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Geospatial Distribution of Some Selected Soil Nutrients in Mubi Area, North-Eastern Nigeria

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ABSTRACT

The present research aimed to evaluate the geospatial distribution of some soil nutrients in Mubi, North Eastern Nigeria. The detailed soil survey was conducted around March 2019 to March 2020 using Geospatial techniques. The soil samples were collected using systematic and purposive sampling techniques. Fifty-six (56) augers samples were collected at each area (Mubi North and South) at the surface depth of 0-20 cm and 20-50 cm subsurface. ArcGIS 10.5's Geospatial software was used to create models based on the global practices in soil modeling and ordinary Krigging interpolation method for fertility mapping. The results revealed that higher concentration of total nitrogen was found in both the western and eastern parts of the study area. The available P concentration was higher at the Kurdi and Mahura villages in the North-eastern part of the area, while Maduguva in the east, Bela at extreme south and at the North-western part of the study area in Zang gude and Kwambula settlements. The potassium content was spatially distributed with high concentration at small area at the western part of the area which includes Ngabda, Kurmin, Mayo-lope and Yadafa settlements. The concentration of organic carbon in the study area was spatially distributed with the maximum accumulation of organic carbon content was found at the western, eastern, extreme north (Kamanda and Mizza settlements) and north-western parts of the study Calcium content in the study area was high at northwestern part and innermost north-central (Muvi and Chambal). The high magnesium content was noted at the western part area and at the eastern part while the lowest agglomeration was mostly dominated the extreme north and central part of the area. Intensive farming with less or no fertilizer application is therefore recommended in the areas with high concentration of soil nutrients and maps obtained should be in future fertilizer application practices and other related agronomic practices.

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INTRODUCTION

Soil is a naturally occurring ecosystem consisting of a mixture of minerals and organic matter with a definite form, structure and composition [1]. It is the most wondrous gift of nature to all the earthlings and vital natural resource base performing fundamental functions for the benefit of humankind and the environment [2]. Soil nutrient balance studies in Africa show evidence of widespread nutrient mining [3].

Declined soil fertility is indicated by the appearance of wide distribution of soils deficient in plant nutrients in areas which were highly productive, ascertained by low crop yields, and soil analytical data, appearance and prominence of plant species which perform well

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on soils with low fertility, changes in soil colour, texture and structure associated with low soil fertility (like poor water and nutrient retention) and widespread nutrient imbalances [4]. According to [5] have reported that savannah soils are generally low in inherent fertility. Lithosols are generally characterized by low nitrogen (N), phosphorus (P), cation exchange capacity (CEC), total exchangeable basis (TEB) and low activity clays.

Globally, Lithosols largely occur within the fertile and problem soil distribution zones and are mostly found in tropical than in the temperate zones. These soils are susceptible to crusting and compaction, surface erosion and leaching of plant nutrients. These soil characteristics make soil fertility management a major task in crop production practices around Mubi area. In the past, crop management practices in the region involve land fallow and shifting cultivation systems for restoring soil fertility through organic matter and plant nutrient build-up over a long period [6]. Due to the intense and continued cultivation with eminent consequences of declined soil productivity have led to the quite studies in Mubi area aimed to analyze fertility status of the area such as the work of [7], [8] and [6]. But there is no research conducted in the area that geospatially mapped out the distribution of soil nutrients concentrations in the area. Therefore, there is need for mapping out the distribution of soil nutrients in the study area with the aim of providing valuable information for sustainable planning and management of the soil towards agricultural production. Thus, the present study saddled to geospatially map out the distribution of some selected soil nutrients in Mubi area, North-eastern part of Nigeria.

METHODOLOGY

The Study Area

Mubi North and Mubi South are Local Government Areas of Adamawa State in Nigeria. Its coordinates are 10°16'N 13°16'E / 10.267°N 13.267°E (Fig. 1) with a total land mass of 506.4Km^2 and a population size of 759,045 people.

The area is home to River Yadzaram which is one of the major rivers that drain into the Lake Chad. The river has a total length of about 330 kilometers takes it source from the Hudu hills south-east of Mubi town and flows northward into the Chad [9].

