Impact of Land Use System of Some Land Degradation Indicators in Atbara, River Nile State

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ABSTRACT

This study was conducted in Atbara Food Security Scheme, River Nile State (lat 16°-22° N and long 32°-36°E), to assess the impact of adopted management systems: crop rotation, irrigation methods, addition of fertilizers, fodder and trees species, on land degradation using some biophysical, climate, physical, chemical and biological indicators of soil properties, species of vegetation cover, salinity, sodality and land productivity. Forty-five soil samples were collected from three farms of different systems and an uncultivated site (control). Also, water samples were taken from the main irrigation canal coming from the River Nile and well used for drinking. Statistical analysis revealed significant ($P \leq 0.05$) differences in some of the soil properties. The results showed that adopted land use systems have a positive impact on land quality by increasing the organic mater content and reducing sand content in the cultivated area as compared with the uncultivated site. The study showed the high suitability of the canal water for irrigation (ECe = 0.157 dS/m, pH, = 8.03). The characteristic of the drinking water in the study area fell within the recommended level of WHO (RSC=1.20).

Key words: Assessment; biophysical indicators; degradation; desertification; land use; management; soil properties

INTRODUCTION

The Substantive analysis of land use systems and patterns and their implication for sustainable development is crucial. Bearing in mind the future status of land resources has important development and human well–being implications. Such analysis requires along time frame and need to incorporate uncertainty. Arable lands are limited through it is imperative to conserve them through sustainable land use. Dry lands are subjected to human induce accelerated desertification processes that reduce their productive capacity and there by constrain their sustainable use (Mustafa, 2008).

The Northern region (North and River Nile States) are severely affected by desertification processes. Moreover, the River Nile State is one of the thirteen States in Sudan affected by desertification (Salih, 1996). The region lies in arid and semi – arid zones. There are two main soil orders along the banks of River Nile, Entisols on the first terrace and Aridsols at the second and third terraces away from the Nile. Entisols form a narrow stripe of recent alluvial fertile soils that are not salt affected, but they adversely affected by gully erosion at the river side, (Salih, 1994, and SSA, 1976). The suitable land of the flood plain, in the northern region has already been developed. Accelerated land degradation results from miss management of land and generally reflects the mismatch between land use patterns and land quality. Ineffective land use planning and management can only lead to over exploitation of resources and contributing to increase land degradation, salinization, soil erosion and determination of fragile ecosystems. Upper lands of the river Nile state have been subjected to extensive practices of land use system which may aggravate the degradation in the area. This paper tackled the impact of land use systems on some land degradation indicators in Atbara, River Nile State.

MATERIALS AND METHODS

The study area lies between latitude (16°-22°N) and longitudes (32°-35°E). The area of the Nile State is amounting to 11.000 $km^2$and locates in the dry zone where the average annual rainfall ranges from zero to 100 mm (Tayfur, 2006).The metrological records indicated the occurrence of long dry season extending from November to April. Very little precipitation received usually in May and June. Mean daily maximum temperature 47°C in May and the mean minimum temperature 8.5°C in January. The lowest relative humidity 22 % recorded in May and the highest 40% in December. The lowest evaporation was 13.5 ml in January and 20.7 ml in June. Wind velocity reaches 7 m/ h during the period from November to February and about 4m/h in the rest of the year. The strong wind (habob) coming from south east may below for 12 hours in April and May with a heavy load of dust and sand. The lands of river Atbara are free hold land acquired through inheritance, high riverains lands are government high terraces lands are allocated to neighboring village- cultivators. The population of the state is approximately 905.000. The privately owned farms (in the flood plains) have developed into an extremely complex land distribution pattern with considerable fragmentation of fields.

The River Nile State is an extremely arid area which can be classified as true desert, semi-desert and desert scrub (Harrison and Jackson, 1958). In the desert zone, the vegetation is, virtually absent, except along the Nile bank and water courses where ephemeral herp and grasses occur after rainfall. In the basin and along the Nile bank, along courses away from the river banks (wadies), the seasonal river Atbara, Acacia species are found. In upper terraces, shrubs, *Calotropis procera*, *Capparis decidua* and *Leptadenia pyrotechnica* are also found

According to COWI consult (1990) there are five main geological units present in River Nile State, superficial desert deposits (quaternary and recent deposits) and of special concern moving sand in the form of sand dunes.

