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Use of GIS to Delineate Site-Specific Management Zone for Precision Agriculture

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ABSTRACT

Soil heterogeneity is one of the several factors that explain within-field variations in crop yielding. To overcome this problem, experiment was conducted within the University of Ibadan to identify the zones with similar soil properties that can be managed uniformly to optimize crop yield. A total of 62 soil samples were collected from 6.5 ha of farmland based on the differences in slope, soil moisture regime, land management and cropping pattern. The spatial distributions of soil properties were mapped out using Inverse Distance Weighing (IDW) interpolation technique and the results were subsequently reclassified into different soil management categories. The results showed that the farmland consists of four classes of total nitrogen (N), phosphorus (P) and soil bulk density (SBD); three classes of carbon (C) and oxygen (Ѳ); two classes of soil $_{p}$H; one class of soil texture. Each of the soil management maps was subsequently overlaid on each other to produce four specific site management units (SSMU) for vegetable cultivation. The four SSMU consisted of highly suitable unit occupying 0.143 ha, marginally suitable unit occupying 0.971 ha, moderately suitable unit occupying 0.517 ha and unsuitable unit occupying 4.9 ha of land. The SSMU will alleviate problems of reduced yield due to over or under applications of agrochemicals.

Keywords:

soil properties, site-specific management units, spatial variability, precision agriculture

INTRODUCTION

Several factors explain variations in the yield and crop performances. Some of the factors include topography, physico-chemical properties of soils and the management practices adopted across fields. Improving crop yield often entails the application of the different agro-chemical products uniformly across the different fields particularly in developing countries like Nigeria due to nearly the absence of the technology that can allow the practise of site-specific agriculture. It is clearly evident that spatial variation of soil nutrients are caused by topography and management practices across the fields. Hence, the need to identify the different soil management units, which can provide the required basis for effective soil and crop management that, can guarantee optimum productivity.

Over the years, field sizes, farming direction, locations of fences, rotations and fertility programmes have changed, and this has reflected in the nutritional status. Consequently, the productivity of the soil is equally affected. In spite of these variations in soil properties, conventional agriculture treats an entire field uniformly with respect to the application of fertilizer, pesticides, soil amendments and other chemical application. However, soil is spatially heterogeneous, with most soil chemical and physical properties varying significantly within just a meter (Fridgen et al., 2000).

Soil spatial variability is one of the major factors that cause within-field variation in crop growth and yields. Other temporarily variable factors influencing the within-field variation in crop yield include: man-related efforts (irrigation management, soil compaction due to equipment, etc.), biological (disease, pests, etc.), meteorological (humidity, rainfall, wind, etc.), and topographical (the slopy aspect, etc.) influences. The inability of conventional farming to address within-field variations, not only have a detrimental economic impact on the soil due to a reduced yield in certain areas of the field, it also detrimentally affects the environment due to excessive application of agrochemical products and wastes finite resources. The spatial domains of soil that can be managed similarly to optimize crop yield by accounting for its variability is important for precision agriculture. Precision farming or site-specific management is a way of managing soil spatial variability by applying inputs in accordance with the site-specific requirements of a specific soil and crop (Khosla et al., 2002; Fleming et al., 2000) A variety of soil physical and chemical properties are known to influence crop productivity include: soil moisture, soil texture and structure, soil depth; restrictive soil layers, organic matter, chemical constituents such as fertilizers, pesticides, trace element and landscape features like micro elevation and topography (Thornley and Johnson, 1990; Hanks and Ritchie, 1991; Lian and Lal, 2011).

Land suitability assessment for agriculture evaluates the ability of a piece of land to provide the optimal ecological requirements of crops. It is one of the most effective methods for proper agricultural land use planning as it evaluates the suitability of soils for a specific crop. Suitability is a measure of how well the qualities of a land unit match the requirements of a particular form of land use (Kilic and Akbas, 2004). It evaluates the specific needs of the respective crop requirements and calibrates them with the terrain and soil variables. Therefore, it makes the identified limiting factors manageable to suit the various crop requirements, and improve the crop productivity. This method provides an insight into the nutrient required by soils in order to produce optimally. Land suitability is also the fitness of a given type of land for a defined use. This is a pre-requisite to productivity maximization in the agricultural sector (Lark, 2002). The process of land suitability classification is the appraisal and grouping of specific areas of land in terms of their suitability for defined uses (Zhang et al., 2010). The new technology that is available for land evaluation consists mainly of the use of remote sensing and Global Positioning System (GPS) device. Land suitability evaluation is therefore formulated with the objective of classifying units of land into their respective suitability using geographic information system (GIS) and remotely sensed data (Khosla et al., 2002). A GIS is the most widely used tool to draw maps based on geo-referenced information (Zhang et al., 2010). This enables application inputs at variable rates within a field (Han et al., 2009; Gupta et al., 2010). Data gathered using GPS can be used to create a map of a farmland (in either vector or raster format) that is linked to a GIS (Phillips et al., 1998).