The soil of Mubi regions, therefore, fall under the category of ferruginous tropical soils of Nigeria based on the genetic classification made by the Food and Agricultural Organization of the United Nations. Mubi region falls within the Sudan Savanna belt of Nigeria's vegetation zones. The region's vegetation type is best referred to as Combretaceous woodland Savanna. It is made up of grasses, aquatic weeds in river valleys and dry land weeds interspaced by shrubs and woody plants [10].The Yedzeram valley soil are mostly hydromophic in nature and fall within the 213 mapping unit made up of Entisol and Inseptisols, based on USDA soil order.

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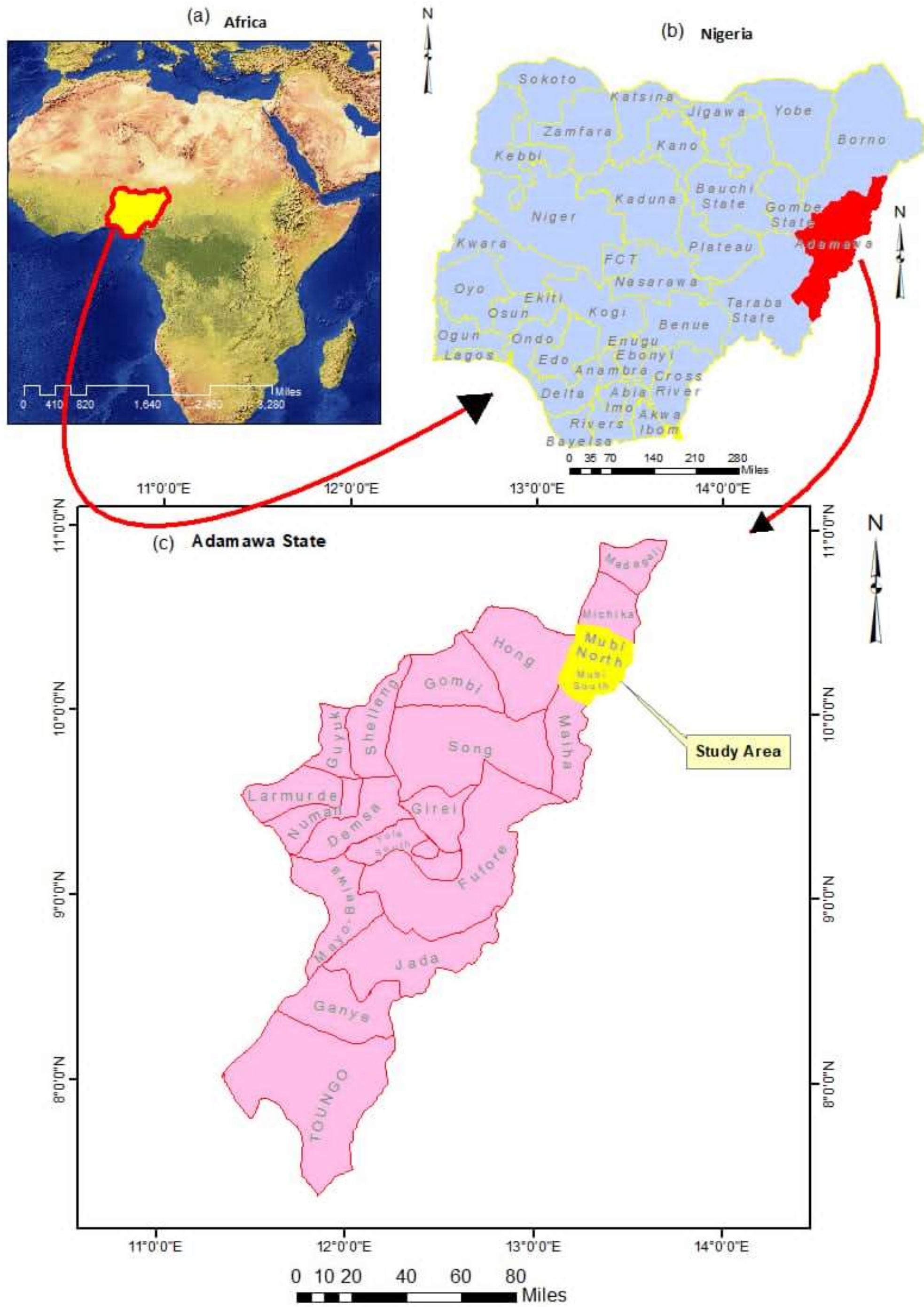

Figure 1: Map of the Study Area

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Field Study and sampling

Pre-field survey was carried out in the surveyed area involving gathering information from soil and topographic maps and also to getting general idea of the soils and their variation.

