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Spatial Variability of pH and Lime Requirement for Sustainable Irrigation of Cross River State Soils

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Abstract

Soil pH in 34 representative sites across all Local Government Areas (LGAs) in Cross River State, Nigeria were investigated using electrometric method at field surveys. Data were statistically analyzed for descriptive statistics using SPSS version 17. Lime requirement was made by filtration. The pH varied between 5.89 and 6.98 making the soils spatially homogenous and fairly acidic (CV = 1 – 7%). Lime requirement for increasing soil pH were plotted on graphs and predictive functions gave second order polynomials with R^2 *= 0.8895 to 0.9951. The average amount (mls) of lime per 100g of soil for unit increase in soil pH, using approximately linear spatial variation, varied between 0.0257ml/unit pH change in Usunutong in Ugep LGA to 0.0605 in Ediba in Ugep LGA, 0.066 in EfutAbua, Calabar LGA and to 0.0703 in ObomItiat, Odukpani LGA. A peak value of 150ml of lime was considered the maximum to cause acidic change to pH pf 7.6 – 8.2. The quality of irrigation water must consider this pH distribution and avoid or amend acid rainfall or water effect to sustain tree crops (rubber), rice and vegetable productivity.*

1. Introduction

Soil is the medium of root development for plants. The organoleptic properties of themedium, the trace elements, the micro and macro – nutrients are sourcesof soil aggregate sustenance for root stability and food for crop sustenance. On many of these soils the soil pH changes much and becomes low below the neutral pH level. Such low pH has adverse consequences on the soil productive capacity and the crop. Low pH soils have their soil pH below 5.5. This might result in:

1) Reduction of crop yield, (2) damages to the crop themselves.

When the pH is less than neutral pH, the availability of micronutrients of manganese (Mn), aluminium (Al) and iron (Fe) increase and this condition might allow toxicity problem of the micronutrient to occur[15].

The problem of low soil pH is enormous, conversely, the availability of essential nutrients such as K, Ca and Mg, is decreased when essential nutrients become low deficiencies might results in crop which condition reduces productivity hence imposes economic problem.

Low pH caused by many natural factors. These include: production of more H^+ in the soil relative displacement of cations by cations of Aluminum.

- Inappropriate fertilization by ammonium fertilizer and acidic irrigation water.
- Intensive fertilization with NH4 – based fertilizer and Urea may lower soil pH.
- High rainfall conditions on soils also leach displace ionic elements of micronutrients, so that soils under high rainfall become more acid that soils formed under dry conditions [1].

- Soil formed under the native forest vegetation of which a vast proportion in Cross River state is in forest reservation, is said to affect soil pH in such a way that it tends to be more acidic [15].
- Soil organic matter left on top soils are decomposed by soil micro-organisms varmints and termites resulting in more H^+ ion brelease so that the soil becomes more acidic [15].

On the other hand, lime applications to acid soils increase soil pH and exchangeable Ca and Mg levels and decrease exchangeable acidity levels [3]. This significant increase in total cations with liming is the consequence of lime increasing [9]. The capacity of the soil to retain nutrients (which means increase in effective cation exchange capacity, CEC), and is a beneficial effect of humming to agricultural productivity and economic land use.

Effect of pH on irrigation is observed when using acidic water on low acidic or any acidic soils. Irrigation water that has a low buffering capacity (or low HCO_3 content) might drastically decrease pH levels in crop growing media when used on acidic soil [15]. Irrigating with such water can also decrease the lime requirement for plant production and can cause adverse plant growth by excessively raising the pH of the soil [6]. Therefore to improve productivity, an adequate source of irrigation water must be available to increase the pH or reduce negative changes on soil surface so that the soil retain the needed soil nutrient.

The most commonly used technique to raise the soil pH is by applying agricultural lime [15]. The amount of lime required is dependent on the soil's natural acidity [5]. Therefore, the knowledge of soil pH is paramount to soil nutrient management and lime requirement or liming potential of the irrigation water for pH moderation. These predicates invite research to establishing the soil pH. Therefore the objective of the research were:

(1) To carry out field survey on pH of representative soils in Local Government Area of Cross River state agricultural zones
(2) To establish lime requirements that influence irrigation water quality selection, crop selection and nutrient management on Cross River Soil.

2. Material and Method

Sampling: With a shovel and a digger profile pits were dug and the horizon was 15cm (6") deep. Enough soil sample were taken at each pits. The pits were separated by an interval of about 1 kilometer, and 10 of this were bulked into 1 bag to make up one sample – similar to the method of Rubins. That is, each pit provided a sub sample, ten of this sub-samples gave out sample. Five samples were obtained in each local government area, this means that 50 pits were dug, fifty sub-samples were collected in each Local Government Area. Plate 1 shows the map of Cross River state where the survey was carried out.

