and stored in the root zone (Ds) of each field

| Test field | Size of the field ($m^2$) | Irrigation event | Volume of water applied (mm) | Mean depth of water stored in the RZ (Rs) (mm) | Application efficiency % |
|---|---|---|---|---|---|
| Field 1 | 1200 | 1st<br>2nd<br>3rd | 79.33<br>75.25<br>72.4 | 31.4<br>38.24<br>30.21 | 39.58<br>50.81<br>41.72 |
| | | **Average** | **63.06** | **31.28** | **44.03** |
| Field 2 | 900 | 1st<br>2nd<br>3rd | 63.16<br>56.5<br>51.2 | 38<br>35.25<br>32 | 60.16<br>62.38<br>62.5 |
| | | **Average** | **56.95** | **35.08** | **61.68** |

due to short length of the furrows. The overall conveyance efficiency of the scheme was then found to be 65.1%.

## Application efficiency (Ea)

The application efficiency of the scheme was calculated by the following equation

$$Ea = \frac{Depth\ of\ water\ added\ to\ the\ root\ zone}{Depth\ of\ water\ applied\ to\ the\ field(cm)} \times 100$$

The application efficiency found in the range of 44.03% and 61.68% for field one and two respectively with average value of 50.32% (Table 4). Since the area

**Table 5** Water storage efficiency of the fields (Es)

| Test field | Mean depth of moisture stored in the root zone (mm) | Water storage efficiency (Es) % |
|---|---|---|
| Field 1 | 31.28 | 94.72 |
| Field 2 | 26.4 | 95.2 |
| Average | 28.84 | 94.96 |

**Table** Total depth of applied water and water lost as runoff

| Test field | Depth of water applied(mm%) | Depth of runoff observed(mm) | Tail water |
|---|---|---|---|
| Field 1 | 54.74 | 25.5 | 0.456 |
| Field 2 | 55.39 | 5.07 | 0.09 |
| Average runoff ration | | | 0.27 |

**Table 6** Fraction of water lost as deep percolation

| Test field | Application efficiency, Ea (%) | Tail water ratio (%) | Deep percolation fraction,DPF (%) |
|---|---|---|---|
| Field 1 | 59.5 | 0.456 | 47 |
| Field 2 | 61.21 | 0.09 | 33.4 |
| Average DPF (%) | | | 40.2 |

practiced traditional irrigation schemes there was low application efficiency, however according to the conclusion of Solomon(1998) and Keller(1992), the water application efficiency of the command area was below acceptable.

### System adequacy (storage efficiency of the fields) (Es)

The evaluation of water storage efficiency for selected test fields was done based on the mean value of three irrigation events observed. The result show that the average water storage efficiency for the scheme is 94.96%(Table 5). According Ley and Clyma (1981), the potential achievable value of water storage efficiency for furrow irrigation is 85-100%. Therefore, it is possible to say that the water applied would successfully met the root zone moisture content at field capacity.

### The distribution uniformity of irrigation water in the area

Distribution uniformity is the most commonly used uniformity index in surface irrigation application. The soil moisture stored at the effective root zone of the crops tested for field one and two were 91.25% and 86.16% which is below 100% and show entire field receives non-uniform depth of water. However, the values of DU found in this study fall within the acceptable limits, which is set by FAO to be 80% (FAO, 1989). The DUs are better than the value of 70 % that was found by Pitts *et al.* (1996) in the irrigations systems of Western United States.

### Irrigation water losses of the area

#### Tail water ratio

The amount of runoff coming out from the fields after irrigation was measured by bucket of known volume installed in at the end of each furrow. The observation results show that, less amount of water lost from field 2 than field 1. But relatively large amount of water was observed to be lost from field 1 and this could possibly be due to the large amount of water being applied to the farm.

During the three events of irrigation, field one received average of 251mm water while field two received only 96mm. The depth of water applied to the fields varied because of the slope of the field.

### Deep percolation fraction (DPF)

The runoff collected from the fields and application efficiencies of each field were used to calculate the deep percolation fraction of the fields. As it can be seen from the table above the water lost through deep percolation from field 1 is greater than that of field 2.

As a matter of fact that field 1 is located near the source of irrigation water, it receives high amount of water per irrigation event with short frequency. However, farmers at downstream part of the scheme tend to use the available water to more effectively than those in upstream as the amount of water reaching the command area is decreased due to percolation loss.

### Crop Water Requirement

The amount of water needed by the sugarcane crop was calculated using CROPWAT computer model. The average ETo of the area was found to be 4mm/day. The Kc values for sugarcane were standard for each growing season. Therefore,

ETc = ETo x Kc (Allen et al. 1998):

This study was undertaken in a field planted with ratoon sugarcane and the total ETo during the growing period of 420 days was 1430 mm and total estimated water requirement was1453mm. the result show that sugarcane have different water requirement at different growth stage.

