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Soil Textural Mapping: A Pathway for Sustaining Urban Agriculture in Metropolitan Lagos, Nigeria

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Abstract
Soil texture is one of the important factors for determining crop yields and information about agricultural viability in any geographical location. For instance, soil fertilization, soil treatment and irrigation designs as well as power requirements for farm machinery require detailed information on soil texture. This paper thus examines soil textural classes in selected urban farming areas of metropolitan Lagos, namely Tejuoso, Alapere, Festac, Barracks, Oko-Oba and Idi-Araba farm communities. It further relates the textural classifications to the cultivation and production of vegetables. Soil samples for textural analysis were collected from 6 selected locations and in each location, 5 samples at 0-15 and 15-30 cm depths were taken using composite sampling techniques. Determinations of textural classes were done in the laboratory using the mechanical analysis method with the aid of hydrometer to calculate the percentage of sand, silt, and clay in the sampled soils. The production of soil texture map was done through remotely sensed data processing. Acquired soil base map was scanned, Geo-referenced and digitized to extract the soil type layers. Updating and superimposing of attribute information of textural classification were done through interactive techniques using Microsoft excel 2007 and Arc Info version 9.2. The finding shows that the soil textural fractions (% sand, % silt, and % clay) were spatially observed, nevertheless, only one-quarter of textural classes are represented in the selected area. The regression model (R^2) result generated denote $P > 0.391$, $P > 0.100$ and $P > 0.529$ for % sand, % clay and % silt respectively.The application of animal feed manure was noted to have contributed to high silts contents in agricultural land of urban Lagos especially around Tejuosho and Alapere areas. Litter decomposition and soil water pressure also accounted for the variability but the effect was not consistent across different soils ($P < 0.06$). The output of the interactive techniques also reveals that there is similarity between laboratory result and the soil map used as baseline information. Interview however reveals that farmers lack knowledge of soil map and textural classes. The study therefore recommends that for soil fertility sustainability in the urban areas of Lagos, farmers need to be enlightened on soil map, textural classes and manure application through effective education awareness.

Keywords: *Soil, urban, agriculture, assessment and GIS*

Introduction
Africa's agricultural viability and food security depend largely on its soil quality. According to Eswaran *et al.*, (2005), degraded soils through mechanical practices are becoming more prevalent due to intensive use and poor management resulting in declining soil quality on a

global scale. Again, the challenges such as erosion, compaction, acidification, and desertification reduce agricultural production capacity, with attendant economic and environmental consequences. It also impacts the ecosystems and livelihoods.

Among the status and impact indicators for monitoring and evaluating soils, soil map and textural evaluation are noted to be of significance (Hurni and Meyer, 2002; Hurni *et al.*, 2006). Of the soil characteristics, texture is one of the most significant. It influences many other properties of great importance to soil and its management. For instance, plant water availability is influenced by soil texture. Coarse-textured soils lose more water and have lower conductivity at higher soil water potentials than fine-textured soils, thus plants growing in coarse soils exhaust their water supply at higher rate than the one growing in fine textured soils (Brown, 1990, Sullivan, 2004 and Hultine *et al.,* 2005). Sandy soils tend to be low in cation exchange and buffer capacities, and rapidly permeable (Kolahchi and Jalali, 2007). It has low organic matter content and fertility, and poor ability to retain moisture and nutrients (Sullivan, 2004; Heerink, 2005).

In Brown, (1990), sandy loams soils are characterized with less sand, and more silt plus clay, than loamy sands. Silt loam contains small amounts of sand and clay, and mostly of silt-sized particles. Litter decomposition affect soil behavior and texture by altering soil water availability, pore size distribution, nutrient availability, and surface area (Scott *et al.,* 1996). Soil texture is an important factor for determining input information about agricultural activities such as irrigation designs, fertilization treatments, and power requirements of farm machinery (Brown, 1990; Hassan *et al.,* 2004). Doerr *et al.,* (2006) noted that knowledge of soil water repellency distribution and factors affecting its occurrence as well as its hydrological effects stems primarily from the nature of soil.

Aside from the understanding of soil textural classes in the urban farm soils, an optimum visual solution for monitoring, examining and updating urban agriculture soils is also needed. This requires the use of a more flexible and mapping tool (GIS) than conventional data processing systems. Different data and information (Soil and human related activities) could be interactively simulated in the geo-information system environment. This provides a viable means of taking large volumes of different data sets, manipulate and combine the data sets into new data sets (field/attribute information)that can be displayed on maps (Hussein, 1993).

