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Original article

Effect of Water Harvesting Techniques on Soil Properties in the South Omdurman Area – Sudan [1]

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Abstract

This study was conducted at Khartoum New International Airport, South Omdurman area, Khartoum State, Sudan. A complete randomized block design was followed to study the effect of Holes and Crescents water harvesting techniques on the soil moisture content soil sample were taken prior and immediately after rains and at three weeks intervals.

The results indicated that the Holes and Crescents water harvesting techniques affected positively some soil physical properties especially at the upper soil layer (0 – 30 cm) which was subjected to excavation by a loader. These soil properties included porosity, field capacity and infiltration rate as they have direct influence on the soil moisture content.

The Holes water harvesting techniques showed an increase of 15% in soil moisture content resulting in better improvement of the soil physical properties as compared to the Crescents water harvesting techniques, hence the farmer techniques recommended for adoption.

Keywords: Holes, Crescents, Water Harvesting Technique, Infiltration Rate, Field Capacity, Moisture Content.

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INTRODUCTION

One of the major critical problems of agriculture is water conservation, especially in rainfed areas. Sound soil and water conservation is based on full integration of engineering, plant and soil sciences. It is essential to develop sound practice that will permit the entrapment and storage in soil profile a greater percentage of available precipitation as by water harvesting techniques which provide an entirely new potential source of water. Water has an essential role in sustaining life and development especially in arid and semiarid regions. According to the United Nations (2003), water resources are envisaged decline steadily because of population growth, pollution and frequent climate changes due to the problem of global warming. Hence, the water crisis is getting more attention among all countries specially the developing ones. Therefore, new strategies and techniques to deal with water problems are highly needed. Water harvesting and spreading techniques succeeded in providing feasible solutions for improving the living conditions of millions of people facing serious domestic water supply problems. Water harvesting goes back in the old history. It is an old and ancient method for collecting water, practiced by man since life existed on this planet. Much of the early history of rain water harvesting has its origin in many parts of the world. The old civilizations developed in western Asia and in central and northern Africa gave strong evidences that they had known water harvesting. In Europe, especially in small islands with no significant river systems, rain water is the only source of water. The island of Gibraltar has one of the largest rain water collection systems in existence. (UNEP, 1983) and (UCWR, 2003). In Sudan the central clay plains, east of the Nile, the use of earth bunds (Terases) are familiar to intercept sheet-flow runoff, following heavy storms, from adjacent catchments. Sixty and seventy percent of runoff is concentrated in the flood period from June to September (Kutsch, 1982; Ahmed and Eldaw, 2003).

This study was conducted with a view to attaining the following objectives:

1. To compare different water harvesting techniques on the basis of soil moisture content (SMC).
2. To examine the viability of improving the physical condition of the soil.

Materials and Methods

The study area

Site location

The study was conducted at Khartoum New International Airport (KNIA) in the south western direction of Omdurman, Khartoum State at Latitude 15˚ 13́ N and Longitude 32˚ 19́ E, at a distance of 50 km South of Khartoum center and 20 km west of the White Nile River.

Meteorological and Soil data

Rainfall

The rainy season normally falls between July and September each year and the annual average rainfall is about 150 mm. The effective rainy season starts in late June, increases in July and reaches its peak in August.

Topography

The topography of the study area is generally fairly flat but few isolated ridges and sand dunes may be observed in the western part of the site and the ground surface slopes gently to the east.

Vegetation

Harrison and Jackson (1955) stated that vegetation of the study area is dominated by *Acacia tortilis* and *Maeruacrassifolia* desert scrub.

Generally, the natural grazing area in Khartoum state is estimated as 40% of total area. The annual grasses and herbs form about 75% of the natural vegetation cover, while the perennial grasses and shrubs/trees form 5% and 20%, respectively.

In summary the degradation of the study area is characterized by the disappearance of trees cover mainly due to conflict between people needs and woodland preservation. Thus, the whole state has badly denuded of its natural tree cover.

