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Interactive Effect of Land Use Type, Depth and Watering Regime on Soil Fertility and Seedling Growth of *Parkia biglobosa* (Jacq.)

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Abstract

Introduction: *Different types of land use, practices and management can alter biogeochemical cycling of a piece of land by the effect it produces on soil properties. The conversion of forest land to agricultural land and wastelands to forest land use have been in practice from primordial days due to land hunger and reclamation.*

Materials and Methods: *Soil samples from two land use area [forest soil (FoS) and farmland soil (FmLS)] were sampled at two depths i.e., 0–15 cm and 15–30 cm and analyzed for biogeochemical properties. The soils were then used to raise seedlings of P. biglobosa for a period of 14 weeks.*

Results: *The results shows that P. biglobosa grown with FmLS at 15–30 cm depth and watered twice daily performed better across all growth parameters tested (stem height: 9.83; total height: 20.33 and leaf number: 16.0).*

Conclusion: *Land use history, soil depth and watering regime are some major abiotic factors that determine soil nutrient deposit, balance and microbial activities and these affect vegetation and types of crop that can grow in a given area.*

Keywords: interaction, land use, soil depth, watering regime

Abbreviations: FmLS: farmland soil; FoS: forest soil

Introduction

Nigeria is a diverse country that is endowed with substantial natural resources. It encompasses three major ecological regions; a humid forest region, a sub-humid region with highland, and a semi-arid region. The natural vegetation varies from rain forest to savanna [1, 2]. There are four broad systems of agricultural land use: a) crop production (rotational fallow, semi-permanent or permanent cultivation) and mixed farming; b) livestock production (predominantly pastoral); c) fisheries (inland freshwater and brackish water); d) forestry (agro-forestry). The land use classification shows that 34% is occupied by crops, 23% by grassland and 16% forests [2]. In Nigeria, farmers destroy natural ecosystem for the establishment of agricultural land through the practices of shifting cultivation. The changes that takes place on the land has greatly impacted on the soil carbon (C), nitrogen (N) and phosphorus (P) cycle and their storage capacities in the soil [3–6]. Previous researchers has shown that land use practices and management can alter the C, N, P and the biogeochemical cycle and the effects it will produce on the soil properties. Many studies have reported that soil properties differ considerably between agricultural lands and forest lands [7]. The changes observed in the results of soil properties over a period of time could be linked to types of plant grown on the land. Differences between forest land and lands used for all year round crop production systems can be seen in the quantity and quality of soil fertility which may affect the general growth and nutrient composition of plants and metabolism. The type of agricultural system practiced in a given community would highlight the buildup of soil organic matter and fertility over time and depth due to the activities of man on the ecosystem. Traditional farmers make use of fertilizers containing soluble inorganic nitrogen and other nutrients which are directly available to the plants, but at the end of the growing period a large percentage of unutilized compounds end up below the root zone. The root zones of agricultural crops differ from forest tree crops. Different plant species can effect soil nutrient through debris and litter decomposition (which in turn depend on the chemical and physical composition of living plants), root secretion, nitrogen fixation, soil mineralization, and contributions to soil ecosystems from resident animals, insects, and microorganisms [8–11]. It is important for researchers to estimate the immediate and ultimate impact of land use change on soil nutrient storage [12, 13]. Comparable determinations of differences between major soil nutrients C, N, and P density for forested and agricultural soils are necessary to understand the impact that past deforestation and future land use changes has on C, N, and P stocks. This study investigate changes in C, N, and P density and storage in Wudil area of Kano state of Nigeria after extensive land use changes has taken place.

Land use history, soil and plant type as well as the associative management practices utilized were closely related to soil C accumulation and nutrient dynamics.

Materials and Methods

Study area

The study area is located within the savanna region of Nigeria (forest soil latitude 11°30'N; longitude 8°82'E and farmland soil latitude 11°86'N and longitude 8°77'E). The prevailing vegetation of the region is grouped as Sudan and Sahel savanna type [14, 15] (Figure 1).

