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Enhancing Water Productivity of Alfalfa (*Medicago Sativa*) Under Centre Pivot Irrigation System

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Abstract: *The objective of this study was to evaluate water productivity of alfalfa (Medicago sativa) under centre pivot irrigation system. The experimental works were conducted at three centre pivot irrigation projects (Indian, Arab Authority for Agricultural Investment and Development (AAAID) and Sedonix projects) located at Khartoum State during the period from April 2011 to April 2013. In each project, three irrigation systems were randomly selected for the study treatments. Crop water requirement was obtained using CROPWAT 8 computer model. The parameters tested were Christiansen coefficient of uniformity (Cu%), distribution uniformity (Du%), Scheduling uniformity (Su) and Water productivity (kg/m^3). SAS (statistical package) was used to analyze the data. The variations among means were checked by the least significant difference (LSD). The results showed that Cu%, Du%, Su and water productivity significantly affected by the management practices in different irrigated projects. Sedonix project gave the highest values of hydraulic characteristic (Cu 85%, Du 81% and Su 1.23) while AAAID project recorded the lowest values (Cu 74%, Du 70%, Su 1.43). Water productivity significantly increased in Sedonix project (0.45 kg/m^3/cut) followed by Indian projects (0.38 kg/m^3/cut) and AAAID which ranked the least (0.27 kg/m^3/cut). It is concluded that for improvement water productivity; proper technical guidelines for system management, operation and scheduling should be followed.*

Keywords: Water Productivity; Alfalfa; Center Pivot Irrigation System

1. INTRODUCTION

The optimum use of irrigation water is a fundamental aspect to reach a sustainable agriculture (Ortega, 2002). Due to the absence of proper water management; there is an urgent need for optimum use of water for agriculture and an extra emphasis should be directed towards water management to prevent water pollution or deterioration of water quality. Irrigation water management is a polices to conserve water supplies, reduce impact on water quality and improve net economic returns of crops by applying less water than crop required (deficit irrigation), shifting to alternative crops or high yield varieties of the same crop that use less water, or adopting more efficient irrigation technologies (Patil et al., 2015). Playan and Mateos (2006) mentioned that, modernized irrigation systems at farm level implies selecting the appropriate irrigation system and strategy according to the water availability, the characteristics of climate, soil and crop, the economic and social circumstances, and the constraints of the distribution system. Irrigation modernization is accepted as a strategic option to increase water productivity particularly in arid and semi-arid regions. This can be achieved by introducing modern irrigation system namely overhead (sprinkler) and drip irrigation systems as mentioned by Ismail and Al-Marshadi (2013). Centre pivot irrigation system has capable to improve climate change, optimize water use, decrease operation costs of irrigation by reducing the power used and enhancing agricultural production. In Sudan the total area under irrigation which is almost entirely under conventional surface methods is estimated to be about two million hectares while the area under centre pivot irrigation systems is estimated to be about 15000 hectares mainly in the Northern, River Nile and Khartoum States (El-Hassan, 2008). The superiority of centre pivot system over conventional system is attributed to the fact that, centre pivot irrigation system should be uniformly applied water at the right time to maximize forage or pasture yield and quality as stated by Shideed *et al*. (2005). Taking into consideration that there is a little information regarding the operation, management and the economic efficiency of the centre pivot systems in Sudan and the limited scope under which these systems are used. Most of the centre pivot irrigation systems in Khartoum State are used for production of alfalfa (*Medicago sativa*) for export. The systems are expensive and require electrical energy to operate. The systems are normally operated all the year around and stopped only when there is rainfall or breakdown. 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 are represent the major problems facing agricultural production (Bush *et. al.*, 2017) . 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 (Ministry of Finance and National Economy, 1996). Therefore, the objective of this study was adopted to improve water productivity (kg/m^3) for alfalfa (*Medicago sativa*) under centre pivot irrigation system.

