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Soil characterisation for precision agriculture using remotely sensed imagery in southeastern Nigeria

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Soil characterisation for precision agriculture using remotely sensed imagery in southeastern Nigeria

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Abstract. Remote sensing techniques have been widely used for spatial assessment of soil properties. Traditional techniques involving soil sampling and laboratory analysis are expensive and labour intensive for large areas.High resolution remote sensing data and geographic information systems (GIS) were used for spatial characterization of soil properties in southeast Nigeria. Thesoil parameters investigated include soil texture, pH and drainage pattern. Thetexture, which indicates the sand, silt and clay content in the soil, showed that sandyclay and loamy sand are predominant for the areas investigated. The soils pH ranged from slightly acidic to strongly alkaline. The study has been specifically conducted to making adequate soil data available and acts as a reference for improving soil quality within the area.

1.Introduction

Soil, a natural and non-renewable resource found on the surface of the earth, supports human existence and plant growth. A good knowledge of its complex and dynamic nature helps to nurture healthy plants and improve crop yield. The heterogeneous nature of soil affects crop productivity [1]this sometimes makes agricultural inputs such as fertilizer, pesticides as well as irrigation activities inadequate for precision agriculture [2]. Suitable soils for both agricultural and engineering constructions are getting depleted [3 - 5]. Remote sensing and geographic information system (GIS) are advanced tools used to analyse spatial-temporal variability of soil properties. This technology from airborne and satellite platforms enable quick assessment of vegetation and soil properties and their response to global change over large areas [6-10]. Soil surface characteristics are mostly influenced and controlled by key environmental issues such as excess runoff, soil erosion, floods, contaminations and unbalanced water cycle, among others. For sustainable agriculture implementation an improved understanding of the soil is required [11].

In southeast Nigeria, particularly Abia, Anambra, Ebonyi and Imo states, soil erosion is one of the predominant ecological challenges they face as in most parts of the humid tropical

zone [12, 13]. The soils are structurally unstable and therefore prone to gully erosion [14 -16]. Basically, traditional practices such as mining on sloppy hills, bush burning and continuous cultivation are prevalent in the area [17]. Food insecurity, decline in agricultural productivity, loss of soil structure and soil fertility depletion are some of the severe ecological damages resulting from the massive soil loss in southeastern Nigeria [13 - 19]. The gully erosion incidences observed in the area have eroded about 45 to 90% of total sediment output on agricultural lands in the region [20].

The menace of soil erosion in this region has made agricultural practices in the area more challenging. Although, the traditional approach of soil sampling and laboratory analysis had been used to produce soil maps that have assisted and supported agro-based and scientific projects. However, the methodology has been consideredtime consumingand relatively expensive [21 - 23].Thus,remote sensing and GIS applications are appropriate methods for obtaining information about the spatial characteristics of the soils. Quick quantitative, high resolution and more accurate soil maps from remote sensing and GIS applications seem to have inundated the traditional soil maps [23]. This paper therefore presents a remote sensing and GIS based assessment of some soil parameters including soil texture, pH and drainage pattern.

