Rainwater Harvesting Techniques for Soil Moisture Conservation on the Upper Terraces of the Blue Nile-Sennar State (Sudan)

Abdel Rahman Mohamed Nour Hamid*, Abdel Moneim Elamin Mohamed and Omer Mohamed Eltom Elshami*****

مستخلص:

تمت دراسة ثلاثة طرق حصاد المياه للحفاظ على رطوبة التربة في منحدرات" كرب" النيل الأزرق في ثلاثة مناطق في موسم ١٩٩٨/١٩٩٧ وقد تم اختيار التصميم ذو القطاعات العشوائية للتجربة. طرق حصاد المياه التي تمت دراستها : الهلالات، الحفر العميقة، مجاري صغيرة وأخرى تقليدية تركت بدون معاملة كمستوى للمقارنة. لقد تمت دراسة تأثير المعاملات المذكورة أعلاه على محتوى التربة الرطوبي. أعطت الهلالات أفضل القراءات للمحتوى الرطوبي في كل المواقع مقارنة بالحفر العميقة والمجاري والتقليدية على التوالي معا في المحتوى الرطوبي.

Introduction

Although water may seem like a boundless resource, it is far from it. Only 2.5 percent of the planet's water is fresh, and 74 percent of that is tied up in the polar icecaps. Groundwater accounts for another 25 percent, leaving just 1 percent of freshwater to be found in lakes, rivers, soil, and air. Due to population growth, drought, and pollution, groundwater resources are seriously declining. Today the world fights over oil; tomorrow (if not already) it will fight over water (Robin, 2005).

Water harvesting is a proven technology to increase food security in drought prone areas. Erosion control and recharge of ground water are additional advantages of water harvesting techniques (FAO, 2000).

Water harvesting techniques are practiced in the arid and semi-arid zones where annual rainfall is insufficient for plant requirements either for poor rainfall or rain water is not available to plant root zone.

* Assistant prof., Faculty of Agricultural Technology & Fish Science, Elneelain University

** Department of Agricultural Engineering, Faculty of Agriculture, University of Khartoum, Sudan

*** Department of Agricultural Engineering, Faculty of Agriculture, University of Khartoum, Sudan

According to Proud (1988), the strategies to improve the availability of soil moisture for use by trees and crops can be enhanced by managing the supply of water so that losses through run-off and evaporation are minimized and managing the trees and crops to reduce their demand for moisture

In supply management the mount of rainfall available to roots can be increased by : increasing the rate and depth of infiltration into the soil, reducing evaporative losses by mulching and intercepting and concentrating run-off. Such procedure, referred to as water harvesting, is providing an entirely new potential s source of water (Schwab, 1966)

Rain water harvesting can be defined to comprise the harvesting of run-off from roofs, artificial surfaces at ground level and land surface with slope.

Rain water harvesting has been defined by Cullis (1986) as the gathering and storage of run-off water from a surface on which rain has directly fallen and not the harvesting of valley flood water or stream flow. The principle of collecting and using precipitation from a small catchment area is often referred to as rain water harvesting. Whereas, Pieck (1985) defined the rain water harvesting concept as the collection and storage of any surface run-off water. While, Fergusson (1987) defined the water harvesting concept as: The generation of rain fall run-off and the collection of that run-off for use. Whereas, Proud (1988) defined the water harvesting as the interception and concentration of rainfall run-off and its storage in the soil profile for use by crops, grasses or trees. By supplying the plant with run-off water in addition to rainfall it is essentially a form of low- cost natural irrigation.

Basically the catchment is an artificial surface or natural ground surface which has been specially prepared and demarcated

to generate water run-off to be utilized. There are several types of catchments used in rain water harvesting as: roofs tops catchments, artificial surfaces catchments and the natural surface catchments, where the ground surface must be suitable for rain water harvesting, also the ground or catchment surface should have a degree of slope and prepared in such a way that run-off can easily be generated. It is very important that the soil must be relatively impermeable and with gentle slope towards the storage area. There are several methods and techniques of natural surface catchment that were used to provide water for agricultural purpose such as: contour furrows, micro-catchment techniques, terrace techniques, inundation techniques, flood water techniques, and run-off farming techniques by building high bunds, banks or terraces along the contour, water will infiltrate slowly so that crops can be planted (Cullis, 1986).

Advantages and benefits of rainwater harvesting are numerous (Krishna, 2003).

Rainwater provides a water source when groundwater is unacceptable or unavailable, or it can augment limited groundwater supplies.

Rainwater harvesting reduces flow to storm water drains and also reduces non-point source pollution.

Rainwater harvesting helps utilities reduce the summer demand peak and delay expansion of existing water treatment plants.

Rainwater harvesting reduces consumers' utility bills.

Materials and methods

The experiment was conducted in season 1997/98 at three different sites.