Climate

The climate is hot, dry, dusty during the summer season and dry, cold during the winter.

Soil

The area is covered by a light brown and very thin gravely sand layer (about 10mm thick), and few angular to sub-angular, 20 to 60mm sized fragments of the ferruginous sandstone. The southern part of the site is covered by sandy gravel probably formed due to the weathering of Nubian Group rocks which are outcropping in some places in the area. Runoff usually occurs during heavy rains.

Experimental treatments

These included two water harvesting techniques which were constructed before the onset of the rainy season; each treatment was represented by a block which included the plant species. The Holes and Crescents types of water harvesting techniques were used; mainly because the site is known to be extremely rough terrain.

(a) Holes (Deep pits) technique

Each Hole was 2.5 m in width, 4 m in length and 50 cm deep. The distance between holes in the row was 10 meters while the distance between rows was also 10 meters. The slope direction was made from the upper side to trap the sheet flow run-off after rain storms.

(b) Crescents or curved terraces technique

Each Crescent was 30 meters in diameter and 50 cm deep. The crescents were laid 15 m apart.

Soil mechanical and physical properties

Soil mechanical and physical analysis was performed at the Soil Science Department, laboratory of the Faculty of Agriculture, University of Khartoum.

Soil class and bulk density

Soil class was determined using the hydrometer method proposed by Bouyoucus (1951). Samples were taken from six locations in each plot. From each location 3 samples were taken at depths of 30, 60 and 90cm below the soil surface.

The mean bulk density in gm/cm^3 for each depth was determined using the following equation:

Bulk density (gm/cm^3) = Dry soil weight (gm) / Soil volume (cm^3)

Bulk Density =m / v (gm/cm^3)

Where:

m = mass of sample in g

v = volume of sample in cc (ml)

Infiltration rate

Steady state infiltration rates were measured for each treatment (plot) using the double ring infiltrometer following the procedure described by Michael (1978).

The double ring infiltrmeter was made of 0.25 cm thick metal sheet and consisted of two concentric cylinders, 28 cm height with diameter of 28 cm for the inner ring and 55 cm for the outer one. The infiltrometer was pressed firmly in the soil and hammered gently with the help of a wooden plate until it was driven to a depth of 10 cm in the soil. A filter paper was then placed at the bottom of the inner cylinder to prevent disturbing the surface of the soil, then water was poured gently into the inner cylinder. The space between the inner and the outer cylinders was filled immediately with water after filling the inner one to prevent the horizontal water movement. Readings of the depth of the pond water in the inner cylinder was taken every 5 minutes then the rate of water intake over time was measured as described by Michael (1978).

Soil moisture content determination

This parameter was determined gravimetrically, soil samples were augured from different locations at 0.3 m increment from the soil surface to a depth of 0.9 m. The samples were oven dried at 105ºC for 24 hours then weighed to determine moisture content on dry basis.

$$\text{Moisture content } \% = \frac{(\text{wt of wet sample} - \text{wt of oven dry sample})}{\text{Wt of oven dry sample}} \times 100$$

Where:

wt = the sample weight in gm.

Equipment

The following equipment was used in the experiments:

1. A Loader was used to construct the rain water harvesting structures
2. Auger for soil sampling.
3. Sample containers for the determination of the moisture content of the soil and plastic bags to keep the soil samples.
4. An oven for drying the soil moisture.
5. Measuring tools (metering tape, a sensitive balance.
6. Double ring infiltrometer.

Statistical analysis

Data for each trial were analyzed as Complete Randomized Block Design (C.R.B.D) by standard analysis of variance techniques. Mean significant ($p \leq 0.05$) treatments were separated using Duncan's Multiple Range Test procedure (Steel and Torrie, 1980).

