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Assessment of Yield and Soil Properties using Agroforestry Practices in a Degraded Land

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Abstract. Continuous mechanized agriculture has led to land degradation in central clay plains of Sudan, which is climatically classified as low rainfall savanna, hence many schemes were abandoned. Reforestation of the abandoned agricultural schemes with *Acacia senegal* was restored to as a measure of reclaiming these degraded sites. The present study is an attempt to investigate the effect of inter-cropping systems with tree species *Acacia senegal* and agricultural crop sorghum to facilitate crops yield and improving certain soil properties. A field experiment was conducted in Abu Naama Forest Reserve over two seasons compared yield in three treatments (inter-cropping for both 4×4 m and 4×8 m tree spacing, and sole cropping) with three replications by using Randomized Complete Block Design sampling. The results showed that there were significant differences in inter-cropping systems having positive effect on crops yield and soil characteristics. However, this may be attributed to the effect of inter-cropping on soil productivity and fertility.

Keywords: Inter-cropping, Agroforestry systems, *Acacia senegal*, Soil properties.

1. Introduction

Rain fed agriculture is the development project operating in central clay plains of Sudan e.g. Blue Nile. Over the years, mechanized agriculture extended from 292.32 to 294 hectares (ha) in 1960-1961 to over 1260 ha in 1973-1974 to 3593.34 ha in 1990-1991 [1]. Continuous mechanized agriculture led to land degradation in this area of Sudan, which is climatically classified as low rainfall savanna, hence many schemes were abandoned. A survey of Dali mechanized agricultural schemes in 1988 carried out by the Institute of Environmental Studies of the University of Khartoum in collaboration with the Institute of Terrestrial Ecology of the United Kingdom, showed that nitrogen had decreased from 0.07% to 0.04% due to continued mono-cropping and hard pan developed at 5 cm depth due to shallow ploughing. It was therefore recommended that trees be planted in these schemes to break the hard pan and to improve soil properties. Reforestation of the abandoned schemes' was resorted to as a measure of reclaiming these degraded soils. This was enforced since early 1970 in Abuhugar governorate in Dali and Mazmum mechanized schemes. In 1971, the abandoned schemes were handed over for rehabilitation with *Acacia senegal*: 33 schemes were planted with trees. In 1990, one of these schemes was handed back for agricultural cultivation and sorghum, yield averaged 871-1088 kg/ha for two seasons 1990-1991 and 1991-1992 compared with 89.285 kg/ha previously obtained. It was indicated by several authors that *Acacia senegal* restores soil fertility of trees and harvesting wood of 2 m diameter at the age of 15 years [2]. Dean [3] found that *Acacia senegal* can added 2.5 mg/g, 60 mg/g and 35 meq/100g of nitrogen (N), phosphorus (P) and potassium (K) respectively. Moreover, food production depends on availability of land and techniques for reducing cost, this can be reached by putting for-

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est land into production. In this study, two advantages can be considered for agroforestry in Blue Nile compared with agroforestry in western Sudan. One of these is the high amount of the annual rainfall which extends for approximately more than four months and this period is enough for water supply for different crops from sowing to harvest. The second advantage is that the type of soil is dark cracking vertisol soil which is characterized by high water holding capacity. The objective of this study is to investigate the effect of agroforestry practices (4×4 m and 4×8 m inter-cropping) on yield of agricultural crop sorghum and maintaining soil macronutrients and certain physical and chemical properties.

2. Materials and Methods

The study area was Sinnar State in Sudan. It is located about 400 km south to southeast of Khartoum along the Blue Nile River. The topography of the state is generally flat. The soil is dark coloured alkaline clay, which swells and becomes extremely sticky when wet, but develops wide and deep cracks when dry (vertisol). However, near the Blue Nile River the soil is permeable, fertile, sand-silt to clay-silt mixture (gerif soils). The temperature varies from a mean daily minimum of 14° C to a mean daily maximum of 40° C. The mean annual rainfall is about 500 mm, falling mainly between June and October. The site was thoroughly weeded and cleared manually of undesirable vegetations and fenced wherever necessary. The experimental design used randomized complete block design (RCBD) with three treatments and three replications. During May, it was laid down 10×20 m, and seeds were sown during August after testing for germination at the recommended spacing of 25 cm for sorghum. The seed rates were 3 seeds per hole as per the standard practice of Abu Nama Agricultural Research Station. Crop was cultivated for two seasons. Samples of soil were collected from two soil depths (0-25 cm and 25-50 cm). The soil pH was measured by using TOA pH meter. Loss of ignition method was used to estimate moisture content, organic matter and organic carbon in the soil. Soil macronutrients were determined by the following methods such as nitrogen by wet-oxidation method [4], potassium by using a Flame Photometric [5] and available phosphorus was extracted with Bray and Kurtz no. 2 extractant and measured by $SnCl_2$ reduced molybdophosphoric blue colour method using spectrophotometer [5]. Soil samples were analyzed statistically by using SPSS software.