Geospatial measurements of soil properties are a powerful tool in site-specific management when combined with GIS and spatial statistics. Site-specific soil management is a means of managing the spatial variability of edaphic (soil related factors), anthropogenic, topographical, biological, and meteorological factors that influence the crop yield with the aim of sustaining the soil-plant environment, optimizing inputs, and/or minimizing detrimental environmental effect on the soil. The objective of this study is to integrate spatial statistics, GIS and geophysical techniques in order to (i) identify zones with similar soil properties and (ii) use this spatial information to delineate site specific management units that can be managed similarly to optimize crop yield.

MATERIALS AND METHODS

Developing the suitability map requires both primary and secondary data sources. The primary data used includes the soil samples which were collected from a 6.532 ha field located within the University of Ibadan, Nigeria. The site is bounded by Longitude 3^0 53’ 33” and 3^0 53' 53" on the western and eastern sides, while it is bounded in the north and south by Latitude 7^0 27' 05" and 7^0 26' 49" respectively. It has a mean altitude of 180 – 210 m above sea level. Annual temperatures range from a high of 31.2^0C to a low of 21.3^0C. Ibadan has a percentage sunshine that ranges between 16% in August to 59% in February and December with an average of 44%. Hence the climatic parameters favour optimum productivity of vegetables. The soil of the area was derived from sedimentary rocks of south western Nigeria and this has been classified as an Alfisol under subgroup Oxic Paleustalf according to the USDA classification (Soil Survey Staff, 2006).

Spatial variation in soil properties was measured in December 2010 using 269 cm^3 soil cores to sample 30 cm depth. Since the study area is currently devoted to the cultivation of shallow root crops, the soil sample collection was limited to the top 0-30 cm. The farm was sampled based on slope, soil moisture regime, land management and cropping pattern. In all, sixty-two soil samples were collected and analysed for physical and chemical properties. It is assumed that the closer and the more the number of the sampling points, the better the result. Soil samples were analyzed based on the important physical and chemical properties that are relevant to the determination of the soil suitability for optimum vegetable productivity. Physical properties that were determined include: particle size distribution, bulk density and volumetric moisture content. The particle size distribution of the soil samples (< 2mm) was analyzed by using hydrometer method (Gee and Or, 2002). Core samples of 7 cm diameter by 7 cm height were used to sample the soil depth of 0-30 cm to determine the bulk density by core method (Grossman and Reinsch, 2002). Soil moisture at the time of sampling was determined gravimetrically (Lowery et al., 1996) and the values obtained were multiplied by their respective bulk densities in order to get volumetric moisture content (Θ) (Hillel, 2003). The sieved soil samples were analyzed for pH in a 2:1 soil: water ratio using the Coleman's pH meter. Available phosphorus was extracted by Bray -P1 method and read on spectrophotometer. Organic carbon was determined by the Walkey and Black procedure (Nelson and Sommers, 1982). Kjeldahl apparatus was used to determine total nitrogen (Bartels et al., 1996).

A high resolution satellite image of the University of Ibadan, Nigeria was downloaded from Google Earth website using Google Earth Professional software. The image was geo-referenced by using existing road network intersections within the University of Ibadan. The field boundary was clipped from the entire imagery so that it is easy to control the extent of the analysis within the GIS software. Subsequently, GIS tools were used to digitize the boundary of the study area (Figure 1). The GPS device was used for recording the coordinates of locations where soil samples were collected. Khosla et al. (2002) noted that the GPS device permits the collection of data on specified profile, cross section and boundary locations. The laboratory results for each of the parameters were subsequently linked to their corresponding coordinates within the GIS. Since it was impossible to collect data on nutrients at every point within the farmland, the laboratory results were generalised (interpolated) with a view to developing a nutrient surface map. The laboratory result for each of the elements was interpolated using an Inverse Distance Weighting (IDW) method in a GIS. The IDW interpolation determines cell values by using a linearly weighted combination of a set of sample points. The weight is a function of inverse distance separating the points. This method assumes that the variable being mapped out decreases in influence with a distance from its sampled location. The resultant maps were subsequently classified into different suitability classes based on well established rating scales for each of the parameters under consideration (Tables 1 and 2) using the laboratory results. In order to derive different suitability classes, the various nutrient maps were overlaid on each other within a GIS. The various measures of central tendency were employed in the description of variation in the analysed samples over space.