Using simple soil textural field measurements, socio-economic survey, and laboratory result will allow upgrading and as well enhance the resolution of soil maps. In Oberthür *et al.,* (1994) study on mapping topsoil texture using GIS software, the result shows that there is a relationship between the soil base map of particle size distribution and interpolated field estimates of soil texture. This proved to be valuable surrogates for laboratory measurements of soil texture classes. This study therefore examines urban agriculture soil textural classes within the Metropolitan Lagos for sustainable urban farming and food security.

The Study Area

The Metropolitan Lagos is located between Longitude 3^0 11^1 and 3^0 27^1East, and Latitude 6^0 24^1 and 6^0 38^1North, stretching from Ojo Local Government Area (LGA) in the west to Kosofe LGA in the east and from Amuwo/Odofin LGA in the south to Alimosho and Ifako/Ijaiye LGAs in the north (Fig. 1). Metropolitan Lagos accounts for about 27.4% of the total 3,577 km^2 of Lagos State area extent. The area has bi-modal rainfall in April and July, with short break in August. Average daily temperature ranges between 32^0C in the hottest month (March) to 28^0C in the coldest month (August). Relative humidity varies between 70% and 100%. The highest elevation in the region is about 20m and the lowest level is about 0.8m above sea level (Odumosu, 1999).The intensity ofagriculturalpractices in this area under varied soil management techniques adopted by the urban farmers has contributed to the local economic development of Lagos.

