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EFFECTS OF EXCHANGEABLE CA:MG RATIO ON THE DISPERSION OF SOILS SOME SOUTHERN NIGERIA SOILS.

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ABSTRACT

Soil surface sealing and erosion which are the result of soil dispersion can be harmful or detrimental to soil, soil resources and also agricultural production thereby leading to great economic loss. Soil samples were collected at 0-30cm depth in eight locations in southern Nigeria. Dispersion behaviours of soil contents were studied at different Ca: Mg ratios. The range of values of properties determined are as follows; clay 10-22%, silt 1-18%, sand 64-89%, WDC 6-14%, WDS 1-16%, CDR 0.44-0.86%, DR 0.41-0.84%, ASC 2-18%, CEC 4-15.6cmolkg^{-1} , percentage base saturation 18-66%, available phosphorus 1.87-34.57mg/kg. The soils studied were acidic, low in nutrient level, showed high dispersion rate, high water- dispersible clay content and the textural class were loamy sand and sandy loam. The exchangeable Ca^{2+} and Mg^{2+} contents of the soils dominated the exchange complex. The cation exchange capacity (CEC) ranges between 4 and 15.6 cmol kg^{-1}. Values of percentage base saturation are between 18 and 66%. The available phosphorous ranges between 1.87-34.57 mg/kg. The distribution of Ca and Mg varied with the quantity of ratio of $CaSO_4$ and $MgSO_4$ added. The higher the proportion of Mg the higher the clay content while a lower Mg proportion had a lower clay content. Secondly, a higher Ca^{2+} proportion resulted to smaller clay content while a lower Ca^{2+} proportion led to a high clay content. From this study it was discovered that high Mg, silt and clay cause soil dispersion which will be detrimental to the soil. Also high CDR and DR are indicators of high soil dispersity. Therefore, monitoring dispersion in soil is important to avoid its negative impact on the soil. Management practices should be applied in the form of application of fertilizer and liming materials to the soil as higher concentration ($Ca^{2+}$and Mg^{2+}) will be introduced to the soil which will bring about dispersion in the soil.

Keywords: *Dispersion, Ca: Mg ratio, dispersion ratio, clay dispersible ratio, dispersible silt.*

INTRODUCTION

It is generally accepted that the right approach to fight soil degradation such as erosion is through good management and protection of the soil and this cannot be achieved without conservation of available resources. Soil erosion has been directly linked to the rate and volume of water-dispersible clay in a soil, (Igwe and Udegbunam ,2008).

The exchangeable form of an element is the form in which the element exists as a cation or an anion adsorbed on the surface of organic compounds or clay minerals. Dispersion occurs when excessive sodium attached to clay forces the clay particles apart in water resulting in clouds of clay forming around aggregate. Dispersible soil loses all its structure and dissolves in water because the soil crumbs or blocks separate into single particles due to the fact that the bonds between the particles are not strong enough to keep them together. Dispersion depends on the mineralogy (the clay), physical (sand, silt and clay) and exchangeable cation of the soil. The chemical and mineralogical compositions of soil materials have a particular influence on the physical properties and soil erodibility of soil in dry climatic conditions (Birkeland ,1984; Reichert and Norton, 1994). Emerson (1971) noted that low organic carbon content of the soil can cause severe dispersion of clay in water while

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those with high organic carbon content shows low dispersion in water. It has been observed that Mg causes dispersion of soil colloids and enhance surface sealing during rainfall (Curtin *et al.*, 1994; Keren, 1991).

Dispersible soils are difficult to cultivate, not-trafficable, become sticky after light rainfall, and produce patchy crop emergence which finally collapse after heavy rainfall. Therefore, dispersible soils are generally and structurally degraded soils.

Gypsum applied to soils with dispersible clays improves the permeability to water by reducing the dispersion of the clay. Dispersion reduction allows more of the rainfall to enter the soil, reducing run-off and erosion risk and improving drainage after heavy rain.

Bohn et al (1985) reported that cation with large hydrated radius favours dispersion, stating that a possible reason for specific Mg effect is that the hydration energy of Mg is greater than Ca, therefore, the hydration radius is also greater. Consequently, soil surface where exchangeable Mg is present, will tend to absorb more water than where exchangeable Ca is present. This will tend to weaken forces that keep soil particles together which in turn will tend to increase clay swelling and dispersion. Aydin *et al* (2004) reported that hydraulic conductivity values showed a great sensitivity to pH. Suarez *et al* (1984) showed that high pH has an adverse effect on hydraulic conductivity. However, when Mg is present it will reduce the hydraulic conductivity thereby reducing the pH of the soil which will not be in the favour of pH.