2.Study Area

Southeast Nigeria consists majorly of Abia, Anambra, Enugu, Imo and Ebonyi States as shown in Figure 1. The area is characterized by a tropical climate with distinct wet and dry seasons and mean annual rainfall of about 1700 mm [24].Mangroove swamp is the vegetation commonly found in the coastal area to the rainforest and savanna is peculiar in the interior Abia and Abakaliki [25].
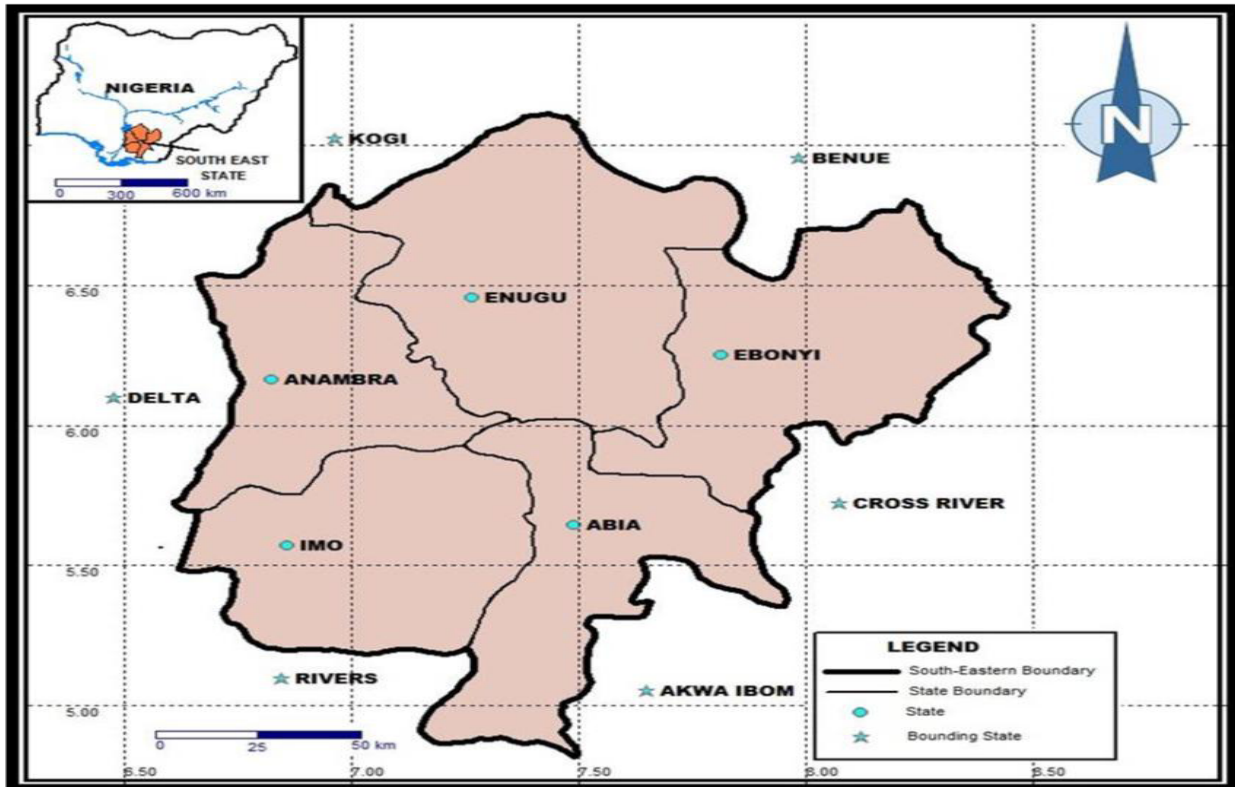
Figure 1: Map of Southeast Nigeria [13].

3. Methodology

Existing soil maps of Nigeria of sheets 1 to 8 at a displayable scale of 1: 650,000, acquired by the Federal Department of Agricultural Land Resources (FDALR,), Abuja, Nigeria and four sheets of the political map of Nigeria acquired from the office of the Surveyor General of the Federation, Abuja, Nigeria were used for this study [23]. The data were first studied to identify their weaknesses then scanned and spatially referenced to WGS (1984) UTM geographic coordinate system. GIS operation was carried ouLeica Geosystem ERDAS IMAGINE 9.1 and ESRI ArcGIS 9.3 were both use to carry out GIS operation. A non-spatial soil data base consisting soil pH, texture and drainage patterns for the study area was created from the GIS interface after being checked and vectorized.

4. Results and Discussion

The results of the soil parameters investigated are discussed below.

4.1   Soil pH

The measure of acidity and alkalinity in soils is known as soil pH. This measurement of soil Ph is important as it determines how easily plants can absorb nutrients from the soil. Soil with a pH of 7 is considered neutral. The lower a soil's pH the more acidic it is, and the higher the pH, the more alkaline the soil. Figure 2 presents the soil pH distribution for the study area. Anambra, part of Enugu and Ebonyi state have moderately acidic soils with soil pH ranging from 4.1to 5.1.

Moderately acidic to strongly acidic soils with soil pH range of 2.1 to 4.5 is dominant in Imo and some part of Anambra States. Towards the northern Ebonyi State and northern Enugu states has soils pH units ranging from slightly acidic to neutral. Enugu soils predominantly ranged from slightly acidic to slightly alkaline with soil ph range of 6.1 to 6.8 and 7.2 to 8.0. Imo and Abia States soils have soil pH units ranging from 2.0 to 3.0 and 6.2 to 6.8 that is, strongly acidic to slightly acidic while towards the eastern part of Enugu state soils pH units ranges from very strongly acidic to strongly alkaline.