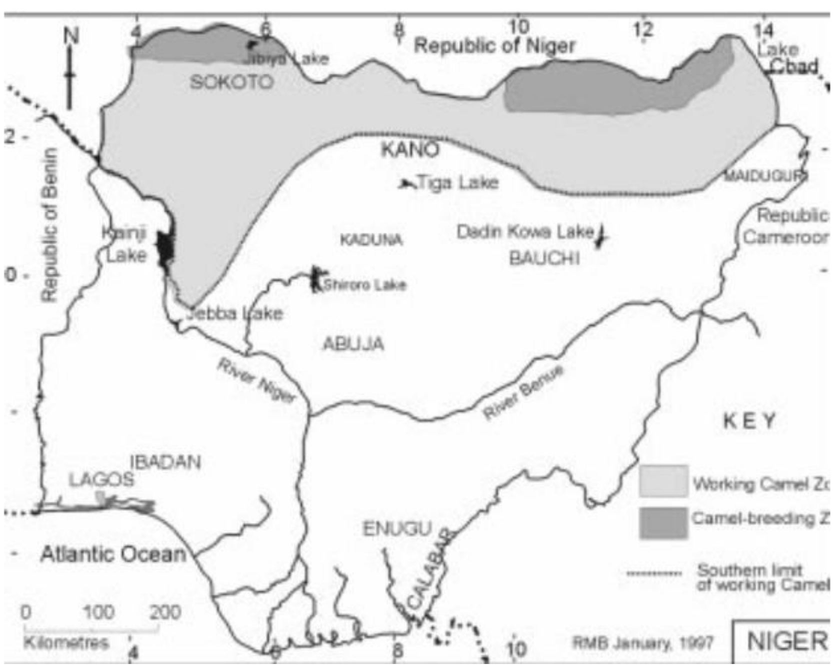

Figure 1: Map of Nigeria showing study area. Area above Kanji Lake, district Kano and Maiduguri is predominantly Sahel savanna farmland and forest soil in this region around Kano was collected and used in this study. Shaded area above Sokoto is highly prone to desert.

Land use history

The land use history of the area shows that it has been subjected to agricultural use for over ten decades with a portion dedicated to fruit trees such as *Parkia* which is used in production of dadawa (a food seasoning) and *Acacia* (gum arabic).

The soil type is subtropical red soil. The topography of the area is a mixture of low hills and valley with floodplains. Sometimes farming activities is carried out along the low hills using terracing which is common in northern Nigeria. Total area is 207.96 ha.

Soil sampling protocols

Soil sampling was carried out from February 30–April 1, 2016. Soil was sampled at two depths *i.e.*, 0–15 cm and 15–30 cm. Two major land use types in the study area were selected, (FoS and FmLS) from which two soil profiles were taken.

For each land use type, four replicates for each of the two depths were obtained for soil sampling. Each soil sample was collected by excavating soil from a 1 m radius circle at the specific soil level until a net weight of 1 kg of wet soil was collected. Soil samples were then stored in a refrigerator until they could be processed for chemical analysis. Soil physical and chemical data including data on land use, environment, and soil composition were obtained using laboratory methods. Soil organic carbon (SOC) was determined using the $K_2Cr_2O_7$ volumetric dilution heating method [16]; total nitrogen (TN) was determined using the Kjeldahl procedure [17]; total phosphorus (TP) was determined using H_2SO_4 + $HClO_4$ digestion [18]; soil bulk density was determined by the core method; soil pH was measured using the potentiometric method with a soil:water ratio of 1:2.5 (w/v).

Statistical analysis

Concentrations of C, N, and P for each soil sample were used to determine the C:N, C:P, and N:P ratios. C, N, and P stoichiometry was calculated as a mass ratio. Differences between C:N, C:P, and N:P ratios were found in several soil layers. Seedlings of *P. biglobosa* were raised for 14 weeks on the soil samples. The data obtained were evaluated using one-way analysis of variance (ANOVA), followed by the least significant difference (LSD) test. Statistical analyses were carried out using Graph Pad Prism 5 software (Graph Pad Inc., USA).

Results and Discussion

Nitrogen is a major component in organic compounds of plant including nucleic acids which is required for cell growth and elongation. The percentage concentration of nitrogen in FmLS and FoS at 0–15 cm depth is high and sufficiently adequate to enhance seedling growth while the concentration at 15–30 cm depth of FoS is deficient to support plant growth. This could be as result of inadequate deposition of dead organic materials and soil micro-organism at various depths to aid decomposition and replenish soil nutrient. The removal of nitrogenous compounds from this depth over the years could equally contribute to low deposit. Sanchez et al. commented on the depleting nutrient level of African soils [19]. Oxygen and carbon concentrations are low compared with expected standard in vegetation zones at 0–15 cm depth of FmLS and FoS respectively and agrees with report by Girmay et al. who worked on similar semi-arid soil in Ethiopia, East Africa [20]. At 15–30 cm soil depth of FoS, oxygen availability is low. Other essential nutrients are available in there required concentrations and could support growth (Table 1).

