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Full Length Research Paper

Effect of management practices on water use efficiency of Gezira irrigated scheme – Sudan

Adam Bush Adam*[1], Ali Widaa Mohamed Elamin[2] and A.M.N. Hamid[3]

[1]Department of Agricultural Engineering, Faculty of Natural Resources and Environmental Studies, University of Peace, Sudan
[2]Department of Agricultural Engineering, Faculty of Agriculture, University of Khartoum, Sudan
[3]Department of Agricultural Engineering, Faculty of Agricultural Technology and Fish Science, University of Al-Neelain, Sudan
*Corresponding Author's E-mail: adambush99@gmail.com

Abstract

This study was conducted at Gezira scheme - Sudan during the period from 2009 to 2010 in a heavy clay soil to investigate the effect of management practices on water use efficiency for the different crops irrigated in Gezira scheme. The data was collected from the scheme Administration. The study was organized by using T-Test. Cropwat4 Windows was used to calculate crop water requirements (CWR) and the net irrigation requirements (NIR). The results showed that, Water use efficiency significantly ($P \leq 0.05$) affected by the different management practices. Sorghum gave the highest mean value (0.48) of economic water use efficiency as compared to cotton which ranked the least (0.19). Technical water use efficiency for Sorghum and groundnut recorded the highest means values (0.34 and 0.30 kg/m^3) while cotton gave the lowest (0.07 kg/m^3). Wheat gave the highest mean values (0.87) of Hydraulic water use efficiency as compared to sorghum which ranked the least (0.59). It can be concluded that, proper technical guidelines for irrigation network management, operation and scheduling should be developed and followed.

Keywords: Management; Water use efficiency; Gezira scheme

INTRODUCTION

In many arid and semi arid areas water is becoming an increasingly scarce resource and planners are forced to consider any source of water, which might be used economically and effectively to promote further agricultural development.

At the same time, with population expanding at a high rate, the need for increased food production is apparent (Pescod, 1992). A great challenge for the agricultural sector is to produce more food under water scarcity conditions particularly in arid and semi arid regions (Ali *et al.,* 2009). Good water management is to ensure that the crop is supplied with adequate water throughout the season to achieve highly yield (tons per hectar) with less cost, high quality, conserve water supplies, reduce water-quality impacts and improve producer net returns (FAO, 1999).

The agricultural sector in the Sudan contributes to about 48% of the Gross Domestic Production (GDP) and to about 93% of the foreign currency earnings. It also employs about 65% of the labor force. Water supply is becoming a major constrain to irrigate agriculture in Sudan. The surface irrigation is predominantly used in country with low irrigation efficiency. An estimate made by FAO (1999) mentioned that distribution losses constitute 15%, field application losses 25%, other losses 15% and the water effectively used by crops constitutes only about 45% of the total irrigation water. Gezira scheme consumes about one third of Sudan share in the Nile water (6-7 billion m^3 per year), which used 80% of the water stored in Sennar and Roseries Dams on the Blue Nile during December to end of March. So any saving of irrigation water in the scheme will be quite significant for the other users. A 10% increase in the water use efficiency in the Gezira scheme amount to about 200 million m^3 which is equal to the water requirement of the whole Guneid factory for 5 months (December to May) (Abdel Hadi *et al.,* 2003). (Eldaw, 2004) reported that, until 1995, the management of the irrigation network and irrigation practices in the Gezira, Rahad and New Halfa Schemes were a joint responsibility between the Ministry of Irrigation and Water Resources and the administrations of these schemes.

The Ministry of Irrigation was in charge of the maintenance of the irrigation network, with budgets allotted by the government. Gezira Board was responsible for water management in the minor canals up to the field level, with a budget borne by the joint account system. A problem of cost recovery for irrigation water was the main factor affected Gezira scheme production (Eldaw, 2004). Poor management has been cited as the most frequent cause of inefficient water use in irrigation schemes (Jensen *et al.* 1990). Ahmed (2000) stated that, mismanagement of the irrigation network and water losses from the irrigation system, inadequate supply of irrigation water were the main factors faced Gezira scheme.

Improving water use efficiency (WUE) in agriculture will require an increase in crop water productivity (an increase in marketable crop yield per unit of water removed by plant) and a reduction in water losses from the plant rooting zone, a critical zone where adequate storage of moisture and nutrients are required for optimizing crop production. Improving water use efficiency by 40% on rainfed and irrigated lands could reduce the need for additional withdrawals for irrigation to zero over the next 25 years.

