Land Clearing Effect on the Variability of some Soil Properties of an Alfisol in South-Western Nigeria

A. E. Eneji* & B.B. Ayade**

Keywords: Land clearing - Soil properties Variability - Nigeria.

Summary

The variability of some soil properties of a mechanically cleared plot was compared with an adjacent plot under natural vegetation in an Alfisol of South-western Nigeria. The soil properties studied were pH, total N, available P, exchangeable acidity, Ca, Mg, Na, K and effective cation exchange capacity (ECEC), organic matter and particle size fractions. Land clearing increased the variability of total N, exchangeable acidity, Ca, Mg, Na and ECEC while it decreased that of available P, exchangeable K, organic matter and soil texture. The variability groupings differed between the plots for available P, exchangeable Mg and silt content. Results of t-tests showed significant differences between the plots for total N, exchangeable Ca and organic matter.

Résumé

L'effet de l'essart sur la variabilité de quelques propriétés d'un alfisol au sud-ouest du Nigeria

La variabilité de quelques propriétés du sol d'un champ alfisol essarté a été comparée à celle d'un champ adjacent non essarté dans le sud-ouest du Nigéria.

Les propriétés du sol étudié sont: le pH, le N total, le P assimilable, l'acidité potentielle, le Ca, le Mg, le Na, le K, la capacité d'échange (CE), la matière organique ainsi que la texture du sol. Essarter un champ a augmenté la variabilité de la quantité totale de N, de l'acidité potentielle, du Ca, du Mg, du Na et de la C.E. Par contre le fait d'essarter a réduit la variabilité du P assimilable, du K échangeable, de la matière organique et de la texture du sol. Les différences significatives ont été observées en ce qui concerne le P assimilable, le Mg échangeable, le contenu en limon, le Ca échangeable et la matière organique.

Introduction

Land clearing is a usual pre-planting/cultivation operation in the humid tropics. Under the traditional farming system, land clearing is a manual operation. However, faced with increasing population and declining food supply, many individuals and government agencies have employed mechanized land clearing as a means of bringing more land into food production. Available information indicates that land clearing, especially by mechanical means has adverse effects on soils of the tropics (1,5,6,9). These effects include accelerated run-off, soil compaction, poor infiltration, loss of soil fertility and poor crop growth. Mechanized clearing could also affect crop performance through the introduction of variability in the soil. Basic information on such variabilities is needed to enhance post-clearing soil management for sustainable production.

Ogunkunle and Erinle (13), referred to the alternate dotting of a typical farm in Sitiung (Indonesia) with bare spots and stripped green lands as evidence of acid sterilisation from the subsoil exposed by bulldozers. Post-clearing operations such as ploughing, harrowing and ridging may introduce some variations to the soil, and the effects of such variations might become pronounced on crop production in the long run. Sharratt et *al.* (17) presented experimental evidence which suggested that structural modifications caused by vehicular traffic may persist for >100 years.

The random influence of compaction, erosion, poor infiltration, surface soil removal and mixing introduced by the farm machines is expected to affect soil variability. As variability in soil properties within a given field increases, the problem of assessing the true average quality, say fertility patterns becomes more difficult. This in effect could lead to improperly fertilized field. Furthermore, variations in soil properties could decrease the feasibility of estimating differences among soil units with a satisfactory degree of precision.

Ogunkunle and Erinle (13) studied the influence of tillage on the variability of an Alfisol in south-western Nigeria and observed that fallowing increased the variability of soil organic matter, Na, Ca, Mg and available P. However, ten-year period of cultivation decreased the variability of soil texture, exchangeable K and acidity. Soil variability arising from land clearing in the same area has not been investigated. This study was therefore aimed at providing some information on the variability in soil properties due to mechanized land

* Department of Crop Science, University of Calabar, Nigeria.
** Department of Botany and Microbiology, University of Ibadan, Nigeria.
Corresponding author: A.E. Eneji (Present address: egrinyaeneji@hotmail.com; Graduate School of Agriculture, Tottori University, Minami, 4-101, Koyama-Cho, Tottori 680, Japan).
Received on 04.06.99 and accepted for publication on 03.09.99.