### Water management practices of the farmers and related problems

During this field evaluation, the interval of irrigation by which the farmers were irrigating was not fit with actual irrigation scheduling which lead the farmers to loss water. Therefore,

Scheduling of irrigation has to be based on the readily available moisture (RAM) content of the soil.

## CONCLUSION AND RECOMENDATION

This study was initiated to evaluate the trend of irrigation water management in Wesha Soyema irrigation scheme and to identify the gaps. The major problem in this scheme is poor management of irrigation water. Therefore, the amount of water applied during the crop's growing period was more than the crop's requirement, which indicates that much amount of water is being wasted due to poor irrigation water management practice. With this great effort should be made to minimize water loss from canals.

## REFERENCES

Abiti Getaneh (2011). Water Resources Potential and Development of Ethiopia. Ministry of Water and energy, Ethiopia.

Allen RG, Pereira LS, Raes D and Smith M (1998). *Crop Evapotranspiration:- Guidelines for Computing Crop Water Requirements. Irrigation and Drainage Paper, 56.* FAO, Rome.

Asfaw Dingamo (2008). Ethiopian groundwater resource management. The international Geological Congress. 33rd IGC conference, Oslo.

Awulachew S, Yilma A, Loulseged M, Loiskandl W, Ayana M, Alamirew T (2007). Water Resources and Irrigation Development in Ethiopia. International Water Management Institute (IWMI Working Paper 123), Colombo, Sri Lanka.

Cai X, McKinney DC and Rosegrant MW (2003). Sustainability analysis for irrigation water management in the Aral Sea region. Agric. Syst. 76:1043-1066.

Chancellor FM and Hide JM (1997). Smallholder Irrigation: Ways Forward. Guidelines for achieving appropriate scheme design. Volume 1: Guidelines. FID. TDR Project R5830. Report OD 136. HR Wallingford

Chancellor FM, Hide JM (1997). Small Holder Irrigation: Ways Forward. Guidelines for Achieving Appropriate Scheme Design. Volume1 and II Guidelines.HR Willingford, UK.

Edkins R (2006). Irrigation efficiency gaps - review and stock take. Report No L05264/2, Aqualinc Research Ltd, New Zealand.

Eduardo A. Holzapfel, Alejandro Pannunzio, Ignacio Lorite, Aureo S. Silva de Oliveira,

English MJ, Solomon KH, Hoffman GJ (2002). A paradigm shift in irrigation management. J. Irrig. Drain. Eng. 128:267-277.

FAO (2003). Irrigation Water Management: Introduction to irrigation. FAO Corporate Document Repository. Natural Resources Management and Environment Department.

FAO (Food and Agriculture Organization) (1989). Guidelines for Designing and Evaluating Surface Irrigation System*:* Irrigation and Drainage Paper.No.45. FAO, Rome.

FAO (Food and Agriculture Organization) (1992). *Cropwat: A Computer Program for Irrigation Planning and Management:* Irrigation and Drainage Paper. No. 45. FAO, Rome.

Fitsum H, Godswill M, Regassa E and Awulachew S (2009). Importance of irrigated agriculture to the Ethiopian economy: Capturing the direct net benefits of irrigation. International Water Management Institute (IWMIResearch Report 128), Colombo, Sri Lanka.

Heermann DF and Kohl RA (1980). Fluid Dynamics of Sprinkler Systems. In: Design and Operation of Farm Irrigation Systems, ME Jensen (ed), ASAE, St. Joseph, MI, pp 583-618.

IWMI (2007). "Water Management Urgent Need for More Food with Less Water", Spearheaded by International Water Management Institute (IWMI), Science Daily (Press Release)-USA, March 27, 2007.

James LG (1988). *Principles of Farm Irrigation System Design*. John Wiley & Sons, Inc. New York. 543p

James LG (1988). Principles of Farm Irrigation System Design. John Wiley and Sons, New York

Jorma R (1999). Financing Irrigation Development and Private Sector Initiative with Special Reference to Sub-Saharan Africa*:* FAO E-mailconference 15 March to 23 April. Rome

Jureims M, Dawit Zerihun, Boonasta J and Feyen J(2001). SURDEV: surface irrigation software. ILRI publications 59. Waggenningen, The Netherlands.

Jurriens M, Zerihun D, Boonstra J and Feyen J (2001). *SURDEV: Surface Irrigation Software.* Publication 59, ILRI, Wageningen.

Kassa Tadele (2003). Evaluation of the performance of furrow irrigation system in the Middle Awash Valley. pp. 17-27. In: Ethiopian Journal of Water Science and Technology. Water Vol. 7 No. 1, September 2003. Arbaminch, Ethiopia.

Keller J (1976). Irrigation Scheduling and Efficiency. Proceedings, Rain Bird Seminars Relating to Irrigation Decision Making, Rain Bird, Glendora, CA, pp 85-95.

Kenneth HS (1988). Irrigation System and Water Application Efficiencies. Fresno, California.