A depth of 15cm was chosen since this is the depth at which most of the agricultural vegetable crops grow [11]. Starting from Akamkpa samples were collected all over the state at the same interval. Altogether 85 samples were taken, that is, 850 sub-samples for the whole state. Each sample was differentiated from the other by the name of the village and the local government area where they were collected. Analysis of these soil samples were also carried out separately. ANOVA was applied to determined variance differences or homogeneity so that similarity of treatment and crop selected can be used. The descriptive and inferential statistics used SPSS version 17 software (Word) for processing.

1.1. Determination of pH (Acidity) was done by electrometric method.

Portion of each sample was air-dried and passed through 2mm sieve. Then 20gm of this soil was placed in 50ml beaker and 20mls of distilled water added. The determination of this pH was by the method of Davis [4]. The glass electrode of the pH meter was inserted into the partly settled suspension and measured. With each sample four readings were taken and the average pH recorded. This is soil pH measured in water. Before the pH meter was used, it was standardized with a standard solution. The distilled water used was also measured and its pH was exactly 7.0.

1.2. Lime Requirement Determination

Whether or not liming is necessary and how much lime is needed to be applied is from the results of a soil test conducted at a state or commercial laboratory [16]. The spatial survey was done to test spatial variability of soil pH and lime requirement, because individual soils can differ greatly in their lime requirement, which is the amount if lime required to raise the pH to some specified level between 6.0 to 7.0 [16].

One gramme of calcium oxide was dissolved in distilled water and made up to 1000mls. Portions of 5mls, 20mls, 30mls, 40mls and 50mls were added separately to six 100mls beaker each containing 10gm of air dried sample soil. The volumes of the solution were increased by the addition of water so that the ratio of soil to water was 1:5.

The seventh beaker – blank, had no solution of calcium oxide, rather 50mls of water were added to the 10gm of soil. The whole seven beakers were covered tightly and allowed to