Samples was purposively sampled within the grid cells, the exact field location was determined and properly marked with global positioning system (GPS) using Are GIS. The whole study area was divided into 5, 000 by 5,000 m as geo-referenced on the grid maps as shown in figure 2. Auger samples were collected at the depth of 0-20 cm and 20-50 cm for surface and sub-surface respectively, where the cells are not square, the number of the core samples was reduced equivalent to the size of the portion within the grid cell that is affected and a composite sample was made. A total of 112 samples of both surface and sub-surface were collected.

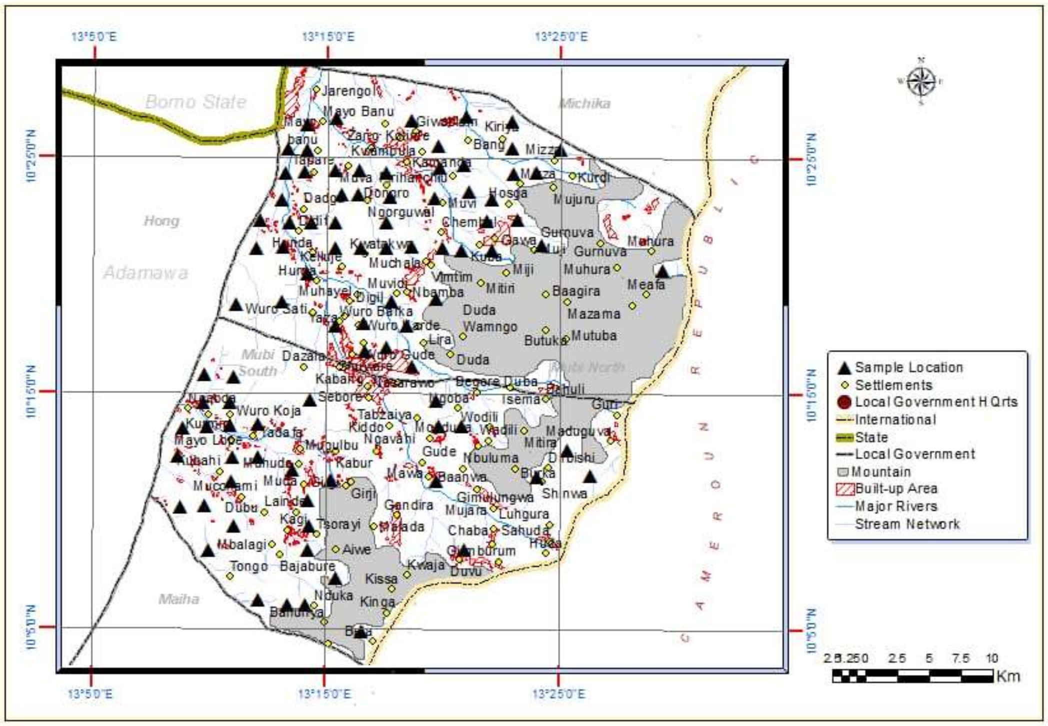

Figure 2: Map showing the sampling points of the study area

Laboratory Analyses

The soil samples collected were air-dried, and crushed using pestle and mortar to pass through a 2mm sieve, some of the samples were further passed through 0.5mm for chemical analysis. The soil samples collected were analyzed for their chemical using standard laboratory procedures at the Department of Soil Science Laboratory, Modibbo Adama University Yola

Soil chemical properties

The pH of the soil was measured in a 1:2:5 soil-water suspension ratio and also in 0.5M KCl solution using glass electrodes pH meter [11]. The electrical conductivity of the soil sample was measured alongside pH with an EC meter using the same soil-water suspension used for measuring the soil pH in water [11]. Organic carbon was determined by wet oxidation method of [12]. In this method organic carbon is oxidized by $K_2Cr_2O_7$ in the presence of H_2SO_4. Total nitrogen content of the soil was determined

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by the Kjeldahl's wet digestion method [13]. Available phosphorus content of the soil samples was determined by bicarbonate extraction method for near neutral and slightly alkaline soils while for acidic soils, the determination of available phosphorus was done by Bray No. 1 method [11]. The exchangeable cations in soil samples were determined in the extract of 1N neutral ammonium acetate (NH_4OAc) [11]. The exchangeable calcium and magnesium content of soil were determined titrimetrically while the exchangeable was determined by flame photometer.