RESULTS AND DISCUSSION

Soil texture is an intrinsic and fundamental property of soil that was grouped into management units according to Hillel (2003), a grouping, which is based on the degree of coarseness or fineness as determined by the percentage of sand, silt and clay (Table 1). It was classified into very coarse texture (low in water and nutrients retention), coarse texture (moderately low in water and nutrients retention), medium texture (medium in water and nutrients retention) and fine texture (very high in water and nutrients retention) (Table 5). Particle size distribution showed that all samples were sandy suggesting that the whole farmland belongs to one textural management unit. This confirms Hulugalle, (1994) assertion that it takes a long period of time for soil texture to change.

Soil bulk density (SBD) which is commonly used to characterize physical behaviour of soils is moderately variable with CV of 17.53% (Tables 3 and 4). Based on the bulk density classes established by Oshunsanya (2011), soil bulk density values were grouped into very coarse texture (unsuitable for vegetable cultivation) with a range of 1.6 to 1.9 Mg m^{-3} occupying 2.8 ha, moderately coarse texture (marginally suitable for vegetable cultivation) with a range of 1.4 to 1.6 Mg m^{-3} occupying 2.3 ha medium texture (highly suitable for vegetable cultivation) with a range of 1.2 to 1.4 Mg m^{-3} occupying 0.3 ha and fine texture (moderately suitable for vegetable cultivation) with a range of 0.8 to 1.2 Mg m^{-3} occupying 1.1 ha of land area (Table 1). Each bulk density management unit will require different agronomic management as values SBD increases with increase in the coarseness of the soil, which is a function of porosity and water retention (Figure 6). For example, SBD management unit with 1.6 to 1.9 Mg m^{-3} occupying a 2.8 ha is highly porous and it encourages leaching of soil nutrients. Therefore, urea fertilizer can only be applied in split to prevent the leach beyond the root zone. However, area with low bulk density values of 0.8 to 1.2 Mg m^{-3} occupying a 1.1 ha and signifying a type of soil with a high percentage of clay with high water retention ability will have problem of low aeration. Soil aeration capability of this zone must be improved by tilling or ploughing to lose the sticky massive soil. Germination of small vegetable seeds and root establishment for amaranths, celosia, cochorus and pepper would be difficult in a clayey soil (Hillel, 2003).

The volumetric moisture content values range between 0.02 and 0.36 m^3 m^{-3} with a mean of 0.14 and a standard deviation of 0.07 with a coefficient of variation of 53.42%. This shows that there is a wide variation in the volumetric value that was observed. The distribution of the volumetric moisture content did not show any consistent discernible pattern, because areas of both high and low volumetric values exist in unison. Although more areas around the south eastern section have highly volumetric moisture content probably because it is more swampy than the north western segment. Based on the range of the volumetric moisture values, the farmland was classified into three management units: medium (0.22 – 0.25 m^3 m^{-3}) occupying 0.7 ha, moderately low (0.11 – 0.21 m^3 m^{-3}) occupying 1.5 ha and low (0.0 – 0.10 m^3 m^{-3}) occupying 4.3 ha of land (Figure 7). The variation in soil water contributes to the variation in infiltration and infiltration influences soil erosion. Low soil water management unit could be improved by mulching or adding compost or organic fertilizer to increase the ability to retain water for plant's use. Vegetables with low water use efficiency can also be planted to low water content management unit. The use of classical statistics characterized by mean of soil water (0.4 m^3 m^{-3}) and standard deviation (0.07) allowed grouping of soil water variability of 57.14% CV as being high (Tables 3 and 4) indicating that soil water is a dynamic property of soil, which depends on the soil texture, organic matter, land management, slope and vegetation (Kachanoski et al., 1988).

The pH values from the farm ranges between 4.5 and 7.3 with a mean of 6.30 and a standard deviation of 0.5 in most part of the farmland. Plants thrive best on different soil pH ranges (MSU, 2011). Soils with pH values greater than 7.0 were found at the south eastern part of the farmland, while soils with pH values lower than 6.0 (acidic soils) were common in the in the north western part of the farmland as presented in Figure 2. The spatial distribution map of soil pH grouped the soil of the studied area into two soil pH management units as neutral (6.6 to 7.3) and slightly acidic (6.1 to 6.5) occupying 1.68 ha and 4.88 ha respectively (Figure 2). These two management units require different soil management in order to make it optimal for vegetable cultivation. The neutral area could be suitable for growing vegetables such as tomatoes, lettuce, pumpkins, cucumbers and cabbage (MSU, 2011). On the other hand, the slightly acidic land condition could be suitable for growing vegetables such as spinach, okra, onions, peppers and egg plants for optimal performance (Table 2). Soil pH values above or below the optimal (6.0 – 7.0) range may result in nutrient deficiencies and consequently reducing the growth and yield of vegetables. This is because the soil pH value directly affects the nutrients availability (Rodenburg et al., 2003).