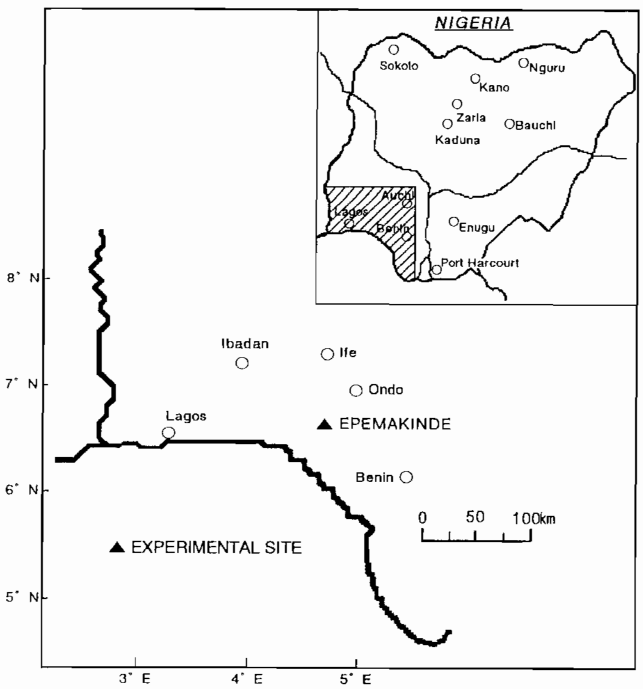

Figure 1. - Map of South-western Nigeria showing the location of project site.

clearing in the Nigerian rainforest zone.

Material and methods

The study was carried out at Epemakinde, the headquarters of the Ondo State World Bank-sponsored Afforestation Project (4-5°E; 6-7°N) (Figure 1). The experimental site was a secondary high forest with no record of disturbance for over 70 years. It is characterized by a large number of dead and standing trees, giving it a semblance of an overmature, disintegrating forest. The area has a humid tropical climate with two distinct seasons - the rainy season (April-October) and the dry season (November-March). The annual total rainfall is about 1800 mm, while temperatures range between 24-26°C. The soils in the area have been studied in standard soil profiles (2). They are well drained sandy loams to loamy sands formed from crystalline metamorphic-igneous rocks of Basement Complex, and, based on FAO (7) criteria the soils are classified as Lixisols. The soils have been mapped as Alfisols with Tyic Kandiudalf as the modal profile (12). The morphological properties of a typical soil profile at the experimental site is shown in Table 1. Table 2 presents the physico-chemical characteristics of the profile.

Two adjacent plots on the same physiographic position were used for the study. One of the plots was cleared with a D83E Komatsu bulldozer which knocked down and removed all trees from the plot in one operation. The plot was planted to maize followed by cowpea for one cropping cycle before soil sampling was carried out. At harvest, the grain yield was 2600 kg/ha for maize and 900 kg/ha for cowpea respectively (5). The other plot was marked out from the undisturbed forest adjacent to the cleared plot. Each plot measured 30 m x 20 m. For soil sampling, the 30 m side of each plot was divided into ten 3 m sections, while the 20 m

Table 1
Morphological properties of a typical soil profile at the experimental site.

Horizon	Depth (cm)	Colour (moist)	Boundary	Structure	Texture	Concretionary nodules
A	0-17	10YR4/3	c, w	2, f, sab	SL	n
Bt1	17-32	7.5YR3/4	c, w	2, m, sab	SCL	n
Bt2	32-57	9.5YR5/6	c, w	2, m, sab	C	m
Bt3	57-100	7.5YR5/6	c, w	2, c, sab	C	f
B	100-106	10R6/6		2, c, sab	SL	f

Legend

Boundary	Structure	Concretionary nodules
c = clear	2 = moderate	n = none
w = wavy	f = fine	f = few
	m = medium	m = many
	c = coarse	
	sab = subangular blocky	

Source: Agboola and Ogunkunle, 1993. (2)

Table 2
Chemical analysis of the soil profile at the experimental site

Depth (cm)	pH	Total N (g/100g)	Available P (mg/kg)	Exchangeable cations (cmol/kg) K	Mg	Ca	Na	Exch. Acidity (cmol/kg)	ECEC* (cmol/kg)	(Organic M) (g/100 g)	Sand (g/100g)	Silt	Clay
0-15	6.3	0.22	6.5	0.42	0.16	2.0	0.21	0.24	3.00	1.80	75.3	21.0	3.7
15-30	6.4	0.16	5.8	0.38	0.12	2.0	0.20	0.22	2.23	1.11	66.8	21.2	12.0
30-45	6.4	0.11	5.3	0.46	0.11	1.6	0.21	0.22	2.61	0.78	68.8	21.2	10.0
45-60	6.5	0.11	4.7	0.39	0.10	1.8	0.22	0.18	2.70	0.65	66.8	23.2	10.0
60-75	6.5	0.10	4.6	0.30	0.11	1.9	0.22	0.16	2.80	0.60	62.8	27.2	10.0
75-90	6.2	0.09	4.4	0.31	0.10	1.6	0.20	0.12	2.76	0.45	60.8	31.2	8.0
90-105	6.5	0.07	3.7	0.33	0.10	1.4	0.20	0.12	2.50	0.43	62.8	27.2	10.0

* Effective cation exchange capacity.

side was divided into six 3.3 m sections. Soil samples (0-15 cm) were taken at the intersection of these co-ordinates to give a total of 45 samples per plot (i.e. 9 samples for each of the five rows).

