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

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Abstract

The experiment was conducted at Khartoum New International Airport (KNIA), 40 kilometers south of Omdurman during 2010-2011 and 2011-2012 rainy seasons in an area of 5 hectares. Five water harvesting techniques namely, semi- circular water traps, V-shaped water dikes, pits, deep ditches and land without water harvesting technique were used. Soil analysis was also carried out including soil pH, electrical conductivity (E.C.), Ca^{++}, Mg^{++}, sodium (Na^{+}) contents and sodium adsorption ratio (SAR).The results showed that, with the exception of control and V-shape treatments in the first season and semi-circular, deep ditch and V-shape treatments in the second season, soil pH after rainfall was significantly higher than before rainfall. For Ec, with the exception of semi-circular, pits and deep ditch treatments in the first season, E.C. was significantly higher before rainfall as compared to after rainfall. Except the control and V-shape in the first season and control and deep ditch in the second season, Ca+Mg, Na^{+} contents and SAR were significantly lower after rainfall as compared to that before rainfall in both seasons.

Keywords

Micro-Catchment Techniques, pH, Electrical Conductivity, Sodium Adsorption Ratio

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1. Introduction

Rainwater harvesting is broadly defined as the collection and concentration of runoff for productive purposes such as crop, fodder, pasture or trees production, livestock and domestic water supply in arid and semi-arid regions (Fentaw *et al.*, 2002; Gould, 1999; Stott, 2001). For agriculture purposes, it is defined as a method for inducing, collecting, storing and conserving local surface runoff in arid and semi-arid regions (Prienz & Singh, 2001).Run-off is the portion of the precipitation which makes its way towards stream channels, lakes, seas or oceans (FAO, 1987). It is divided into surface, sub-surface and ground surface components (Duried, 1985).

Surface run-off develops either when rainfall intensity exceeds the infiltration capacity of the soil (Bache and MacAskill, 1984) or when the volume of rainwater exceeds the storage capacity of the soil (Dunne and Black, 1970). In the former mechanism surface run-off occurs before the soil has become fully saturated, so it is more appropriate on bare shallow soils and on upper slopes. While in the latter mechanism, surface run-off occurs after saturation of the soil, even with rainfall of low intensity and volume, because it

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occurs particularly in soils with shallow water tables. Thus, it is more likely on areas near drainage channels (Tauer and Humborg, 1992) or with topsoil layers overlying an almost impermeable subsoil or rock (Betson and Maruis, 1969). In both cases, run-off occurs on a partial area basis after the surface depressions are filled with water (Critchley and Siegert, 1991). For these reasons, short lived intense storms contribute more to run-off than the prolonged storms of low intensity (Hudson, 1967; Morgan, 1986). This is because in the former case the infiltration capacity of the soil is exceeded, whereas in the latter case most of the rainwater infiltrates into soil.

2. Materials and Methods

The experimental work was conducted at Khartoum New International Airport (KNIA) during 2010-2011 and 2011-2012 rainy seasons. The experiments covered an area of 5 hectares as a part of the airport which lies south of Omdurman city at a distance of 40 kilometers. The climate of the area is semi desert, which was characterized by high temperature 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 and 90 cm height. The distance between one trap and the other was 20 meters. The water dikes were composed of 3 units, and the dikes were 50 meters from the next unit of dikes.

(2) V-shaped water dikes (T_2): Each side was 30 meters long and at the bottom of the V-shaped dike the distance was also 30 meters. 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).

Soil analysis was also carried out in the laboratories of Al-Neelain University. Soil analysis covered soil pH, electrical conductivity (E.C), Ca^{++} and Mg^{++} content, sodium (Na^{+}) and sodium adsorption ratio (SAR).

3. Results

3.1. Soil pH

In the first season, Table (1) shows that soil pH under semi-circular, pits, and overall treatments after rainfall was significantly higher ($p \leq 0.01$) than before rainfall, whereas the reverse was true for deep ditch treatment, in which, pH was significantly higher ($p \leq 0.01$) before rainfall than after rainfall. On the other hand, soil pH under control and V-shape treatments was not significantly affected by the rainy season.

In the second season, soil pH before rainfall under the control, pits treatments and overall were significantly higher ($p \leq 0.05$) than after rainfall, whereas this character under the semi-circular, deep ditch and V-shape treatments was not significantly affected by rainfall (Table 1).pH after rainfall was lower under the control, semi-circular, pits, deep ditch, V-shape and overall as compared to its values before rainfall by about 4%in the first season and 3.84, in the second season, respectively.

3.2. Electric Conductivity E.C. *(ds/m)*

In the first season E.C. was significantly higher ($p \leq 0.05$) before rainfall under the V-shape and overall ($p \leq 0.01$) treatments as compared to after rainfall, whereas it was not significantly affected by the rainy season for the control, semi-circular, pits and deep ditch treatments (Table 2). On the other hand Ec. was significantly greater ($p \leq 0.05$) before rainfall for control, pits and deep ditch, and significantly greater ($p \leq 0.01$) for semi circular, V – shape and overall in the second season. Ec. after rainfall was lower under the control, semi-circular, pits, deep ditch, V-shape and overall as compared to its values before rainfall by about 16.6%, 38.4%, 51.8%, 52.8%, and 80.2%, respectively in the first season (Table 2).

