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Effect of Some Micro-Catchment Water Harvesting Techniques on Some Soil Physical Properties

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Abstract: The experimental work was conducted at Jebel Awlia locality 40 kilometers south of Omdurman city during 2010-2011 and 2011-2012 rainy seasons to investigate the effect of micro-catchment water harvesting techniques on some soil physical properties. Techniques used were, semi- circular, V-shaped, pits, deep ditches and land without water harvesting technique control. Soil properties studied were infiltration rate, saturation percentage, bulk density and the percentages of clay, silt and sand. The results showed that infiltration rates in all treatments were lower than that of the control, the mean differences between treatments were not significant in the first season but significantly lower means were obtained by the semi circular and pits in the second season. Saturation percentage in both seasons, were significantly lower after rainfall as compared to that before rainfall for all treatments. Except for the semi-circular and the V-shaped treatments in both seasons and deep ditches in the first season and pits in the second season, bulk density after rain fall was significantly lower than that before rainfall. Clay content in both seasons was not significantly affected by the water harvesting techniques, except under deep ditches in the second season and overall in both seasons. Silt content, in both seasons, was not significantly influenced by the technique for all treatments, except during the first season, in which the techniques before rainfall had a significantly higher mean as compared to that after rainfall. Effect of the water harvesting technique on sand content had insignificant effect, except the overall mean of the techniques during the second season, in which before rainfall was significantly higher as compared to that of the control treatments.

Keywords: Micro-Catchment Techniques, Infiltration Rate, Saturation Percentage, Bulk Density

1. Introduction

Dry lands cover about 5.2 billion hectares, a third of the land area of the globe (UNEP, 1992). Roughly one fifth of the world population lives in these areas.

Dry lands have been defined by FAO on the basis of the length of the growing season, as zones which fall between 1-74 and 75-199 growing days to represent the arid and semi-arid dry lands, respectively, and receiving rainfall between 0 – 600 mm annually (FAO, 1978).

The main feature of “dryness” is the negative water balance between the annual rainfall (supply) and the evaporative demand. Many of the world’s dry lands are grazing rangelands and characterized by the need to manage and cope with erratic events of rain that constrain opportunities for development. In dry-lands, production is possible only when additional water is made available for cultivation. With declining investments in irrigation in developing countries, alternative methods, such as soil and water conservation, have become more important in recent decades (Devi *et al.*, 2005). Water harvesting is one such technique and is based on the collection and concentration of surface runoff for cultivation before it reaches seasonal or perennial streams (Reij *et al.*, 1988).

2. Materials and Methods

The experimental work was conducted at Jebel Awlia locality 40 kilometers south of Omdurman city and 25 kilometers from the west bank of the White Nile River during 2010-2011 and 2011-2012 rainy seasons. The experiments covered an area of 5 hectares as a part of the area designated for Khartoum New International Airport. The climate of the area is semi desert, which was characterized by high temperature of an average of 45^{O}C during the summer. Wind speed is very high evoking dust. Very sparse herbaceous plants and *Acacia* trees comprise the plant cover which is green during the rainy season. The soil is light to sandy in composition except at lane beds especially Mansourab dam. Soil changes gradually to clay and sand-clay according to level and topography.

Five water harvesting techniques were used as follows:

(1) Semi- circular water traps, (T_1) designed with 30 meters diameter, 90 cm height and 20 meters distance between one trap and the other. The water dikes were composed of 3 units, with a distance of 50 meters from the next unit of dikes.

(2) V-shaped water dikes (T_2): Each 30 meters side length and 30 meters bottom of the V-shaped width. The distance between a set of dikes and the other was 20 meters. The water trap was composed of 3shapes at the front and 2shapes at the rear at a distance of 50 meters between the front and rear.

(3) Pits (T_3): The pits were designed at 5 meters width, 10 meters length and 10 meters between pits. Pits were dug according to the land gradient. Water trap was composed of 3 pits at the front and 2 pits at the rear at a distance of 50 meters between the front and rear pits.

(4) Deep ditches (T_4): The deep ditches were dug by a motor grader. The length of each ditch was 30 meters and depth of 90cm, at a distance of 20 meters between ditches. The water trap in this design was composed of three ditches at the front and two ditches at the rear, the distance between the front and rear ditches was 50 meters.

(5) Land without water harvesting technique (control) treatment denoted by (T_0).