2. METHODOLOGY

The experimental works were conducted at three centre pivot irrigation projects (Indian, Arab Authority for Agricultural Investment and Development (AAAID) and Sedonix projects) located at Khartoum State during the period from April 2011 to April 2013. In each project, three irrigation systems were randomly selected for the study treatments. A crop grown was alfalfa (*Medicago sativa*). Wind speed and direction, humidity, temperature were recorded at nearby meteorological station.

a. Crop water requirements:

Irrigation water amounts were calculated according to crop water requirement (ETc). It is generally related to reference evapotranspiration (ETo) which is calculated from meteorological data using Penman Monteith equation as stated by Smith *et al.* (1998).

$$ET_o = \frac{0.408\Delta(Rn - G) + \gamma\left(\frac{900}{T} + 273\right)U_2(es - ea)}{\Delta + \gamma(1 + 0.34U_2)} \quad \ldots\ldots(1)$$

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 height (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 (sm^{-1})

G = Soil heat flux (Mj m^{-2} day^{-1})

Irrigation water amounts were measured using a V-notch 90^o weir. The discharge over the weir was calculated using the following equation as stated by Michael (1978).

$Q = 0.0138\ H^{5/2}$ **…………………………………………**.(2)

Where:

Q = discharge over the weir in l/s.

H = the head over the weir in cm.

b. 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).

c. 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 ………………………………………………………. (3)

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.

d. Infiltration rate (mm/h):

Double ring cylinder infiltrometers were used to calculate infiltration rates. The diameter of the inner cylinder from which the infiltration measurements were taken was 28cm and the outer cylinder was 60cm. the height of both cylinders was 25cm.The cylinders were installed at 10cm depth in the soil. Care was taken to keep the installation depth of the cylinders the same in all the experiments. A graduated measuring cylinder (one liter) was used for measuring the water added at each time. Water was poured gently into the inner cylinder during the first filling through a polythene sheet to minimize disturbing the soil. After pouring the water, the sheet was then removed gently. The space between outer and inner cylinders was filled immediately with water so as to act as a buffer area. A stop-watch was used to note the time taken for each applied liter of water to disappear in the soil as mentioned by Michael (1978).

e. System performance

The application efficiency, uniformity coefficient and pattern efficiency were calculated using spray catch cans as described by Michael (1978). Eighty cans were placed at equal distances along the pivot point outwards. The centre pivot was allowed to pass over the cans for three runs, at each run measurements were recorded. Volumetric measurements were converted into depth in millimeters.

1. The application efficiency (Ea%)

The application efficiency was calculated by dividing the average depth of water caught in the catch cans by the average depth of application as monitored by the system flow meter as follows:

$$Ea\% = \frac{Dc}{Ds} \times 100 \qquad \text{………………… (4)}$$

Where:

Ea = Application efficiency (%).
Dc = Average depth of water in catch cans (mm).
Ds = Average depth of application as recorded by the system flow meter (mm).

2. The uniformity coefficient (Cu%)

A measurable index of the degree of uniformity obtainable for any sprinkler system under a given condition has been developed and is known as uniformity coefficient (Cu). One of the first criteria defined to express uniformity was the coefficient of uniformity (Cu) as defined by Christiansen (1942). Christiansen's coefficient of uniformity (Cu) is the most widely used and accepted criterion used to define uniformity. The coefficient is computed from field observations of the depths of water caught in open cans placed at regular distances within a sprinkled area (assuming that the catch cans represent the same area) as follows:

$$Cu = \left(1 - \frac{\sum x}{mn}\right) 100 \qquad \text{………….. (5)}$$

Where:

Cu = Christiansen's coefficient of uniformity.
m = Average value of all observations (average application depth) (mm).
n = total number of observation points.
x = numerical deviation of individual observation from the average application depth (mm).