Soil properties can influence the rate at which the soil disperses. Igwe (2005) remarked that pH, soil organic carbon, exchangeable Ca, exchangeable acidity, cation exchange capacity, sodium adsorption ratio, clay and silt contents of the soil are the soil factors that influence the water dispersible properties of the soils. The objective of this study was to determine the effect of exchangeable Ca and Mg on dispersion, chemical composition of soils from eight locations in Southern Nigeria.

MATERIALS AND METHODS

Soil Samples were collected at the depth of 0-30cm from eight southeastern and South eastern states of Nigeria namely; Agbor, Asaba (Delta State), Ovim, Ahaba-Imenyi (Abia State), Okigwe, Owerri (Imo state) and Nsukka, Ngwo (Enugu State). The soil samples were air dried and sieved through a 2-mm sieve for laboratory analysis.

Particle size distribution was determined by hydrometer method as described by Gee and Bauder (1986). This was done in three stages; with water, calgon and in different ratios of Ca and Mg (0:100, 25:75, 50:50, 75:25 and 100:0) and was left for 24 hours undisturbed. Calgon was the dispersing agent and the purpose of this analysis was to determine the amount of individual soil separates in other to determine the textural class of the soil. The pH of the soils was determined using pH meter. The soil organic carbon was determined by dichromate oxidation method by Walkey and Black method as described by Nelson and Sommer (1982). Total nitrogen was determined using Macro-kjeldahl method. Exchangeable Na^+ and K^+ were measured in the flame photometer while exchangeable Ca^{2+} and Mg^{2+} were determined by titration method (Jackson, 1958). Cation Exchange capacity (CEC) were determined by the modified ammonium acetate method of Chapman and Prat (1961). Available phosphorous was determined by the Bray and Kurtz 2 method.

The clay dispersible ratio (CDR), dispersion ratio (DR) and aggregate silt and clay (ASC) were calculated using the relationships stated below;

CDR =% clay (H_2O)/ %Clay (dispersed)

DR = (%Clay + %Silt)H_2O/(%Clay+%Silt) dispersed

ASC = %Clay + % Silt (dispersed) – %Clay +% Silt (H_2O).

RESULTS AND DISCUSSION

Soils

The particle size distribution of the soils(Table 1) shows that the soils are mostly loamy sand and sandy loam. Coefficient of variation estimate showed highest variability in silt, indicating that there is high difference in silt content among the eight samples. The clay fraction has a mean value of about15% while the silt fraction had a mean value of about 9%. The chemical properties of the soils (Table 2) shows that the soils are all within the acid range. The organic carbon (OC) and the nitrogen contents were low. The exchangeable Ca^{2+} and Mg^{2+} contents dominated the exchangeable complex. There were traces of Al^{3+} in all location. From this study, hydrogen was low and according to Black (1954), a considerable part of exchangeable part of the exchangeable-cation content may be aluminum rather than hydrogen in acid soils. It is recognized that Al solubility and mobility increases with hydrogen saturation. Dispersion equally depends on cation exchange capacity (CEC) as noted by Birkeland (1984) and Reichert and Norton (1994). The CEC of soil varies with the kind of clay, percentage of clay and percentage of organic matter. The actual CEC at any point in the field would be considerably lower and in turn, the percentage base saturation (BS) would be considerably higher (Brady and Weil 1999). It was also noted that soil pH increases with increase in base saturation at pH greater than 5.5 (Thompson, 1957). A similar trend in this relationship between CEC, BS and pH was observed in this present study.