The infiltration rate was determined using a double ring infiltrometer as described by Michael (1978). The double ring infiltrometer consisted of two concentric cylinders each 0.25 cm thick, 30 cm height with diameter of 30 cm for the inner ring and 60 cm for the outer one. The infiltrometer was pressed firmly in the soil and hammered gently with the help of a wooden flank until it was driven to a depth of 10 cm. A filter paper was then placed at the bottom of the inner cylinder to prevent disturbing the surface of the soil. Water was then poured gently into the inner cylinder. The space between the inner and the outer cylinder was filled immediately with water after filling the inner one to prevent the lateral water movement. Readings of the depth of the ponded water in the inner cylinder were taken every 5 minutes then the rate of water intake over the time was measured as described by Michael (1978). Soil analysis included saturation percentage (S.P), bulk density (B.D.) and soil mechanical analysis (Clay%, Silt% and sand %) were carried out in the laboratories of Al-Neelain University.

3. Results

Table 1. *Mean infiltration rate under the different micro catchment techniques during 2011/2012 and 2012/2013 seasons.*

treatments	Mean infiltration rate (mm/h)	
	2011/2012 season	2012/2013 season
T0	157.7	162.0
T1	107.9	90.5
T2	114.3	91.7
T3	134.4	102.1
T4	113.4	110.7

Table 1 shows the mean infiltration rates under the micro catchment techniques in both seasons. The results showed that infiltration rates in all treatments were lower than that of the control. The mean differences between treatments in the first season were not significant. The percentage of decrease in infiltration rate for the semi circular, pits, deep ditch and V-shaped micro-catchment as compared to the control was 46.2%, 38.0%, 17.3% and 39.1%, respectively. In the second season, all micro catchment treatments had lower mean of infiltration rate than the control, with significantly lower mean obtained by the semi circular and pits. The treatments of semi circular, pits, deep ditch and V-shaped catchments showed decreased infiltration rate as compared to the control by about 79.0%, 76.7%, 58.7% and 46.3%, respectively.

In both seasons, saturation percentage (SP) was significantly lower after rainfall as compared to the before rainfall for all treatments (Table 2). In the first season, (SP) after rainfall under T_0, T_1, T_2, T_3, T_4 and overall was reduced by about 54.4%, 48.4%, 38.9%, 50.4%, 43.3% and 47.9%, respectively, as compared to that before rainfall. On the other hand, in the second season, the reduction in SP for the same treatments after rainfall as compared to before rainfall was 0.8%, 33.3%,44.5%, 21.4%, 53.2% and 30.8%, respectively.

Table 2. *Saturation percentage before and after rain fall under the different micro catchment techniques during 2011/2012 and 2012/2013 seasons.*

Treatments	Saturation percentage			
	2011/2012		2012/2013	
	before rain fall	after rain fall	before rain fall	after rain fall
T0	20.40	44.83	45.15	45.53
T1	24.13	46.80	28.82	43.20
T2	28.60	46.80	25.44	45.80
T3	21.47	43.27	34.19	43.50
T4	25.73	45.40	22.00	46.97
Over all	24.07	45.42	31.12	45.00

Except T_0 and T_1 in both seasons and T_4 in the first season and T_3in the second season bulk density (Bd) after rain fall was significantly lower than that before rainfall (Table 3). In the first season T_2, T_5 and overall showed a reduction in (Bd) after rainfall as compared to those before rainfall of 21.6%, 25.3% and 20.6%, respectively, whereas T_4 and the overall means in the second season for the same condition reduced this bulk density by 20.7%, 3.6% and 6.6%, respectively.

Table 3. *Bulk density (gm/cm^3) before and after rain fall under the different micro catchment techniques during 2011/2012 and 2012/2013 seasons.*

Treatments	Bulk density (gm/cm^3)			
	2011/2012		2012/2013	
	before rain fall	after rain fall	before rain fall	after rain fall
T0	1.65	1.48	1.74	1.60
T1	1.57	1.25	1.62	1.55
T2	1.67	1.31	1.69	1.34
T3	1.78	1.33	1.65	1.65
T4	1.81	1.35	1.67	1.61
Over all	1.70	1.35	1.67	1.56

Clay content in both seasons was not significantly affected by the water harvesting technique, except under T_4 in the second season and overall in both seasons (Tables 4). In the second season, T_4 treatment after rainfall had a significantly higher mean of clay content as compared to the before rainfall and the percentage of increase was 41.6%. On the other hand, after rainfall in both seasons clay content for overall effect of micro catchment techniques was significantly high as compared to that before rainfall and the percentage of increase was 7.3% and 21.8% for the first and second seasons, respectively.

