Ife Journal of Agriculture, Vol. 12, Nos. 1 & 2 1990

Effects of removal of organic matter and Sesquioxides on surface soil structure of some selected Nigerian Soils.

P. O. AINA
Department of Soil Science
Obafemi Awolowo University
Ile-Ife, Nigeria.

Abstract

Changes in water-stable aggregation depicting those associated with bringing soils under bush fallow to continuous cultivation were determined for six soils from Nigeria as related to artificial removal of organic matter and/or sesquioxides from the soils. Wet sieving, and mechanical analysis methods of aggregate analysis were used.

Water-stable aggregation was appreciable under fallow with mean weight diameter of the aggregates ranging from 2.1 to 4.3 mm. More than 75% of the water-stable aggregates of the soils was due to individual or combined effects of organic matter and sesquioxides. Organic matter binding was prominent in all the soils, virtually responsible for aggregation in the Alagba and Iwo soils (Alfisols), and Ngala (Vertisol) and produced equivalent enhancement of water-stable aggregation as sesquioxides in the more acid Itagunmodi and Ikom soils (Ultisols). Aggregation in the plinthic Gambari soils was attributed mainly to sesquioxides of the selected soils. Results indicate greater vulnerability of the Alfisols compared to Ultisols reflecting differences in the sources of aggregate stabilisation.

Introduction

Soil structural condition is important in relation to soil and water conservation and crop production. This is particularly so in more weathered and vulnerable soils of the tropics where structural stability is usually maintained by periods of fallow and deteriorates rapidly with subsequent cultivation. These Soils are also noted to be very responsive to the adverse effects of cultivation (Pereira et al, 1954; Stephens, 1969) reflecting apparently the mechanism of aggregate stabilization of the soils.

Aggregate stability depends among other factors on the nature of organic and inorganic colloidal materials and the resultant cohesive forces binding the soil particicles into rigid aggregates (Emerson, 1959; Greenland, 1965). Aggregation is most commonly attributed to the cementation effects of organic matter and hydrous oxides of iron and aluminium. Water stable aggregation has been correlated with organic matter (Strickling, 1950; Lugo-Lopez and Juarez, 1959, and Kemper and Koch, 1966) and hydrous oxides of iron or aluminium (Lutz, 1936; Chesters et al, 1957; Kemper and Koch, 1966; Greenland et al, 1968). Stabilization by hydrous oxides of iron and aluminium however depends on the "activity" (Deshpande et al, 1968) of the oxides in the clay fraction and is therefore less consistent compared to that by organic matter. This, in addition to the high rate of organic matter mineralization in the tropical region, may impart varied degrees of aggregate stability to soils even within the same soil group. A knowledge of the changes in soil aggregation due to those aggregate stabilizing agents will thus be useful in recognizing their relative contributions and predicting the structural behaviour of different soils under continuous cultivation that should lead to the development of better management practices for soils. This study evaluated aggregation with and without the removal of organic matter, sesquioxides or both organic matter and sesquioxides of six contrasting soils sampled from different parts of Nigeria.

Materials and Methods

Six soils selected to represent a wide range of soil properties were sampled at 0-15cm depth under secondary bush regrowth from different parts of Nigeria (Fig. 1). Some physical and chemical attributes of surface samples and the classification of the soils are given in Table I.

Soil samples were air dried and crushed to pass through a 2-mm sieve, and analysed for pH (potentiometrically) in 0.01M $CaCl_2$ solution (1:2 soil/solution ratio); organic carbon by Walkey-Black method (Allison, 1965) and free sesquioxides (iron and aluminium oxides) by dithionite-acid method (Mackenzie, 1954).

The initial soil pretreatments involved the removal of organic matter with 30% hydrogen peroxide, sesquioxides by dithionite-acid method (Mackenzie, 1954), or both by first removing sesquioxides then removing organic matter. The untreated soil (control) was given similar handling except that distilled water substituted for the chemical reagents. Soils were air dried after the pretreatment.

Structural stability of the soils was then determined with and without the following soil constituents removed, namely organic matter, sesquioxides and both organic matter and sesquioxides. Two different techniques used for the aggregation analysis included: particle size distribution analysis carried out with and without dispersing agent (2N NaoH) and particles 0.5 — 2.0 mm diameter wet sieved while silt (2 - 50 u) and clay size particles were determined by sedimentation method using a pipette; aggregate analysis by the wet-sieving method as described by Van Bavel (1949) and using sieves having openings of 2.0, 1.5, 1.0, 0.5, 0.25 and O.10mm.

