Soil salinity and its implications on sustainable agriculture in Southern and Northcentral States of Nigeria

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Abstract. Soil salinity impedes agricultural production, threatens global food security and agricultural profits. Soil salinity is a global issue and the accurate assessment of salt affected areas can assist in combating global climate change, effectively manage and utilize limited land and water resources. Landsat series of the multispectral remote sensing provides the potential for frequent surveys for soil salinization at various scales and resolutions. For this research, twenty tiles of Landsat 8 imagery between 2018 and 2019 were used to generate the soil salinity index map for the study area. The result revealed the salinity index status for all the areas investigated. Reclamation of salt affected land and management practices to curb soil salinity is highly recommended.

Keywords: Agricultural soils, Landsat-8, Salinity, Sustainable agriculture, Southern, Northcentral, Nigeria

1. Introduction

Agricultural sustainability has been greatly threatened in this century by increase in population and reduction in cultivable lands [1-2]. The available cultivable lands for agricultural production have been grossly affected by salinization. Salinization refers to the concentration and movement of salts in agricultural landscape. Salt is accumulated in agricultural soils as a result of various environmental factors such as climate change, excessive use of groundwater, poor drainage associated with massive irrigation and intensive farming, and the use low quality water in irrigation [3]. In non-agricultural soils of arid and semi-arid areas it causes corrosion and subsidence of urban structures leading to land degradation and further soil erosion [4]. Soil salinity is a major threat to agricultural productivity across the world [5-7]. Several countries such as USA, Spain, Jordan, China, Greece and Senegal have used various techniques and algorithms to tackle soil salinity on their farm lands [8 – 14]. Effects of salt infected soils include, nutritional disorder, poor soil physical conditions, osmotic stress, reduced crop yield, toxicity,
low agricultural output and low economic returns [15 – 16]. [17] have reported that 19 million hectares of sub-Saharan African are already affected by soil salinity. Remote sensing and GIS based approaches have been accurately used to study, map and model soil salinity by several scholars [4, 18 - 20]. Therefore, agricultural technologies are needed to better manage soil salinization in Nigerian agricultural soils to achieve sustainable agricultural systems. This study aims to identify areas that have been affected by saltas at the time of study in southern and northcentral states of Nigeria (Figure 1) using Landsat-8 satellite multispectral imagery.

Figure 1: Map of the study area covered by the Landsat-8 satellite imagery.

2. Methodology

Twenty (20) sheets/tiles of Landsat-8 imagery covering the southern and northcentral states of Nigeria for the period of January 2018 and December 2019 were obtained from the United States Geological Survey website. The map of the areas covered by the Landsat-8 satellite imagery is shown in Figure 1. The Landsat 8 satellite multispectral image has 11 bands each measuring different ranges of frequencies along the electromagnetic spectrum (visible and invisible colour ranges). Some areas covered by cloud and shadows were not captured by the imager; such areas are excluded from the estimation process.

The layout of the twenty tiles used for the analysis is displayed in Figure 2. Each band of the tiles of Landsat 8 used for the study was mosaiced in ArcGIS version 10.6 and the study area clipped before the map was been produced.
Reflectance rescaling degrees were used to mutate the digital rate (DN) to topmost of atmosphere (TOA) planetary physical units (reversal) in the Landsat-8 operational land imager (OLI) sensor [21]. The DN values were mutated to reflectance for OLI data using this relation:

$$\rho \lambda = \frac{M \rho \times \text{cal} + A \rho}{\sin(\theta)}$$  \hspace{1cm} 1.1

$M \rho$ is reversal multiplicative factor for the band, $A \rho$ is reflectance additive scaling factor for the band, $q_{\text{cal}}$ is the pixel value in DN, $\rho \lambda$ is TOA planetary reversal and $\theta$ is the sun altitude Angle. The indices in equation 1.1 were used to get equation 1.2.