Alluvial deposits of the Nile and main wadis (quaternary and recent deposits) the alluvial deposits of the Nile which occur in the site between Muberika north Barber and on the Nubian formation or on the crystalline basement. Nubian Sand stone formation 70-80 % of the formation consist of fine sand to gravely sand and 20-30% consist of layers of silt sand stone, silt stone and mud stone, this type occurs in the state from south of Shandi to Muberika crystalline basement complex underlies the Nubian Sand stones formation and out-crops at the surface in the northern part of the Bayuda desert and the eastern part of Nubian desert. The Nile traverses this complex from Mubesika to Kerima. Basalt occurs in both Nubian formation and in the crystalline complex in Bayuda desert. The soil is (classified as Arid soils) type Natrargids, Atbara series (SSA, 1976).

Soil samples were collected by auger from three cultivated farms and uncultivated site as control. The cultivated farms are the following: site (1) crop, site (2) vegetable, site (3) fodder and site (4) control. Soil samples were taken from three depths: 0-30cm, 30-60 cm and 60-90 cm, with a distance between each hole of 50 m along 150 m and three replicates were obtained. The farms were irrigated from the main canal.

Two water samples were collected from the main irrigation canal and a well for drinking water in the first farm. Site 1 Salah, site 2 Omer, Site 3 Arabic company farms and Site 4 uncultivated areas (control). Irrigation system is central pivot. Suitable methods (Black *et al.,* 1965 and Bower *et al.,* 1952) were used for biophysical and chemical analysis such as: soil texture, exchangeable cautions, and soluble anions, N, CEC, ECe, OM, SAR, ESP and RSC. The soil and water analysis results were subjected to analysis of variance (ANOVA) to determine statistical difference between means by (SAS).

RESULTS AND DISCUSSION

Soil properties

The obtained results of physical and chemical analysis of the soil, in Atbara Food Security scheme, reflected the alkaline reaction of sites, where pH ranged between 7.56 and 8.28 (Table1) in all sites but there were significant differences ($P \leq 0.05$) of pH among all sites. The lowest pH value was recorded in site (3) in depth (60-90 cm) with pH mean of (7.56) and the highest value (8.29) in site (2) depth (30-60). Values in the same rows followed by similar letters are not significantly different ($P \geq 0.05$) using least significant difference (LSD). The ECe values were significantly different ($P \leq 0.05$) among sites at all depths. The highest ECe value (6.3dS/m) was recorded in site 3 at the 0-30 cm depth which reflects the accumulation of salts, while the lowest value (0.37 dS/m) was recorded in site 1 at the 30-60 cm depth, which indicates leaching of salts from this layer (Table 2).

Na^+ in different sites and depths:

Soil sodium content showed significant differences among sits at depths of 0-30 cm and 60-90 cm. The highest Na^+ value (26.20 meq /l) was recorded in site 3 at the 0-30 cm depth, whereas the lowest value (4.56 meq/l) was found in site 1 at the 30-60 cm depth. High Na content found in site 3 in the plough layer indicates strongly saline (Table 3).

K^+ in different sites and depths:

The K^+ was not significantly different among sites and along depth, the highest value (0.21 meq/l) was recorded in site 3 at depth (0-30cm) and lowest value (0-06 meq/l) was found in site (1) at depths (30-60 cm) and (60-90 cm). The results of Calcium (Ca^{++}) showed significant differences ($P \leq 0.05$) between cultivated sites and the control at depths (0-30cm) a (60-90m), while there was no significant difference between site (3) and (4) at depth (60-90cm) and the highest value was recorded in site (2) at depth (0-30cm), Table (5). The potassium status in the soils generally is normal.

Mg^{++} in different sites and depths.

There was no significant difference in magnesium content ($P>0.05$) between the sites at depths of 0-30cm and 30-60m. However, at the lower depth (60-90cm) there was significant difference between the cultivated sites and the control where 6.33 meq/l was recorded in site 3 at 0-30 cm depth, while site 1 recorded the lowest value (0.53meq/l) at the depth of 60-90cm (Table 6).

CEC in different sites and depths

The CEC showed no significant differences among sites at depths of 30-60m and 60-90m, meanwhile at depth of 0-30m of site 1)and site 3 recorded the highest CEC value (58.20meq/100g soil) at depth of 0-30cm, while site 2 recorded the lowest value (38.23meq/100g soil) at depth of 0-30cm (Table 7).

Calcium carbonate ($CaCO_3$) in different sites and depths

The $CaCO_3$ content reflected significant differences ($P \leq 0.05$) between all sites including uncultivated site (control) along different depths. The highest $CaCO_3$ content (7.22%) was recorded in site 4 at depth of 60-90cm and the lowest (4.19%) was found in site 1 at the depth of 60-90cm and site 3 at depth of 30-60cm. This indicates the calcareous condition of the soil (Table 8).