However, this is a big challenge for many countries (Ronald and Marlow, 1999). Fang *et al.* (2009) revealed that scheduling irrigation based on crop responses to stress at different growth stages can improve water use efficiency. Ibragimov *et al.* (2007) stated that, more deficit irrigation rate provided both high yields and optimum water use efficiency. Kang, *et al.* (2002) revealed that, controlled ranges of soil water content during growing seasons can improve the grain yield and water use efficiency. On the other hand Hassanli *et al.* (2009) mentioned that, innovations are needed to increase irrigation water use efficiency and to provide water savings.

Low crop productivity is one of the major problems that are facing agricultural production in Sudan. Low crop productivity in addition to high production costs, low prices and high taxes had all resulted in a general deterioration of the agricultural sector. This has contributed in converting agriculture from an attractive business to a repellent activity and caused many farmers to abandon agriculture and migrate to cities. Low water use efficiency is normally associated with poor timing and a lack of uniformity in water applications, which leaving parts of the field over- or under-irrigated relative to crop needs (Shajari *et al.*, 2008).

Also it is influenced by weather conditions which affected plant growth and development and ultimately yield (Garcia *et al.,* 2009).On the other hand, water use efficiency is greatly affected by management (soil, crop and water), local weather conditions of the irrigated schemes, available soil water and soil texture (Katerji and Mastrorilli, 2009), lower water applied, distance of water resource from farm, water logging, timeliness of planting date, planting depth, quality of tillage practices, new seed varieties, applied fertilizers, education, age and experience of farmers, extension services and location of the farm (Shajari *et al.*, 2008) and non uniformity of water distribution over the whole scheme (Widaa *et al.,* 2011 and Adam, 2014). Therefore the objective of this study was to investigate the effect of management practices on water use efficiency of the main crops irrigated in Gezira scheme - Sudan.

METHODOLOGY

Study area

This study was conducted at Gezira scheme - Sudan during the period from 2009 to 2010 in a heavy clay soil. It is characterized by a semi-arid climate. Annual mean air temperature is 28.0 ^oC, and monthly means solar radiation ranges between approximately 20 and 26 MJm^{-2}, with the minimum occurring in July and December. Total precipitation is 280 mm (20 year average), almost all of which falls between July and October. Dry spells occur during the rainy season, resulting in delaying crop growth. All cultural practices were executed according to the recommendations from the administration of Gezira scheme.

Data collection and test

The data was collected from the scheme Administration. The study was organized by using T-Test. Cropwat4 Windows was used to calculate crop water requirements (CWR) and the net irrigation requirements (NIR).

Crop water requirements (CWR)

Crop water requirement was calculated using the following equation.
ETc = ETo × Kc ……… (1)
Where:
ETo = reference evapotranspiration mm/day
Kc = crop coefficient

Reference crop evapotranspiration (ETo)

Reference crop evapotranspiration (ETo) can be calculated by Penman-Monteith equation as stated by Smith *et al*., (1998).
ETo =

$$\frac{0.408\Delta(Rn-G)+\gamma\left(\frac{900}{T}+273\right)U_2(es-ea)}{\Delta+\gamma(1+0.34U_2)} \text{…………(2)}$$

Where:

ETo = Reference crop evapotranspiration (mm day^{-1})
R_n = Net radiation at crop surface (Mjm^{-2}day^{-1})
T = Average temperature at 2m height (^{o}c).
e_s = Svp, kPa e_a = Actual vp (kPa)
(e_s –e_a) = Saturation pressure deficit for measurement at 2m height (kPa).
U_2 = Wind speed at 2m hight (ms^{-1}).
Δ = Slope of vapor pressure curve (k Pa ^{o}c).
γ = Psychometric constant (k Pa ^{o}c)
900 = Coefficient for reference crop (Kj Kg day^{-1})
0.34 = Wind coefficient for the reference crop (S m^{-1})
G = Soil heat flux (Mj m^{-2} day^{-1})
Soil heat flux (G) may be ignored if the period is less than 10 days which can be calculated according to the following equation:

G_{month} =0.14(T_{month} –$T_{month-1}$) ………… (3)
Where:
T_{month} =Average temperature for the mentioned month (^{o}C)
$T_{month-1}$ = Average temperature for the month before (^{o}C)
e_a = e_s × relative humidity as a fraction (Esmail, 2002)………. (4)

Wind speed formula

The following formula is used to adjust the wind speed data from 20m to the standard height of 2m as stated by Smith *et al*. (1998).

$$U_2 = U_z * \frac{4.85}{Ln\left(\frac{Zm-0.8}{0.15}\right)} \text{………………. (5)}$$

Where:
U_z = mean wind speed measured at height (z) (m/sec).
U_2 =mean wind speed measured at height 2m (m/sec).
Zm = height at which wind speed is measured (m). When there is no enough data to calculate U_2, it is possible to use the International Average Wind Speed (1 +3)/2 =2m/sec.