3. Results and Discussion

3.1. Crop Yield (kg/ha)

Yield of sorghum was found significantly higher at the inter-cropping spacing of 4×8 m (1786 kg/ha) as compared with the inter-cropping spacing of 4×4 m (1205 kg/ha) and sole cropping (750 kg/ha) in 2010. In the second season, sorghum yield followed the same pattern as season one; giving yield of 1346 kg/ha for 4×8 m, 842 kg/ha for 4×4 m, and 408 kg/ha for the sole cropped system (Fig. 1). The result is similar to that obtained in sandy soils by Mohamed [6] in Eldemokeya forest reserve who reported a yield of 166 kg/ha for inter-cropped and 135 kg/ha for sole cropping. Similar finding was reported by Nsereldin [7] in Nyala Gardud soil giving 600 kg/ha and 380 kg/ha yields for sorghum at the inter-cropping spacing 8×8 m and 4×8 m respectively. So, from these results, it is clear that certain spacing inter-crop practices helps for increasing the yield of sorghum crop.

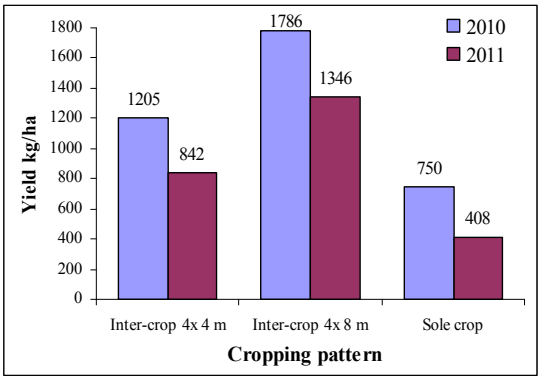

Fig. 1: Crop yield assessment under three cropping patterns

3.2. Soil Properties

In this study, inter-cropping with *Acacia senegal* reveals positive advantages with regard to soil physical and chemical characteristics.

Soil characteristics such as bulk density, hydraulic conductivity, moisture content, and organic matter are presented in Table 1. All the soil parameters, except the hydraulic conductivity, are decreasing when the soil depth is increasing. Between two inter-cropping systems in two different soil depths, the soil bulk density, pH, moisture content and organic matter was found higher in 4×4 m spacing than 4×8 m. However, hydraulic conductivity is not significantly varied between cropping patterns and soil depth.

Changes in soil physical properties and nutrient content have been associated with different cropping systems [8] and intensive agriculture [9]. Jimenez [10] found lower bulk density in soil under plantation in the Caribbean lowland of Costa Rica compared with that in agricultural land. The high soil bulk density indicated soil compaction and this would ultimately lead to reduction of soil porosity and decrease in permeability [11]. Hajabbasi [12] suggested that higher bulk density could result in a lower soil quality. In our study, the highest soil bulk density was found in both soil depths for sole cropping and the crop yield (kg/ha) was also found lowest there (Fig. 1).

Hydraulic conductivity extracts showed no significant differences among the different crop systems in both soil depths. Less vegetation may have encouraged removal of bases by run-off and leaching and intensive leaching of bases in open land enhances reduction in soil pH [13]. In our study, soil pH was found lowest in sole cropping practices.

Moisture content and organic matter are found higher in soil depth of 0-25 cm for three cropping systems due to higher litter fall and undergrowth vegetation compare to 25-50 cm depth.

Table 1: Different soil parameters and three cropping patterns in two different soil depths

Parameters ►	B.D.		H.C.		pH		M.C.		O.M.	
	Soil depth (cm)									
Treatments ▼	0-25	25-50	0-25	25-50	0-25	25-50	0-25	25-50	0-25	25-50
Inter-crop 4×4 m	0.88 StD± 0.02	0.82 StD± 0.01	0.04 StD± 0.002	0.04 StD ± 0.006	7.49 StD± 0.04	7.25 StD± 0.03	9.65 StD± 0.02	9.17 StD± 0.06	1.25 StD± 0.02	0.99 StD± 0.02
Inter-crop 4×8 m	0.83 StD± 0.03	0.72 StD ± 0.01	0.03 StD± 0.006	0.03 StD ± 0.003	7.43 StD± 0.02	6.91 StD± 0.05	9.51 StD± 0.03	9.24 StD± 0.07	0.93 StD± 0.05	0.83 StD± 0.03
Sole crop	1.44 StD± 0.04	1.41 StD± 0.03	0.03 StD± 0.002	0.03 StD± 0.001	6.92 StD± 0.01	6.62 StD± 0.01	9.11 StD± 0.09	8.73 StD± 0.04	0.64 StD± 0.02	0.52 StD± 0.02

Notes: B.D. is bulk density, H.C. is hydraulic conductivity, M.C. is moisture content, O.M. is organic matter, StD is standard deviation

Soil macronutrients such as nitrogen (N), phosphorus (P) and potassium (K), and soil organic carbon were found highest in 4×4 m tree spacing for 0-25 cm soil depth. Macronutrients and soil organic carbon was found lowest in two soil depths for sole cropping system (Fig. 2). For nitrogen, potassium and organic carbon, there were significant differences were found among the three cropping systems in two different soil depths. However, phosphorus content in three cropping systems between two depths was not varied significantly.