SAR in different sites and depths:

Table 9 shows that the values of SAR were not significantly different ($P>0.05$) among sites at the 60-90 cm depth. The highest SAR value (19.32) was recorded in site 3 at the depth of 0-30cm and this may be attributed to sodic pocket in this site, while the lowest value (4.86) was found in site 1 at the 60-90 cm depth.

Exchangeable sodium percentage (ESP) in different sites and depths

The results of EPS showed no significant differences (P>0.05) among sites at depths of 0-30cm and 30-60cm, whereas in the 60-90 cm depth, there were significant differences between site 2 and site 3 as shown in Table 10. Accordingly, salinity may be described to range between moderate to strong.

Organic matter in different sites and depths

The results of organic matter (OM) showed that the highest percentage (0.55) was found in the 0-30 cm depth of site 1 and indicated significant difference (P≤0.05) from other sites in including the control. Moreover, the other depths showed no significant differences among sites. The lowest value of OM (0.09%) was recorded in site 4 at the 60-90 cm depth (Table 11).

C/N ratio in different sites and depths:

The results of C/N ratio (Table 12) reflected no significant difference at (P≥0.05) among different sites and depths. The highest C/N (4.66) was recorded in site 1 at the 60-90 cm depth, while the lowest ratio (1.11) was found in site 4 at depth of 30-60cm. In general, the C/N ratio indicated the low fertility of the soil.

Water characteristics:

The water from main irrigation canal which came from the main River Nile and underground water were used for drinking and sometimes for irrigation in the study area. The ECe values showed significant differences between the two water sources (Table 13). The irrigation water of the canal showed the minimum ECe value (0.16ds/m) while the drinking water showed the highest ECe value (0.33 ds/m). The average pH in the canal water and ground water reflected slight salinity. Also, SAR of irrigation water was 1.52 while in drinking water reached a value of 1.96, although results showed no significant differences (P>0.05). Moreover, the RSC showed no significant differences between the canal water and underground water with average values of 0.73 and 1.20, receptively

Land use systems have their impact on land degradation that could be understood through some biophysical indicator such as physical chemical and biological deterioration of soil, range land, forest and agricultural areas. Assessment of land degradation based on the biophysical indicators was adopted by CSD (1992) and suggested by AOAD (2002). Arid zone soils are generally salt affected soils due to low precipitation, low moisture content and high temperature. According to the results of the studied sites could be classified as follows:

Site (1) none saline soil

Site (2) none saline soil
Site (3) saline soil
Site (4) none saline soil

On this basis of agricultural practices, Site 1 could be considered the most appropriate to the environment than other sites and this can be attributed to the type of tillage used in which the previous crop residues were incorporated. The study area is characterized by the presence of considerable quantity of $CaCO_3$ and the bare land (site 4) recorded the highest percentage (6.72) at the depth 30-60cm.

Mustafa (2007) stated that the scarcity of rainfall and dry climate hindered the natural leaching of salts, which resulted in accumulation of calcium carbonate.

According to Blot and Brunggenwert (1976), the typical C/N ratio are in the range of 8/1-15/1, the result showed that C/N ratio in all sites was below the typical values, where the highest C/N was in site 1 at the depth of 0-30cm. The low ratio of C/N reflects the depletion of fertility of these soils.

CONCLUSIONS

The land use practices in the study area consisted of fodder production, cultivation of wheat and vegetables in small area, in addition to animal and poultry production. The diversity of crops and rotation led to diverse soil flora and fauna as the roots excrete different organic substances that attract different types of bacteria and fungi, which play important role in transformation of these substances to provide plant with available nutrients. The uncultivated site was affected by sand encroachment therefore the adopted land use practices may protect the cultivated areas from sand creeping. The canal water is suitable for irrigation than underground water, which used as secondary source of irrigation by few farmers. Some of desertification factors and indicators of land degradation are prevailing in the study area. The impact of land degradation in the areas could be considered as not completely negative, and it can be derive to more positive areas by adoption of appropriate planed land use systems patterns. Application of biophysical indicators is useful for monitoring land degradation and desertification.

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Table 1. pH in different sites and depths

Sites/depths	Site (1)	Site (2)	Site (3)	Site (4) Control
0-30 cm	7.59 [b]	8.16[a]	7.64[ab]	7.61[b]
30-60 cm	8.02 [a]	8.29[a]	7.67[b]	7.64[b]
60-90 cm	7.94 [ab]	8.19[a]	7.56[c]	7.71[b]

Table 2. ECe in different sites and depths

Sites/depths	Site (1)	Site (2)	Site (3)	Site (4)
0-30 cm	0.67[c]	0.69[c]	6.3[a]	1.3[b]
30-60 cm	0.30[c]	1.65[a]	1.58[a]	0.85[b]
60-90 m	1.61[a]	0.43[c]	1.76[a]	1.30[b]