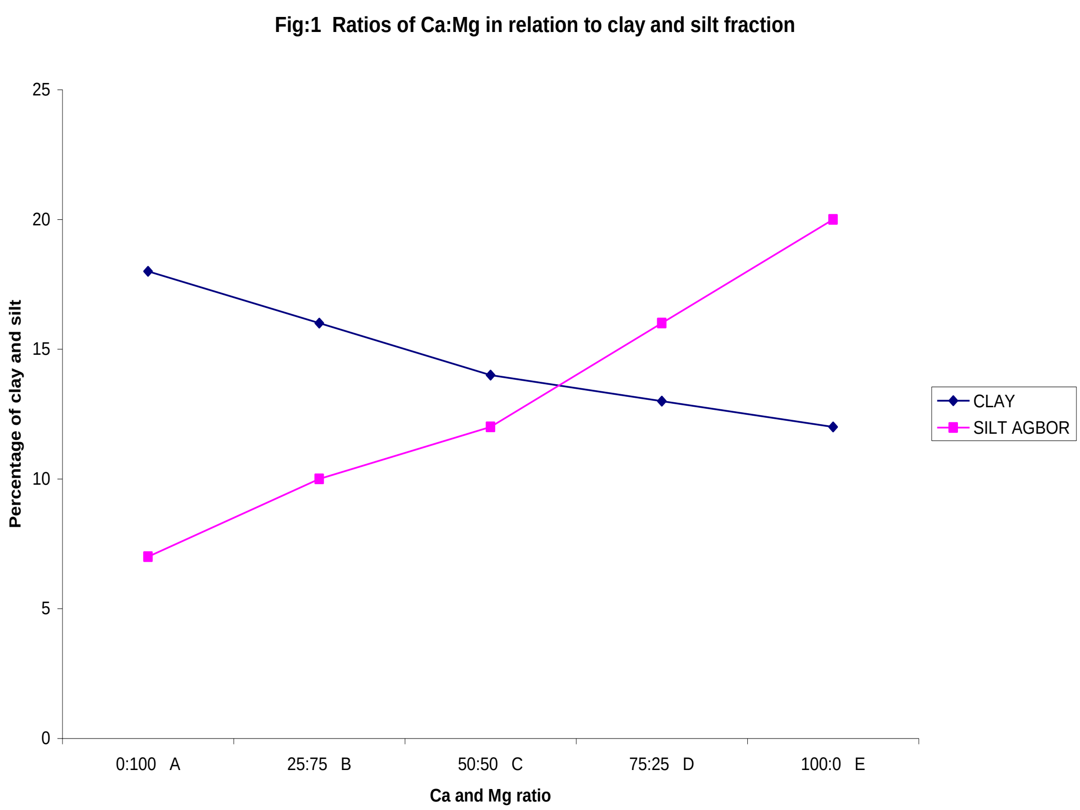

Fig.1: Ratios of Ca : Mg in relation to clay and silt fraction in soil from Agbor location

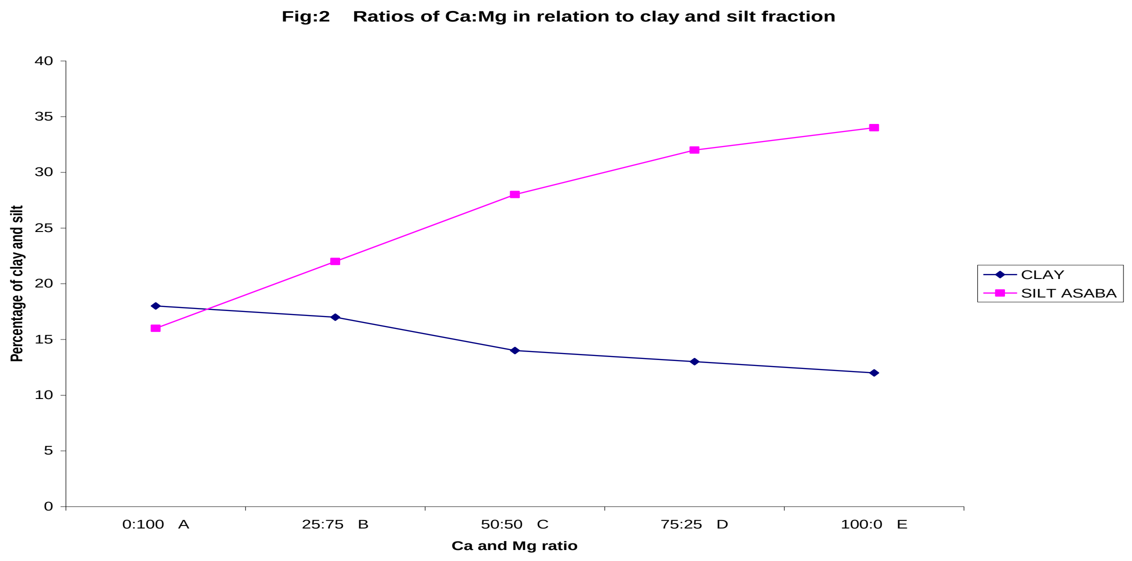

Fig. 2: Ratios of Ca:Mg in relation to clay and silt fraction in soil from Asaba location.