Acacia species are legumes and, in symbiotic association with root-nodule bacteria, are partners in fixation of atmospheric N fixation [14]. Singh [15] mentioned that the deposition and release of N through litter fall and its decomposition was highest in legume species of *Acacia senegal*, *Acacia auriculiformis*, *Albizia spp.* plantations. In our study, both inter-cropping systems nitrogen content was found higher than sole cropping. Nitrogen-fixing species have high P requirements, which are essential for the high levels required during N-fixation, and therefore lower available soil P concentrations may result under nitrogen-fixing species than under non-fixing species [16]. In our study the same trend of P distribution was found in three different cropping systems.

Potassium content in both soil depths are decreased significantly at the tree spacing increased (Fig. 2). The highest K content was found in 4×4 m inter-cropping system in depth of 0-25 cm (0.35 meq/100 g) and 25-50 cm (0.24 meq/100 g). Potassium have a beneficial effect on symbiotic N fixation by legumes and in *Acacia senegal* and sorghum agricultural crop inter-cropping practices, it was found highest both in 4×4 m and 4×8 m tree spacing compare to sole cropping. Barua [17] found that the organic carbon concentration and storage under agroforestry practice was significantly higher than those in the open land. In the study, results of available soil organic carbon was showed a general trend, in both soil depths, organic carbon in the 4×4 m tree spacing was greater than the other two cropping systems (Fig. 2).

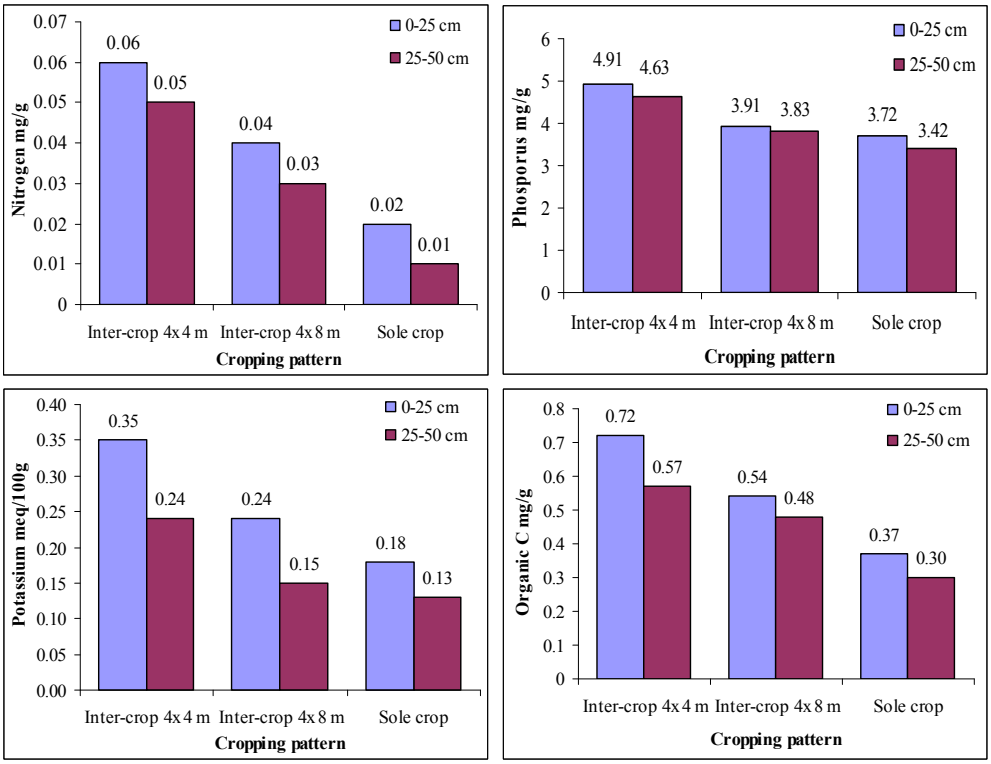

Fig. 2: Soil macronutrients and organic carbon distribution in three cropping systems

4. Conclusion

Agroforestry presents an opportunity to increase land productivity and improve soil fertility. In addition, agroforestry practices can increase the plant diversity, helps to cycle the nutrient, and control the soil erosion and sequestration of biomass and organic carbon.

5. Acknowledgements

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