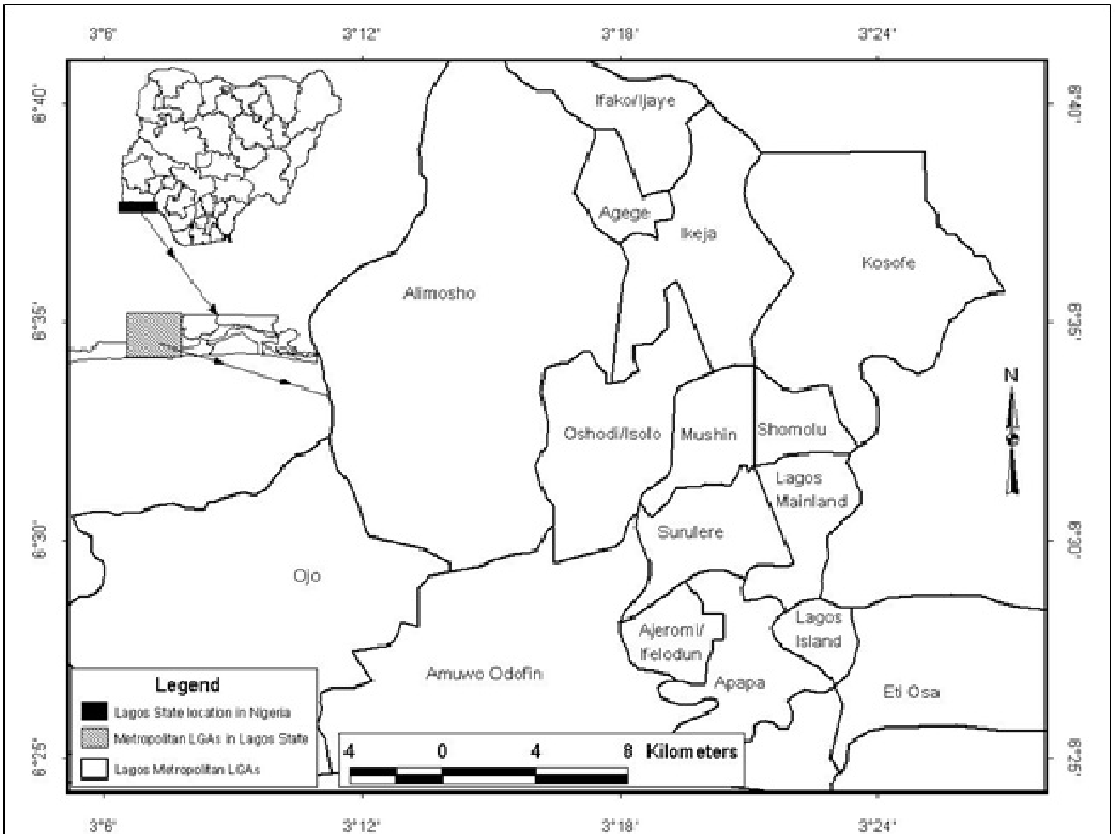

Fig. 1: Metropolitan LGAs of Lagos

Materials and Methods

Soil samples for textural analysis were collected from six (6) selected locations (Tejoso, Oko-Oba, Barracks, Idi-Araba, Alapere, and Festac) within metropolitan Lagos based on land use types and dominant soils maps (See fig. 2 & fig. 3). In each location, five (5) samples at 0-15cm and 15-30cm depth (50g per depth) were taken within $0.01km^2$ through composite sampling techniques. The analysis of soil texture was done in the laboratory using the mechanical analysis method for soil analysis (Bouyoucos, 1961; Skaggs *et al.*, 2001; Plante *et al.*, 2006; Haluschak, 2006). Each 50g sampled soil was separated to permit independent settling of the particles at room temperature of 20^oC. To achieve this, the samples are treated with hydrogen peroxide to remove the organic matter and also with sodium hexametaphosphate to disperse the clay particles. The dispersed sample was then stirred in 1 liter of water. Since the particle settling rate is a function of the radius of the particles, sand being largest in size settles first in about 40 second. The silt size particles settle in about 2 hours while only the clay particles remain in suspension. The hydrometer reading after 2 hours of suspension therefore represents clay value in g/l. The hydrometer readings were used to calculate the percentages of sand, silt and clay. The procedure for mechanical method for soil analysis is given thus:

$$Sand\ (\%) = \frac{Sample\ mass - Hydrometer\ reading\ at\ 40\ sec}{Sample\ mass} \times 100$$

$$Clay\ (\%) = \frac{Hydrometer\ reading\ at\ 2hrs}{Sample\ mass} \times 100$$

$$Silt\ (\%) = 100 - (Sand\ \% + Clay\ \%)$$

Subsequently, the textural triangle was therefore used to determine the textural class of each sampled soil (Brown, 1990; Wayne *et al.*, 2007)

The base maps data used for this study were dominant soils map of Nigeria with special focus on Lagos State Metropolitan area and Lagos State land-use map as well as remotely sensed spot multi-spectral data covering Metropolitan Lagos (Table 1).

Table 1: Base map information

S/n	***Data***	***resolution / Scale***	***Coverage***	***Year of production***	***Source***
1	Dominant soils map of Nigeria	1:1300,000	Nigeria	1997	SOW-VU, Amsterdam
2	Lagos land-use map	1:125,000	Lagos state	2008	Lagos State Ministry of Physical development
3	Spot multi-spectral	5m/RGB	$3^0 11^1$ - $3^0 27^1$E and $6^0 23^1$& $6^0 48^1$N	2004	Daimler Geographic, Lagos

The land use and soil base maps were scanned, Geo-referenced and digitized. On screen extraction of shape-file layers and attribute information were later done appropriately on both maps to ascertain layers types. The geo-rectified spot multi-spectral image was used to confirm the spatial accuracy of land-use in relation to urban agriculture areas. Updating and superimposing of attribute information of textural classification were done through interactive techniques using Microsoft excel 2007 and Arc Info version 9.2. Apart from field observation, opinion survey was randomly done to gather information on the soil management practices in the study sites through face to face interview.

Results and Discussions

Based on categorisation of Nigeria dominant soil, three distinct dominant soils predominates the Metropolitan Lagos (Sonneveld, 1997). These are deep well drained soils, very deep well drained soils and very deep - poorly drained soils. As shown in Fig. 2, deep well drained soils drapes the north-eastern part of metropolitan Lagos, very deep well drained soils covers the north-western part while the very well - poorly drained soils dominates the entire southern area.Analysis revealed that nine (9) different land-use types spread all over the entire Metropolitan Lagos of which residential and agriculture cover about 56% and 3% respectively. Residential dominates the vast area of the 2 dominant soils (deep well drained soils and very deep well drained soils) inthe Northern part.Recreation and water-body aremore conspicuous in the southern dominant soils (very deep - poorly drained soils). Other land-use types appeared in patches and less conspicuous in spatial view.

