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Effect of Cultivation on Some Soil Attributes of a Long-term Pastoral Land in the Semi-arid Tropics of Sudan

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Abstract: Cultivation may have various effects on soil properties and could therefore be a useful guide of soil quality indices. This study was conducted to determine the effects of more than 20 years cultivation of pastoral lands on selected soil chemical [pH, SOM and TN] and physical properties [particle size distribution (PSD), bulk density (BD), dry aggregate stability (DAS) and saturation percentage (SP)]. Samples (0-20, 20-40 and 40-60 cm) were taken from eight profiles of a cultivated and grazed land. In the top 0-20 cm soil depth, SOM in the pastoral land (6.3 g kg^{-1}) was significantly (P £ 0.01) double that under cultivated pasture (3.5 g kg^{-1}), TN in pastoral land (0.35 g kg^{-1}) was also significantly (P £ 0.01) higher than that under cultivation (0.26 g kg-1), DAS in the pastoral land (543 g kg^{-1}) was significantly (P £ 0.01) higher than that under cultivation (306 g kg^{-1}). However, soil pH, SP, clay and sand contents in all depths were not affected by cultivation, though pH values determined in pastoral lands were consistently lower. Under pastoral land, BD was significantly (P £ 0.01) lower than that determined under cultivated pasture. It is concluded that conversion of pastoral land to arable lands may subject the soil to depletion of OM and TN, decrease in DAS and increase in BD, thereby, rendering the surface layer to degradation due to crust formation and erosion and may also raise concern about future sustainability.

Key words: Management, degradation, grazing and soil properties

INTRODUCTION

Grasslands are the natural biome in many dry lands, partly because rainfall is insufficient to support trees, and partly because prevailing livestock management systems that encourage their sustainable use are poor. Grassland when subjected to control grazing, generally have higher soil carbon levels than cropped land[11] and also higher structural stability[19]. Due to the rising demand for food, exotic varieties of cereals are replacing the traditional varieties at the expense of grasslands and this further causes genetic erosion[9]. The use of annually sown pastures to provide forage is common in many regions of the world, such as in Butana of the Khartoum State, Sudan. The evaluation of changes in soil organic matter (SOM) due to land use and mismanagement is needed to identify adequate strategies to increase agricultural production without soil degradation and without increasing emission of green house gases (CO_2, CO, N_2O and NH_4).

Pasture soils could potentially sequester large amounts of atmospheric C in soils compared to cultivated soils[6]. Sustainable pasture was defined as a well managed pasture that is adapted to the soil, climate and livestock system is more likely to survive drought than is a pasture that is poorly matched to the environment is in appropriately managed[22]. Blank and Fosberg[2] stated that when grasslands are tilled for crop production, and during years of subsequent tillage, mineralization of SOM causes significant reduction in soil organic carbon (SOC). Also, it was reported by Mubarak *et al.*[20] that cultivation in semi-arid tropics (for more than 50 years) is known to decrease SOC by 59%.

In the eastern State of Khartoum, appreciable grasslands areas have been converted to cropland. Attempts o estimate changes in soil quality of these areas were greatly lacking. Therefore, the aim of this study was to evaluate the effects conversion of grasslands to arable land on some soil quality attributes.

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MATERIALS AND METHODS

Site Description: Khartoum State (15°47 N 32°43 E) is the capital of Sudan and constitutes of three States: mainly Khartoum (15° 37' N 32° 33' E), Khartoum North (15° 38 N, 32° 38 E) and Omdurman (15° 40 N, 32° 28 E). This study was conducted in Hedibab Scheme (15º 30` N 33º 8`E), which is located in the Butana scheme of about 45 km south east of Khartoum North. This scheme was used to be a pastoral land (grasses, scattered trees e.g. *Acacia tortitlis*, *Acacia raddiana*, and shrubs and herbs e.g. *Cenchrus ciliaris*, *Cassia senna*). Since 1980 part of the scheme was converted to arable land for the production of rain-fed fodder sorghum (*Sorghum bicolor*) where tillage operations included disc plowing, harrowing, leveling and ridging. According to the Soil Survey Staff (1996), the soil of the site (i.e both the pastoral and cropped lands) was classified as loamy, typical orthid (Table 1).

Climate: Khartoum State lies in the semi-desert region of the country. The climate of the area is arid with hot dry summer (March-June), low rain fall (100-300mm/ year) mainly falls during July to October and dry cold winter season (November-February). The maximum mean annual temperature in the area ranges between 32.1ºC in January and 41.9ºC in May, while the minimum mean temperature ranges between 15.7ºC in January and 26.8ºC in June. The relative humidity values are low (14-27%) and reflect the aridity of the climate during most months of the year (October-June), and they are relatively high (31-51%) during the period between July and September.

Soil Samples Collection, Preparation and Analysis: In both the pastoral and cropped lands, four areas (i.e. four real replications) of 1 ha each are selected for soil sampling. In each replication, samples were collected by digging four profiles (60cm wide, 80cm length and 60cm deep) in the pastoral land and similar profiles in the cropped land. Samples were taken carefully from each profile at an interval of 0-20, 20-40, and 40-60cm depth using a tray and a hammer with shunted head. The samples were transferred to the laboratory inside labeled bags for analysis.