The phosphorus value ranges from 0.01 to 24.13 mg kg^{-1} with a mean of 9.70 mg kg^{-1} and a standard deviation of 6.10 mg kg^{-1} as presented in Table 3. More than 95% of the sites with lower phosphorus values (below the mean value) were located in the north western extreme of the farmland, while higher values (above the mean value) were observed in the south eastern section of the farmland. Based on phosphorus critical ranges established by Adepetu (1986) for southwestern Nigeria, the studied area was divided into four sub-areas as: very high (0.1 ha), medium (0.4 ha), moderately low (2.6 ha) and low (3.4 ha), and requiring different phosphorus applications (Figure 3 and Table 5). The area with very high percentage of phosphorus does not need further application of phosphate fertilizer as this could kill fungi needed by the vegetables. It can even reduce the plant`s ability to absorb micro-nutrients, including iron (Diane et al., 2009), while areas with moderately low and low need certain amount of phosphorus to avoid stunted nodes on the vegetable stems, slow growth and maturity culminating in poor vegetable production. Understanding the classes of phosphorus is necessary because the area with adequate phosphorus will contribute to the root development, increased strength of the stem and a uniform and earlier crop of vegetable (Diane, 2009). It is therefore obvious that treating the whole farm uniformly becomes a threat to sustainable vegetable production.

Nitrogen (g kg^{-1}) is an essential element in the cultivation of vegetable and for the studied area, it ranges between 0.39 and 2.21 with a mean of 1.42 and a standard deviation of 0.63 in the farm. The distribution of nitrogen shows a consistent north western and a south eastern trend with nitrogen decreasing from the south eastern section through north western part of the area (Figure 4). Hence, higher nitrogen values were noticed in the south eastern while the north western section recorded lower values. It also appears that nitrogen decreases with increasing distance from the rivers that traverse the sites because lower values were recorded in locations further inland while higher values were recorded in locations closer to the river (Figure 4). The studied area was classified into four N- fertilizer management zones after interpolating the laboratory results of nitrogen and based on critical ranges identified by Uponi and Adeoye (2000) for Nigerian soils (Table 2). The classes and areal coverage are; very high (2.6 ha), medium (2.3 ha), moderately low (1.2 ha) and low (0.4 ha). According to Uponi and Adeoye (2000) areas with moderately low nitrogen, can benefit from additional nitrogen application to bring its concentration to sufficiency level in order to boost vegetable yield. But the amount of fertilizer to be applied depends on the amount of nitrogen that is already present in the soil. However, adding N-fertilizer to the 2.6 ha of land with high concentration of nitrogen could result in vegetables having vines and stems with smaller leaves (Chang et al., 2004). Areas with low nitrogen (0.4 ha) would likely result in a costly production and might also result in crop failure. Failure to add nitrogen based fertilizer could cause a stunted growth, yellowing the leaves, and a reduced size of vegetables (Diane et al., 2009). Classical analysis reveals that the coefficient of variation of N is 44.4%, showing that N is with strong variance, which is, changing with space or distance. Managing such farm with CV of 44.4% N uniformly therefore could be detrimental, non-profitable and unsustainable.

Organic carbon varies with cropping patterns, soil management, drainage, level of degradation and slope (Fleming et al., 1999; Romanya and Rovira, 2009). The minimum organic C value recorded was 4.53 g kg^{-1} while the maximum was 33.46 g kg^{-1} with a mean of 20.70 g kg^{-1} and a standard deviation of 8.0 (Table 3). It should be noted that there is no discernible pattern in the distribution of organic carbon. However, much higher values were recorded in the south eastern section of the farm and at a considerable distance from the river. Based on the organic carbon classes established by Adepetu, (1986) for south western Nigeria, soil organic C was categorised into three management units based on Table 2. These are very high (3.7 ha), medium (1.9 ha) and moderately low (0.9 ha) respectively without low concentration of organic C found anywhere in the field (Figure 5). Table 5 suggests that 59.5% (very high, 22.5 – 75 g kg^{-1}) of the total farmland has sufficient organic matter to sustain dry season vegetables. While 30.7% (medium, 20 – 22.5 g kg^{-1}) need some amounts of organic matter depending on what is already present in the different soil management units identified. The remaining 0.9 ha which occupied 9.8% requires heavy organic materials application for sustainable vegetable production. This could be achieved by applying the organic materials such as mulch materials, organic fertilizers, compost, farm yard manure and green manure (Chenu et al., 2000). The high coefficient of variation of organic C (38.5%) observed on the field was due in part to differences in moisture regime, N, cropping pattern and drainage over the farm (Table 3) (Dell and Sharpley, 2006). The C: N ratio for different management units mapped was 1.42, 0.82 and 0.75 respectively for the very high, medium and moderately low. The decomposition rate which is a function of microbes' activities and microbes' population increases with the increase in C: N ratio suggesting that medium and moderately low classes require more microbes for the decomposition of the materials in these management units. This could be achieved by planting leguminous crops such as cowpea, groundnuts etc.