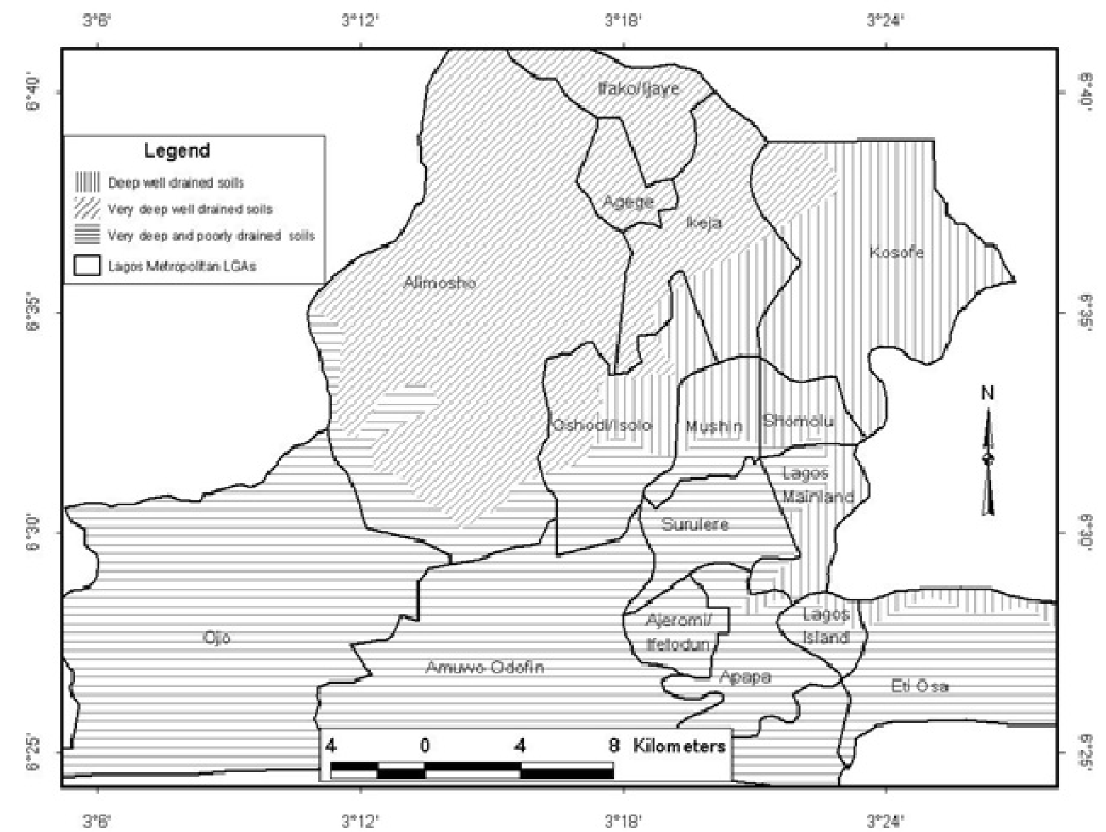

Fig. 2: Dominant Soils of Metropolitan Lagos

As revealed in the spatial interpolation of land-use types and dominant soils, of the six (6) selected sites only Oko-Oba farm appeared visible on the acquired land-use map (Fig. 3).