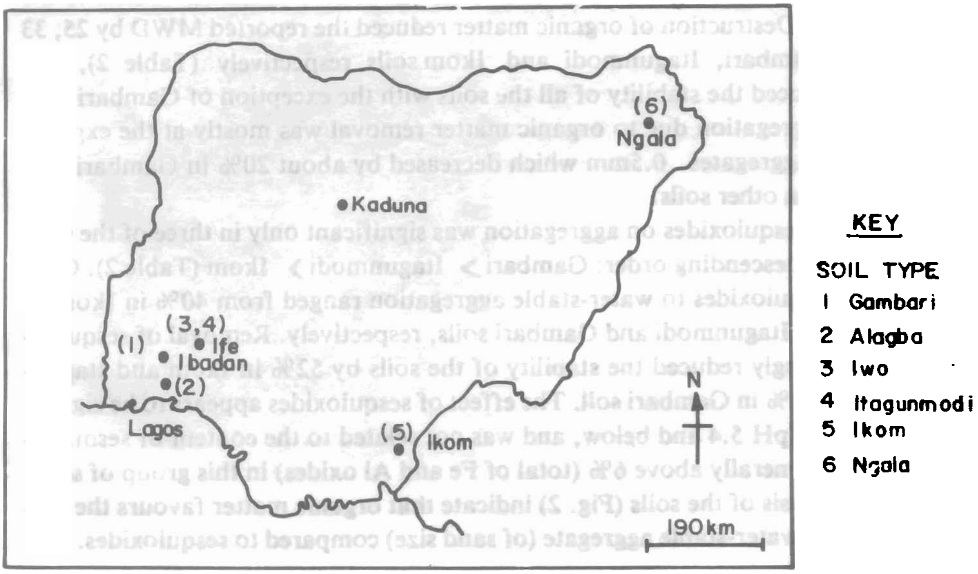

Fig. 1 : Map of Nigeria showing sampling sites.

TABLE 1: CLASSIFICATION AND SOME PHYSICAL AND CHEMICAL PROPERTIES OF SOILS USED

Soils	Classification	pH ($CaCl_2$)	Org. C	Fe_2O_3	Al_2O_3 %	Sand	Silt	Clay
Itagunmodi	Paleustult	5.21	2.11	89	2.62	38.4	25.2	36.4
Ngala	Vertisol	7.32	0.75	20.47	1.08	42.0	24.4	33.6
Ikom	Orthoxic Tropohumult	5.12	3.51	10.06	2.82	34.4	25.0	40.6
Iwo	Oxic Paleustalf	5.81	1.91	2.85	1.89	70.1	14.0	15.9
Alagba	Oxic Paleustalf	6.25	1.74	1.69	1.06	75.7	10.4	13.9
Gambari	Plinthustalt	5.54	1.67	2.36	3.61	64.1	14.0	21.9

Results

Degree of water-stable aggregation of the soils was appreciable under fallow with mean weight diameter (MWD) of the aggregates ranging from 2.1 for Ngala soil to over 4.0 mm for Ikom, Itagunmodi and Gambari soils (Table 2). Water-stable aggregates 0.5mm averaged 85% for Ikom, 82% for Itagunmodi and Gambari soils, and 78, 76 and 55% respectively for Alagba, Iwo and Ngala soils. The proportion of water-stable aggregates in the 2.0 to 4.0mm size range varied from 20% for Ngala soil to 70% for Ikom soil. The trend of results was generally consistent whatever the method of aggregate analysis for soils. Water-stable aggregation in the soils was attributed to the individual or combined effects of organic matter and sesquioxides.

Organic matter was responsible for the major portion of aggregation in Iwo, Alagba and Ngala soils, contributing on the average of more than two-thirds of the reported MWD. Destruction of organic matter reduced the reported MWD by 25, 33 and 50% in Gambari, Itagunmodi and Ikom soils, respectively (Table 2), and significantly reduced the stability of all the soils with the exception of Gambari soil. Reduction in aggregation due to organic matter removal was mostly at the expense of water-stable aggregates 0.5mm which decreased by about 20% in Gambari and more than 65% in other soils.

The effect of sesquioxides on aggregation was significant only in three of the soils in the following descending order: Gambari > Itagunmodi > Ikom (Table 2). Contributions of sesquioxides to water-stable aggregation ranged from 40% in Ikom to 50% and 75% in Itagunmodi and Gambari soils, respectively. Removal of sesquioxides correspondingly reduced the stability of the soils by 52% in Ikom and Itagunmodi soils and 74% in Gambari soil. The effect of sesquioxides appears to be significant in soils with pH 5.4 and below, and was not related to the content of sesquioxides which was generally above 6% (total of Fe and Al oxides) in this group of soils. Mechanical analysis of the soils (Fig. 2) indicate that organic matter favours the formation of larger water-stable aggregate (of sand size) compared to sesquioxides.