The final vegetable suitability map was produced by combining all the six maps for different soil properties. The resultant map was reclassified into four major categories of suitability. The four distinct specific site management units (SSMU) are identified and mapped out as: highly suitable (0.143 ha), marginally suitable (0.971 ha), moderately suitable (0.517 ha) and unsuitable (4.900 ha) for sustainable dry season vegetables cultivation (Figure 8). Fleming et al. (1999) suggested that grouping the farmland into specific site management units will bring about effective management of each unit, in terms of agrochemicals application, resulting to a highly profitable enterprise.

CONCLUSION

Four specific site management units were generated for effective vegetable cultivation. The developed site specific management unit maps could serve as soil fertility management zones. This is essential information for a sustainable agricultural cultivation. This will also alleviate the problems of reduced yields due to over or under application of agrochemicals.

The use of classical statistics and coefficient of variation (CV) allow for easy grouping of the variability into the least variable (< 15 %CV- sand, soil pH), moderately variable (16 – 35 %CV - clay, bulk density) and extremely variable (> 35% CV- silt, volumetric moisture content, organic C, N, P) indicating that the soil nutrients and soil water are highly dynamic over a small land scale, thus requiring a micro-management. The variability of the surface soil properties found on the field was influenced by moisture content, soil pH, organic matter content, total N and available P. It is then obvious that treating the whole farmland uniformly is a threat to a sustainable vegetable cultivation.

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Table 1: Critical Ranges of Soil Physical Properties

Parameter	Very coarse texture	Moderately coarse texture	Medium texture	Fine texture	Author
Texture (%)	Sand(85-100), Silt(0-15), clay(0-10)	Sand(55- 84), Silt(16-30), clay(11-17)	Sand(23-54), Silt(31-50), clay(18-27)	Sand(0- 53), Silt(49-100), clay(28-10)	Hillel, 2003
Bulk density (Mg m^{-3})	1.6 - 1.9	1.4 – 1.6	1.2 – 1.4	1.0 – 1.2	Oshunsanya, 2011
Moisture content (m^3 m^{-3})	<0.10	0.10 – 0.20	0.20 - 0.25	>0.25	Rawls *et al.*, 1991
Interpretation	Unsuitable	marginally suitable	highly suitable	moderately suitable	

Table 2: Critical Ranges of Soil Nutrients for Southwest Nigeria

Factor	very high	medium	Moderately low	low	Author
Org. C (g kg^{-1})	40 – 75	22.5 – 40	12.5 – 22.5	<12.5	Adepetu, 1986
Total N (g kg^{-1})	>3.0	2.5 – 3.0	1.5 – 2.5	<1.5	Uponi and Adeoye, 2000
P (mg kg^{-1})	>25	20 – 75	15 – 20	<15	Adepetu, 1986
Soil pH (H_2O1:1)	Alkaline	Neutral	Moderately acidic	Highly acidic	MSU, 2011
	>8.0	7.0 - 8.0	5.0 – 6.8	<5.0	

The interpretation of these classes is as follows:

Very high = fertilizer response is unlikely

Medium = variable response to fertilizer

Moderately low = cropping without fertilizer is marginal

Low = cropping without fertilizer is uneconomical

Table 3: Measures of Central Tendency of the soil physical and chemical properties