Growth indices of *P. biglobosa* obtained at the end of the experimental period (14 weeks) shows that although there were positive increase in the parameters measured, there were no statistical difference in the growth of seedling raised with FoS both within and across treatments of soil depth at 0–15 cm and 15–30 cm respectively and watering regime (Table 2). However, the result showed that there were significant difference in stem height, total height and leaf number of *P. biglobosa* seedlings grown on FmLS within and across treatments (Table 2). FoS at 15–30 cm depth showed better growth than that at 0–15 cm depth. This could be as result of increasing deposit of nutrients and soil micro-organism at these levels in the soil. Seedlings under twice daily watering regime performed better than those watered once daily and once in two days respectively in stem height, total height and leave number.

Overall, P. biglobosa grown with FmLS at 15–30cm depth and watered twice daily performed better across all growth parameters tested (stem height: 9.83; total height: 20.33 and leaf number: 16.0) (Table 3). This result could be an outcome of interactive effect of nutrients deposit, water percolation in the soil and micro-organisms deposit and their activities, plant turgidity and water movement in growing seedlings aided by photosynthetic activities. This agrees with Lawlor and Cornic, who reported that foliar photosynthetic rate of higher plants is known to decrease as the relative water content and leaf water potential decreases [21].

Conclusion

Previous land use, soil depth and watering regime are some major abiotic factors that determine types of crops *vis-à-vis* vegetation of give area. The use to which a piece of land was previously disposed to affect the soil nutrient deposit, balance and microbial activities. From the above findings, it could be summarized that root penetration of crop plants up to and beyond 15 cm soil depth is very minimal, hence nutrients washed deep into the soil accumulate and remain unutilized. Where inorganic compound are used, such could be washed further down to the underground water level thereby causing pollution. Woodland plots both in natural and artificial plantations has served as underground purifiers since their root penetrate deep into the sub-soil (beyond 15–30 cm depth) thereby utilizing washed down nutrients and bringing such back to the soil surface.

Land use type	**Soil depth**	**pH**	**EC**	**N%**	**O.C %**	**SP**	**Na**	**K**	**P**	**Ca**	**Mg**	**Clay %**	**Silt %**	**Sand %**
Forest soil	0–15 cm	7.53	1.23	0.055	0.46	33.3	3.40	0.01	3.36	12	7	23	33	44
	15–30 cm	7.43	5.34	0.029	0.38	24.5	1.84	0.02	3.30	6	3	22	30	50
Farmland soil	0–15 cm	7.78	0.75	0.056	0.56	28.2	3.88	0.02	3.35	6	3	21	29	51
	15–30 cm	7.66	0.70	0.043	0.45	28.65	9.42	0.01	3.29	7	4	23	32	45

Table 1: Soil physico-chemical properties of different land use types.