Following the procedures of [21], the near infra-red (NIR) band 5, which is used to detect biomass content and shoreline is also suitable for detecting soil salinity when the red and green bands of the visible spectrums are combined using the formula:

$$SI = \frac{NIR-RED}{GREEN}$$  \hspace{1cm} 1.2

where SI means salinity index.
Processing steps to mapping soil salinity from Landsat-8 Imagery[21 – 23]

Step 1 - Satellite images were converted from DN to reflectance physical units where the Landsat-8 image is placed within the range of 0 to 65535.

Step 2 - The region of interest (ROI) and samples are selected based on SWIR2, NIR and Green combination band

Step 3 - Image was classified by maximum likelihood method

Step 4 - Bare soil class was segmented from the classes of the images

Step 5 - Soil indicator used in the research that is, soil salinity was introduced at this stage. The segment image in step 4, shows the resulting soil salinity images. Find the associated salinity index values associated with the Gray scale values for each of the images obtained in step 4

Step 6 - A plot is then made for each of the extracted salinity values with corresponding soil indicator (grassland) images to find the minimum and maximum values.

Step 7 - Subsequently, spatial analysis tools in ArcGIS 10.6 software were used to compute indices and analyze the indices.

3. Results and Discussion

The range of salinity values (Table 1) are represented by different colours for low and high salinity soils in the areas investigated.

| SI Ranges | Salinity Index |
|-----------|----------------|
| Low       | 0.000 – 5044.31|
| Mid       | ≥ 5044.31      |
| High      | ≥ 80978.8      |

The soil salinity index maps for the study area (Figure 3) showed high, medium and low salt affected parts of the study area. High soil salinity is observed towards the north-central part of Nigeria covering states such as; Niger, Plateau, some part of Benue, FCT and Kwara. The riverine area of south-south Nigeria, consisting of Bayelsa, Rivers, Delta, Akwa-ibom and Cross River have low soil salinity. Other states in south-south such as Edo, northeastern part of Cross River and Benue states have areas affected by soil salinity at low to medium level. Lagos, Ogun, Ekiti and some parts of Oyo states also have low to moderate soil salinity index. Abia, Imo, Enugu and some parts of Anambra and Ebonyi have low to moderate soil salinity.
Figure 3: Soil salinity index map for southern and northcentral states of Nigeria.

The result revealed that high soil salinity is fast spreading towards the northcentral states of Nigeria such as Niger, Federal Capital Territory (Abuja), Nasarawa and Plateau. The high salinity recorded in the northcentral states is as a result of intense agricultural activities in that region. Farm management practices such as crop rotation, nutrient management (fertilizers doses correctly chosen and adjusted), proper management of irrigation and tillage will curb soil salinity on our agricultural lands[21]. Soil reclamation requires the removal of salt from the root zone and may be difficult to overcome. However, certain measures such as the application of amendments to increase soil permeability and reduce the exchangeable levels of sodium have been practiced. The reclamation involves the addition of gypsum (CaSO4) in large quantities to soil in other to substitute sodium in the soil with calcium ions [3, 22]. An alternative to gypsum is sulfuric acid and elemental sulfur which reacts with soil microbes converting sulfur to sulfuric acid [3]. Leaching with irrigation water on farmlands [22] is another method of reclaiming the salty portion of the agricultural lands in the affected states. However, in coastal saline soils, the planting of rice has been used to improve soil salinity in agricultural lands [23].

4. Conclusion and Recommendation

Globally, salinization is a major challenge to sustainable agricultural production and food security. Mismanagement of agricultural lands and overexploitation of water resources in arid climates have been highlighted as some of the major causes of soil salinization. Increasing crop yield have proved to have negative impact on the environment if not properly managed. The Landsat-8 satellite imagery has provided a quick information on the soil salinity status of the study area. The areas with high soil salinity are parts of the northcentral states of Nigeria and this
is due to intense agricultural practices carried out in this region. Low to medium salinity index is observed in the southern states of the country. Urgent farm management measures such as adequate irrigation practices especially in northcentral states of Nigeria should be adopted in other to curb and reclaim our agricultural lands from salination and land degradation.

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