Crop coefficient (KC)

Crop coefficient is mainly controlled by the crop characteristics namely the resistance to transpiration of different plants. To maintain good growth and high yields of good quality a regular water supply is needed throughout the year with a possible exception just prior and during harvest and at winter time. The crop coefficient was determined by the following equation.
KC = (KCb . KS) + Ke …………………… (6)

Where:
KC = the basal crop coefficient when the water is not a limiting factor for plant growth.
KCb = set equal to 0.8 (Doorenbos and Pruitt, 1977).
KS = soil water availability factor (0 - 1).
Ke = soil water evaporation coefficient (equal to 0.1 from experimental data measuring soil evaporation under the canopy at different locations).

The net crop water requirements (NCWR)

The net Crop water requirement was calculated by subtracting the daily effective rainfall (ERF) as:
NCWR = CWR- ERF …………………… (7)

Measurement of rainfall

Daily rainfall was measured using the standard ordinary rain gauge exposed 1 m above ground level away from buildings and trees. The diameter of the standard gauge is 5 inches (12.7 cm). There was a measuring Jar calibrated to read the rainfall in mm this Jar should only be used with 5in diameter rain gage.

A recording rain gauge was used to give a continuous record of rainfall, this type of rain gauges is very important because it gives the intensity of rainfall (Adam, 2014).

Effective rainfall

Effective rainfall is defined as the fraction of rainfall that is effectively intercepted by the vegetation or stored in root zone and used by the plant-soil system for evapotranspiration. It can be estimated by the following equation mentioned by Adam (2014).

Pef = E. Ptot + A …………………. (8)
Where:
Pef = Effective rainfall over the growing season.
E = Ratio of consumptive use of water (cubic) to Ptot.65.
Ptot = Total rainfall over the growing season.
A = Average irrigation application.

Indicators Plants

Indicators plants were included cotton, sorghum, wheat and groundnut grown in different sowing date.

Parameters for crops productivity evaluation

The following parameters were used to evaluate crops productivity:

Economic water use efficiency (EWUE)

Economic water use efficiency refers to the economic benefits and costs of water use in agricultural production (Edet *et al.,* 2007).
EWUE = Net return/ Total cost …………… (9)
Net return was calculated by subtracting the total cost from the total return.

Technical water use efficiency (TWUE)

Technical water use efficiency (kg/m^3) was determined by dividing seed yield (kg/ha) into the consumptive use (m^3/ha) (Ouda *et al.*, 2007).
TWUE = Seed yield (kg/ha) / Consumptive use (m^3/ha) ………….. (10)

Hydraulic water use efficiency (HWUE)

Hydraulic water use efficiency was computed by dividing the net crop water requirement (NCWR) to the total water applied (TWA) (Burt *et al.,* 1997).
HWUE = NCWR/ TWA ………….. (11)

Data analysis

A computer program (SAS statistical package) was used to analyze the data. The variations among means were checked by the least significant difference (LSD).

RESULTS AND DISCUSSION

Effect of management practices on economic, technical and hydraulic water use efficiency for sorghum, groundnut wheat and cotton

As shown in table 1 and figure 1, there is a variation in water use efficiency for the different crops. Water use efficiency significantly ($P \leq 0.05$) affected by the different management practices. Sorghum gave the highest mean value of economic water use efficiency as compared to cotton which ranked the least.

These results may be attributed to the fact that, economic water use efficiency is normally affected by mismanagement of the irrigation network, water losses, and inadequate supply of irrigation water, poor timing and non uniformity of water applications as mentioned by (Shajari *et al.,* 2008). The results were in agreement with the result obtained by (Kang, *et al.,* 2002) who reported that available water is the most important factor limiting crop yields and water use efficiency.