Stem height																
	Farmland soil (0–15 cm)				**Forest soil (0–15 cm)**				**Farmland soil (15–30 cm)**				**Forest soil (15–30 cm)**			
	Once daily	Twice daily	Once in two days	Sig	Once daily	Twice daily	Once in two days	Sig	Once daily	Twice daily	Once in two days	Sig	Once daily	Twice daily	Once in two days	Sig
2 WAT	1.23^{a}	1.97^{a}	1.13^{a}	NS	1.07	1.43	0.87	NS	2.03^{a}	2.50^{b}	1.30^{a}	NS	2.57	2.90	2.47	NS
4 WAT	3.07^{a}	3.83^{c}	2.60^{a}	*	1.50	1.93	1.57	NS	3.50^{ab}	4.30^{bc}	2.87^{a}	NS	3.13	2.80	2.30	NS
6 WAT	3.83^{a}	4.43^{c}	3.33^{a}	**	1.83	1.90	1.33	NS	4.17^{ab}	4.83^{bc}	3.67^{ab}	NS	3.17	3.33	3.17	NS
8 WAT	3.56^{c}	4.57^{b}	3.50^{c}	*	1.90	2.43	1.90	NS	5.40^{b}	6.17^{bc}	4.17^{abc}	**	3.83	3.33	3.03	NS
10 WAT	4.43^{bc}	5.70^{b}	4.00^{b}	*	2.20	2.13	1.63	NS	5.10^{ab}	7.17^{abc}	5.12^{bc}	***	3.83	3.77	3.53	NS
12 WAT	5.83^{bc}	7.10^{b}	5.10^{b}	*	2.20	2.60	2.17	NS	6.23^{ab}	7.83^{ac}	5.63^{c}	**	4.60	4.07	3.60	NS
14 WAT	7.43^{b}	8.73^{b}	6.27^{b}	*	2.43	2.33	1.87	NS	6.33.93^{a}	9.83^{a}	5.93^{c}	***	4.73	4.50	4.00	NS
Sig	*	*	*		NS	NS	NS		*	*	*		NS	NS	NS	
Total height																
2 WAT	3.53^{b}	4.03^{b}	2.60^{a}	NS	2.90	3.00	2.20	NS	1.30^{a}	4.23^{a}	3.93^{a}	**	4.90^{b}	4.57^{b}	4.73	NS
4 WAT	2.60^{a}	6.17^{b}	5.57^{ab}	*	3.17	3.13	3.40	NS	5.73^{ab}	8.17^{a}	6.67^{a}	*	6.90^{b}	5.37^{b}	4.67	NS
6 WAT	6.83^{b}	8.00^{b}	8.50^{ab}	*	3.80	3.70	2.90	NS	7.33^{ab}	9.50^{ab}	8.33^{a}	NS	6.27^{b}	5.67^{b}	5.83	NS
8 WAT	8.17^{b}	8.17^{a}	5.57^{b}	*	3.90	3.60	3.80	NS	8.67^{ab}	12.33^{b}	9.80^{ab}	**	8.33^{ab}	6.33^{a}	6.00	*
10 WAT	9.17^{b}	11.07^{a}	7.03^{b}	**	4.30	4.13	3.30	NS	6.77^{a}	13.73^{ab}	10.17^{b}	****	7.87^{ab}	6.47^{a}	6.87	NS
12 WAT	13.90^{b}	17.00^{a}	9.40^{b}	**	4.33	3.97	4.27	NS	10.23^{a}	15.83^{ab}	10.67^{b}	***	10.90^{a}	11.17^{a}	6.97	**
14 WAT	16.33^{b}	19.17^{a}	12.07^{b}	***	4.93	4.57	3.63	NS	11.90^{a}	20.33^{a}	12.00^{b}	***	10.67^{a}	11.13^{b}	7.83	NS
Sig	*	*	*		NS	NS	NS		*	*	*		*	*	NS	
No of leaflets																
2 WAT	5.00^{b}	5.33^{b}	4.00	NS	4.67	5.00	4.67	NS	5.00	5.00^{c}	4.67^{a}	NS	8.67	8.00	8.33	NS
4 WAT	5.00^{b}	5.33^{b}	4.00	NS	5.33	5.00	5.67	NS	5.00	5.00^{c}	4.67^{a}	NS	9.33	8.67	9.00	NS
6 WAT	6.33^{b}	7.00^{b}	6.00	NS	6.00	6.33	6.00	NS	6.33	6.67^{bc}	6.33^{a}	NS	9.67	8.33	9.00	NS
8 WAT	7.67^{b}	8.33^{ab}	6.67	NS	6.67	6.00	7.00	NS	6.67	7.67^{abc}	7.00^{a}	NS	10.33	9.33	9.67	NS
10 WAT	9.00^{ab}	10.70^{ab}	7.33	*	7.33	7.33	7.33	NS	8.00	10.00^{a}	9.00^{ab}	**	11.00	9.00	10.33	NS
12 WAT	10.33^{ab}	14.33^{a}	8.67	**	7.33	6.67	8.00	NS	9.33	13.33^{a}	10.33^{ab}	**	12.00	9.67	10.33	NS
14 WAT	13.33^{a}	16.00^{a}	9.67	**	8.00	8.33	8.33	NS	11.70	16.00^{a}	12.00^{b}	NS	11.67	9.67	11.00	NS
Sig	*	*	NS		NS	NS	NS		NS	*	*		NS	NS	NS	

Table 2: Mean comparison of stem height, total height and number of leaflets of *P. biglobosa* at soil depth 0–15 cm and 15–30 cm. *** = highly significant; ** = moderately significant; * = slightly significant; NS = not significant.