Table 4 shows that silt percentage in both seasons was not significantly influenced by the water harvesting technique, except during the first season, in which the overall techniques before rainfall had significantly higher means as compared to that of the control.

Table 4. *Clay, silt and sand % before and after rain fall under different micro catchment techniques during 2011/2012 season.*

Treatments	before rain fall			after rain fall		
	Clay%	Silt%	Sand%	Clay%	Silt%	Sand%
T0	34.52	31.10	34.37	33.74	30.72	35.54
T1	32.90	32.31	34.79	38.22	30.82	30.95
T2	35.03	31.27	33.37	37.22	29.39	33.39
T3	35.33	25.80	38.87	36.99	25.25	37.76
T4	34.58	29.89	35.53	48.67	28.82	32.51
Over all	34.47	30.08	35.39	36.97	29.00	34.03

Table 5. *Clay, silt and sand % before and after rain fall under different micro catchment techniques during 2012/2013 season.*

Treatments	before rain fall			after rain fall		
	Clay%	Silt%	Sand%	Clay%	Silt%	Sand%
T0	32.65	27.02	40.33	32.06	27.08	40.86
T1	27.46	34.81	37.72	35.57	31.77	32.66
T2	27.60	35.82	36.58	35.85	33.25	30.90
T3	28.74	37.08	34.18	30.71	36.63	32.66
T4	34.08	29.36	36.56	49.19	24.86	25.95
Over all						

Effect of water harvesting technique on sand content (Table 4) was insignificant, except the effect of the overall techniques during the second season. (Table 4).

4. Discussion

The mean of the infiltration rate were lower under the micro-catchment techniques as compared to the control, but statistical analysis showed that only means of both T_1 and T_2 in the second season were significantly lower than the control. The lower mean infiltration rate under the micro-catchment techniques as compared to the control may be attributed to the land preparation for construction of these measures as well as the effect of these measures on accumulation of clay by rain water flow from the natural upslope area. Elboshra (2011) observed that both holes and crescents positively affected infiltration rate of the soil where the present study was conducted. However, Hillel (1982) and Hensly and Bennie (2003) stated that micro-catchment measures as tied ridge/bund, contour furrow/bund and bench terraces enhanced infiltration rate and soil moisture storage, while the conventional farming systems reduce infiltration due to compaction, soil crusting, hard pan formation and hence reduce water holding capacity.

Both clay contents and saturation percentage under micro-catchments technique increased in the micro-catchments as compared to the control, mainly under T_4. Capturing of clay material which was carried in the flowing water from the upslope area and accumulation of it in these catchments may be the reason of higher clay content under the micro-catchments mainly the V-shaped. The study also indicated that clay content relative to depths was increased in the catchments after rainfall as compared to that before rainfall particularly at 30 – 60 and 60 – 90 cm depths. This finding is in line with that of Ali and Yazar (2007) who observed that clay content slightly increased after rainfall with depth, while sand decreased with depth. Jianxin *et al.*, (2007) pointed out that micro-catchments gain higher moisture content due to the runoff collected and infiltration at each depth. On the other hand, the higher saturation percentage under the micro-catchments after rainfall as compared to that before rainfall may be attributed to the higher clay content in the catchments after rainfall.

The study also showed that silt, sand contents and bulk density were slightly reduced under the micro-catchments and depths after rainfall as compared to those before rainfall. The reduction in silt content in the catchments after rainfall as compared to that before rainfall may be attributed to the movement of these materials down the profile with the infiltrated water. Meanwhile the reduction in sand content under the micro-catchments after rainfall maybe due to the reduction of this substance at the soil surface during the micro-catchments construction as well as the reduction of soil erosion due to rain water runoff which was interrupted by these micro-catchments. The slight higher sand content under the control treatment after rainfall compared to that before rainfall may reflect the effect of rain water runoff on such substance when it carries out the clay and silt particles and leaving a rough soil surface.

5. Conclusion

The micro-catchment water harvesting techniques improve some soil physical properties.

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