For the study area the soil pH units with high dominance are the slightly acidic soils found in Ebonyi State and the strongly acidic soils found in Imo and Abia States. Crops take up nutrients from the soil when the nutrients are dissolved in water. Nutrients such as iron, nitrogen, phosphorus and potassium are not able to dissolve efficiently in soil solution when soil's pH is too acidic or too alkaline. Although factors such as temperature, previously grown crop or vegetation and rainfall can affect soil pH level. Dry climates will have more alkaline soils while areas with heavier rainfall will have more acidic soils.Nonetheless, farmers and horticulturists can adjust soil pH to suit their specific needs.
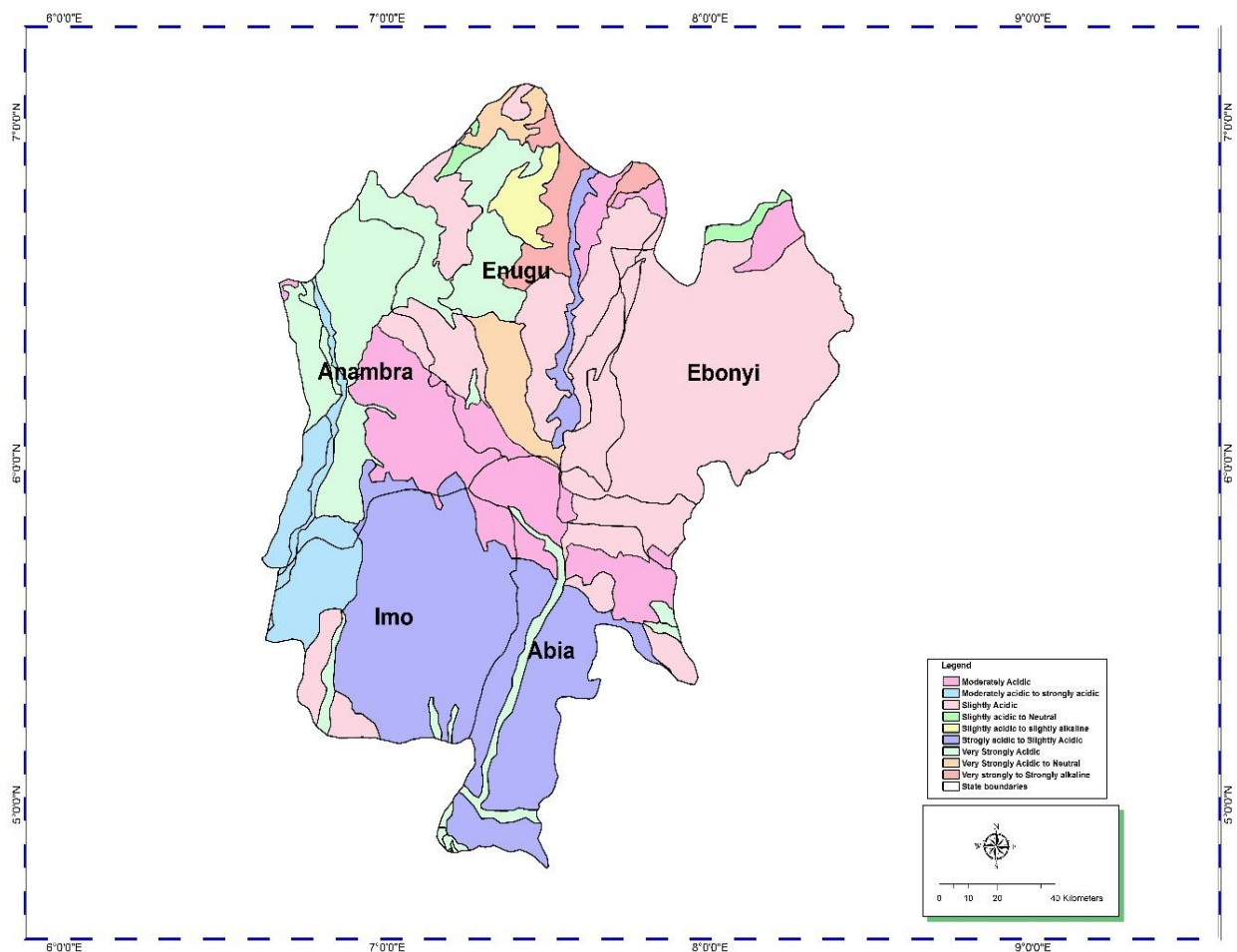

Figure 2: Soil pH distribution for Southeast Nigeria.