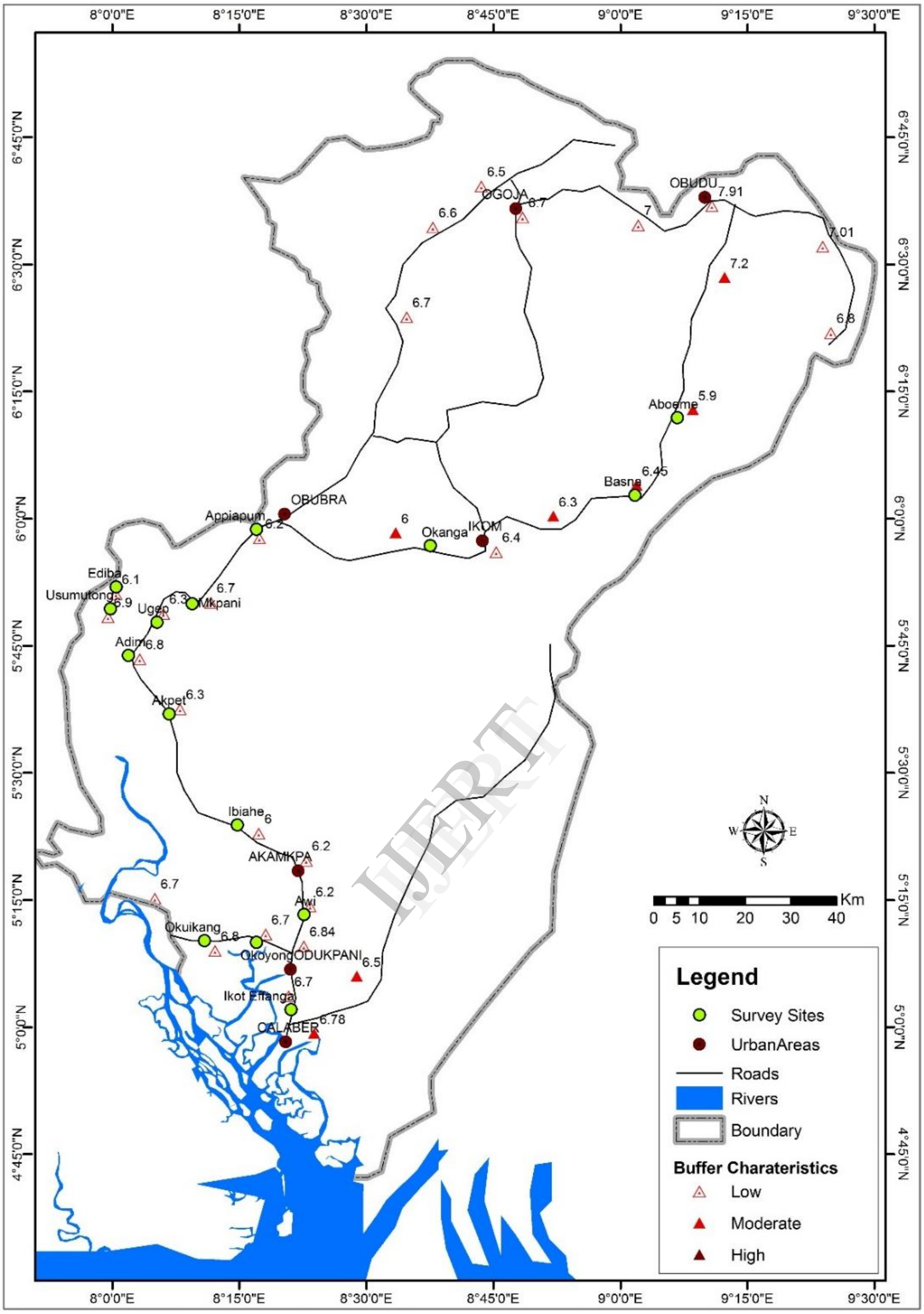

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Plate 1: Cross river state showing soil survey

remain for 3 days. At the 3rd day the pH of each beaker containing the sample soil were measured and the result used to plot the lime requirement curve against 100gm of soil.

The method employed here is that of Peech [8]. The amount of mill equivalence of Calcium Oxide per ml can be calculated from the equation.

$$\frac{Me}{E} = \frac{10X}{V} \times 1000$$

where X is the amount of calcium oxide dissolved in water, E is the equivalence and V is the volume of calcium oxide solution. According to Chapmann and Pratt in [14], 1 ml of calcium Oxide on the graph is equivalent to 158.76 kg of Lime per acre assuming the lime is mixed with 9.072×10^5 kg soil per acre.

3. Results

Results of the field survey of pH at different representative agricultural zones in Cross River state were obtained and average pH for soils in representative Local Government Areas of the State are indicated in Table 1. The pH were clustered into areas with similar values or homogenous distribution. Their comparisons of the lime requirement for the pH of soils were plotted into graphs showed in Figs. 1, 3, 5, 7, 9, 11. The mean lime requirement/pH of soils were also compared using bar charts to visualize the difference. These are shown in Figs 2, 4, 6, 8, 10, 12. The lime requirement for the different soil pH of the agricultural zones are thus indicated in the aforementioned figures.

Knowledge of the lime requirement and the region can enable the usually massive tonnes of lime requirement to be reduced by proper timing of its application [11].

