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Full length Research paper

Soil study using environment roughness and normalized discrepancy plants manifestation in Wafongo-Yola background, Northeast Nigeria

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A soil survey analysis using terrain ruggedness and normalized difference vegetation index (NDVI) of Wafongo-Yola Terrain, Northeast Nigeria was conducted to examine and characterize geographic bodies such as vegetation, soils and terrain features which play an important role in evaluating soils conditions for agricultural production. In agriculture, a regional reconnaissance soil survey is usually carried out to identify soils that may support agricultural production. The Terrain Rugged Index Analysis showed the top right quadrant through to the top left quadrant and down the bottom left quadrant at a higher level of abstraction appeared homogeneously leveled. This confirms the earlier suggestion that the area could support agricultural production having a regular terrain and vegetative cover. Terrain Ruggedness Index values of 0.00 to 2.00 were regarded as leveled, 2.00 to 6.00 as nearly leveled which could support agricultural cultivation and values >6.00 are considered to be rugged and might need erosion control measures in the study area.

Keywords: Soil survey, Terrain Ruggedness, Soil Resources, Landsat, Vegetation index.

INTRODUCTION

Soil and land resources are essential to the life of farmers and other land users in Sub Saharan Africa (SSA) due to their huge importance in the daily activities of the people. The people in the region depend heavily on land resources to produce food and improve their lives and the environment they live in. In many cases, little or insufficient effort and measures are put in place to use the land resources in a renewable way for sustainability and environmental protection. This leads to soil fertility losses and land degradation. Lack of scientific measures and inadequate measurements is a challenge in the northeastern parts of Nigeria and where scientists carry out research study; it may be expensive and moreover take long period to carry out soil survey and environmental impact assessment. (Christian*et al.,* 2004). Remote sensing has the general cost-effective advantage of providing spatially distributed measurements on a temporal and/or frequent basis; it mostly observes the surface of the earth. Physical features of the landscape such as alignments are detected in satellite images, and provide relevant information for studies. Spectral reflectance, aerial photography, visible and near-infrared satellite observations are widely used in exploration of the earth (Waters, 1990; Engman and Gurney, 1991; Meijerink, 2000; Jackson 2002; Witheetrironge*t al.,*2011). To better understand and interpret these data, links must be established between the surface observation and the soils and/or environmental phenomena. A wide range of biophysical data attributes (image, texture, slope, topography, vegetative cover, etc.) are used to classify and characterize geographic bodies (such as vegetation and soils) and play an important role in evaluating soils conditions and processes over broad regions (Jones, 2008). Soil map classification can be done at several scales depending on available spatial data. For instance, community-level assessments and urban applications

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rely relatively on high resolution spatial data, whereas nationwide evaluations often involve use of coarser spatial data (Walker *et al.,* 2002).

In mapping suitable agricultural soils, the understanding of soil biophysical properties from remote sensing perspective is important. One of the biological pointers/measures of soil biophysical properties is the vegetation index commonly known as the Normalized Difference Vegetation Index (NDVI) which reflects the vigor of soil vegetative cover. The NDVI is one of the most widely used vegetation indices. Its strength is the vegetation cover and it is tailored to give desirable characteristics for various parameters associated with vegetation, type and ecosystem environment. Its value range between -1 to 1, no vegetation to complete healthy green vegetation cover (Gibson and Power, 2000).

The NDVI is a numerical indicator that uses the visible and near-infrared bands of the electromagnetic spectrum, and is adopted to analyze remote sensing measurements and assess whether the target being observed contains live green vegetation or not. The NDVI has found a wide application in vegetative studies as it has been used to estimate crop yields, pasture performance, and range-land carrying capacities among others. Vegetation properties such as length of growing season, onset date of greenness, and date of maximum photosynthetic activity are often derived from NDVI time series for monitoring changes in agricultural systems (Du, 2002; Li *et al.,*2005 and Liu and Kogan 2002).

Soil physical properties are normally deduced from terrain characteristics such as slope ruggedness and aspect. The terrain model offers a better insight into the soil characteristics. The terrain model may be understood as a digital representation of a portion of the earth's surface thus, generally referred to as Digital Terrain Model (DTM). In a more general sense, a DTM may be used as a digital model of any single-valued surface. However, the term terrain often implies attributes of a landscape other than altitude of the land surface alone (Burrough, 1986).