Table 3. Na^+_ in different sites depths

Sites/depths	Site (1)	Site (2)	Site (3)	Site (4)
0-30 cm	5.21[a]	8.90[c]	37.00[a]	13.05[a]
30-60 cm	7.01[a]	4.56[a]	10.63[a]	10.00[a]
60-90 m	4.62[b]	7.18[b]	29.50[a]	5.30[a]

Table 4. K^+ in different sites and depths

Sites/depths	Site (1)	Site (2)	Site (3)	Site (4)
0-30 cm	0.08[a]	0.10[a]	0.21[a]	0.13[a]
30-60 cm	0.06[a]	0.10[a]	0.09[a]	0.07[a]
60-90 m	0.06[a]	0.08[a]	0.12[a]	0.16[a]

Table 5. Ca^{++} in different sites and depths

Sites/depths	Site (1)	Site (2)	Site (3)	Site (4)
0-30 cm	1.40[c]	0.90[c]	14.40[a]	3.90[b]
30-60 cm	1.27[b]	1.13[b]	2.40[ab]	3.40[a]
60-90 m	1.27[b]	1.00[b]	1.30[b]	5.00[a]

Table 6. Mg^{++}in different sites and depths

Sites/depths	Site (1)	Site (2)	Site (3)	Site (4)
0-30 cm	0.087[a]	0.87[a]	6.33[a]	2.00[a]
30-60 cm	0.60[a]	0.57[a]	2.80[a]	1.87[a]
60-90 m	0.53[b]	0.70[b]	1.53[b]	3.87[a]

Table 7. CEC in different sites and depths

Sites/depths	Site (1)	Site (2)	Site (3)	Site (4)
0-30 cm	52.93[a]	38.23[b]	58.20[a]	40.90[b]
30-60 cm	44.73[a]	51.87[a]	56.43[a]	48.27[a]
60-90 m	55.83[a]	45.23[a]	55.47[a]	43.40[a]

Table 8. $CaCO_3$ in different sites and depths

Sites/depths	Site (1)	Site (2)	Site (3)	Site (4)
0-30 cm	5.13[b]	5.08[b]	4.22[c]	6.44[a]
30-60 cm	4.83c[b]	5.31[b]	4.19[c]	6.72[a]

60-90 m	4.19[b]	4.50[b]	4.44[b]	7.22[a]

Table 9. SAR in different sites and depths

Sites/depths	Site (1)	Site (2)	Site (3)	Site (4)
0-30 cm	4.89[a]	8.59[b]	19.32[a]	8.5a[b]
30-60 cm	7.26[ab]	8.59[a]	5.50[b]	6.84[ab]
60-90 m	4.86[a]	6.81[a]	9.11[a]	4.92[a]

Table 10. ESP in different sites and depths

Sites/depths	Site (1)	Site (2)	Site (3)	Site (4)
0-30 cm	5.61[a]	21.16[a]	6.29[a]	6.81[a]
30-60 cm	5.76[a]	14.96[a]	10.25[a]	8.66[a]
60-90 m	7.28[ab]	13.99[a]	9.43[ab]	10.52[ab]

Table 11. OM in different sites and depths

Sites/depths	Site (1)	Site (2)	Site (3)	Site (4)
0-30 cm	0.55[a]	0.329[b]	0.24[b]	0.18[b]
30-60 cm	0.26[a]	0.15[a]	0.32[a]	0.12[a]
60-90 m	0.25[a]	0.23[a]	0.27[a]	0.09[a]

Table12. C/N ratio in different sites and depths

Sites/depths	Site (1)	Site (2)	Site (3)	Site (4)
0-30 cm	3.56[a]	1.94[a]	1.69[a]	3.01[a]
30-60 cm	1.94	1.68[a]	2.97[a]	1.11[a]
60-90 m	4.66[a]	2.30[a]	1.83[a]	1.15[a]

Table13. Water analysis of the study area

Water Characteristics	Canal water	Underground water
Ph	8.03[a]	6.43 [a]
ECe dS/m	016[a]	0.33 [a]
SAR	1.96 [a]	1.52 [a]
RSC	0.73 [a]	1.20 [a]
Na^{+}meq/l	1.55 [a]	2.12 [a]
K^{+}meq/l	0.21 [a]	0.04 [a]
Ca^{++}meq/l	0.53 [a]	1.77[b]
Mg^{++}meq/l	077 [a]	1.37[b]
Cl^{-}meq/l	0.37 [a]	0.50 [a]
SO_4,meq/l	0.3 [a]	0.92 [a]
HCO_3-meq/l	2.37 [a]	4.33 [a]