(a) Elsuneit Forest, Rufaa circle-Gezira State. It is situated at the east bank of the Blue Nile (Latitude 14° 4′ N, Longitude 33° 19′ E). The experiment was carried on compartment number 8, approximately 142 kilometres south of Khartoum. This site represented the area north of Sennar dam.

(b) Sabun Forest, Essuki circle – Sennar State. It is situated at the east bank of the Blue Nile (latitude 12° 41′ N, longitude 32° 52′ E). The experiment was carried on compartment number 13, approximately 353 kilometres south of Khartoum.

(c) Wad ELais Forest, Essuki circle – Sennar State. It is situated at the east bank of the Blue Nile (latitude 12°35′ N, longitude 32°58′ E). The experiment was carried on compartment number 9, approximately 380 kilometres south of Khartoum. The last two sites (b,c) represented area south of Sennar dam.

The randomized block design (R.B.D) was selected. The area of the block in each site was 1400m (20 m. width, 70 m. length).

All the adopted techniques were carried out before the onset of the rainy reason in the three sites, each site represented by block as a combination of species and the treatments, was divided into four equal plots of dimension 20 m. x 17.5 m. one of the four plots remain as a control i.e. No water harvesting technique was used. The other plots are:

(a) Crescent- shaped or curved terraces:

This method was adopted because the karab site known to be extremely rough terrain. Earthen bund was raised with hoes 25 cm surrounding the saucer–shaped pit (where the seedlings were planted).The distance between crescent horn and the centre equal 1/3 the distance between two centres (the distance between every two centres within rows was 2m. and between rows also 2 m.). The curved terraces were made along the lower edges of the depression to holdback the rain water. The terraces placed on the contour line alternatively in order to receipt the sheet flow between upper terraces.

(b) Holes (deep pits) techniques:

Also this method was adopted because the karab site known to be extremely rough terrain. The holes centres were made at the spacing of 2 meters within and between rows. The holes were dug 50cm deep, natives hoes were used.Earthen walls raised surrounding the hole of 50cm radius except the slope direction (upper side) to trap the sheet flow run-off after rain storms. This technique depends on the fact that the roots use up the soil moisture in these vicinities, water moves to the drier zones near the roots from damper areas of the soil.

(c) Ditches (trenches) with width and depth of 1/3 m:

The distance between each two trenches 2 metres. Trenches are perpendicular to the slope direction. Soil raised towards the lower side with native hoes.

(d) Control (Traditional):

This plot remained flat ground to represent the practices applied now in the field adopted by the traditional farmers, shallow pits with hoe were made at spacing of 2 metres by 2 metres.

During all the season (97/98) rain gauges were installed at each site in order to measure rainfall amount and duration in millimeters.

The soil moisture content was taken monthly starting at 15 October. This parameter was determined gravimetrically, soil sample were augured from different locations at 0.2 m. increment from the surface to a depth of 0.6 m. the samples were over dried at 105°C for 24 hrs weighed to determine moisture content on dry weight basis.

$$\text{Moisture content\%} = \frac{\text{wt of wet sample- wt of oven dry sample x100}}{\text{wt of oven dry sample}}$$

Where: wt = the sample weight in gms.

Data for each trial were analyzed as randomized block design (R.B.D) by standard analysis of variance techniques. Means of significant ($p \leq 0.050$) treatments were separated using Duncan's Multiple Range Test procedure.

Results and Discussion

Soil moisture content measurements were carried out as described Table 1 shows the means of soil moisture content as well as Fig. 2. Analysis of variance for soil moisture content for different time intervals were shown in Table 2. The soil moisture content closely linked to the amount rainfall during the rainy season. Table 2 shows a considerable variation in rainfall was encountered during the season, consequently a considerable variation in soil moisture content is expected.

The statistical analysis of variance for soil moisture content Table 2 after the 1st and 2nd readings showed a significant difference ($p \leq 0.050$), after the 3rd, 5th, 6th, and 7th readings showed a highly significant difference ($p \leq 0.01$) and after the 8th, 9th, and 10th readings showed no significant difference ($p \geq 0.050$) among the blocks. The result of 8th and 9th readings showed that the level of the soil moisture content decreased due to the effect of summer period and the level of the moisture content at the 10th reading increased due to the onset of rain.

The statistical analysis of variance for the soil moisture content Table 2 at the four different treatments after the 1st, 2nd, 3rd,4th, 6th and 7th readings showed a highly significant difference ($p \leq 0.01$) existed among the treatments while 8th, 9th and 10th readings showed no significant difference between them ($p \geq 0.05$). After the first seven readings crescents and holes were not significantly different but were significantly different from ditches and the control which were not significantly different from each other. This result clarified that crescents and holes were the best treatments to conserve moisture compared to ditches and control. The results of each readings showed that the crescents were the best followed by holes, ditches and control successively. after the 8th and 9th readings the moisture level decreased due to the effect of Summer period and increased after the10th reading due to the onsets of the rain. The reasons for the low moisture content obtained by the controlled treatments may be attributed to high surface soil bulk density, low porosity, retarded infiltration and low water holding capacity of the soil compared to the other treatments.