3. Distribution uniformity (Du%)

The distribution uniformity was determined using the following equation as stated by Zoldoske and Solomon (1988) who mentioned that:

$$Du\% = 100 \left[\frac{qn}{qave}\right] \qquad \text{……………………… (6)}$$

Where:

Du%= distribution uniformity.
qn= average rate of discharge of the lowest one fourth of the field data of nozzle discharge (l/h).
qave= average discharge rate of all the nozzle checked in the field(l/h).

4. Scheduling uniformity (Su)

The scheduling uniformity is calculated according to the following equation mentioned by Michael (1978):

$$Su = \frac{1}{Du} \qquad \text{………………….. (7)}$$

Where:
Su = Scheduling uniformity.
Du = Distribution uniformity (as decimal).

3. RESULTS AND DISCUSSION

a. Infiltration rate (mm/h) and accumulative infiltration (mm)

Infiltration rate (mm/h) and accumulative infiltration values (mm) for three projects (Indian, AAIAD and Sedonix) were presented in Fig, 1, 2 and 3 which show the best fitted curves for the mean values. The infiltration rate values were 205, 190 and 210 mm/h, respectively during the first five minutes and it is considered very high while at the end decreased to reach 58, 42 and 65 mm/h, respectively. The high initial infiltration rate was due to the soil type (sandy clay loam – sandy clay) as mentioned by Michael (1978).

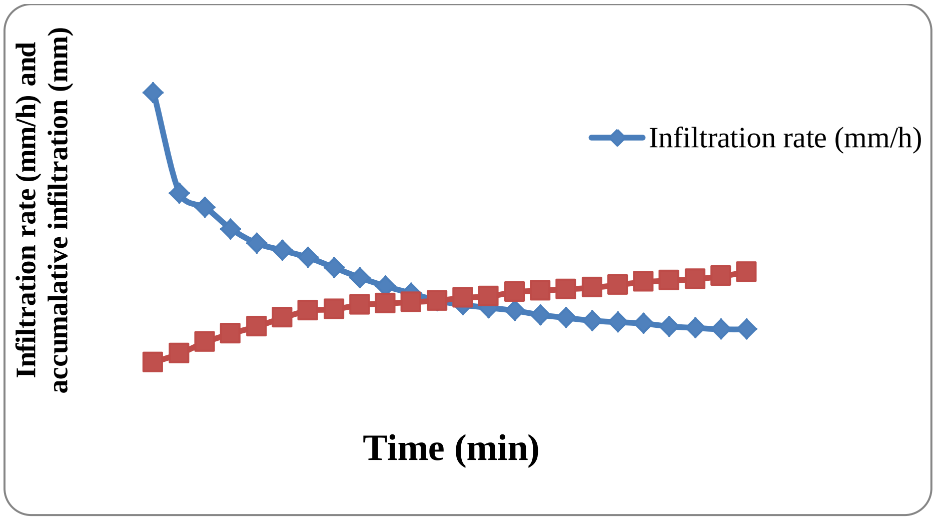

Fig. 1 Infiltration rate (mm/h) and accumulative infiltration (mm) (Indian Project)