Soil samples were air-dried, and divided into two parts. The first part was crushed and sieved through a 2mm sieve for the determination of organic carbon[21], total nitrogen[4], $pH_{(paste)}$ (digital pH-meter), SP and particle size distribution[11]. The second part was left without disturbance for determination of dry aggregate stability[16] and bulk density[3]. The t-test[23] was used to detect statistical variations in soil quality indices between pastoral and cropped lands.

RESULTS AND DISCUSSION

Effect of Cultivation on Soil Properties: Table 2 shows effects of cultivation on changes in pH, OC, TN, DAS, BD, SP and PSD. Across all depths, conversion of pastoral lands to arable lands showed no significant effects on pH, SP and PSD. Content of OC was significantly lower in arable land compared to pastoral lands. It was reduced by 44%, 40% and 36% for the 0-20 cm, 20-40 cm and 40-60 cm soil depths, respectively. Similarly, TN was significantly reduced by 26%, 30% and 35% for the 0-20 cm, 20-40 cm and 40-60 cm soil depths, respectively. Dry aggregate stability (DAS) was also significantly lower in arable lands compared to pastoral land by about 34%, 33% and 9% for the 0-20 cm, 20-40 cm and 40-60 cm soil depths, respectively. However, across all depths, BD was significantly increased (by 17% to 14%) due to cultivation of pastoral lands. Annual pasture involving conventional tillage results in a substantial loss of soil organic matter, soil microbial activity and soil physical condition[19,20,25]. This is probably due to tillage-induced breakdown of organic material[10]. Ghani *et al.*[13] reported that grass land maintained the greatest SOC compared to arable cropping. Many studies reported that TN in pastoral soils was greater than cropped soils of similar types (e.g.[13,26]). Cleik[5] reported 45% reduction in SOM when pasture was converted to cultivation while Xiao-gang *et al.*[29] reported 26-42% lower SOC and 10-18% lower TN.

Several studies have investigated soil physical quality under pastoral grazing (e.g.[1,7,18]). Some studies showed increased BD with grazing under grass or cereal forage grazing[17,28] or decrease[8] depending on grazing type, animal and season.

Since organic matter is central to the formation and stabilization of soil aggregates[27], there is normally a close correlation between soil organic matter content and water stable aggregation[14]. Increase in DAS could possibly be due to the production of binding carbohydrates which are not water extractable[15] .

In general, the study area is characterized by a slight slope towards the River Nile, thereby the conversion of pastoral lands into arable land would possibly hastens topsoil removal through runoff. Accordingly, this may subject the soil to depletion of OM and TN, decrease in DAS and increase in BD, and may also raise concern about future sustainability.

Table 1: Some selected soil chemical and physical properties of the study site (0-30 cm)

Location	pH	TN g kg^{-1}	OC	DAS g kg^{-1}	BD t m^{-3}	Sand g kg^{-1}	Silt	Clay	Texture
pastoral land	7.33	0.42	6.0	697	1.35	568	99	333	Loam
Cultivated pastoral land	7.54	0.30	4.0	303	1.44	617	101	282	Loam

TN: total nitrogen, OM: organic carbon, DAS: dry aggregate stability, BD: bulk density

Table 2: Effect of cultivation on soil properties of a pastoral land (average ± standard deviation, n=4)

Location	pH g kg^{-1}	OC	TN	DAS	SP	Clay	Sand	Silt	BD t m^{-3}
				0-20 cm					
Pastoral land	7.4±0.2	6.3±0.5	0.35±0.01	543±134	730±92	308±38	585±38	107±10	1.39±0.04
Cultivated pastoral land	7.6±0.1	3.5±0.9	0.26±0.01	360±64	757±67	319±28	578±26	103±7	1.44±0.02
Probability	P£0.13	P£0.001	P£0.01	P£0.01	P£0.68	P£0.66	P£0.78	P£0.59	P£0.01
				20-40 cm					
Pastoral land	7.6±0.3	5.8±1.2	0.33±0.02	433±91	728±63	306±27	591±31	103±6	1.40±0.05
Cultivated pastoral land	7.7a±0.1	3.5±1.2	0.23±0.04	291±73	823±36	346±15	549±11	105±7	1.46±0.0
Probability	P£0.5	P£0.01	P£0.01	P£0.01	P£0.09	P£0.08	P£0.12	P£0.72	P£0.01
				40-60 cm					
Pastoral land	7.7±0.4	5.5±1.7	0.31±0.01	362±61	750±82	316±34	580±36	104±4	1.41±0.05
Cultivated pastoral land	7.8±0.1	3.5±1.2	0.20±0.0	329±92	735±37	310±15	585±13	105±2	1.48±0.03
Probability	P£0.5	P£0.01	P£0.01	P£0.01	P£0.6	P£0.59	P£0.70	P£0.54	P£0.01

TN: total nitrogen, OM: organic carbon, DAS: dry aggregate stability, BD: bulk density, SP, saturation percentage.

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