4.2   Soil Texture

Soil texture is the relative weight percentage of sand, silt and clay of the soil. The texture of a soil determines soil characteristics that affect the growth of plants. Sand is the largest of the mineral particles. Sandy soils have large pore spaces that improves aeration and water flow through the pores easily. Although sandy soils lack the ability to hold nutrients and are not fertile, this group of soils are generally well drained. Figure 3 presents the soil texture distribution of the study area. Sandy clay texture are dominant in Anambra, Ebonyi and eastern Enugu.Sandy loam are observed to dominate Abia, Imo and most parts of Enugu. Silty clay is found towards the eastern flank of Enugu state while loamy fine sand is observed to have cut across central part of Enugu. Some portion of Anambra and Imo states are observed to have silty loamy soil texture in low proportion. While concretionary clay texture is noticeable towards the northeast of Enugu state.

Generally, southeast Nigeria has soil texture mostly composed of sandy clay and sandy loam soil. Although, Enugu state is noticed to have almost all the available soil texture found within the state. Clay is the smallest size of the soil particles and has the ability to hold nutrients and water that can be used by plants. They are relatively fertile soils but lack the capacity to adsorb cations, however, they contribute less to soil fertility. Clay has poor aeration and poor water drainage capacity due to small pore spaces. Sandy loamy soils are made up of sand particles with varying amount of silt and clay. This type of soil material is good for agriculture because it normally allows for good drainage but cannot hold sufficient water or nutrients for healthy plant growth. Sandy loam soil are often deficient in some micro nutrients frequent irrigation and fertilizer will be required to enhance it.
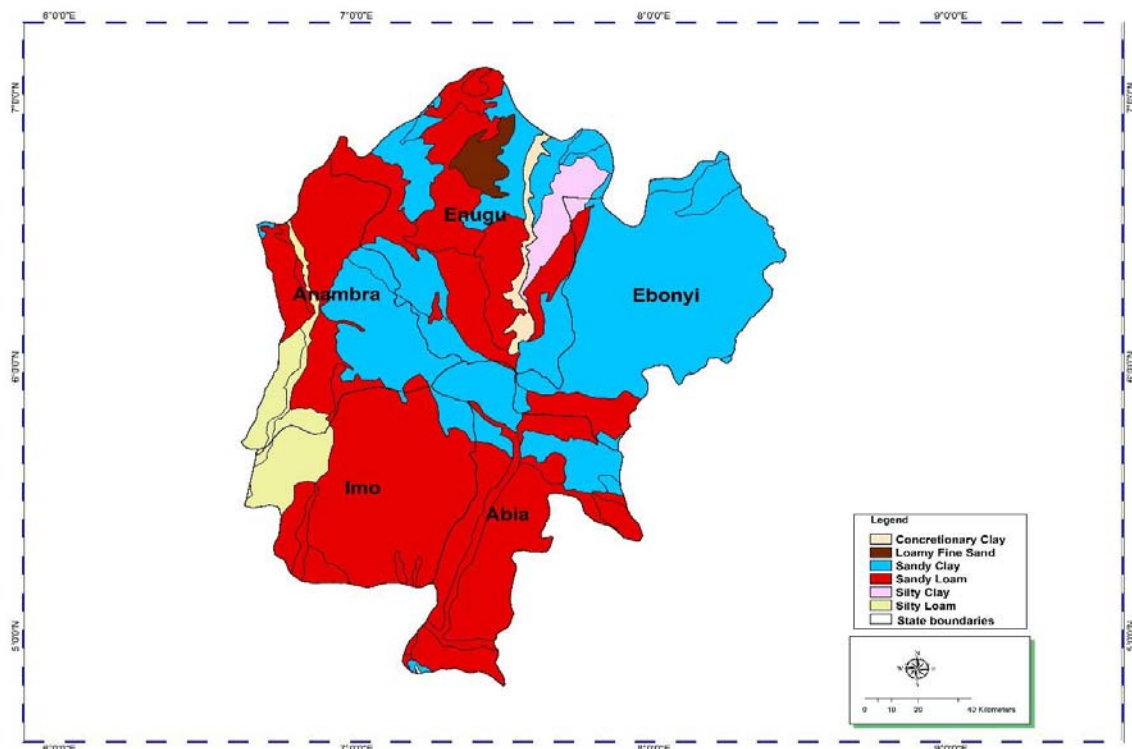