Soil parameter	Range	Mean	SD	CV%
Sand (g kg^{-1})	809.80 – 949.70	844.10	2.68	3.00
Silt (g kg^{-1})	7.40 – 117.60	50.40	2.47	48.99
Clay (g kg^{-1})	48.00 – 113.00	62.00	1.00	16.26
BD (Mg m^{-3})	0.67 – 1.72	1.31	0.23	17.53
Ɵ (m^3 m^{-3})	0.02 – 0.36	0.14	0.07	53.42
Soil pH (H_2O1:1)	4.5 – 7.0	6.30	0.50	7.80
Org. C (g kg^{-1})	4.53 – 33.46	20.70	8.00	38.50
Total N (g kg^{-1})	0.39 – 2.21	1.42	0.63	44.40
P (mg kg^{-1})	0.01 – 24.13	9.70	6.10	63.60

SD = Standard deviation, CV% = Co-efficient of variation, Ɵ = volumetric moisture content

Table 4: Grouping of soil properties into variable classes

Variable class	CV%	Soil properties
Least variable	< 15	Sand, soil pH
Moderately variable	16 – 35	Clay, Bulk density,
Extremely variable	> 35	Silt, volumetric moisture content, org. C, total N, P

Table 5: Spatial distribution of the mapped out management farmland areas ha^{-1} for different soil properties for vegetable cultivation in Ibadan, Nigeria

Critical range	Org. C	Total N	P	pH	Bulk density	Volumetric moisture
Very high	3.7	2.6	0.1	-	2.8	-
Medium	1.9	2.3	0.4	1.7	2.3	0.7
Moderately low	0.9	1.2	2.6	4.8	0.3	1.5
Low	-	0.4	3.4	-	1.1	4.3

Very high = highly suitable, medium = marginally suitable, moderately low = moderately suitable, Low = unsuitable

Fig. 1: Satellite Image Showing the sampling points at the Studied Site

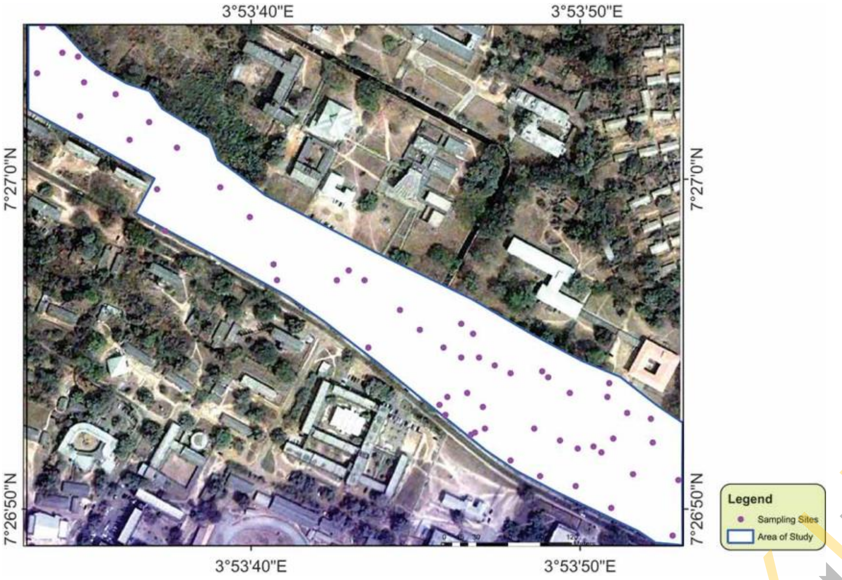
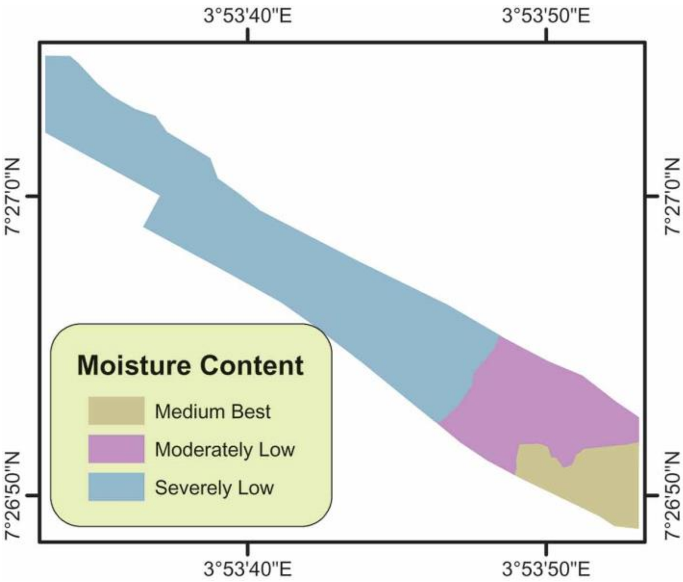
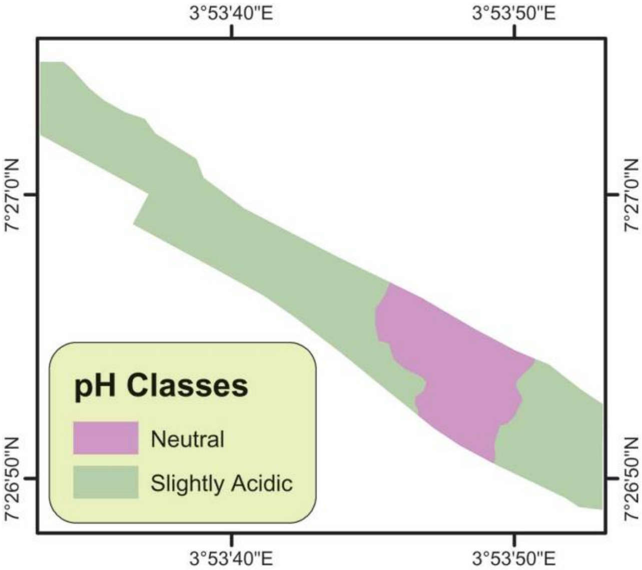