The samples were air-dried, ground and screened through a 2 mm sieve. Each sample was analysed in the laboratory for pH in water using the Coleman's pH meter with glass electrode; organic carbon was determined using the Walkley-Black (18) procedure. Soil organic matter was estimated by mutliplying organic carbon by a factor of 1.724 (11). Available P was extracted with Bray's P1 solution (4) and P in the extract determined with the Bausch & Lomb spectronic 70 spectrophotometer at 660 nm. Exchangeable cations (i.e. Na, Mg, Ca and K) were leached from the soil samples with neutral ammonium acetate. Exchangeable Potassium and Na in the leachate were read from the flame photometer while Mg and Ca were read from the atomic absorption spectrophotometer (Model 403 Perkin-Elmer Corp, Norwalk, Connecticut). Exchangeable acidity was determined by extracting soil with 1N KCl and titrating the extract with 0.1N NaOH. Effective cation exchange capacity (ECEC) was determined as summation of total exchangeable bases plus exchangeable acidity. Textural analysis was done by hydrometer method.

The mean, standard deviation and coefficient of variation (CV) for each soil property was calculated for each plot. Soil properties were grouped on the basis of CV (%) as suggested by Wilding and Drees (19). The significance of the differences in soil properties between plots was assessed using the t-test.

Results and discussion

The advent of large tractors and implements bolstered the efficiency of farming operations in the 20th century (17). Consequently, fewer transverses across the field are required today than was the case in earlier years. However, improved efficiency in field operations may not always be beneficial to long term soil productivity because soil deformation or compaction can occur as equipment is being driven across the field (8). In the tropical rainforest of Africa, the use of bulldozers and tractors for cultivation is a common practice in government and parastatal farms.

As can be observed from the CV of the measured soil parameters in this study, mechanical clearing using bulldozer increased the variability of total N, exchangeable Mg, Ca, Na, exchangeable acidity and ECEC, while it decreased the variability of available P, exchangeable K, organic matter and particle size fractions (Table 3). Soil pH was not affected. The magnitude of change in variability is different among the soil properties. According to Ogunkunle and Erinle (13), such variations indicate differences in the sensitivity of some soil properties to cultivation. The coefficient of variation is about double for available P, exchangeable Mg, organic matter, sand and silt content. It is moderate for exchangeable K, Ca, ECEC and clay, while it is only slight for exchangeable acidity and Na.

The soils in South-western Nigeria are generally heterogeneous, with properties drastically changing even over a distance of a few meters (10). Soil differences within relatively small areas could affect the interpreta-

Table 3
Mean (x), standard deviation (Sd) and coefficients of variation (CV) of soil properties in cleared and uncleared plots together with a summary of the t-test results.

Property	Mechanically cleared plot			Uncleared plot				
	X	Sd	CV (%)	X	Sd	CV (%)	t (0.05)	level of significance
pH	6.4	0.35	5.5	6.4	0.35	5.5	1.9	NS
Total N (g/100g)	0.2	0.04	7.5	0.3	0.02	5.4	2.1	*
Available P (mg/kg)	6.0	0.77	12.9	6.2	2.34	37.2	1.9	NS
Exchangeable K (cmol(+)/kg)	0.3	0.09	28.1	0.5	0.16	34.4	2.1	*
Exchangeable Mg (cmol(++)/kg)	0.1	0.02	22.9	0.2	0.01	10.2	1.5	NS
Exchangeable Ca (cmol(++)/kg)	1.8	0.57	31.9	3.2	0.95	29.8	2.1	*
Exchangeable Na (cmol(+)/kg)	0.3	0.04	12.2	0.4	0.04	10.8	0.6	NS
Exchangeable Acidity (cmol(+)/kg)	0.2	0.09	45.4	0.2	0.09	44.0	1.8	NS
ECEC# (cmol(+)/kg)	2.7	0.99	33.7	4.5	0.99	22.4	2.1	*
Organic matter (g/100g)	3.0	0.15	5.0	5.3	0.52	10.0	2.2	*
Sand (g/100g)	74.9	3.51	4.7	81.2	6.00	7.4	1.9	NS
Silt (g/100g)	21.3	2.88	13.6	16.3	4.08	25.0	1.7	NS
Clay (g/100g)	3.8	2.55	67.2	2.5	1.69	86.3	1.8	NS

# = Effective cation exchange capacity; * = significant at p=0.05.
n = 45.

Table 4
Variability grouping of soil properties in uncleared and mechanically cleared plots.