In large agricultural projects and in finding soils suitable for agricultural practices, a regional reconnaissance soil survey is usually carried out to identify soils that may support agriculture. These surveys are hectic, time consuming, laborious and cost a fortune. Many of the land users in the Northeast of Nigeria are resource poor farmers who might not invest in such an expensive and time-consuming venture. More so, these surveys are usually based of soil biophysical properties to determine capability and suitability of the soils. For instance, to determine if a soil would support agricultural production, the soil vegetative cover, texture, slope and terrain are considered before subsequent series of soil surveys and analysis can follow to determine what type of agricultural produce they can support. In tackling these problems, a cost-effective remedy is recommended through the use of remote sensing data and analysis. Therefore, this study was aimed at providing soil map for agriculture using remote sensing techniques by identification of proper soil parameters through generating a NDVI of the study area and create a Terrain Ruggedness Index (TRI) map of the study area.Ruggedness implies the variation of slope in a terrain (Mukherjee *et al.,* 2012).

MATERIALS AND METHODS

Location and extent

The study area covers the following settlements Wafango, Girei, Damare andthe Modibbo Adama University of Technology, Yola on route “A3” from Jimeta to Girei. It is bordered by the following coordinates, 09º 24’ 14” N 12º 35’ 03” E, 09º 24’ 14” N 12º 25’ 44” E, 09º 16’ 55” N 12º 25’ 44” E, 09º 16’ 55” N 12º 35’ 03” E (Figure 1). The sketch of the study area shows a portion of the Benue River at the bottom left corner and a section of Mubi road across the map.

Overview of methodology

The general framework of this study involved the acquisition of data, primarily satellite imageries and soil physical and chemical properties of the aforementioned project site. It also involved the validation of these data using known profiling techniques and transforming these data to models such as the TRI and NDVI maps. Analysis were performed to determine point or areas of interest. All technologies and/or platforms used were low cost – high end.

Data Sources

The Satellite images were downloaded from the United State Geological Survey (USGS archives, 2006;http://earthexplorer.usgs.gov/). The data of interest were developed from Landsat-7 Enhanced Thematic Mapper (ETM+) which has a spatial resolution observation of 30m for multispectral measurements, Shuttle Radar Topography Mission (SRTM) 1” Arc (30m spatial resolution) and soil textural data required for ground truthing were acquired from the Department of Soil Science, School of Agriculture and Agricultural Technology (S.A.A.T.), Modibbo Adama University of Technology, Yola.

MATERIALS AND EQUIPMENT

Hardware

A laptop computing device (Futjisu AH530) with the following specifications was used for map preparation and data analysis: Processor (Intel Pentium Dual Core