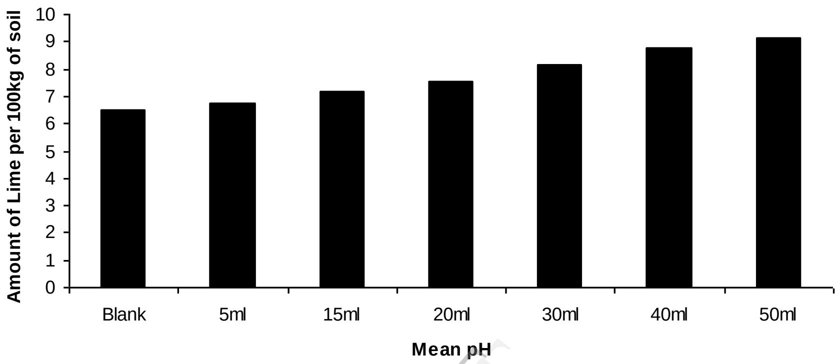

Fig.1. Mean Lime requirements for acid soils in Calabar Municipality

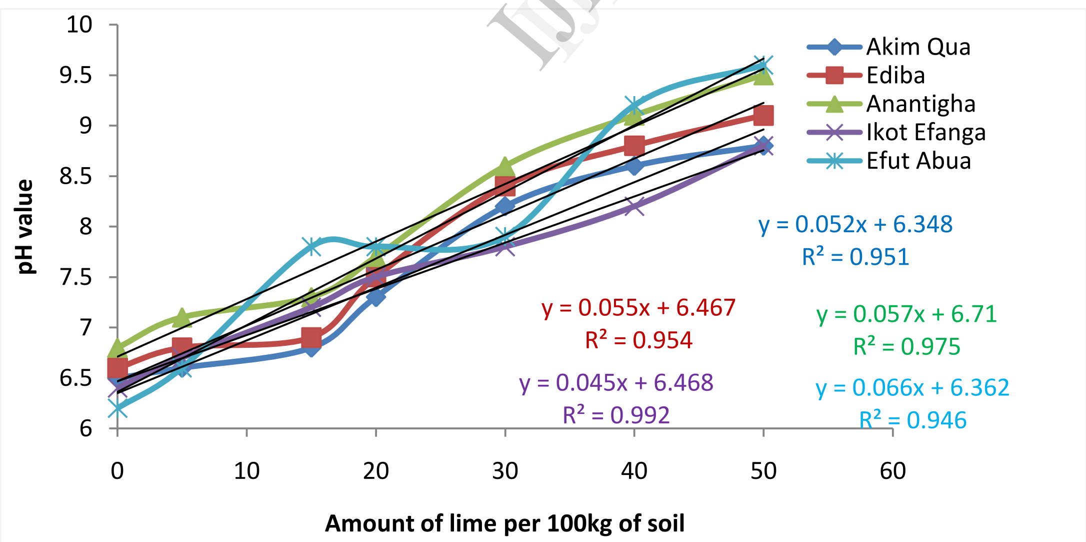

Fig.2. Comparison of Lime Requirement for soils of selected villages in Calabar Municipality

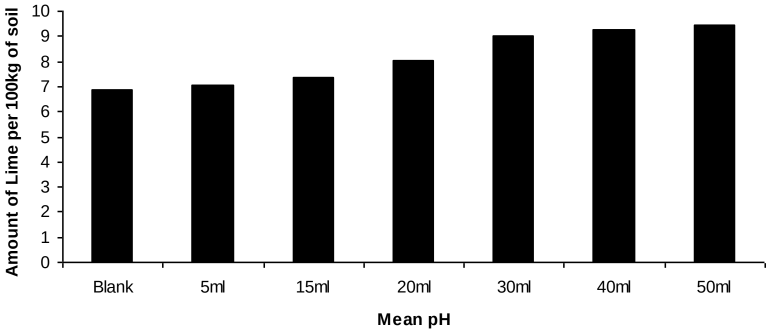

Fig.3. Mean Lime requirements for acid soils in Odukpani Local Government Area

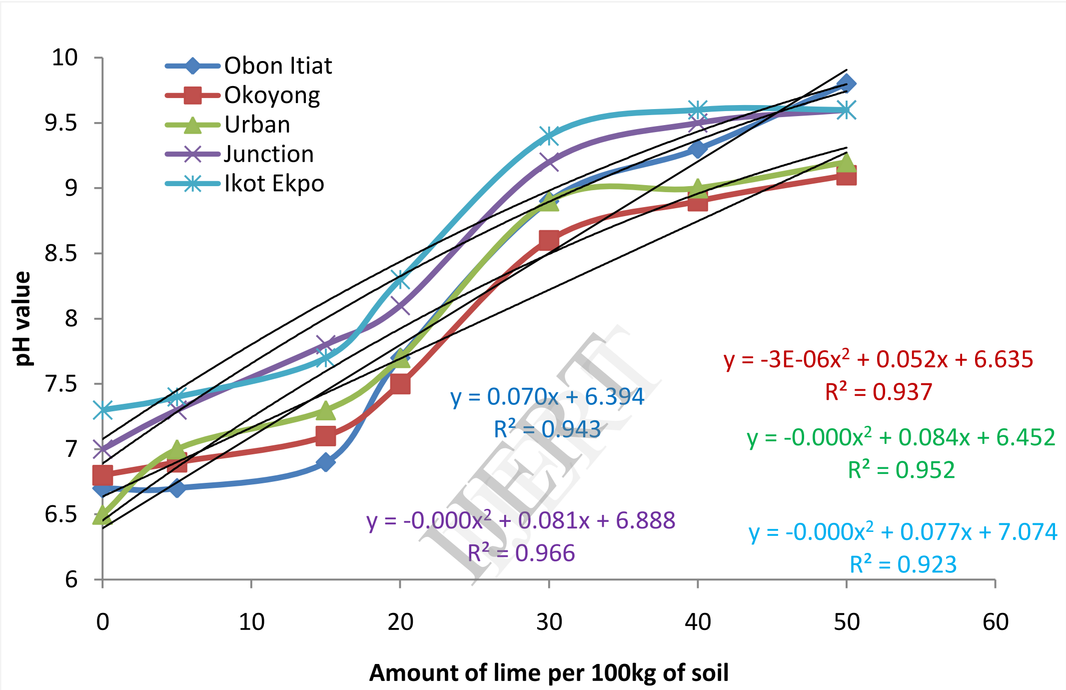

Fig.4. Comparison of Lime Requirement for soils of selected villages in Odukpani Local Government Area