3.3. Ca+Mg Content *(mmol/L)*

Except the control and V-shape in the first season and control and deep ditch in the second season Ca+Mg content was significantly ($p\leq 0.05$) for deep ditch in the first season, ($p\leq 0.01$) for semi circular, pits and overall in the first season, and for semi circular, pits, V - shape and overall in the second season, lower after rainfall as compared to that before rainfall (Table 3).

In the first season the reduction in Ca+Mg content after rainfall as compared to that before rainfall for semi-circular, pits, deep ditch, V-shape and overall treatments was 74.3%, 53.4%, 55.0%, 69.8% and 56.0%, respectively, whereas the reduction in the second season was 62.4%, 57.8%, 26.8%, 69.1% and 45.4%, respectively (Table 3).

3.4. Na^+ Content *(mmol/L)*

In both seasons Na^+ content was lower after rainfall as compared to that before rainfall for all treatments. This reduction was significant ($p \leq 0.05$) under semi-circular and pits and ($p \leq 0.01$) overall for the first season, semi-circular, deep ditch, V-shape and overall for the second season (Table 4). The reduction in Na^+ content after rainfall in comparison to that before rainfall in the first season for the control, semi-circular, pits, deep ditch, V-shape and overall was 86.5%, 97.6%, 94.15, 90.2%, 96.8% and 93.4%, respectively, while it was 8.5%, 46.5%, 42.5%, 45.2%, 75.1% and 42.5% in the second season for the same treatments, respectively (Table 4).

3.5. Sodium Absorption Ratio (SAR)

For all treatments in both seasons, SAR value was low after rainfall as compared to that before rainfall. The reduction was significant ($p \leq 0.05$) under semi-circular and pits in the first season, semi-circular and deep ditch in the second season and at ($p \leq 0.01$) level for overall in the first season, V-shape and overall in the second season (Table 5). The percentage of reduction in SAR after rainfall for the control, semi-circular, pits, deep ditch, V-shape and overall as compared to that before rainfall was 88.3%, 95.2%, 91.3%, 85.0%, 94.8% and 90.4% for the first season, while in the second season for the same treatments it was 6.0%, 12.8%, 11.6%, 35.4%, 55.3% and 24.9%, respectively (Table 5).

4. Discussion

Almost after rainfall in both seasons, soil pH, Electric conductivity (Ec.) Ca^{++}, Na^+ and Sodium Absorption Ratio (SAR) were significantly reduced under most of the micro catchments. This may be due to the surface distribution of salt accompanied with water. This is supported by the results obtained by Singh *et al.*, (2012) who was showed that both soil pH and Ec. under four micro catchments were reduced as compared to the control.

The increase in pH values in the first season may be due to the dissolved carbonates which increase the pH over time by neutralizing H^+ ions in the solution as mentioned by Oster *et al.*, (1999).Also, may be due to the large amount of free carbonates which resisted any decline in soil pH as mentioned by Schleiff, (2006).Whereas, the reduction in pH values in the second season may be due to the reason that saline-sodic soil, during a leaching process, undergoes the following changes: reduction of salts, substitution of exchangeable Na^+ by Ca^{++} supplied by calcite dissolutionas mentioned by Lebron *et al.,* (1994).The decrease in SAR may be due to decreasing Ca^{2+}: Na^+ ratio in the soil solution as it moved down the profile displacing exchangeable Na^+ as mentioned by Hussain *et al*., (2001).

The reduction in Ec was the result of leaching of salts by water as mentioned by Miyamoto *et al.,* (1986) who said that, to prevent excessive salt accumulation in the soil, it is necessary to remove salts periodically by application of water in excess of the consumptive use. He also mentioned that, the excess water applied will remove salts from the root zone provided that the soil has adequate internal drainage which allows salts to be leached below the root zone.

Table (1). Comparison between pH before and after rainfall as affected by micro catchment treatments during 2011/2012 and 2012/2013 seasons

treatments	d.f	First season 2011/2012					Second season 2012/2013				
		pH. before rainfall	pH. after rainfall	S.E±	t. value	Sig.	pH. before rainfall	pH. after rainfall	S.E±	t. value	Sig.
T0	4	7.51	8.08	0.14	3.93	ns	7.52	7.44	0.01	7.21	*
T1	4	7.46	8.07	0.06	10.73	**	7.45	7.55	0.25	0.39	ns
T2	4	7.55	7.96	0.04	9.41	**	7.57	7.01	0.12	4.85	*
T3	4	7.66	7.40	0.02	10.96	**	7.60	7.45	0.15	1.03	ns
T4	4	7.50	7.65	0.06	2.25	ns	7.70	6.98	0.23	3.08	ns
Over all	28	7.53	7.83	1.08	19.79	**	7.57	7.29	0.11	2.71	*