Group	CV (%)	Soil Properties	
		Mechanically cleared plot	Uncleared plot
1 (least variable)	<15	pH, N, P ,OM, Na, sand, silt	pH, N, Mg, OM, Na, sand
2 (medium variable)	15-35	K, Mg, Ca, ECEC	K, Ca, ECEC, silt
3 (most variable)	>35	EA, clay	P, EA, clay

tion and extrapolation of experimental results (16). In the humid tropics, this situation underscores the need for location-specific soil management investigations. The high variability also poses a problem in interpreting data on management-induced changes in soil properties. Several factors are responsible for this variability. These factors include biogenetic (eg, soil fauna and tree species), geogenetic and pedogenetic factors. Other factors that contribute to the variability in the area include soil thickness and size and concentration of gravel (10). The distribution of the properties down the profile may be a factor responsible for soil variability. As can be observed from Table 2, the concentration of all properties except pH decreases down the profile.

Compared with the uncleared forest, mechanical clearing increased the variability of six of the 13 measured properties. Beckett and Webster (3) attributed the higher variability of cultivated over uncultivated plots to contrasting crops and soil amelioration, such as addition of fertilizers. In this study, the apparently lower variability of some properties in the cleared plots could be due to mixing of soil materials during clearing and subsequent windrowing. The mixing process constitutes a major threat to the soil system by breaking the nutrient cycling mechanism that maintained soil productivity under natural forest. Soil erosion, compaction as well as nutrient and biological degradation may become evident even within days after clearing in the sub-humid and semi-arid areas (14).

The t-test results of the differences between the cleared and uncleared plots show that significant differences existed between the plots for total N, exchangeable K, Ca, ECEC and organic matter (Table 3). The cleared plots exhibited lower levels of these respective properties. Agronomic research on long-term basis indicate that a rapid decline in soil fertility is triggered by land clearing and logging using the bulldozer (15), and the drop in soil fertility is attributed to decline in soil organic matter, erosion and leaching. Soil organic matter and N are extremely important to crop production because of their role in soil fertility maintenance. However, variability in these properties are only temporary and could be easily ameliorated through external inputs such as mineral fertilizers and organic wastes.

Table 4 presents the variability groupings of the soil properties according to CV (%). The groupings differed between the plots for available P, exchangeable Mg and silt content. These groupings tend to suggest that the differences found between the cleared and uncleared plots in the CVs of pH, total N, organic matter, exchangeable Ca, Na, ECEC, sand fraction, etc, may in reality not be significant. However, this may not be so because a small CV value in one property may have more serious impact on crop production than larger CV values in other properties (13). For instance, the present data indicate that least variations occurred in soil organic matter and total N, but these are the greatest determinant of soil fertility, and hence crop yield in tropical soils. Soil organic matter is the main reservoir of nutrients and a source of CEC and stability of these soils, hence variations in this property, nor matter how small may have a large impact on crop production. Generally speaking, the less variable a soil is the less difficult it is to manage, and information on the degree of variability of soil properties is useful in formulating appropriate soil management options. The CV values on which the grouping is based are mostly used as a guide to workers on the degree of variability, that is, either low or moderate. For practical application such as creating mapping units for soil fertility capability classification, information on the degree of variability in soil properties could be useful as modifying criteria. Natural soil classification systems place more emphasis on sub-surface (20-60 cm) soil properties because of their more permanent or less variable nature, even though most soil management practices are largely limited to the plow layer (16). Together with climatic and socio-economic data, information on the degree of soil variability is essential to enable the transfer of research findings from one particular site to other sites with similar characteristics.

Conclusion

The results of this study confirm earlier findings that mechanical land clearing introduces marked alterations in soil physical and chemical properties. Such alterations include the introduction of variability in soil properties. It increases the variability of total N, exchangeable acidity, Mg, Ca, Na and ECEC, while decreasing that of available P, exchangeable K, organic matter and particle size fractions. Mechanical land clearing has significant detrimental effects on total N, exchangeable K, Mg and soil organic matter. Post-clearing soil management must therefore take cognisance of the variations introduced by, and the effect of mechanized land clearing on soil properties. Further work is needed to compare variations induced by manual and semi-mechanical clearing methods with the results of this study in the same area. The resulting information could be useful in deciding whether it is possible to manage a mechanically cleared plot in the same way as plots cleared by other methods.