Figure 3: Soil texture map of southeast Nigeria

4.3   Soil Drainage Pattern

Soil drainage is the natural removal of excess water from soil root zone as a result of the force of gravity. The water that supports springs, baseflow and aquifer recharge are provided by this natural process. Soil drainage improves soil moisture and ventilation, accelerates the drying of soils to maintain healthy plant root and also supports microbial activities. Figure 4 shows the soil drainage pattern distribution for the study area. Predominantly, Enugu, Ebonyi, Imo and Abia states have well drained soil pattern with pockets of poorly drained soil pattern towards northern Ebonyi and Enugu States; however, there is a small portion of imperfectly drained soil pattern towards the northeast portion of Enugu State. Soils of Anambra state are basically moderately drained but poorly drained towards the eastern part.
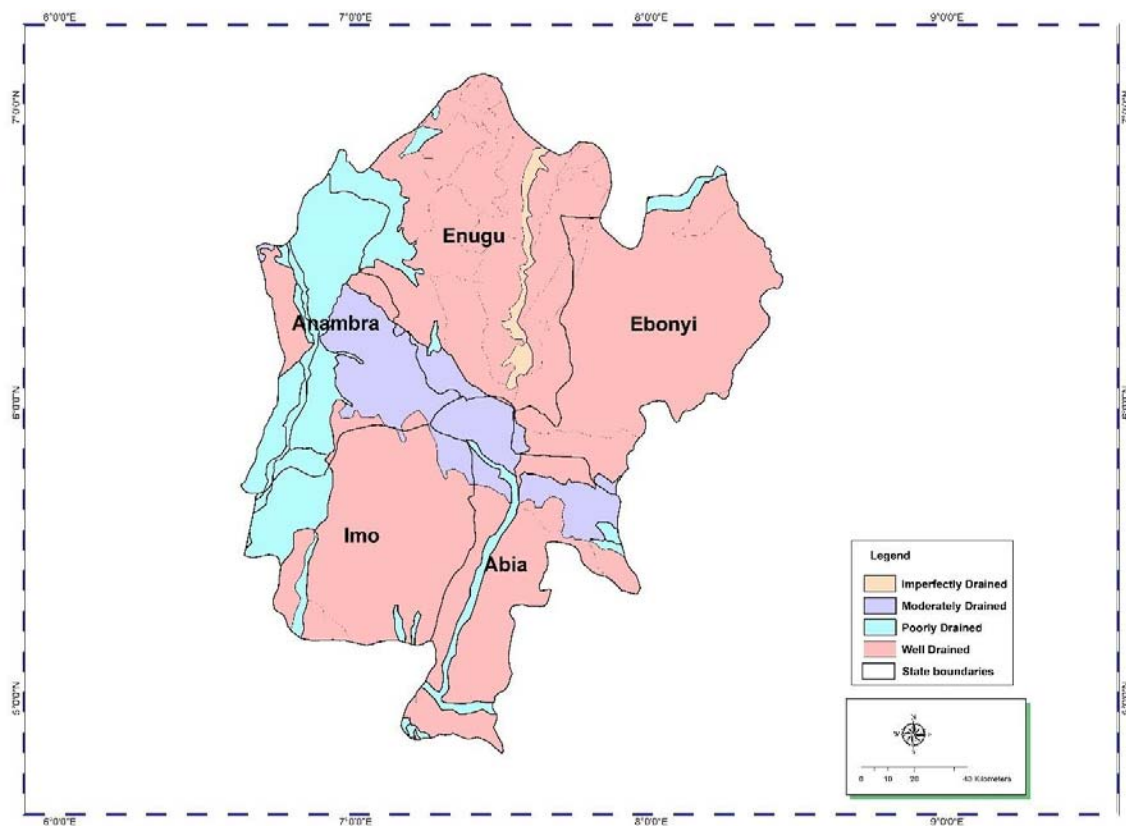

Figure 4: Soil drainage pattern for southeast Nigeria.

5. Conclusion

Remote sensing data and geographic information system have been used to map the spatial distribution of soil properties in southeast Nigeria. Soil parameters study can be used for soil amendment analysis, risk assessment and decision making necessary for precision farming. Crop yield is guaranteed on well drained soils and sandy loam soils of Imo, Abia and some portion of

Anambra and Enugu States. Erosion is noted as one of the major causes of soil depletion in eastern Nigeria; thus, adequate soil management, frequent irrigation and fertilization may be required for utmost crops yield in the area. High resolution remote sensing techniques are highly recommended for soil mapping and monitoring because it allows for coverage of very large areas within the shortest time possible.

Acknowledgement

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