Table 1: Particle size distribution and textural class

Location	Clay	Silt	F Sand	C Sand	T Sand	T class
	%					
Agbor	10	1	24	65	89	LS
Asaba	22	12	11	55	66	SL
Ahaba	12	18	38	32	70	LS
Imenyi						
Ovim	18	18	54	10	64	SL
Okigwe	14	6	29	51	80	LS
Owerri	14	2	17	67	84	LS
Nsukka	18	12	25	45	70	SL
Ngwo	10	2	27	61	88	LS
Mean	14.8	8.9	28	48	76	-
CV%	28	79	46	39	13	-

Table 2 Chemical Properties of the soils

Location	pH H_2O	KCl	OC	N %	Na^+	K^+	Ca^{2+}	Mg^{2+} Cmol/kg	EA	CEC	% Base Sat.	Av.P Mg/kg
Agbor	4.9	4.2	1.13	0.08	0.53	0.11	2.2	1.0	0.4	10.4	37	5.60
Asaba	5.5	4.3	0.47	0.05	0.59	0.04	3.8	0.2	0.4	9.2	50	2.80
Ahaba Imenyi	5.2	4.6	1.99	0.16	0.59	0.08	7.2	0.8	0.4	13.2	66	6.53
Ovim	5.3	4.1	2.07	0.15	0.53	0.25	2.4	1.6	1.2	15.6	31	8.39
Okigwe	6.7	5.0	1.05	0.08	0.65	0.10	4.8	0.2	0.4	9.6	60	34.51
Owerri	5.5	4.8	1.05	0.08	0.41	0.03	3.0	1.4	0.4	11.2	43	1.87
Nsukka	5.4	3.2	0.90	0.08	0.47	0.03	1.4	0.2	0.8	11.6	18	4.66
Ngwo	6.0	3.6	0.47	0.04	0.47	0.01	0.4	1.0	0.8	4.0	47	2.80
Mean	5.6	4.2	1.1	0.09	0.53	0.08	3.15	0.80	0.60	10.6 0	44.00	8.40
CV%	10	14	53	48	15	96	67	69	50	32	35	128

OC = Organic carbon
EA = Exchangeable acidity

Water-dispersible characteristics of the soils

Table 3 presents water-dispersible clay, silt, CDR, DR and ASC. Water Dispersible clay (WDC), can influence soil erosion by water. The values obtained were in the range of 6-14%. It was observed in this experiment that the soils have high WDC content. Igwe (2005) noted that water dispersible clay constitute major problem to soil and environment. High clay dispersion by water causes accelerated dispersion and deposition of sediment of clay with nutrient element. Water-dispersible silt ranged from 1-16%. The clay dispersion ratio and dispersion ratio have high values ranging from 0.44-0.86 and

0.41-0.84 respectively. In highly erodible soils there is need to monitor the clay dispersion characteristics to direct and modify soil conservation strategies. Soil degradation such as soil erosion by water is directly linked to water dispersible clay in the soil (Igwe and Udegbunam, 2008). Igwe (2005) remarked that the clay dispersion ratio and dispersible ratio were found to be good indices for predicting erodibility in some soils of southeastern Nigeria. In another study Igwe *et a*l. (1995) observed that DR and CDR correlated very significantly with erodibility in the Universal Soil Loss Equation (USLE) model. The higher the CDR and DR, the more the ability of the soil to disperse (Igwe and Udegbunam 2008). Therefore soils with high DR and CDR are known to be weak structurally and can easily erode. In this present study, it was observed that soils from Owerri, Ngwo and Okigwe recorded relatively high CDR and DR which means that they are more prone to erosion than soils from other locations which have low values of CDR and DR. Bajracharya *et al.* (1992) recommended the use of WDC and CDR in predicting the relative ease of soil to erode in some Ohio soils in the United States of America.

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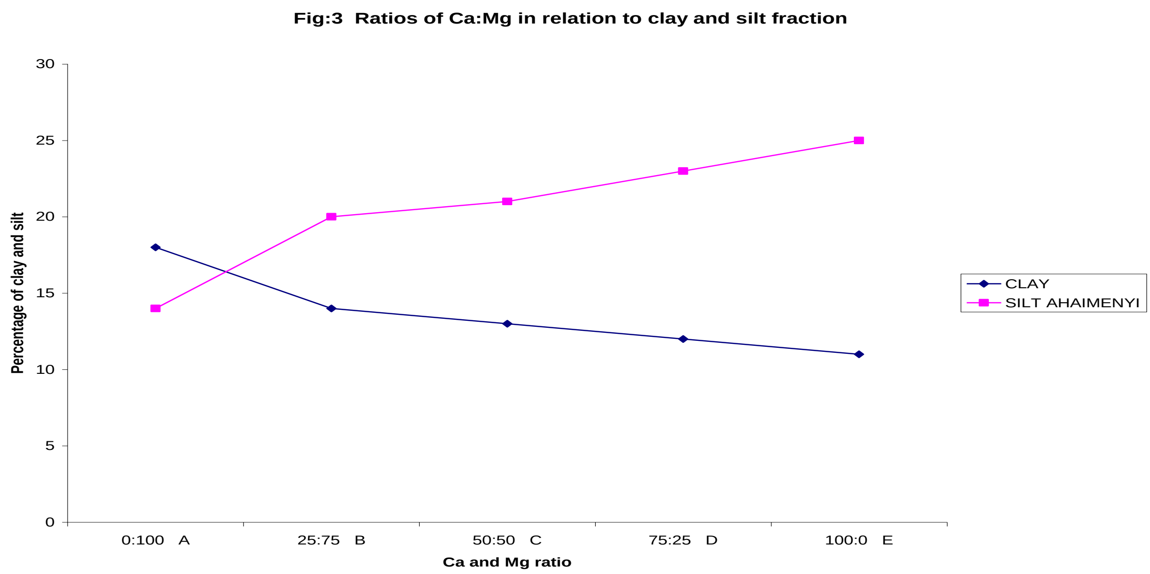