Fig. 2:



3°53'40"E
3°53'50"E
7°27'0"N
7°26'50"N
Moisture Content
Medium Best
Moderately Low
Severely Low

Fig. 3:



3°53'40"E
3°53'50"E
7°27'0"N
7°26'50"N
pH Classes
Neutral
Slightly Acidic

Fig. 4:

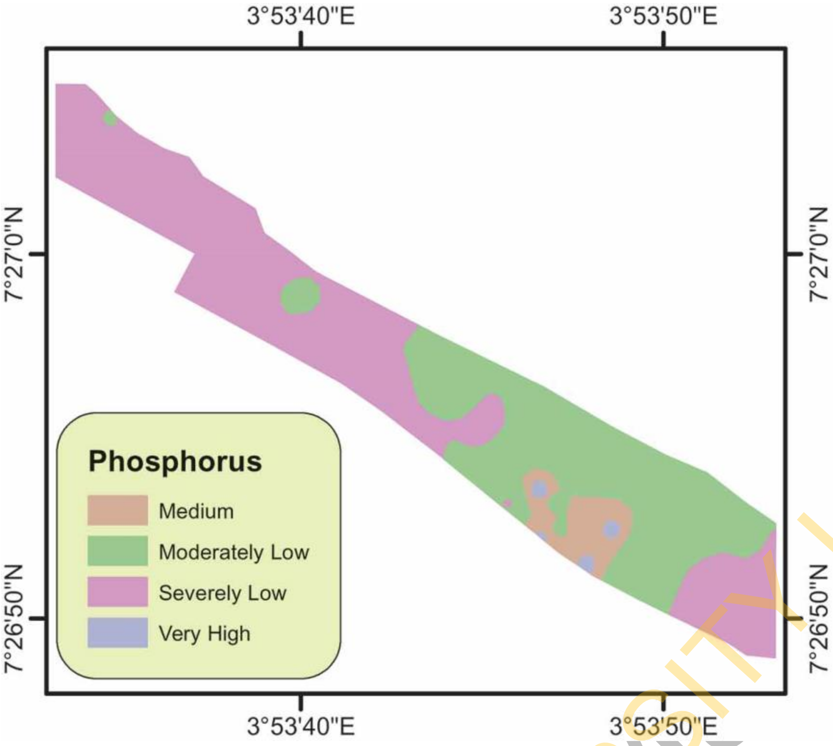

3°53'40"E
3°53'50"E
7°27'0"N
7°26'50"N
Phosphorus
Medium
Moderately Low
Severely Low
Very High

Fig. 5:

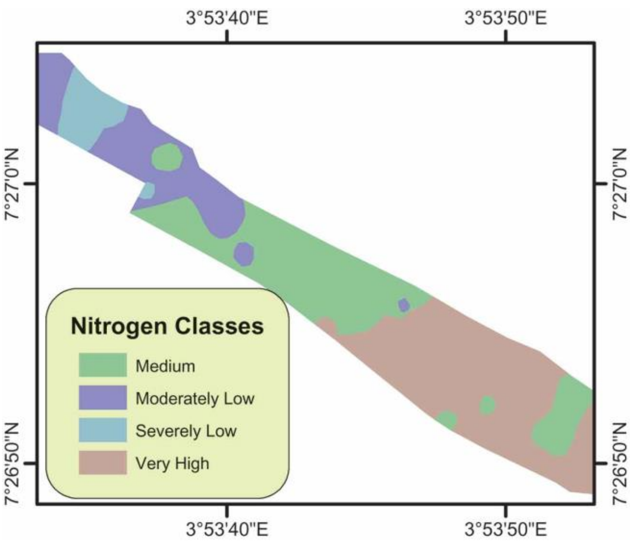

3°53'40"E
3°53'50"E
7°27'0"N
7°26'50"N
Nitrogen Classes
Medium
Moderately Low
Severely Low
Very High