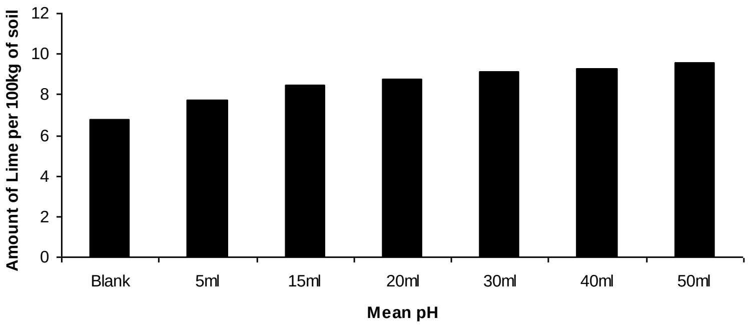

Fig.5. Mean Lime requirements for acid soils in Akamkpa Local Government Area

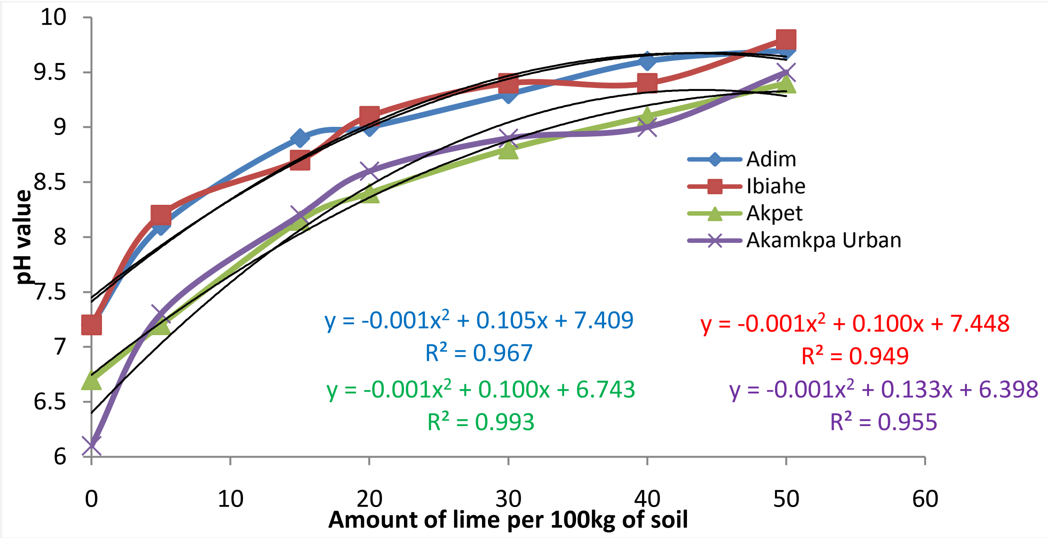

Fig.6. Comparison of Lime Requirement for soils of selected villages in Akamkpa Local Government Area

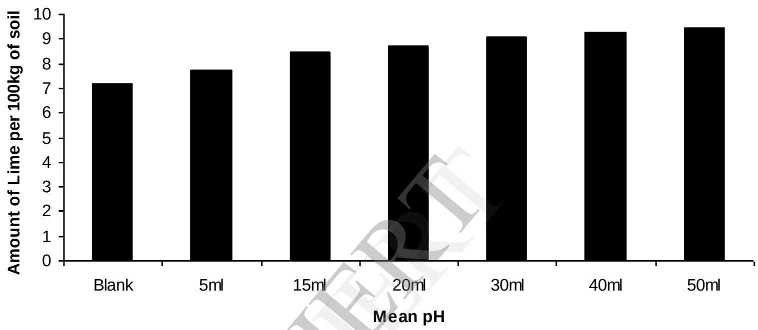

Fig.7. Mean Lime requirements for acid soils in Obubra Local Government Area

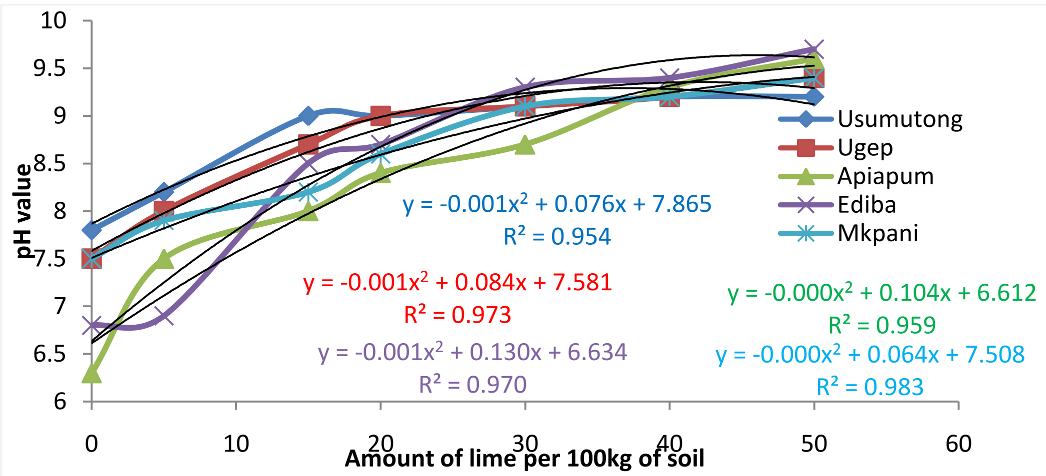

Fig.8. Comparison of Lime Requirement for soils of selected villages in Obubra Local Government Area