Acknowledgements

This study was supported with a research grant from the International Foundation for Science (IFS), Sweden.

Literature

1. Agboola A.A., 1987. Farming systems in Nigeria. In: N. Latham and P. Ahn (editors). Land development and management of acid soils in Africa. Proceedings, Second regional workshop on land development and management of acid soils in Africa held in Lusaka, Zambia. IBSRAM, Bangkok, pp.67-81
2. Agboola A.A. & A.O. Ogunkunle, 1993. Site characterisation at Epemakinde, Ondo state, Nigeria. Technical report on land development for sustainable agriculture in Africa. IBSRAM/AFRICALAND network. Bangkok, Thailand, pp.120-131.

3. Beckett P.H. & R. Webster, 1971. Soil variability: A review. Soils and Fert. 34: 1-15.

4. Bray R.H. & L.T. Kurtz, 1945. Determination of total organic and available forms of phosphorus in soils. Soil Science 59: 39-45.

5. Eneji A.E., 1997. Effects of land clearing methods on soil organic matter, nutrient status and crop yield in soils of Epemakinde, South-western Nigeria. Ph.D. thesis, University of Ibadan, Nigeria. 244 pp.

6. Eneji A.E., E.A. Aiyelari, A.A. Agboola, A.O. Ogunkunle, G.E. Akinbola, J.A.I. Omueti & O. Babalola, 1995. Effects of land clearing on soil physical and chemical properties and crop yield in the forest zone of South-western Nigeria. African Soils, Volume **28**: 345-352.

7. FAO 1998. World Reference Base for Soil Resources. World Soil Resources Reports, 84-88 pp.

8. Hakannson I., W.B. Voorhees & H. Riley, 1988. Vehicle and wheel factors influencing soil compaction and crop response in different traffic regimes. Soil Till. Res. 11: 239-282.

9. Lal R., 1987 Managing the soils of sub-saharan Africa. Science 236: 1069-1076.

10. Lal R., 1992. Tropical agricultural hydrology and sustainability of agricultural systems: A ten year watershed management project in South-western Nigeria. Ohio state University printing services (Columbus) 303 pp.

11. Odu C.T.I., O. Babalola, E.J. Udo, A.O. Ogunwale, T.A. Bakare & G.O. microbiology. Department of Agronomy, University of Ibadan, 83 pp. Adeoye 1986. Laboratory manual for agronomic studies in soil, plant and microbiology.

12. Ogunkunle O.A., 1990. Progress report of IBSRAM land clearing Project. Presented at the 3rd Workshop of the AFRICALAND Programme, Antananarivo, Madagascar, January 9-15, 1990.

13. Ogunkunle A.O. & W.O. Erinle, 1994. Influence of tillage on the variability of some soil properties of an Alfisol in South-western Nigeria. Journal of Science Research, Volume **1**(1): 52-57.

14. Pieri L., 1989. Fertilité des terres de savanes; Bilan de trente ans de Recherche et de Développement Agricoles seed du Sahara. Ministère de la Coopération et du Développement. Montpellier: CIRAD/IRAT.

15. Sanchez P.A. & J.R. Benites, 1987. Low input cropping for acid soils of the humid tropics. Science, 188: 598-603.

16. Sanchez P.A., W. Cotou & S.W. Boul 1982. The fertility capability classification system: interpretation, applicability and modification. Geoderma, 27: 283-309.

17. Sharratt B., W. Voorhees & G. McIntosh, 1998. Persistence of soil structural modifications along a historic wagon train. Soil Sci. Soc. Am. J. 62: 774-777.

18. Walkley A. & I.A. Black 1934. An examination of Degtjareff method of determining soil organic matter and proposed modification of the chromic acid titration method. Soil Science, 37: 29-39.

19. Wilding L.P. & L.R. Drees 1978. Spatial variability: A pedologist's view point. In: Diversity of soils of in the tropics. American Society of Agronomy (ASA) special publication. pp. 1-12.

A.E. Eneji: Nigerian. Ph.D. and Lecturer. Department of Crop Science, University of Calabar, Nigeria.
B.B. Ayade: Nigerian. Ph.D. and Lecturer, Department of Botany and Microbiology, University of Ibadan, Nigeria.