Fig. 3 Ratios of Ca:Mg in relation to clay and silt fraction in soil from Imenyi location

Table 3: Water-dispersible Clays, Silt, CDR, DR and ASC

Location	WDC%	WDS%	CDR	DR	ASC%
Agbor	6	2	0.60	0.81	2
Asaba	14	8	0.64	0.65	12
Ahaba	8	4	0.67	0.41	18
Imenyi					
Ovim	12	16	0.67	0.78	8
Okigwe	10	4	0.71	0.70	6
Owerri	12	1	0.86	0.76	4
Nsukka	8	4	0.44	0.41	18
Ngwo	8	2	0.80	0.84	2
Mean	10	5	0.68	0.67	9
CV%	27	97	19	26	73

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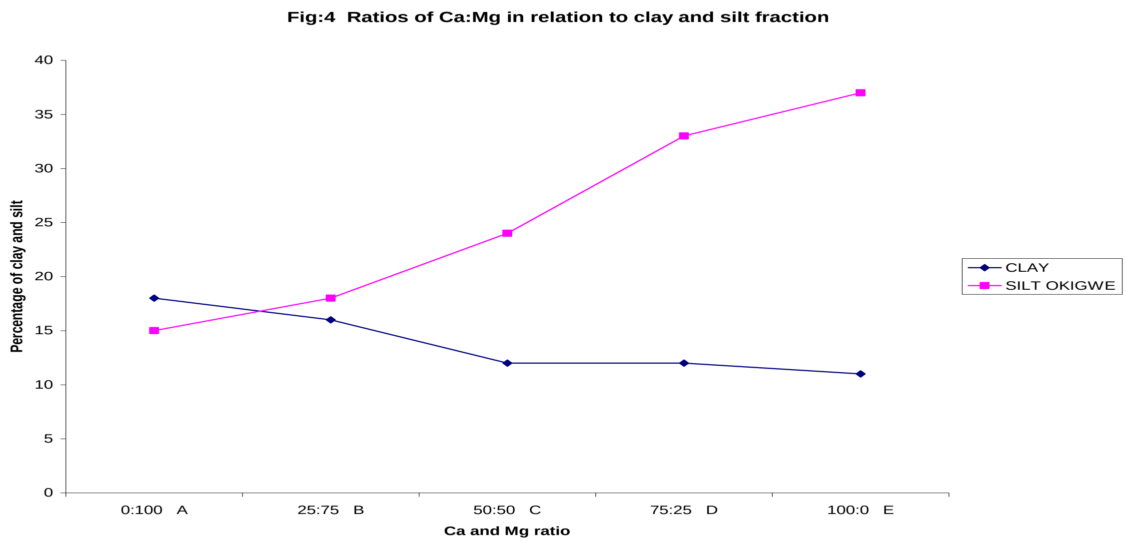

Fig.4 Ratios of Ca:Mg in relation to clay and silt fraction in soil from Okigwe location.