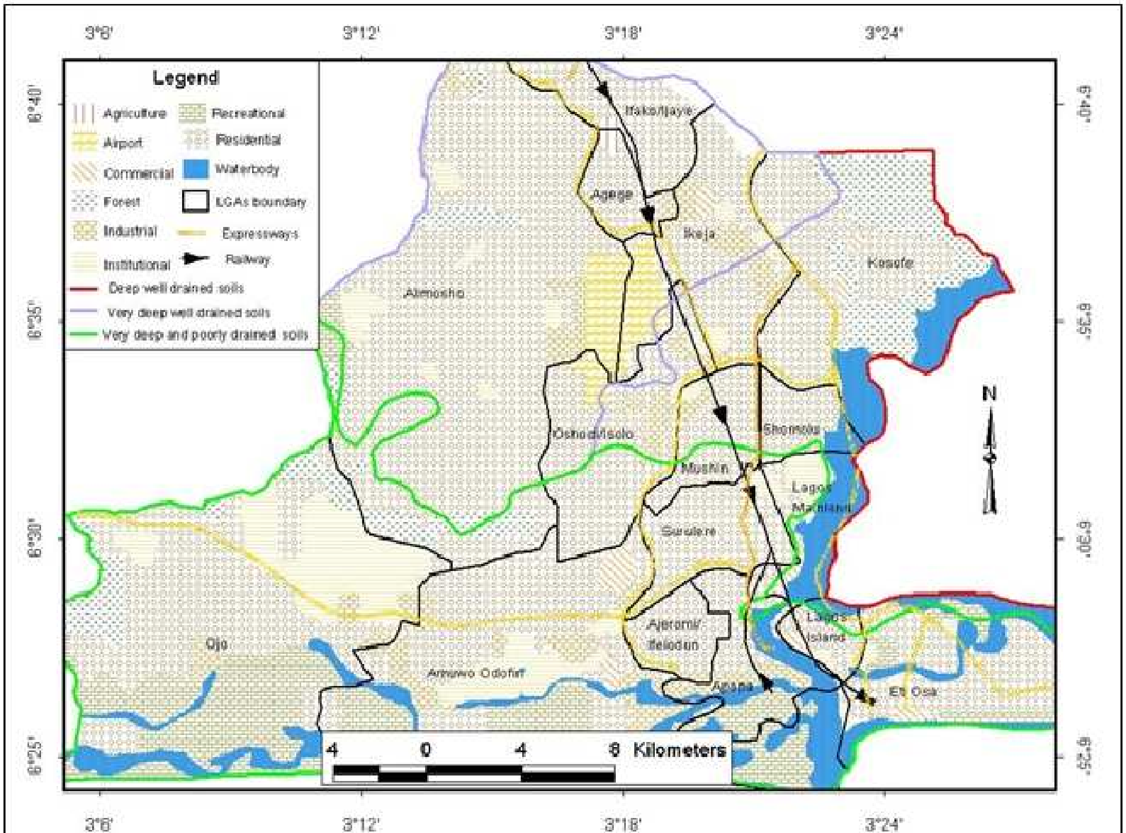

Fig. 3: Metropolitan Lagos Land-use types

Based on the productivity of Nigeria soils, Lagos soil is grouped under light-texture soils with well-defined fine sand, loamy sand and loamy coarse sand (FAO 1964). The result of soil textural examinations using mechanical analysis revealed that three different textural classes characterized the soils of metropolitan Lagos urban agriculture sites. These are sand loams, silt loam and sand clay. Of the six sampled sites, sandy loams are noted to be predominant in four while sandy clay and silt loam are attributed textural classes at Idi-Araba and Alapere (Table 2).

Table 2: Soil textural classes determination

S/n	Urban Agriculture Site	Reading at 40sec for sand (g/l)	Reading at 2hrs for Clay (g/l)	%Sand	%Clay	%Silt	Textural classes
1	Tejuoso	23	7.5	54	15	31	Sandy loams
2	Oko-Oba	22.5	6.5	55	13	32	Sandy loams
3	Barracks	23	6.5	54	13	33	Sandy loams
4	Idi-Araba	26.5	18.5	47	37	16	Sandy clay
5	Alapere	36.5	10.5	27	21	52	Silt loam
6	Festac	23.5	7	53	14	33	Sandy loams

As revealed in fig. 4, Oko-Oba farm site is at the fringe of Ifako/Ijaiye and Agege LGAs in the extreme north of the very deep well drained soils. Alapere farm site is situated between residential and commercial land-uses surrounded by forest land-use of deep well drained soils. Other farm sites (Tejuoso, Barracks, Idi-Araba and Festac) are predominated by the very deep - poorly drained soils.

The result further shows that the soil textural fractions (% sand, % silt, and % clay) were spatially observed, nevertheless, only one-quarter of textural classes are represented in the selected area (Table 2 and Fig. 4). The regression model (R^2) result generated for textural classes denote $P > 0.391$ for % sand, $P > 0.100$ for % clay, and $P > 0.529$ for, % silt . These indicate that virtually all the sampled soils are well represented with appreciable silts contents that make the sites suitable for all year round vegetable cultivation.