Results and Discussion

Soil particles distribution

Figure 1 and Table 1 show that the amount of sand particles was greater in the upper 30 cm depth than in the lower depths (30-60 cm) and (60-90 cm) in both treatments. The soil texture was sandy clay for the upper part for both soil types, while it was clayey for depth (60-90 cm) for both soil treatments, this might be due to eroded slope of the upper terraces where the sand and some gravel were exposed as a result of erosion. The soil is sandy clay in the upper zone (30-60 cm) with more sand in the top 30 cm. The clay content increase with depth more sand and gravel are seen above soil surface mainly due to a washing proves of clay down the slope.

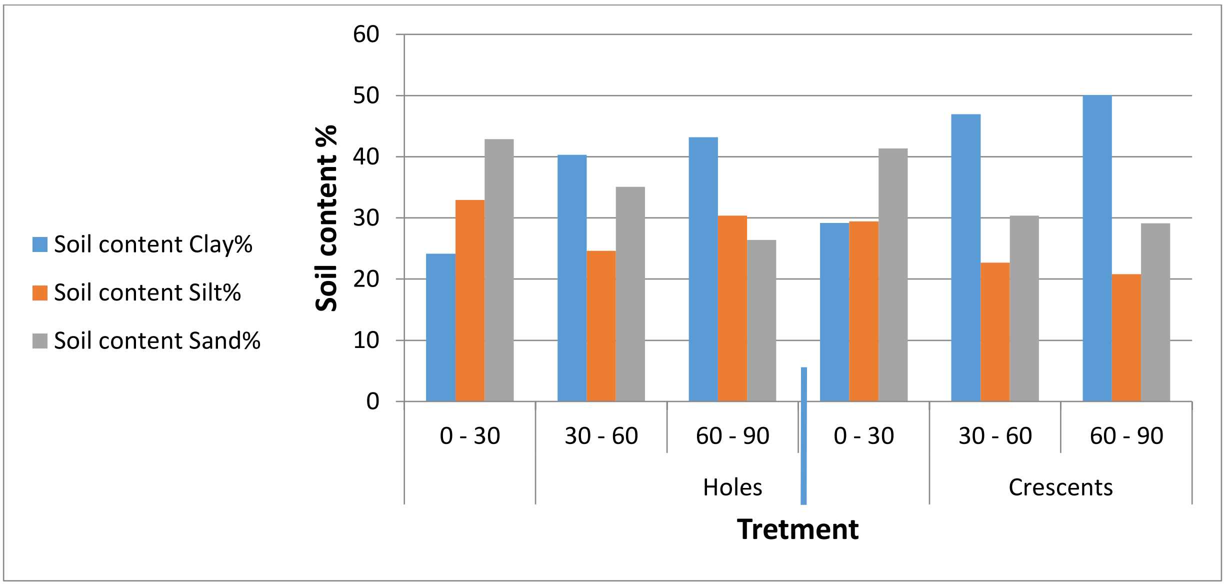

Figure 1. Soil mechanical analysis for different depth and treatments

Table 1. Soil mechanical analysis for the location, different depth and treatments

Treatments	Depths (cm)	Soil content			Soil texture
		Clay%	Silt%	Sand%	
Holes	0 - 30	24.17	32.96	42.87	Sand
	30 - 60	40.32	24.6	35.08	Clay
	60 - 90	43.2	30.38	26.42	Clay
Crescents	0 - 30	29.18	29.45	41.37	Sand
	30 - 60	46.96	22.68	30.36	Clay
	60 - 90	50.09	20.78	29.13	Clay

Soil bulk density

Figure 2 and Table 2 show that the bulk density in gm/cm^3 for each 30 cm increment from the soil surface down to the depth of 90 cm for both the Holes (T1) and Crescents (T2) water harvesting techniques. It becomes apparent that the bulk density was found to increase with increasing depth, with an average of 1.64 gm/cm^3 at all locations. This result may be attributed to the fact that the soil bulk density increases with increase in the clay content, a fact which is supported by the findings of Salah (1991).