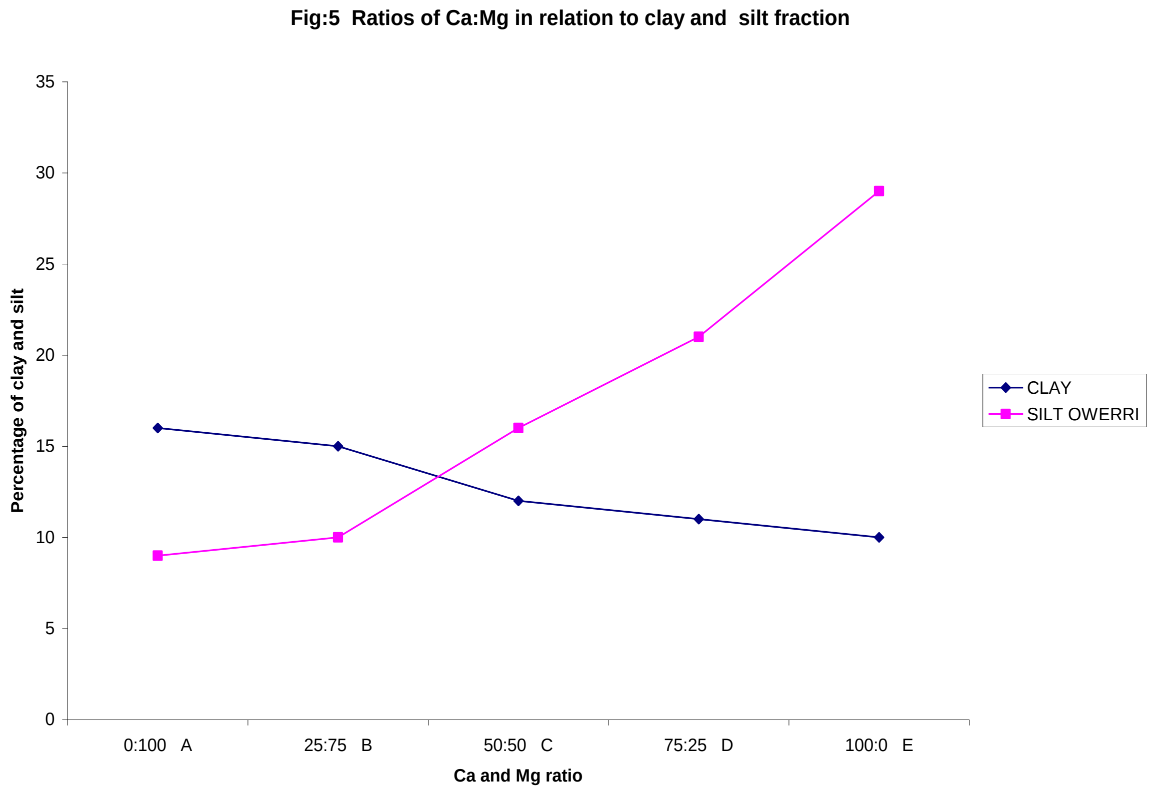

Fig.5 Ratios of Ca:Mg in relation to clay and silt fraction in soil from Owerri location.

Effects of varying Ca: Mg ratio on soils

The Ca:Mg ratio in relation to percentage clay, silt and sand are presented in Figs 1-8.The result showed that increasing Ca:Mg ratio decreases the content of clay and increases the silt content, the proportion of sand also tend to decrease with increase in Ca:Mg ratio. These observations were consistent in all the locations for clay and silt. It has been reported by Dontsova and Norton (2002) that low Ca:Mg ratios and high Mg^{2+} content cause dispersion in soils and also has adverse effect on soil structure. It also has less flocculating effects on soil clays than Ca^{2+} due to its large hydrated radius. Keren (1991) also established that Mg^{2+} in soil could affect erosion rates, explained by the hydration number of Mg^{2+} ion being about 50% greater than that of the Ca^{2+} ion. Norton and Dontsova (1998) also reported that soils with a high percentage of Mg on exchange sites had deteriorated soil structural properties and lower infiltration rates during simulated rainfall compared to similar soils high in Ca. Bohn *et al* (1985) reported that a possible for a specific Mg effect is that the hydration energy of Mg is greater than Ca, therefore the hydration radius is also greater.