Technical water use efficiency significantly ($P \leq 0.05$) affected by the different cultural practices. Sorghum and groundnut recorded the highest means values while cotton gave the lowest. It is very important to mention that, technical water use efficiency is affected greatly by using lower number of irrigation than recommended, distance of water resource from farm, water logging, timeliness of planting date, planting depth, quality of tillage practices, new seed varieties, applied fertilizers, education, age and experience of farmers, extension services and location of the farm.

The result agreed with the result obtained by Hassanli *et al.* (2009) who mentioned that, innovations are needed to increase irrigation water use efficiency and to provide water savings.

Hydraulic water use efficiency for the different crops significantly different and affected by the management practices. Wheat gave the highest mean values of Hydraulic water use efficiency as compared to sorghum which ranked the least.

This may be attributed to the fact that hydraulic water use efficiency was affected by mismanagement of the irrigation network, weather conditions, available moisture content and soil texture (Katerji and Mastrorilli, 2009; Adam 2014).

Table 1: Effect of management practices on water use efficiency for sorghum, groundnut wheat and cotton

Crop	Water use efficiency		
	Economic	Technical	Hydraulic
Sorghum	0.48[a]	0.34 [a]	0.59 [c]
Wheat	0.34 [b]	0.12 [b]	0.87 [a]
Groundnut	0.24 [c]	0.30 [a]	0.73 [b]
Cotton	0.19 [c]	0.07 [b]	0.82 [a]
LSD	0.06	0.11	0.07

Means followed by the same letter (s) in the same column are not significantly difference at 0.05 level of probability.

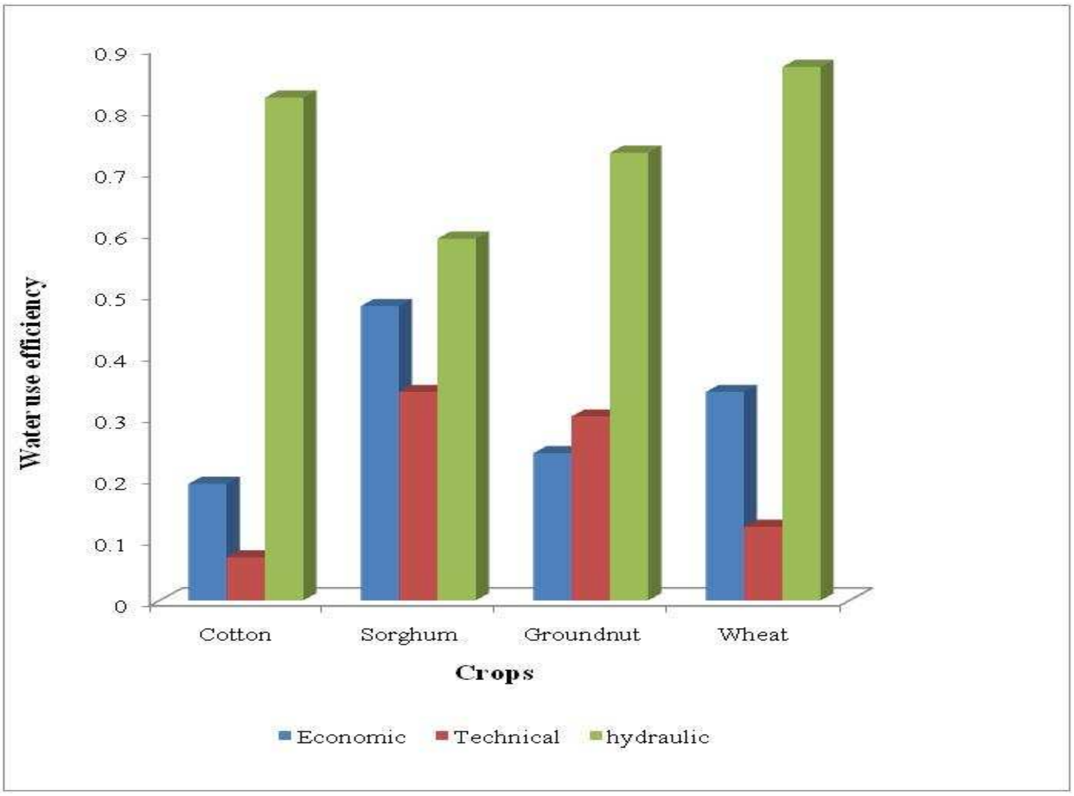

Figure 1: Water use efficiency for the main crops irrigated in Gezira scheme

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