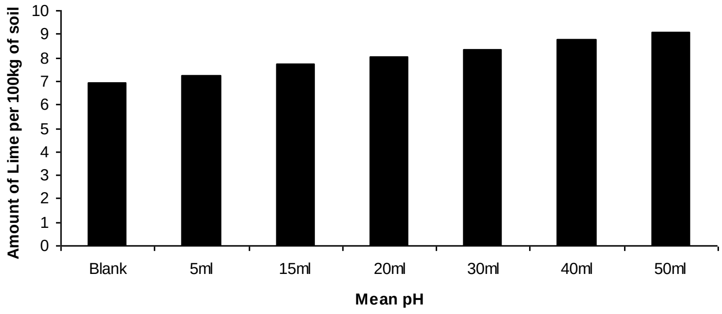

Fig.9. Mean Lime requirements for acid soils in Obudu Local Government Area

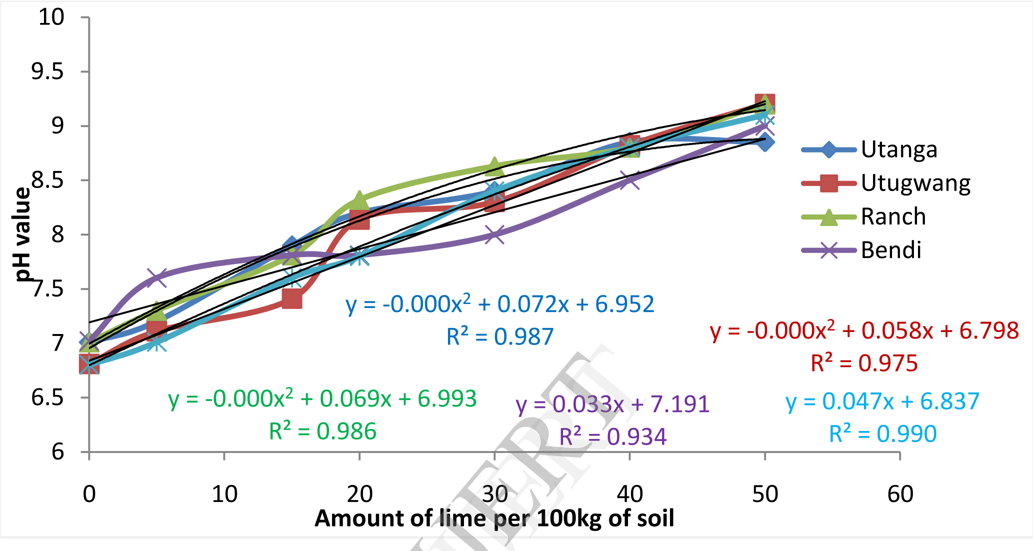

Fig.10. Comparison of Lime Requirement for soils of selected villages in Obudu Local Government Area