Soil dispersion was found to be low in high Ca: Mg ratio and high in low Ca: Mg ratio. In other words the higher the Ca in the ratio the lower the dispersion and the higher the Mg in the ratio the higher the dispersion. Since Mg causes dispersion and this dispersion depend on the mineralogy (clay) and exchange cation of the soil. Its increase in Ca:Mg ratio will lead to reduced infiltration rate, hydraulic conductivity, surface sealing thereby increasing the clay content of the soil which will then enhanced dispersion therefore encourage erosion. More so the hydrated radius of the Mg ion is approximately 50% greater than that of Ca ion. Soil surfaces where exchangeable Mg is present will tend to absorb less water than where exchangeable Ca is present. This will then weaken forces that keep soil particles together and in turn increase clay dispersion. Again Ca ions are more effective than Mg ions in aggregating soil clay and this helps in dispersion reduction. These observations were consistent in all the location for clay and silt. The highest clay percentage was observed in Ovim at 0:100 Ca: Mg ratio after dispersing while the lowest was observed in Owerri at 100:0. Yilmaz *et al*. (2004) reported that an increase in clay does not always result in increased stability. While the clay mineral content is an important factor in aggregation, its influence is modified by the stability of high clay soils, which depends on the physical-chemical properties of the clay. Since dispersion depends on the mineralogy (clay), physical (sand, silt and clay) and exchangeable cation of the soil. It was observed that there were high values of clay, and enhances dispersion which could lead to soil erosion as was supported by Birkeland, (1984); Reichert and Norton, (1994). The chemical and mineralogical compositions of soils have a particular influence on the physical properties and soil erodibility of soils in dry climatic conditions. Heathwaite *et al.*, 2005; Seta and Karathanasis, 1996 also noted that clay and silt dispersion when soils are submerged in water affect a lot of soil physical and chemical properties such as shrink-swell for soils with very high clay contents, water-retention characteristics and hydraulic conductivity, water pollution, including crusting and sealing.

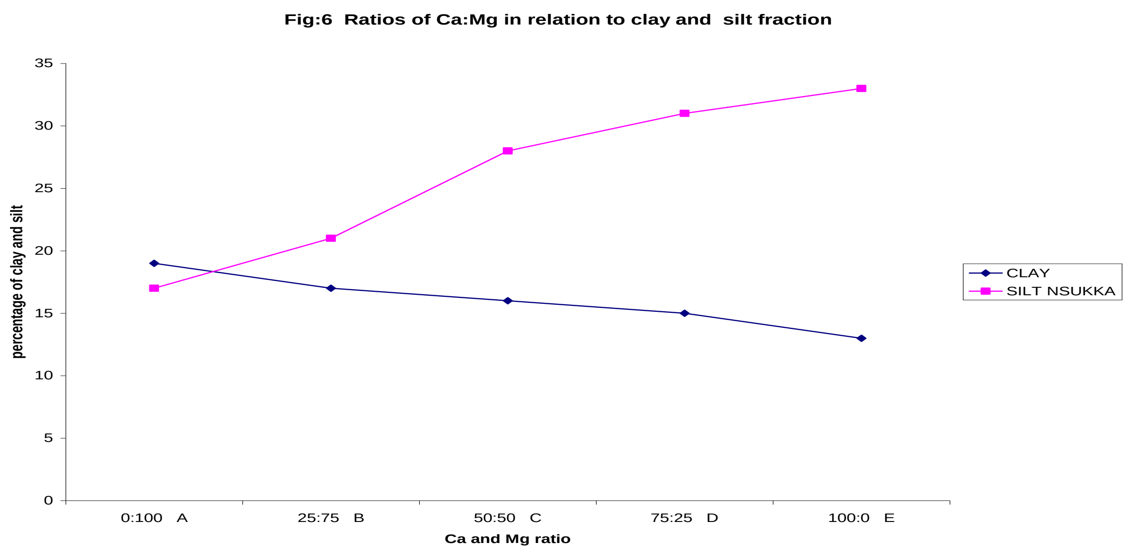

Fig.6 Ratios of Ca:Mg in relation to clay and silt fraction in soil from Nsukka location.