Kumar R and Singh J (2003). Regional water management modelling for decision support in irrigated agriculture. J. Irrig. Drain. Eng. 129:432-439.

Kunde RJ (1985). Life Cycle Costs Resulting from Various Designs Emission Uniformities. Proceedings, 3rd International Drip/Trickle Irrigation Congress, November 18-21, Fresno, CA, Volume II, pp 859-866.

Lameck O. Odhiambo, William L. Kranz and Dean E. Eisenhauer (2009). Irrigation efficiency and Uniformity, and crop water use efficiency. University of Nebraska. EC732. Pg8.

Lesley W (2002). *Irrigation Efficiency.* Irrigation Efficiency Enhancement Report No 4452/16a, March 2002 Prepared for LandWISE Hawke's Bay. Lincoln Environment. USA.

Lincoln Zotarelli, Michael D. Dukes and Kelly TM (2010). Interpretation of Soil Moisture Content to Determine Soil Field Capacity and Avoid Over-Irrigating Sandy Soils Using Soil Moisture Sensors. Publication #AE460

Maidment DR (Ed.) (1992), "Handbook of Hydrology", McGraw Hill, New York.

McCornick PG, Kamara AB and Girma Tadesse (2003). Integrated water and land management research and capacity building priorities for Ethiopia. Proceedings of a MoWR/EARO/IWMI/ILRI international workshop held at ILRI, Addis Ababa, Ethiopia, 2–4 December 2002. IWMI (International Water Management Institute), Colombo, SriLanka, and ILRI (International Livestock Research Institute), Nairobi,Kenya. 267 pp.

Michael AM (1997). *Irrigation Theory and Practice. Evaluating Land for Irrigation Commands.* Reprinted Edition, Vikas Publishing House Pvt Ltd, New Delhi, India.

Mishra RD, Ahmed M (1990). *Manual on Irrigation Agronomy.* Oxford and IBH Publishing Co. PVT. LTd. New Delhi, Bombay, Calcutta.

MoWR (2002). Water Sector Development Programme (2002–2016). Irrigation Development Program, Main report. MoWR, Addis Ababa.MoWR, 2006. Five Year Irrigation Development Programmme (2005/06– 2009/10). MoWR, Addis Ababa.

Pitts D, Peterson K, Gilbert G and Fastenau R (1996). Field assessment of irrigation system performance. 12(3):307-313. American Society of Agricultural Engineers, U.S.A.

Playán E and Mateos L (2006). Modernization and optimization of irrigation systems to increase water productivity. Agric. Water Manage. 80:100-116.

Rockstrom JB and Patrick F (2003). Water Productivity in Rain-fed Agriculture: Challenges and Opportunities for Smallholder Farmers in Drought- Prone Tropical Agro-ecosystems. CAB International.

Roger DH, Lamm FR, Mahbub A, Trooien TP, Clark GA, Barnes PL and Kyle M (1997). *Efficiencies and Water Losses of Irrigation System.* Irrigation Management Series. Kansas.

Rogers DH, Lamm FR, Alam M, Trooien TP, Clark GA, Barnes PL and K. Mankin (1997). Efficiencies and water losses of irrigation systems. Irrigation Management Series. Kansas State University, Manhattan.

Seleshi Bekele Awulachew (2010). Irrigation potential in Ethiopia. Constraints and opportunities for enhancing the system.

Seleshi Bekele Awulachew, Aster Denekew Yilma, Mekonnen Loulseged, Willibald Loiskandl, Mekonnen Ayana, Tenna Alamirew (2007). Water Resources and Irrigation Development in Ethiopia (working Paper 12).

Smith M, Munoz G (2002). *Irrigation Advisory Services for Effective Water Use: A Review of Experience.* Irrigation Advisory Services and Participatory Extension in Irrigation Management Workshop Organized by FAO-ICID. Montreal, Canada.

Solomon KH (1983). Irrigation Uniformity and Yield Theory. PhD dissertation, Department of Agricultural and Irrigation Engineering, Utah State University, Logan UT, 287 p.

Solomon KH (1987). Sprinkler Irrigation Uniformity. Extension Bulletin No. 247, Food & Fertilizer Technology Center, Tapei City, Taiwan, Republic of China.

Solomon KH (1988). Irrigation Systems and Water Application Efficiencies. WATERIGHT. Center for Irrigation Technology. California State University, Fresno, California.

Walker WR (2003). SIRMOD III: Surface irrigation simulation, evaluation and design. Guide and Technical Documentation. Utah State University, USA.

Wallace JS and Batchelor CH (1997). "Managing Water Resources for Crop Production", The Royal Society Journal B, V. 352, pp. 937-947, UK.

Wynn R. Walker (2007). Surface Irrigation Simulation, Evaluation and Design. Guide and Technical Documentation

Zerihun D and Feyen J (1996). Surface Irrigation System. Institute for Land and Water Management, Katholike Universities Leuven, Belgium.