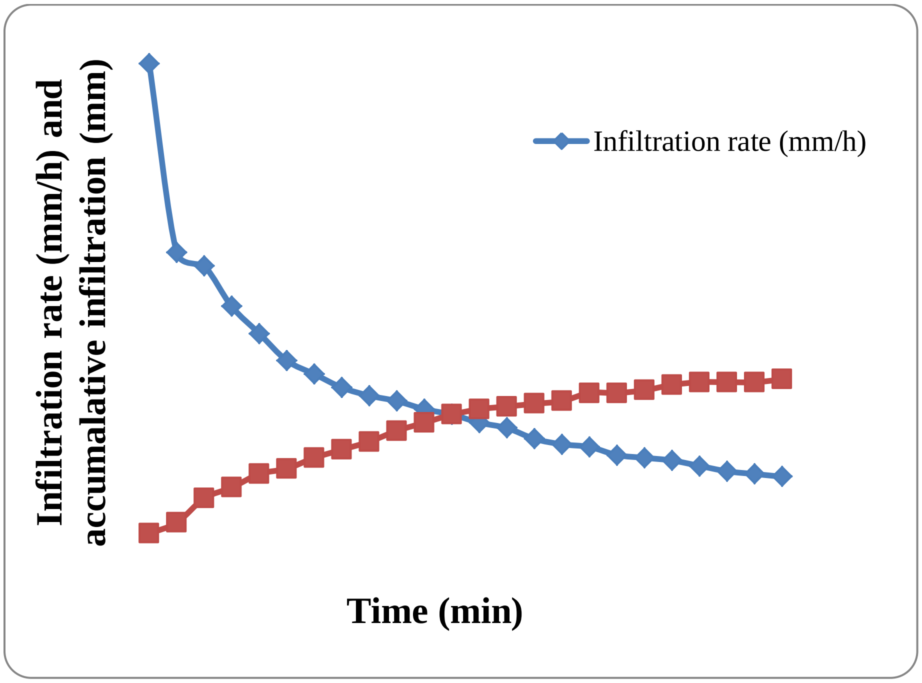

Fig. 2 Infiltration rate (mm/h) and accumulative infiltration (mm) (AAIAD Project)

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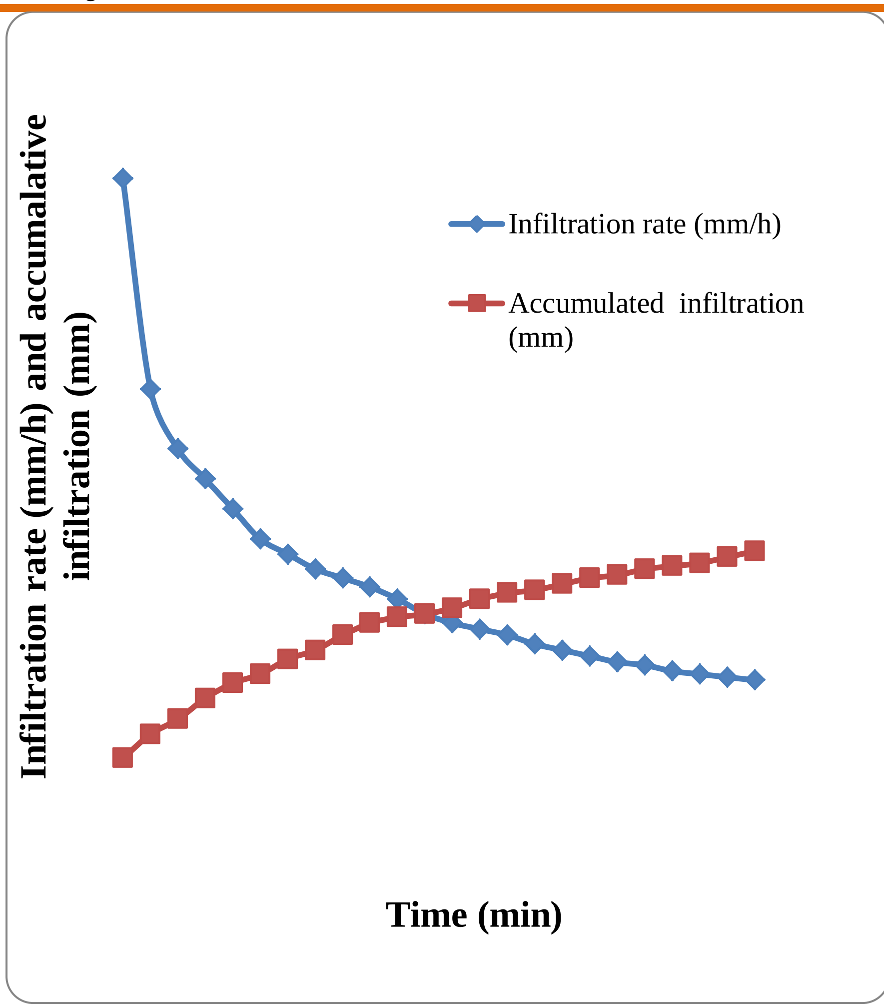