TABLE 2: MEAN WEIGHT DIAMETER OF SOILS AS INFLUENCED BY REMOVAL OF ORGANIC MATTER (M), SESQUIOXIDES (Se) AND BOTH ORGANIC MATTER AND SESQUIOXIDES (MSe).

Mean Weight Diameter

Soil	Untreated Soil	—M	—Se	—MSe	LSD (0.05)
			mm		
Itagunmodi	3.87	2.43	1.93	0.85	1.08
Ngala	2.08	0.67	1.02	0.48	0.33
Ikom	4.23	2.21	2.53	1.10	1.22
Iwo	2.98	0.85	2.58	0.66	1.43
Alagba	3.15	1.15	2.79	0.80	1.42
Gambari	4.12	3.01	0.97	0.64	1.13

Only in Itagunmodi and Ikom soils was there a possibility of significant interactive effect of both organic matter and sesquioxides on water-stable aggregation. The removal of both constituents from these soils resulted in lower aggregation and greater instability compared to the effect of individual constituents (Table 2). The magnitudes of the MWD of soils that had both organic matter and sesquioxides removed suggest the possibility of other, but less significant sources of aggregating agents such as cations (Ahmad et al, 1969).

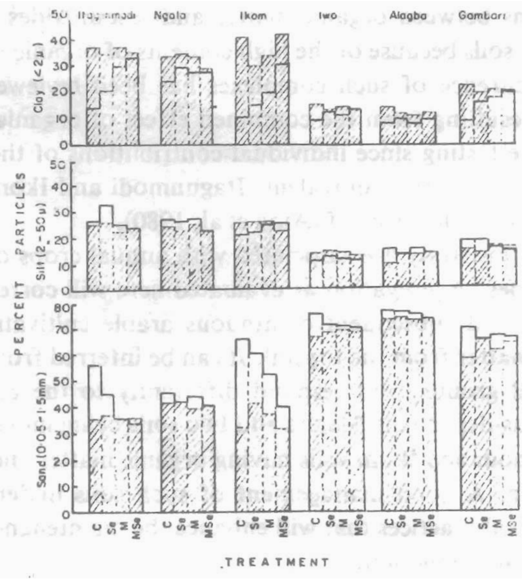

Fig. 2 Effect of removal of sesquioxides (Se), organic matter (M) or both (MSe) on particle size distribution with dispersing agent (hatched histogram) and without dispersing agent (solid histogram)

Discussion and Conclusions

The major source of the high water-stable aggregation exhibited by soils under fallow was attributed to either the organic matter, sesquioxides or an interplay of these constituents, depending on soil constitution. Organic matter binding was prominent in all the soils studied even with organic carbon contents as low as 0.8%. The significant reduction in the MWD of the calcic Ngala soil induced by the removal of sesquioxides was probably due to the inactivation (by acid during pretreatment) of $CaCO_3$ constituents as a cementing agent rather than to sesquioxide effect which is non existent at such high soil pH.

Water-stable aggregation in Alagba and Iwo (Alfisols) soils was due to organic matter; sesquioxides being structurally inactive due to supraoptimal (relative to sesquixide activity) pH of the soils (Deshpande et al 1968; Greenland et al, 1968). Destruction of organic matter therefore resulted in almost complete disaggregation of the soils. Additional aggregation may have resulted from the considerable earthworm casts (Swaby, 1949) observed on Alagba soil. Cultivation which results in rapid depletion of organic matter especially in the tropics will therefore lead to considerable structural deterioration of these soils particularly (Pereira et al, 1954; Stephens, 1969; Aina, 1979) in the first few years of cultivation.

In contrast, the Itagunmodi, Ikom and Gambari soils were less vulnerable and exhibited a higher degree of water-stable aggregation due to the stronger binding of sesquioxides. These soils because of lower pH values contain some active Fe or Al oxides (Greenland *et al,* 1968) and possibly amorphous coatings of noncrystalline alluminiosilicates in the clay fraction which are positively charged (Gallez et al, 1975; Gallez et al, 1976) and act as strong bonding and flocculating agents. Over half their clay was aggregated to water-stable aggregates mainly of sand size (Fig. 2). Significant interactions between organic matter and sesquioxides were possible in Itagunmodi and Ikom soils because of the high contents of organic matter and active sesquioxides. The occurence of such complexes has been reviewed by Greenland (1965). Aggregation resulting from the combined effect of organic matter and sesquioxides will be more lasting since individual contributions of the constituents to aggregation were significant and equivalent. Itagunmodi and Ikom soils are noted for their low erodibility and low runoff (Aina et al, 1980).