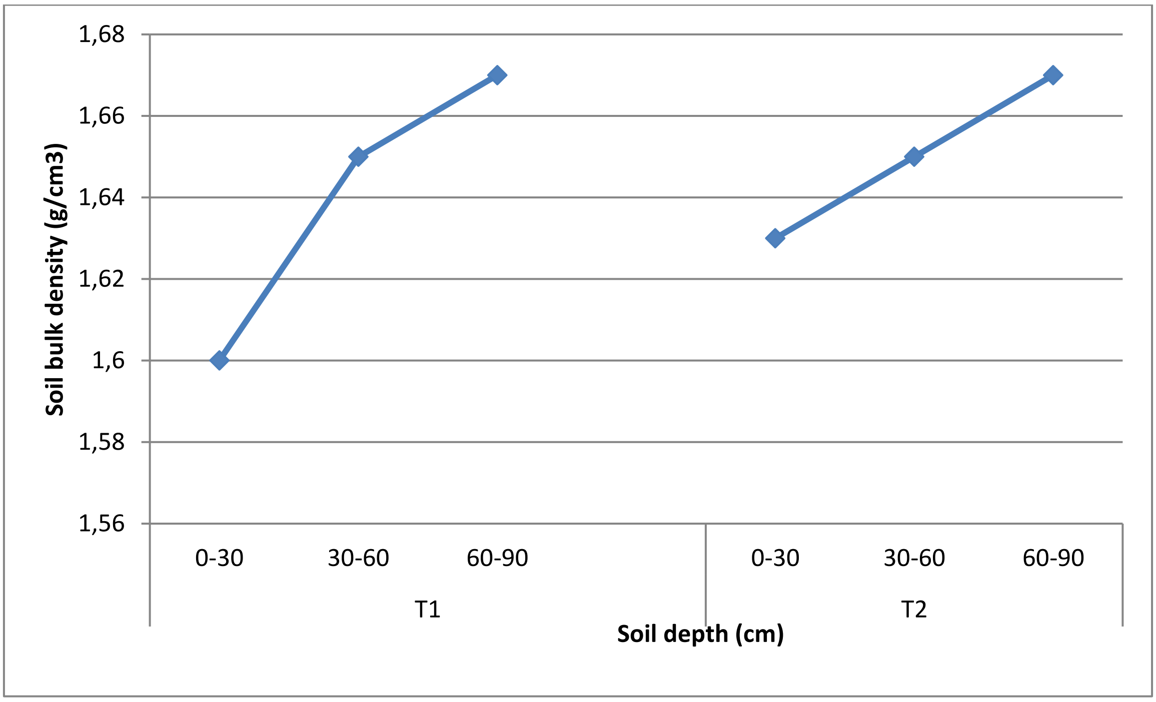

Figure 2. Soil bulk density (g/cm^3) of the treatment

Table 2. The bulk density in g/cm^3 for the location, different depths and treatments

Treatment	Depth	R1	R2	R3	Means
Holes	0 - 30	1.56	1.63	1.61	1.6
	30 - 60	1.62	1.68	1.65	1.65
	60 - 90	1.66	1.70	1.66	1.67
Crescents	0 - 30	1.63	1.58	1.61	1.63
	30 - 60	1.66	1.61	1.67	1.65
	60 - 90	1.66	1.65	1.71	1.67

Infiltration rate

The infiltration rate (mm/h) and the accumulative infiltration rate (mm) for the Holes and Crescents water harvesting techniques treatments can be depicted in Fig (3) and table (3). In both cases the infiltration rate (mm/h) and the accumulative infiltration (mm) were plotted against elapsed cm (min). The infiltration rate started at about 300 mm/h then dropped down gradually for about 30 min before reaching relatively steady state in moderate conditions.