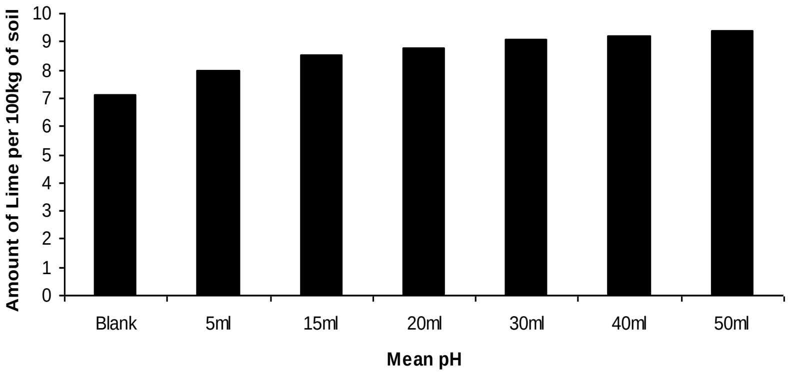

Fig. 11. Mean lime requirements for acid soils in Ogoja Local Government Area

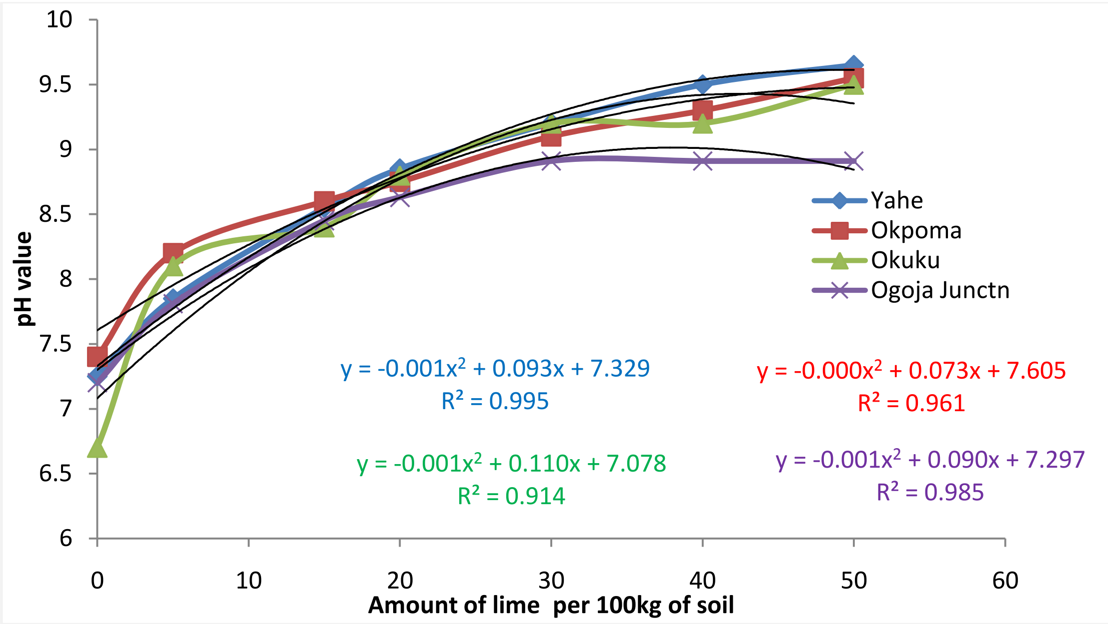

Fig.12. Comparison of Lime Requirement for soils of selected villages in Ogoja Local Government Area

4. Discussion and Conclusion

The pH and Lime requirement for Cross River State soils were investigated and the average values of pH of soils in representative areas of the State's Local Government Areas are presented in the Tables 1. There was no distinctively overall State average pH that could have a clear physical meaning, however, average values for LGAs were meaningful. From Table 1, these were in the order:

Altogether 34 samples were collected all over the State. Each of these 34 samples was made up of 10 sub-samples taken at 1 kilometer apart. These formed the best representative samples of the areas following the approach obtained by Peech [8]. This method was considered to be one of the best taking the accessibility of the areas into consideration.

Areas of identical geological features, hence having identical top soils which constituted sampling zones, were identified using the geological map of Cross River State. The homogeneity of soil in a given sampling area may be necessary to justify the application of the sampling strategy employed. The sampling areas and points were located on a map for identification and for future references if necessary.

Results presented on Table 1, and in Figures 1-11 show that most parts of Cross River State soil are only fairly acidic (pH=5.89-6.87); with Calabar LGA having mean pH values of 8.89- 6.78. The clayey soil in the Cross River State may owe their relatively high acidity to the Alumino -silicate that forms the clay (Geological Survey report of Southern Nigeria, 1962). The aluminum in the Clay may polarize the water in the soil solution and hence give it acidic character [1].

Another cause of the acidity of the heavily forested areas may be decay organic matters which may break down to give carboxylic acid phenolic compounds which are acidic in nature. The basic components of the decayed organic matter like $NH4^+$ easily reacts with rain water just as in the case of magnesium and calcium.What is left over is the acidic part which makes the soil acidic [2], [10], [13].

The results on Lime requirement have been presented in graph (Figures1-12), which show the lime requirement along with the predictive equations (The soils in the Cross River land show low buffer character. The buffer character is the resistance of a soil to change in pH when Lime is applied. It cannot be determined from ordinary measurement of the pH of a soil.

A soil which appears alkaline may even have a high resistance to lime. However, this tendency of the soil appears generally pronounced in areas where acidity is high. With only a few exceptions in some places like Ikom and Bendi, soil resistance to lime is more marked, otherwise soil *resistance tolime is less marked.* As shown in the map, slight buffer characteristic occur in Ikom and Obudu. The factor responsible for buffer activity may be the nutrient of the soil concerned. Where high acidity is available due to organic material, a greater amount of Lime will be required to neutralize the acidity. Another factor is Aluminum which hydrolyses in the soil and exists as Aluminum hydroxide. This compound is amphoteric. It behaves as an acid in the presence of a base and as a base in the presence of acid. It is therefore capable of neutralizing the effect of lime in the soil, hence a greater amount of lime has to be applied in a very small area in order to reduce the acidity.

Another factor responsible for the soil resistance to lime is the nature of the subsoil which is the layer of soil below the cultivatable top soil. If the subsoil is acidic it maintains a type of equilibrium with the top soil. Any attempt to neutralize the top soil with lime, the acid from the subsoil is shifted to the soil - hence buffer characteristics is observed.