Fig. 3 Infiltration rate (mm/h) and accumulative infiltration (mm) (Sedonix Project)

b. Hydraulic performance

As shown in Table 1 and Fig. 4, 5 and 6, the hydraulic performance significantly ($P \leq 0.05$) affected by the management practices (when to irrigate and how much water applied). Due to the good management practices, Sedonix Project gave the highest values of hydraulic performance compared to AAIAD Project which ranked the least due to the absence of proper water management such as incompletely maintenance, replacement of nozzles and low efficiency, there is an urgent need for optimum use of water in this project. The agreed with the result obtained by Ortega (2002) who mentioned that, the optimum use of irrigation water is a fundamental aspect to reach a sustainable agriculture.

c. Water productivity (kg/m3)

Water productivity significantly ($P \leq 0.05$) affected by hydraulic performance of the irrigation system. Sedonix project gave the highest values of water productivity compared to AAAID project. The superiority of Sedonix project over AAAID project may be attributed to the fact that, center pivot irrigation system in Sedonix project uniformly applied water at the right time to maximize forage or pasture yield and quality. The results were inconformity with the result obtained by Bush et. al. (2017) who reported that, low crop productivity in addition to high production costs, low prices and high taxes and low efficiency of irrigation system had all resulted in a general deterioration of the agricultural sector.

Table 1. Hydraulic performance (%) and water productivity (kg/m^3)

Project	Cu%	Du%	Su	Water productivity (kg/m^3)
India	81^b	76^b	1.32^a	0.38^b
AAAID	74^c	70^c	1.43^b	0.27^c
Sedonix	85^a	81^a	1.23^a	0.45^a
LSD	3.1	4.4	0.01	0.03

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Means followed by the same letter (s) in the same column are not significantly different at $P \leq 0.05$.

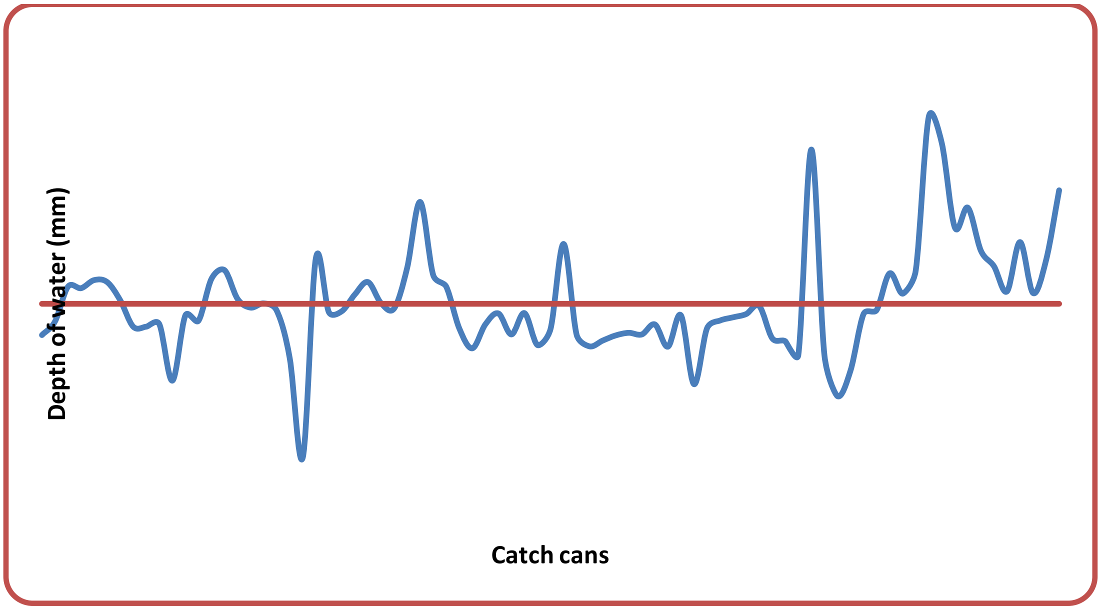

Fig. 4 Depth of water applied in the Indian Project

- 1= First catch can located at 54m from pivot point
- Distance between catch cans 4.5 m
- Mean depth applied in catch cans (mm)
- Depth caught in catch cans (mm)