Fig. 6:

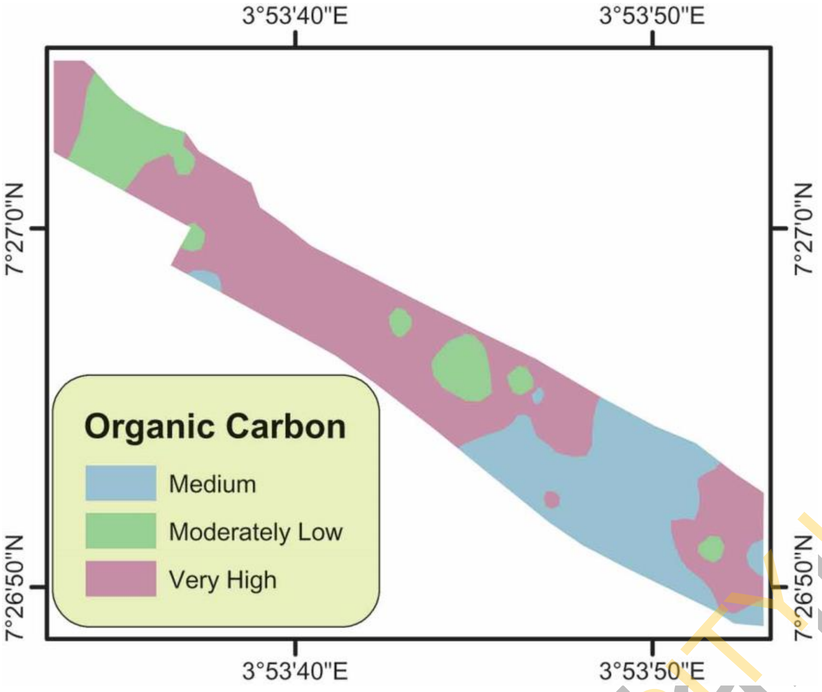
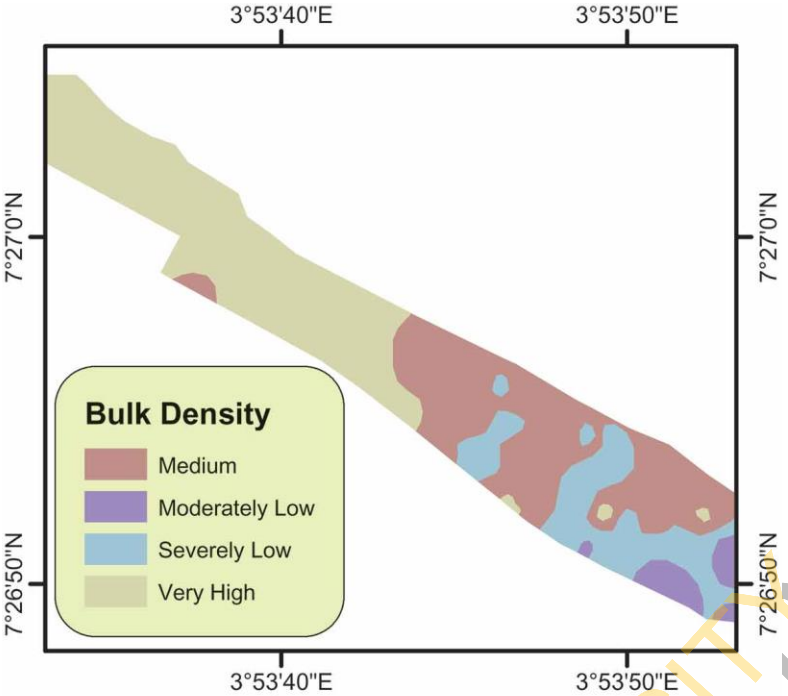

3°53'40"E
3°53'50"E
7°27'0"N
7°26'50"N
Organic Carbon
Medium
Moderately Low
Very High

Fig. 7:



3°53'40"E
3°53'50"E
7°27'0"N
7°26'50"N
Bulk Density
Medium
Moderately Low
Severely Low
Very High

Fig. 8: Four Site-Specific Management Units for Vegetable Cultivation in Ibadan, Nigeria