Soil type/depth	Once daily watering			Twice daily watering			Once in two days watering		
	SH	TH	LN	SH	TH	LN	SH	TH	LN
FoS 0–15 cm	2.43[c]	4.93[c]	8.00[c]	2.33[c]	4.57[b]	8.33[b]	1.87[c]	3.63[c]	8.33
FoS 15–30 cm	4.73[c]	10.67[b]	11.67[b]	4.50[b]	11.13[b]	9.67[b]	4.00[b]	7.83[b]	11.0
FmLS 0–15 cm	7.43[a]	11.90[b]	11.70[b]	8.73[a]	19.17[a]	16.0[a]	6.27[a]	12.07[a]	9.67
FmLS 15–30 cm	5.93[b]	16.33[a]	13.33[a]	9.83[a]	20.33[a]	16.0[a]	6.33[a]	12.0[a]	12.0

Table 3: ANOVA of soil type/depth, watering regime and growth indices of *P. biglobosa*. SH = stem height; TH = total height; LN = leaf number; FoS = forest soil; FmLS = farmland soil.

References

1. Shaib B, Aliyu A, Bakshi J. Nigeria national agricultural research strategy plan: 1996-2010. 1997.

2. State of Plant Genetic Resources for Food and Agriculture in Nigeria 1996-2008. 2008.

3. Houghton R. The annual net flux of carbon to the atmosphere from changes in land use 1850-1990. Tellus B. 1999;51(2):298-13.

4. Scott A, Tate K, Ross D. et al. Processes influencing soil carbon storage following afforestation of pasture with Pinus radiata at different stocking densities in New Zealand. Aust J Soil Res. 2006;44(2):85-96.

5. Cao S, Zhong B, Yue H, et al. Development and testing of a sustainable environmental restoration policy on eradicating the poverty trap in China's Changting County. PNAS. 2009;106(26):10712-16.

6. Jiao Y, Zhu X, Zhao J, et al. Changes in soil carbon stocks and related soil properties along a 50-year grassland-to-cropland conversion chronosequence in an agro-pastoral ecotone of inner Mongolia, China. Journal of Arid Land. 2012;4(4):420-30.

7. Liao C, Luo Y, Fang C, et al. The effects of plantation practice on soil properties based on the comparison between natural and planted forests: a meta-analysis. Global Ecol.Biogeogr. 2012;21(3):318-27.

8. Montagnini F, Ramstad K, Sancho F. Litterfall, litter decomposition and the use of mulch of four indigenous tree species in the Atlantic lowlands of Costa Rica. Agroforest Syst. 1993;23(1):39-61.

9. Roggy J, Prévost M, Gourbiere F. et al. Leaf natural 15N abundance and total N concentration as potential indicators of plant N nutrition in legumes and pioneer species in a rain forest of French Guiana. Oecologia. 1999;120(2):171-82.

10. Warren M, Zou X. Soil macrofauna and litter nutrients in three tropical tree plantations on a disturbed site in Puerto Rico. Forest Ecological Management. 2002;170(13):161-71.

11. Hobbie S, Reich P, Oleksyn J, et al. Tree species effects on decomposition and forest floor dynamics in a common garden. Ecology. 2006;87(9):2288-97.

12. Lal R. Soil erosion impact on agronomic productivity and environment quality. Critical reviews in plant sciences.1998;17(1):319-464.

13. Lal R. Soil erosion and the global carbon budget. Environ Int. 2003;29(4):437-50.

14. Olaniran J. A study of the seasonal variation of rain-days of different categories in Nigeria in relation to the Miller station types for tropical continents. Theor Appl Climatol. 1987;38(4):198-209.

15. Abaje IB, Ati OF, EO Iguisi. Drought in the North-Easthern part of Nigeria and the risk on human health. 2011.

16. Nelson DW, Sommers LE. Agronomy Monograph. 2nd ed. Madison: ASA-SSSA; 1982. Chapter 2: Total Carbon, Organic Carbon, and Organic Matter; p. 539-580.

17. Gallaher R, Weldon C, Boswell F. A semiautomated procedure for total nitrogen in plant and soil samples. SSSAJ. 1976;40(6):887-89.

18. Olsen SR, Dean LA. Methods of Soil Analysis. 2nd ed. Madison: ASA-SSSA; 1965. Chapter 23: Phosphorus; p. 403-430.

19. Sanchez PA, Shepherd KD, Soule MJ, et al. Replenishing Soil Fertility in Africa. 1st ed. Madison: American Society of Agronomy, Inc.; 1997. Chapter 51: Soil fertility replenishment in Africa: an investment in natural resource capital; pp. 1-46.

20. Girmay G, Singh B, Mitiku H, et al. Carbon Stocks in Ethiopian soils in relation to land use and soil management. Land Degrad Dev. 2008;19(4):351-67.

21. Lawlor D, Cornic G. Photosynthetic carbon assimilation and associated metabolism in relation to water deficits in higher plants. Plant Cell Environ. 2002;25(2):275-94.