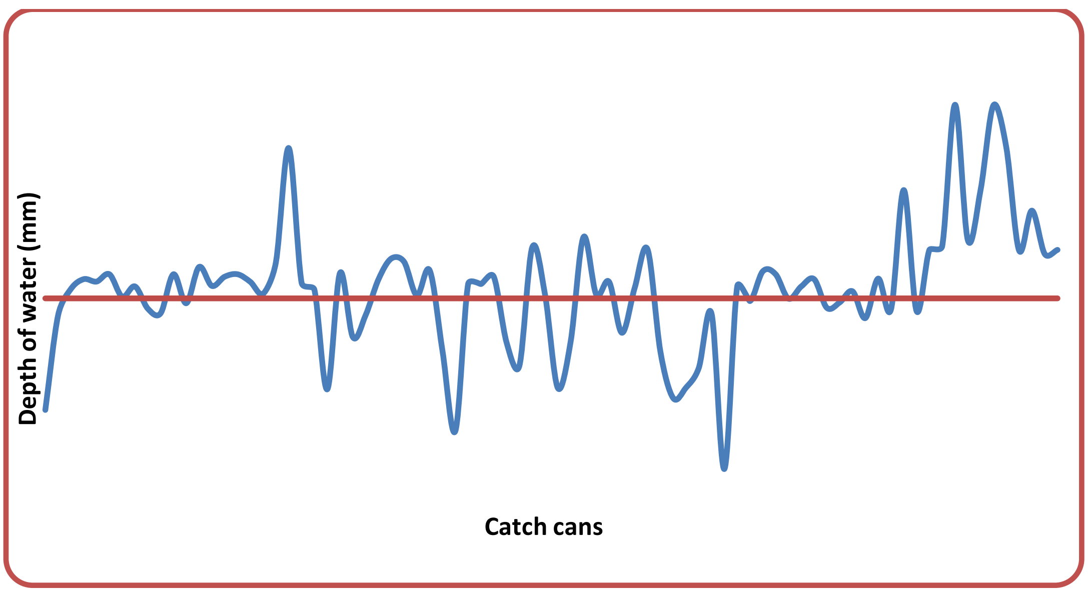

Fig. 5 Depth of water applied in the AAIAD Project

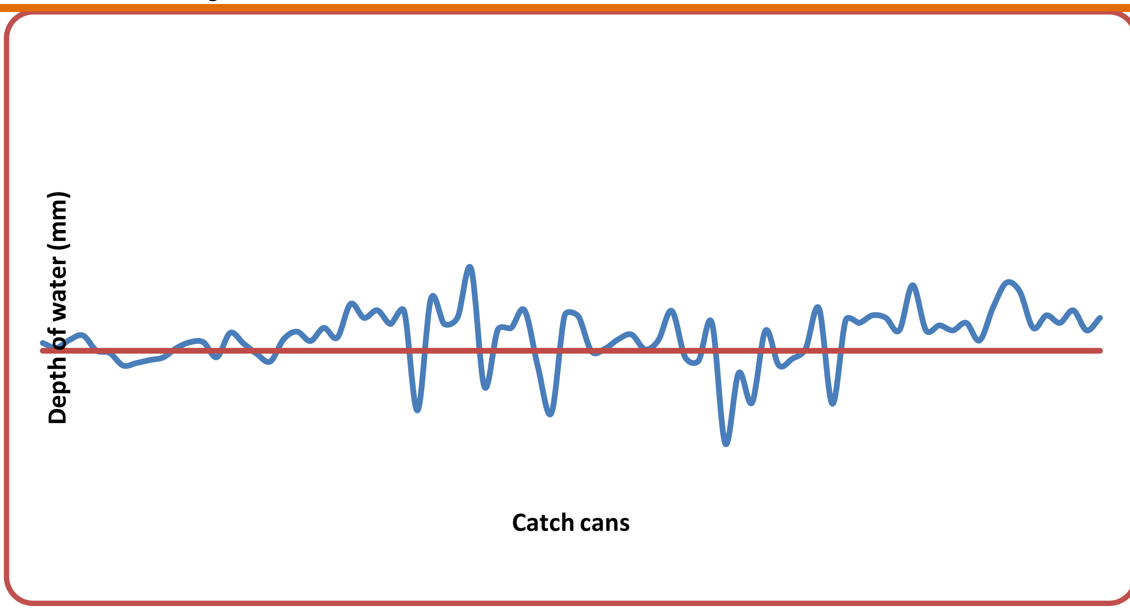

Fig. 5 Depth of water applied in Sedonix Project

- 1= First catch can located at 54m from pivot point
- Distance between catch cans 4.5 m
- Mean depth applied in catch cans (mm)
- Depth caught in catch cans (mm)

REFERENCES

Adam, H.S. (2014). Agroclimatology, Crop Water Requirement and Water Management. 2nd Edition. *University of Gezira Press*, Sudan.

Bush, A.A; Widaa, A. and Hamid, A.M. (2017). Effect of Management Practices on Water Use Efficiency of Gezira Irrigated Scheme, Sudan. *Intl. Res. J. Agric. Sci. and Soil Sci.* Vol 7(3). Pp 40 -45.

Christiansen, J.E. (1942). "Irrigation by sprinkler". Agricultural experiment station, University of California, Berkeley.

El-Hassan, Z.A. (2008). Assembling and Performance evaluation of centre pivot irrigation system, New Hamdab irrigation project, Northern State, Sudan. M.Sc. Thesis, Faculty of Agric. Uni. Khartoum.

Ismail, S.M. and Al-Marshadi, M.H. (2013). Maximizing productivity and water use efficiency of alfalfa under precise subsurface drip irrigation in arid regions. *Journal of Irrigation and Drainage*, 62(1): 57–66.

Michael, A.M. (1978). Irrigation: Theory and Practice. Vikas Publishing , T. L. T. D. New Delhi. India.