Table (1): Duncan's multiple range test for variable: Soil moisture content (SMC) in 10 readings.

Measure-ments	Experimental sites	Means	Experimental treatments	Means
1	Elsuniet Sabun WadElAis	16.225 a 16.200 a 15.225 b	Holes Crescents Ditches control	16.567 a 16.967 a 15.133 b 14.867 b
2	Elsuniet Sabun WadElAis	15.975 a 15.925 a 14.950 b	Holes Crescents Ditches control	16.233 a 16.700 a 14.867 b 14.667 b
3	Elsuniet Sabun WadElAis	15.850 a 15.825 a 14.475 b	Holes Crescents Ditches control	16.200 a 16.433 a 14.433 b 14.167 b
4	Elsuniet Sabun WadElAis	15.550 a 15.500 a 13.925 b	Holes Crescents Ditches control	15.800 a 16.100 a 14.100 b 13.967 b
5	Elsuniet Sabun WadElAis	15.275 a 15.225 a 13.675 b	Holes Crescents Ditches control	15.533 a 15.733 a 13.867 b 13.767 b
6	Elsuniet Sabun WadElAis	14.975 a 14.750 a 12.850 b	Holes Crescents Ditches control	14.900 a 15.100 a 13.533 b 13.233 b
7	Elsuniet Sabun WadElAis	14.075 a 13.075 a 8.450 b	Holes Crescents Ditches control	13.733 a 13.833 a 10.500 b 9.400 b
8	Elsuniet Sabun WadElAis	8.950 a 5.500 a 4.100 a	Holes Crescents Ditches control	8.267 a 8.333 a 4.067 a 4.067 a
9	Elsuniet Sabun WadElAis	8.800 a 5.500 a 4.100 a	Holes Crescents Ditches control	8.167 a 8.233 a 4.067 a 4.067 a
10	Elsuniet Sabun WadElAis	14.750 a 14.200 a 14.075 a	Holes Crescents Ditches control	14.500 a 14.567 a 14.167 a 14.100 a

Table 2 Analysis of variance for soil moisture content (SMC) in 10 readings

Source	DF	SMC 1	SMC 2	SMC 3	SMC 4	SMC 5	SMC 6	SMC 7	SMC 8	SMC 9	SMC 10
BLK	2	1.30*	1.33*	2.48**	3.42**	3.31**	5.45**	36.20**	24.96 n.s	23.29 n.s	0.18 n.s
TRT	3	3.25**	3.01**	3.67**	3.73**	3.33**	2.68**	15.30**	17.09 n.s	17.09 n.s	0.18 n.s
Error	6	0.13	0.13	0.14	0.04	0.03	0.16	0.96	17.92	17.09	0.14

** : significant at ($P \leq$ o.o1).

* : significant at ($P \leq$ o.05).

n.s : not significant

Conclusion

The following conclusions can be drown form the results of this study

1- The study revealed that water conservation potential of crescents was sufficient to improve the soil moisture content at karab area than other treatments (holes, ditches and control treatments respectively).

2- Variation in rainfall in different three sites namely Elsuniet, Sabun and Wad ElAis influenced the soil moisture content percentage accordingly Elsuniet was superior to Sabun and Wad ElAis due to the amount of rainfall water received.

3- Karab slope rainfed areas can be reclaimed by applying water harvesting techniques.

References:

Cullis, A.; Pacey, A. (1986), Rain water harvesting. The collection of rain fall and run-off areas in rural areas, Intermediate Technology Publication. Briggs, D.J., Applied Geography, Butter worth scientific LTD. Westbury Kuse. England.

FAO,(2000). FAO/AGL Land and Water Development

Fergusson B. K. (1987) Urban storm water Harvesting Application and Hydraulic Design, in Journal of Environmental Management Vol.25, No. 1, Academic press London, PP, 71-74.

Krishna H. (2003). An overview of rainwater harvesting systems and guidelines in the United States. Proceedings of the First American Rainwater Harvesting Conference; 2003 Aug 21-23; Austin (TX).

Piek, c. (1985). Catchments and storage of rain water, Tycaol, Amsterdam.

Proud, K. R. S. (1985). Manual on soil an water conservation. technique FAO Forestry Division, Rome.

Robin, S.(2005). *Plants & Gardens News* Volume 20, Number 1.

Schwab, G. O. ; Frevert, R. K. ; Edmister, T. W. and Perry, R. L. (1966). Soil and water conservation engineering(2nd.) John Wiley NewYork, Tothill, J. D. (1948). Agriculture in the Sudan. Ministry of Agriculture Khartoum.