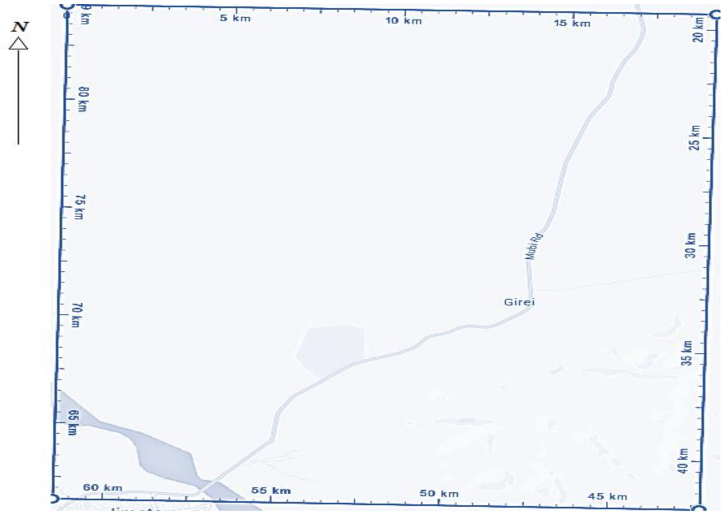

Figure 1: A Sketch of the Study Area

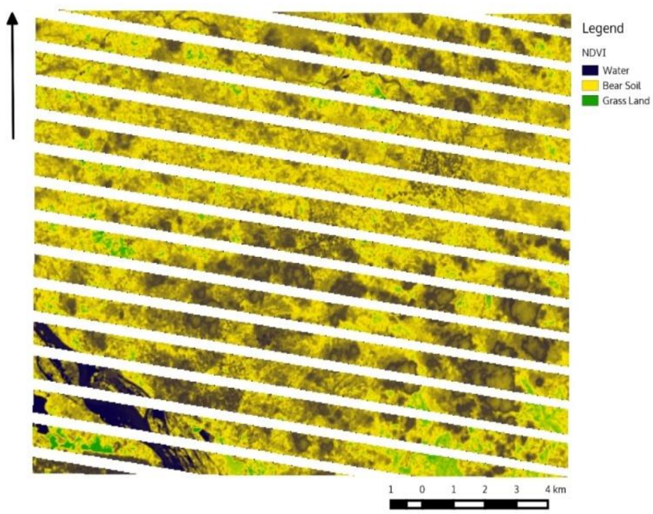

Figure 2: Landsat 7 NDVI Image of the Study Area [September, 2015*]*

@2.1GHz x 2), RAM (4GB), Storage (500GB), Resolution (1020 x 760) and Operating System; Linux (open SUSE 13.2).

Software

The software used in this study was the Quantum Geographic Information System (QGIS) for spatial analysis. These tools satisfy the low cost – high end objective of the study.

DATA ANALYSIS

Developing a NDVI map in the study area

The NDVI of this study was computed using the Quantum GIS Raster Calculator from the Landsat-7 Enhanced Thematic Mapper (ETM+) satellite data. The red band and near infrared band were the bands of interest. The equation used is that developed by Rouse *et al.* (1973).

$$NDVI = [\frac{TM4-TM3}{TM4+TM3}] = [\frac{NI-VR}{NI+VR}] \quad - \quad - \quad (1)$$

Terrain ruggedness index map

The terrain ruggedness index was computed using the Riley *et al.* (1999) formula using the equation:

$$TRI = Y[\sum(x_{\alpha} - x_{00})^2]^{1/2} \quad - \quad - \quad (2)$$

Where;
x_{00} = Elevation of each neighbor cell to cell (0,0).
Y = Column in model grid to the cell.
The DTM yielded a range of values and was categorized using methods adopted by Matthew and Crawford (2008) as follows:

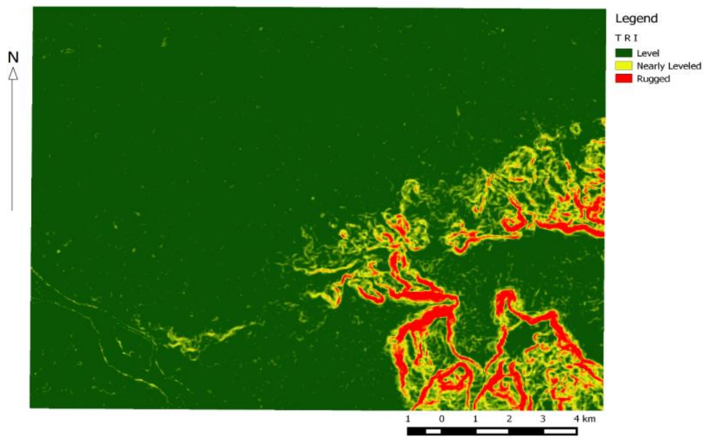

Figure 3: Terrain Ruggedness Index Analysis of the Study Area

Table 1: Terrain Ruggedness Index Classification in Relation to Slope Class

Serial	%Slope	Index Value	Classification
1	<2	0.00 – 2.00	Leveled
2	2 – 6	2.00 – 6.00	Nearly Leveled
3	>6	6.00 above	Rugged

Source: Field Survey, 2016

Highly Level = 0 – 2m; Nearly Leveled = 2 – 6m; Rugged = >6m

RESULTS AND DISCUSSION

NDVI of the study area

The Map of the Landsat 7 NDVI Image of the Study Area is presented in Fig. 2. The map shows River Benue in deep blue at the bottom left quadrant: The green patches are area with grassland vegetation and a positive indication for support for agriculture, generated from evaluating the spatial configuration of vegetation. Similar method was used by Gamon*et al.* (1993) for evaluating the spatial configuration of vegetation, types and its productivity. The NDVI generated using the LANDSAT 7 ETM+ (LANDSAT 7) satellite image of the study area was taken in September 2015, just at the end of the peak of the raining season and generated values ranging from -0.404197 to 0.307973. These values were consistent to finding of Zhou's (2013) in Inter-annual memory effects between soil moisture and NDVI in the Sahel.