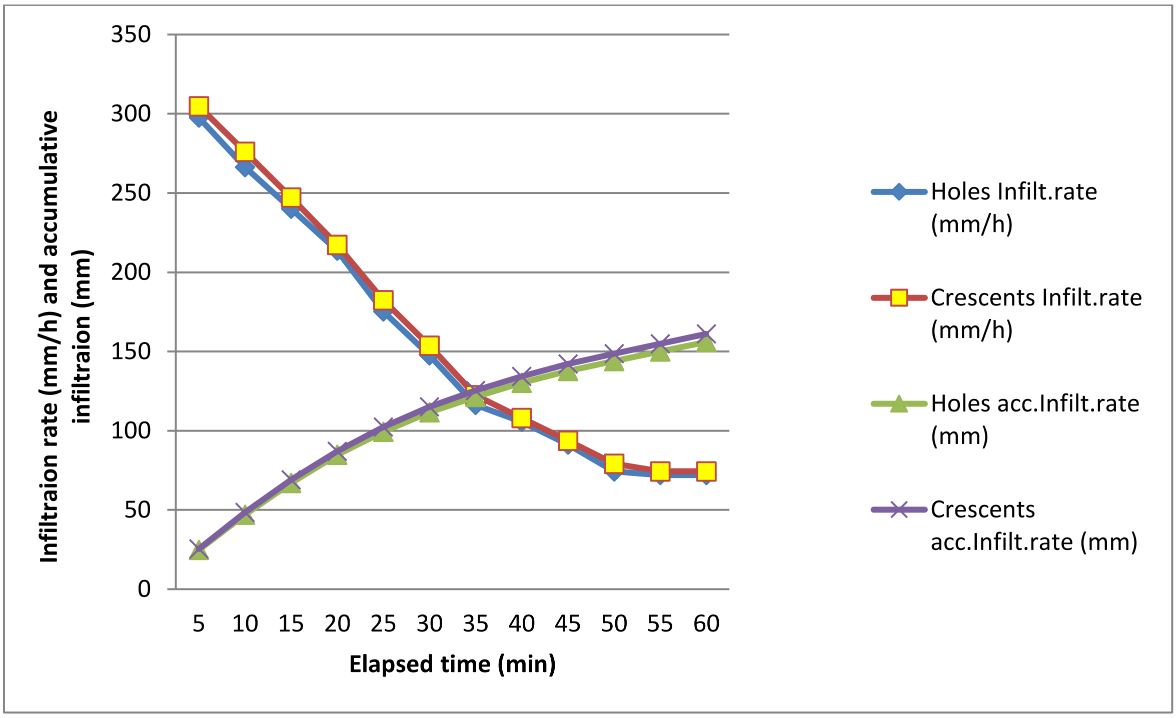

Figure 3. Infiltration rate (mm/h) and accumulative infiltration (mm) versus elapsed time (min) for the site

Table 3. The values of infiltration rate (mm/h) and accumulative infiltration (mm)

Time(min)	Holes		Crescents	
	Infilt. rate (mm/h)	Acc.infilt.values (mm)	Infilt. rate (mm/h)	Acc.infilt.values (mm)
5	297.6	24.8	304.8	25.4
10	266.4	47	276	48.4
15	240	67	247.2	69
20	213.6	84.8	217.2	87.1
25	175.2	99.4	182.4	102.3
30	147.6	111.7	153.6	115.1
35	116.4	121.4	122.4	125.3
40	105.6	130.2	108	134.3
45	91.2	137.8	93.6	142.1
50	74.4	144	79.2	148.7
55	72	150	74.4	154.9
60	72	156	74.4	161.1

Soil moisture content

The moisture contents of the soil before and after rain at different depths are shown in Fig (4) and Table (4). The 1st reading before the rain showed a significant difference ($p \leq 0.05$) for depth (60-90), while the 2nd and the 3th readings for depth (0-30) and (60-90), respectively after the rain showed that a significant difference ($p \leq 0.05$) existed among the treatments. There was no significant difference ($p \geq 0.05$) for 4th and 5th, readings at all depths.