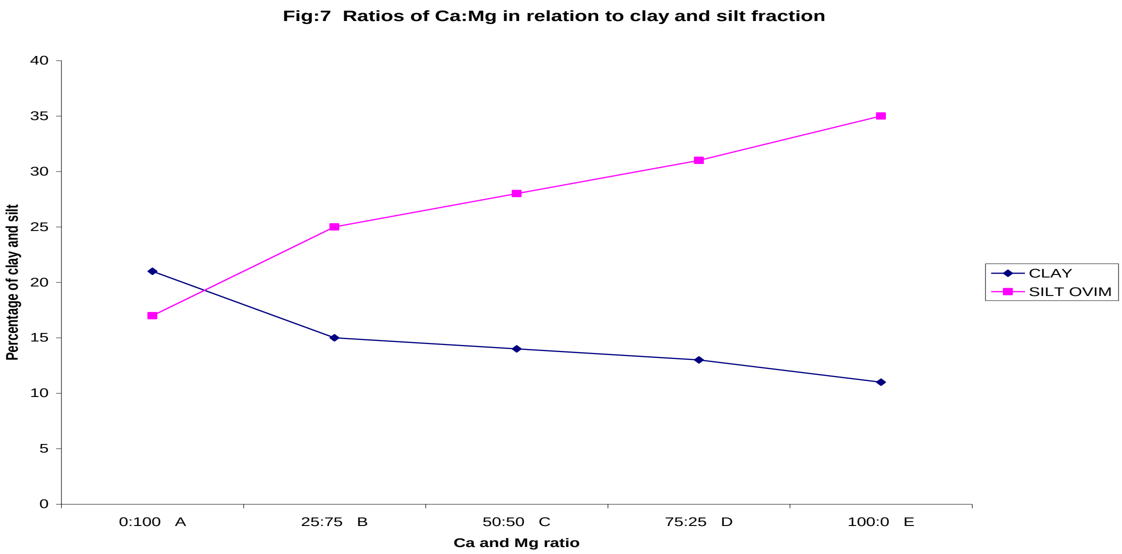

Fig.7 Ratios of Ca:Mg in relation to clay and silt fraction in soil from Ovim location.

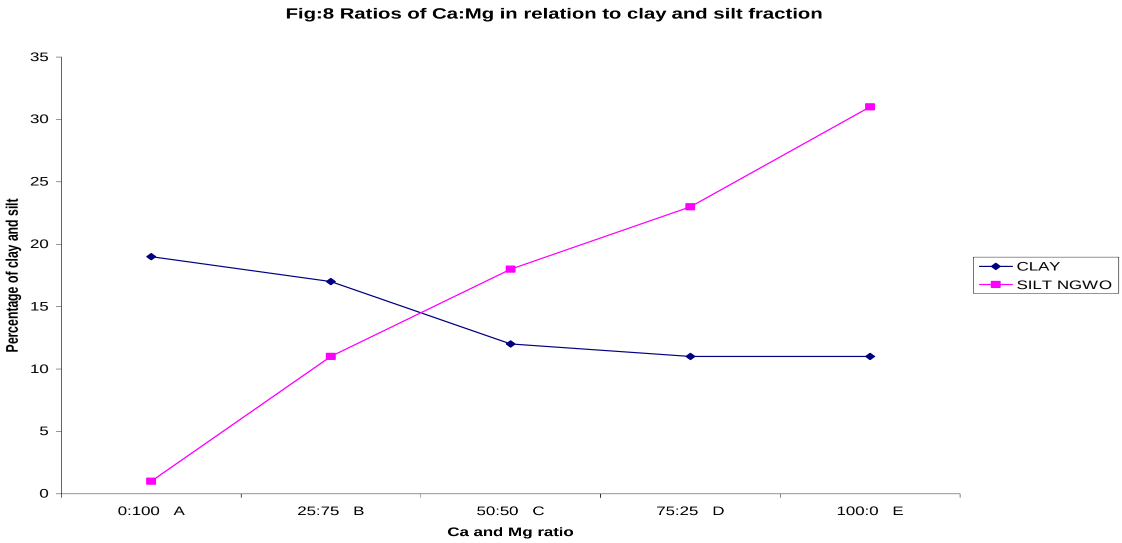

Fig.8 Ratios of Ca:Mg in relation to clay and silt fraction in Ngwo location.

CONCLUSION

Ca:Mg ratios have significant effect on dispersion and surface sealing but it is beneficial to manage soils high in Ca:Mg ratio if they are prone to sealing. It is recommended that to reduce the rate at which dispersion occurs, the manufacture or use of any fertilizer that has high Mg content should be avoided due to its detrimental effects on the soil. It is also suggested that the use of fertilizer that has more of Ca is recommended, since Mg^{2+} ions were more effective than Mg^{2+} in aggregating soil clay and this in turn reduces dispersion. On the other hand the use of liming materials (quality) should be checked since some contain Ca^{2+} ion in them. In this case, it is suggested that the use of more of dolomite limestone ($Ca\ Mg\ (CO_3)_2$) should be discouraged because it introduces Mg^{2+} ion to the soil and this causes dispersion. The use of Calcite limestone ($CaCO_3$) should be encouraged. It is recommended that erosion control measures and practices should be involved since almost all the soil showed high dispersion rate which is a strong indication that they are prone to erosion. The use of WDC and CDR is recommended in predicting the relative ease of soil to erode.

The study shows that high Mg ratio will increase dispersion of soil clay and this will bring about increase in surface sealing thereby increasing erosion.

DEDICATION

This paper is dedicated to the memory of late Mrs. Chisom Stella Ogbonna, a co-author of this paper. Before her death Mrs. Ogbonna, C.S. was a postgraduate student in the Department of Soil Science, University of Nigeria Nsukka. May her soul rest in perfect peace.

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