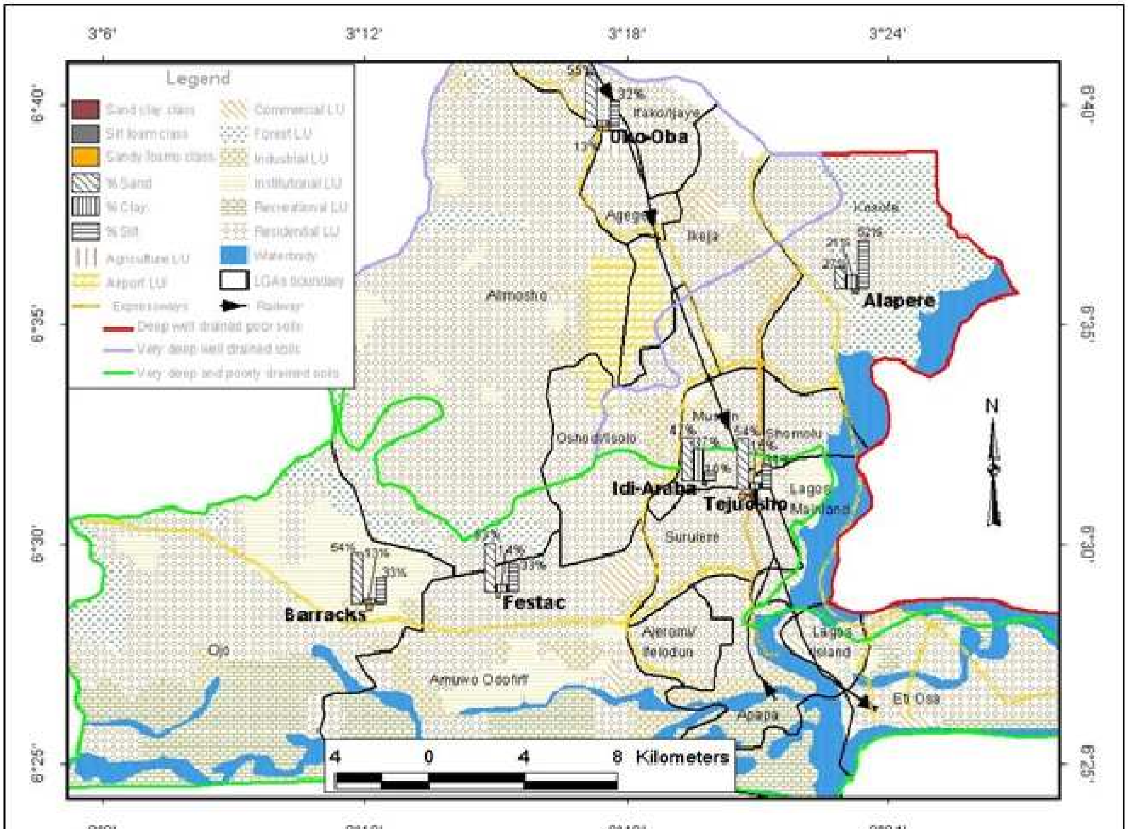

Fig. 4: Spatial interpolation of farm sites textural classes on land-use/dominant soils

The field observation result also shows that at least not less than 500m radius of each selected farms except Oko had been encroached as a result of residential development within the last three decades (Fig. 5).