Terrain Ruggedness Index (TRI)

The TRI of the study area is presented in Figure 3. The TRI analysis of the study area appeared leveled based on Matthew and Crawford (2008) Categorization. The red to yellow ridges at the lower right quadrant are the Bagale Hills. This was generated from values ranging from 0.249 to 9.48275m. Index values of 0.00 to 2.00 were regarded as leveled in green, 2.00 to 6.00 as nearly leveled in yellow and values greater than 6.00 are considered to be rugged in red. The TRI classification (Table1) was adjusted for the study, given that the resolution of the slope used for the study was 30m. The new TRI for this type of application was broken into 3 categories in respect to slope categorization. The adjustment is an adaptation of Matthew and Crawford (2008) classification from the thesis on an Analysis of Terrain Roughness: Generating a GIS application for Prescribed Burning

Table 1 showed the TRI classification in relation to slope classes of the study area. The index value 0.00-2.00 and 2.00-6.00 at <2 and 2-6% slope indicated the soils were leveled (dark green) to nearly leveled (green) respectively. This suggests that the soils of these areas could support agricultural cultivation of crops and increase production of people of the study area. While >6% slope recorded an index value of 6.00 and above and was rugged which implies that the area might be weakly structured and might pose difficulties for agricultural cultivation and might increase erosion hazards. Similar finding was reported by Malgwi and Abu (2011) that the soils at the upper landscape position were weak structured due to rapid erosion at the upper slope.

The terrain to the top right quadrant of Figure 3through to the top left quadrant and down the bottom left quadrant at a higher level of abstraction appear homogeneously leveled. In the bottom left quadrant of Figure 3, a portion of the River Benue appears to be bordered by nearly leveled indices (i.e. yellow borders). These parts of the terrain (in field) have steep sloped to rugged surfaces. Given the limitation in resolution, the bordering of the River Benue might be the averaging effect of leveled to rugged surfaces per pixel. Since the terrain at the river borders are somewhat heterogeneous if considered at a resolution much higher than 30m and undulating from flat to rugged in a short distance of 30m.

The bottom right quadrant of Figure 3 revealed TRI values of greater than 6.00 and are in red: Immediate lower values are in yellow, indicating a nearly leveled terrain. The terrain is rocky in nature and is the Bagale Hills which appear to fence a much level to nearly leveled surface at its center. The leveled regions of the terrain are at the upper parts of the top right quadrant, the top left quadrant and the bottom left quadrant of Figure 3. A detailed review of the terrain reveals that the terrain does not appear to be completely leveled; even though a huge portion is. In the top left quadrant for instance, at the extreme top, are spots that are nearly leveled and a concentration of such spot abound in the bottom left quadrant.

The rate of change of slope for the study area was fairly low; that is the terrain appeared homogeneous. A large portion of the terrain was within the leveled or nearly leveled category which implies that the changes in slope of the terrain are gentle (at a 30m resolution). Since the topography of an area can affect the microclimate, factors of soil formation and geological processes, which seemingly affect soil processes (Birkeland, 1984) either at the physical, chemical or biological level. The leveled or fairly leveled nature of the terrain implies that at a higher level of abstraction, homogeneity can exist among soils of the study area.

CONCLUSION

The outcome of the study showed that it is possible to identify and map out rugged terrain for possible agricultural soils from biophysical properties using remote sensing techniques. The interest in the study was to identify possible terrains for agricultural purpose. Giving the dynamic nature of the terrain, soil fertility and productivity outcome identification can only be an approximation. The Terrain Rugged Index Analysis showed the top right quadrant through to the top left quadrant and down the bottom left quadrant at a higher level of abstraction appeared homogeneously leveled. This confirms the earlier suggestion that the area could support agricultural production having a regular terrain and vegetative cover. However, areas where the terrain is rough and higher levels might need management practices to control erosion hazards.

RECOMMENDATIONS

The following recommendations will improve the survey and agricultural potentials of the study area:

The study focused on targeting and prioritizing terrain that is suitable for agricultural practices based on their biophysical properties.

However, it is possible that such terrain after investigation may need further revision or potential management intervention in the study area. Therefore, more study on the use of remote sensing techniques in understanding soil physical and chemical properties in relation to plants will collaborate and improve on the data of this study.

Terrain Ruggedness Index values of 0.00 to 2.00 were regarded as leveled, 2.00 to 6.00 as nearly leveled which could support agricultural cultivation and values>6.00 are considered to be rugged and might need erosion control measures in the study area.

The study area at the bottom left quadrant is a portion of the River Benue which bordered nearly leveled indices can improve irrigation cultivation and not just rain fed cultivation as is the most practiced.

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