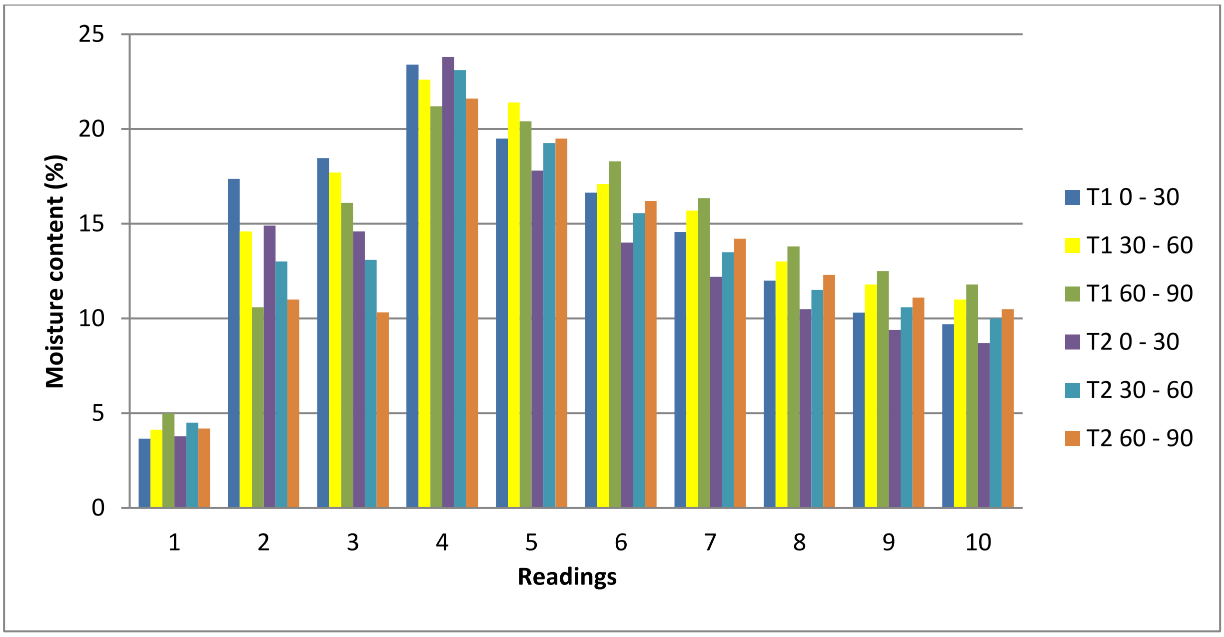

Figure 4. Soil moisture content (SMC) measurement (wt %)

Table 4. Average moisture content before and after rains

Readings		1		2		3		4		5	
Treatment	Depth	Bef	Aft	Bef	Aft	Bef	Aft	Bef	Aft	Bef	Aft
		MC %	MC %	MC %	MC %	MC %	MC %	MC %	MC %	MC %	MC %
Holes	0 - 30	3.65	17.36	18.46	23.4	16.46	19.5	12.0	14.56	9.7	10.3
	30 - 60	4.12	14.6	17.7	22.6	17.1	21.4	13.0	15.7	11.0	11.8
	60 - 90	4.98	10.2	16.1	21.2	18.3	20.4	13.8	16.36	11.8	12.5
Crescents	0 - 30	3.78	14.9	14.6	23.8	14.0	17.8	10.5	12.2	8.7	9.4
	30 - 60	4.49	13.0	13.1	23.1	15.56	19.26	11.5	13.5	10.0	10.6
	60 - 90	4.20	11.0	10.33	21.6	16.2	19.5	12.3	14.2	10.5	11.1

Conclusions and Recommendations

Conclusions

The following conclusions can be drawn from the results of this study:

1. The Holes and Crescents water harvesting techniques improved soil moisture content significantly.

2. Higher values of moisture content were recorded for the Holes type of water harvesting technique as compared to the Crescents type.

Recommendations

From the results obtained and conclusions drawn the following recommendation can be made:

Further research should be conducted to investigate the performance of different indigenous tree species under more water harvesting techniques to enable selecting the water harvesting techniques and the species most appropriate to the environmental conditions of the area.

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