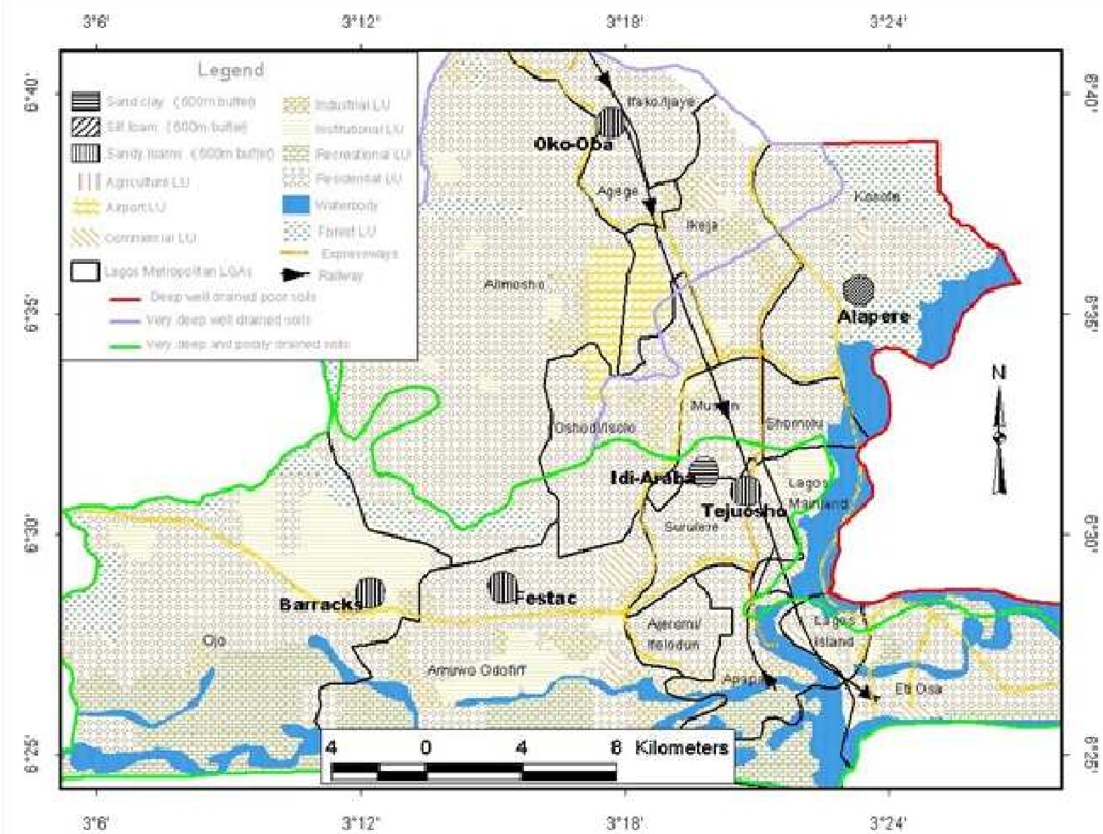

Fig. 5: Encroachment areas (500m radius)

From previous studies, the original soil classes of most metropolitan urban farm areas and their immediate environment have changed (Adeniyi, 1986; Okude and Ademiluyi, 2006; Taiwo, 2011). The changes may have resulted from urbanization and physical development which have considerably affected the soil nature through uncoordinated overland flow and soil erosions (Areola and Ofomata, 1978; Oduwaye, 2009; Akinmoladun and Adejumo, 2011). As depicted in table 2, different soil textural classes exist and may have influenced the degree of agricultural input (organic and synthetic) use, the gestation period of cultivated crops and yield. According to Anosike, (2008), about 797kg of poultry manure is used on a sandy loams soil to cultivate about 3575kg of lettuce on a plot (0.06ha) in Barracks, whereas less quantity of about 700kg is used to produce relatively the same size of lettuce on a silt loam soils in Alapare. The spatial differences in the soil textural class have influence the cost of productions of crops and revenue accrue from producing the same type of crops.

Relatively, on the selected farms soil, evidence of trace of dominant soils structure and texture in the generated textural classes was noted as revealed through interactive techniques. Nevertheless, all the selected farms are well drained and rich in silt at the top except Idi-Araba farm site. The continuous applications of inappropriate fertilizer/manure particularly animal/poultry waste manure have mainly contributed to high silt contents in the selected farms especially around Alapere and Tejuosho. Litter decomposition and soil water pressure also noted to have influenced soil textural variability but the result was quite inconsistent across different soils ($P < 0.06$).

Conclusion

Metropolitan Lagos soils had been described as soil of declining fertility (Areola and Ofomata, 1978; Adetunji, 1994; Nwuche andUgoji, 2008; Adedeji and Ademiluyi, 2009; Taiwo, 2011). Nonetheless, about 98% of the studied urban farm sites are highly suitable for vegetables and occasionally maize. The soil are however prone to leaching and overland flows. These limitations predispose the soils to the application of fertilizer and manures. Furthermore, the loose nature of soils makes some selected sites prone to soil erosion by rain water as it significantly contributes to erodibility factor.

Findings show that the majority of the urban agriculture farmers lack knowledge of importance of soil map and textural classification. For sustainable soil fertility in the urban areas of Lagos, farmers need to be enlightened on the role of textural classes in fertilizer/manure application through effective awareness programm. It is important to note that textural map and classes alone do not give detail information about soil characteristics as regards the behaviour and suitability for different agricultural uses. For instance, a soil may be sandy all through its depth; nevertheless the covering of sand grains by naturally-occurring materials such as organic matter may perhaps advance to the cementation of sand grains and even impedes the pores between sand grains. In addition, anthropogenic factors and water table also influence soil behaviour and thus affect suitability.

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