Ministry of Finance and National Economy (1996). The economic overview, Sudan Government, Khartoum.

Ortega, J.F.; Tarjuelo, J.M. and Juan, J.A. (2002). Evaluation of Irrigation Performance in Localized Irrigation System of Semiarid Regions (Castilla- La Mancha, Spain). Agric. Eng. Int. 5: 1-17.

Patil, V.C.; Al-Gaadi, K.; Madugundu, R.; Tola, E.H.; Marey, S.; Aldosari, A. and Gowda, P.H. (2015). Assessing agricultural water productivity in desert farming system of Saudi Arabia. IEEE J. Selected Topics Appl. Earth Observations Remote Sens. 8(1):1-14.

Playan, E. and Mateos, L. (2006). Modernization and optimization of irrigation systems to increase water productivity. J. Agric. Water. Manag. 80 (1): 100-116.

Shideed, K. (2005). Assessing On-Farm Water-Use Efficiency: A New Approach Methodology and Six Case Studies. International Center for Agric. Res. in the Dry Areas (ICARDA) and The United Nations Economic and Social Commission for Western Asia (ESCWA), Aleppo, Syria.

Smith, M.G; Allan, J.L; Monteith, A; Perrier, L. and Sergen, A. (1998). Report of the Expert Consultation on Procedures for Revision of FAO Guidelines for prediction of Crop Water Requirement UN FAO, Rome, Italy, Pp 56.

Zoldoske, D.F. and Salomon, K.H. (1988). Coefficient of uniformity what is tells us. California State University, Fresno, California.