In Nigeria, soils of this study are associated with annual crops on nearly level to moderately steepy slopes. Aggregation as evaluated here will correlate with that of the soil under fallow and subsequent continuous arable cultivation that favours rapid loss of organic matter from the topsoil. It can be inferred from the results that soils, even within soil groups, will respond differently to the adverse effects of cultivation; the humus-dependent Alagha and Iwo soils being more vulnerable than the more acid Itagunmodi and Ikom soils having organic matter and sesquioxides as sources of aggregation. A good management of such soils under cultivation will therefore require cultural practices that will enhance the maintenance of appreciable amount of organic matter in the soil.

Literature cited

Ahmad, S., Swindale, L.D. and El-Swaify, S.A. 1969. Effect of adsorbed cation on physical properties of tropical Red and Tropical Black Earths I. Plastic limits, percentage stable aggregates and hydraulic conductivity. *J. Soil Sci. 20: 255—268.*

Aina, P.O. 1979. Soil changes resulting from long-term management practices in Western Nigeria, *Soil Sci. Soc. Am. J. 43: 173—177.*

Aina, P.O., Lal, R. and Taylor, G.S. 1980. Relative susceptibility of some Nigerian soils to water erosion: A laboratory investigation. *Nig. J. Soil. Sci. 1: 1—19.*

Allison, L.E. 1965. Organic carbon. In C.A. Black (ed) Methods of soil analysis, part 2. *Agronomy 9: 1367—1378. Am. Soc. of Agron., Madison, Wis.*

Chesters, G., Attoe, O.J. and Allen, O.N. 1957. Soil aggregation in relation to various soil constituents. *Soil Sci. Soc. Am. Proc. 21: 272—277.*

Deshpande, T.L., Greenland, D.J. and Quirk, J.P. 1968. Changes is soil properties associated with the removal of iron and aluminimum oxides. *J. Soil Sci. 19: 108—122.*

Emerson, W.W. 1959. The structure of soil crumbs *J. Soil Sci. 10: 233—244.*

Gallez, A., Juo, S.A.R., and Herbillon, A.J. 1976. Surface and charge characteristics of selected soils in the tropics. *Soil Sci. Soc. Am. J. 40: 601—608.*

Gallez, A., Juo, S.A.R., and Herbillon, A.J. and Mormann, F.R. 1975. Clay mineralogy of selected soils in Southern Nigerian. *Soil Sci. Soc. Am. J. 39: 577—585.*

Greenland, D.J. 1965. Interaction between clays and organic compounds. *Soils and Fert. 28: 415—425.*

Greenland, D.J. Oades, J.M. and Sherwin, T.W. 1968. Electron microscope observations of iron oxides in some red soils, *J. Soil Sci. 19: 123—126.*

Kemper, W.D. and Koch, E.J. 1966. Aggregate stability of soils from the Western Portions of the United States and Canada. *U.S. Dept. Agric. Tech. Bull. 1355.*

Lugo-Lopez, M.A., Juarez, Jr., J. 1959. Evaluation of the effects of organic matter and other soil characteristics upon the aggregate stability of some tropical soils. *J. Agric. Univ. P.R. 43: 268—272.*

Lutz, J.F. 1936. The relation of free iron in the soil to aggregation. *Soil Sci. Soc. Am. Proc. 1: 43—45.*

Mackenizie, R.C. 1954. Free iron oxide removal from soils *J. Soil Sci. 5: 167—172.*

Pereira, H.C., Chenary, E.M. and Mills, W.R. 1954. The transient effect of grasses on the structure of tropical soils. *Empire Journ. Experimental Agric. 22: 148—160*

Stephens, D. 1969. Changes in yield and fertilizer responses with continuous cropping in Uganda. *Exp. Agric. 5: 263—269.*

Stricking, E. 1950. The effect of soyabeans on volume, weight and water stability of soil aggregates, soil organic matter content and crop yield. *Soil Sci. Soc. Am. Proc. 15: 30—34.*

Swaby, R.J. 1949. The influence of earthworms on soil structure, *J. Soil Sci. 1: 182—197.*

Van Bavel, C.H.M. 1949. Mean weight diameter of soil aggregates as a statistical index of aggregation. *Soil Sci. Soc. Am. Proc. 14: 20—25.*