Table (2). Comparison between Ec (ds/m) before and after rainfall according to treatments obtained during 2011/2012 and 2012/2013 seasons

treatments	d.f	First season 2011/2012					Second season 2012/2013				
		Ec. before rainfall	Ec. after rainfall	S.E±	t. value	Sig.	Ec. before rainfall	Ec. after rainfall	S.E±	t. value	Sig.
T0	4	1.43	0.34	0.52	2.09	ns	2.11	1.76	0.06	5.88	*
T1	4	1.70	0.17	0.66	2.34	ns	1.38	0.85	0.04	14.20	**
T2	4	1.57	0.27	0.51	2.54	ns	1.95	0.94	0.16	6.37	*
T3	4	1.53	0.23	0.46	2.82	ns	1.80	0.85	0.13	7.15	*
T4	4	2.03	0.32	0.30	5.64	*	2.17	0.43	0.15	11.29	**
Over all	28	1.65	0.27	0.20	6.98	**	1.88	0.97	0.62	6.71	**

Table (3). Comparison between Ca+Mg *(mmol/L)* content before and after rainfall for the different treatments during 2011/2012 and 2012/2013 seasons

treatments	d.f	First season 2011/2012					Second season 2012/2013				
		Ca+Mg. before rainfall	Ca+Mg. after rainfall	S.E±	t. value	Sig.	Ca+Mg. before rainfall	Ca+Mg. after rainfall	S.E±	t. value	Sig.
T0	4	3.50	3.67	2.05	0.08	ns	5.62	5.33	0.08	3.53	ns
T1	4	5.83	1.50	0.33	13.00	**	6.03	2.24	0.31	12.33	**
T2	4	5.00	2.33	0.17	16.00	**	5.17	2.18	0.22	13.51	**
T3	4	3.33	1.50	0.33	5.50	*	4.25	3.11	0.38	2.99	ns
T4	4	8.83	2.67	3.22	1.92	ns	5.67	1.75	0.16	25.39	**
Over all	28	5.30	2.33	0.87	3.41	**	5.35	2.92	0.40	6.05	**

Table (4). Comparison between Na^+ *(mmol/L)* content before and after rainfall for the different treatments during 2011/2012 and 2012/2013 seasons

treatments	d.f	First season 2011/2012					Second season 2012/2013				
		Na. before rainfall	Na. after rainfall	S.E±	t. value	Sig.	Na. before rainfall	Na. after rainfall	S.E±	t. value	Sig.
T0	4	5.40	0.73	2.16	2.16	ns	13.14	12.03	0.38	2.93	ns
T1	4	8.33	0.20	1.94	4.19	*	10.12	5.41	0.30	15.86	**
T2	4	9.43	0.56	1.53	5.80	*	9.56	5.50	1.02	3.98	ns
T3	4	9.90	0.97	4.48	1.99	ns	12.52	6.86	0.62	9.20	**
T4	4	8.10	0.26	2.45	3.20	ns	11.55	2.88	0.67	13.01	**
Over all	28	8.23	0.54	1.11	6.93	**	11.38	6.54	0.70	6.94	**

Table (5). Comparison between SAR before and after rainfall for the different treatments during 2011/2012 and 2012/2013 seasons

treatments	d.f	First season 2011/2012					Second season 2012/2013				
		SAR. before rainfall	SAR. after rainfall	S.E±	t. value	Sig.	SAR. before rainfall	SAR. after rainfall	S.E±	t. value	Sig.
T0	4	6.32	0.74	2.47	2.26	ns	11.14	10.47	0.31	2.14	ns
T1	4	6.89	0.33	1.58	4.15	*	8.26	7.20	0.20	5.32	*
T2	4	8.41	0.73	1.22	6.27	*	8.39	7.42	0.64	1.52	ns
T3	4	10.54	1.58	4.45	2.01	ns	12.09	7.81	0.86	5.01	*
T4	4	6.73	0.35	2.11	3.02	ns	9.71	4.34	0.36	15.00	**
Over all	28	7.78	0.75	1.04	6.77	**	9.92	7.45	0.56	4.40	**

n.s: Not significant.
*: significant at 0.05 level of probability.
**: significant at 0.01 level of probability.
T_0= control; T_1= semi-circular; T_2= pits; T_3= deep ditch; T_4= V-shape.

5. Conclusions

1. The soil pH for the semi-circular and pits treatment increased after rainfall in the first season while it decreased for the deep ditch treatment. The pH was not affected during the second season.
2. The electrical conductivity (E.C.) of the soil was found to be lower after rainfall in all the treatments.
3. The calcium and magnesium (Ca^{++}+mg^{++}) content in the soil decreased after rainfall in all the treatments for the two seasons.
4. The sodium (Na^+) content and sodium adsorption ratio (SAR) values lowered after rainfall in all the treatments in both seasons.

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