The geology of Akamkpa and Obubra may explain the result for the area. The subsoils of these areas are made up of calcium carbonate rocks – hence buffer characteristics due to subsoil is not observed. The nature of crops grown in different parts of the Cross River State tends to follow this soil property distribution. In the North East part of the Cross River State where the acidic soil is moderately buffered – the Cocoa plants tends to flourish. The presence of large quantity of Cocoa in Ikom and areas of Obudu, especially Bendi and other portions of Bete Clan may be explained by the present result.

In areas like Ogoja where potential acidity (i.e. acidity determined by Lime requirements as opposed to the active acidity measured directly by the use of pH meter) is comparatively low and the rainfall pattern quite different from that of any other part of the State; and groundnut grows very well [12].

In terms of acidity, any portion of the State, apart from swamps, is suitable for the cultivation of any species of yam. Yam (D. rotundata) requires a pH not lower than 5.9 [12]. In factyam grows all over the Cross River State. It can be concluded that the soil property is an important index that determines the type of crop to be planted at a particular area. [2].

Some soils exhibited simple or curved linear increase in limestone requirement (**LM**) for unit increase in soil pH.Obubra urban is an example. Some paired zones exhibited parallel or contrast lime requirements per increase in soil pH. These included Odukpani junction/ Odukpani urban. Some paired localities with dissimilar pH reached a point of convergence in their lime requirements as their pH changed in opposing direction, thereafter, further lime requirement could only come about by increasing divergence of pH of their soils. Such included Okuku/ Ogoja urban, Yahe/Okpoma, Ediba/ Mkpani and Utugwang/ cattle ranch. Still, others exhibited similarity of lime requirement for increase in. the pH. A fourth set showed convex profile of lime requirement for increase in soil pH i.e. their lime requirement increased in response to increase in pH up to a peak point above which lime requirement declined on further increase in pH.Examples are Okuku/Ojala urban, Usumotong/obubra

Those with convergence- divergence**LM**response to increasing soil pH indicated the point of 175 ml at pH of 8.2 lime requirement Therefore, there is no rule-of-thumb value for LM , however,it appears that excess LM above is counter-purpose to the solution.

Table 1: Average pH and lime requirement for soils in local Government areas of Cross River state.

Locality	Average pH	Avg. Lime Req.
Calabar Local Government Area		
Akim Qua	6.78	0.0523
Anantigha	6.64	0.0571
Ikot Effanga	5.71	0.0458
EfutAbua	5.89	0.066
Ediba	6.15	0.0552
	Average	6.234
	Spatial Std deviation	0.4645
	CV	7%
Odukpani Local Government Area		
ObomItiat	6.79	0.0703
Okoyong	6.71	0.0528
Odukpani Urban	6.52	0.0575
Odukpani Junction	6.84	0.0574
Ikot Ekpo		0.0575
	Average	6.602
	Spatial Std deviation	0.2805
	CV	4%
Obudu Local Government Area		
Obudu Urban	7.01	0.0478
Utuquang	7.00	0.0482
Utanga	7.21	0.039
Ranch	7.14	0.0434
Bendi	7.19	0.0338
	Average	7.11
	Spatial Std deviation	0.9925
	CV	1%
Obubra Local Government Area		
Ugep	6.34	0.0349
Usumutong	6.93	0.0257
Apiapum	6.24	0.0589
Ediba	6.18	0.0605
Mkpani	6.77	0.0383
	Average	6.492
	Spatial Std deviation	0.3366
	CV	5%
Ogoja Local Government Area		
Ogoja urban	6.71	0.0317
Yake	6.77	0.0462
Okuku	6.59	0.0463
Okpoma	6.63	0.0379
	Average	6.675
	Spatial Std deviation	0.0806
	CV	1%
Akampa Local Government Area		
Awi	6.22	0.0587
Ibiake	6.03	0.0446
Akpet	6.31	0.0523

Akamkpa urban	6.23	0.0587
Adim	6.87	0.0449
	Average	6.332
	Spatial Std deviation	0.3178
	CV	5%
Ikom Local Government Area		
Akparabong	6.34	0.036
Okanga	6.01	0.0361
Bansara	6.45	0.054
Abo	5.91	0.0523
Ikom urban	6.45	0.0388
	Average	6.232
	Spatial Std deviation	0.2548
	CV	4%

4.1. Recommended Work

Soil has numerous properties each depending on the other. To have a full understanding of Cross River State soil, other studies like the organic matter content, dissolved ions, organic carbon determination, heavy metals and total phosphorus determinations are very essential complementary exercises that have to be done.

It is further recommended that samples should be collected in different periods but vary with time [7], [12].

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