Geospatial Analysis

Statistical and geostatistical analysis of soil fertility was carried out using all surface soil properties, ordinary krigging (OK) and semivariogram will be used for estimation and analysis of spatially dependent variables. Ordinary krigging is an estimation technique known as the best linear unbiased estimator (BLUE) that has the advantage of using semivariogram information. Ordinary krigging (OK) allows interpolation of values of unsampled location and production of maps exhibiting the spatial distribution of variable as described by [14]. Figure 3 below described geospatial flow which provides a set of tools that allow models that use spatial coordinates to be constructed and were used to map out the spatial distribution of soil properties of the unsampled locations which provides information on the pattern and variation of each of defined soil properties.

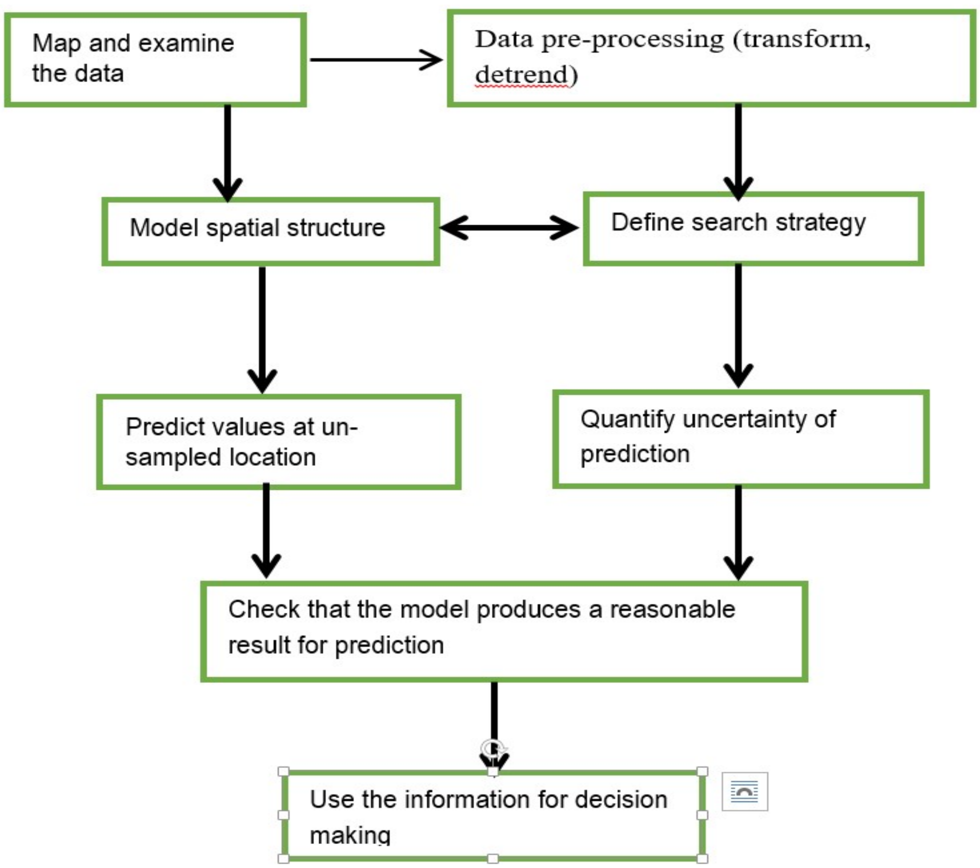

Figure 3. Geostatistical Workflow [14].

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RESULTS AND DISCUSSIONS

Spatial Distribution of some selected soil nutrients of the study area

Total nitrogen

The spatial distribution of total nitrogen presented in figure 4. The TN content was generally very low with varied values from 0.01-0.37 g/kg which is < 0.5 g/kg limit of extremely low defined by [5]. This result conforms to findings of [15], [8] and [6] who reported very low to low content of TN which might be partly due to the complete crop residue removal by the farmers in the area, continuous cropping and poor soil management. [16] Also affirmed that low values of TN could also be attributed to crop removal and sparse natural vegetation cover. However, more concentration of TN (0.12-0.37 g/kg) was observed in the southern part while less TN content (0.01-0.12 g/kg) was at the north and north-western parts of the area.

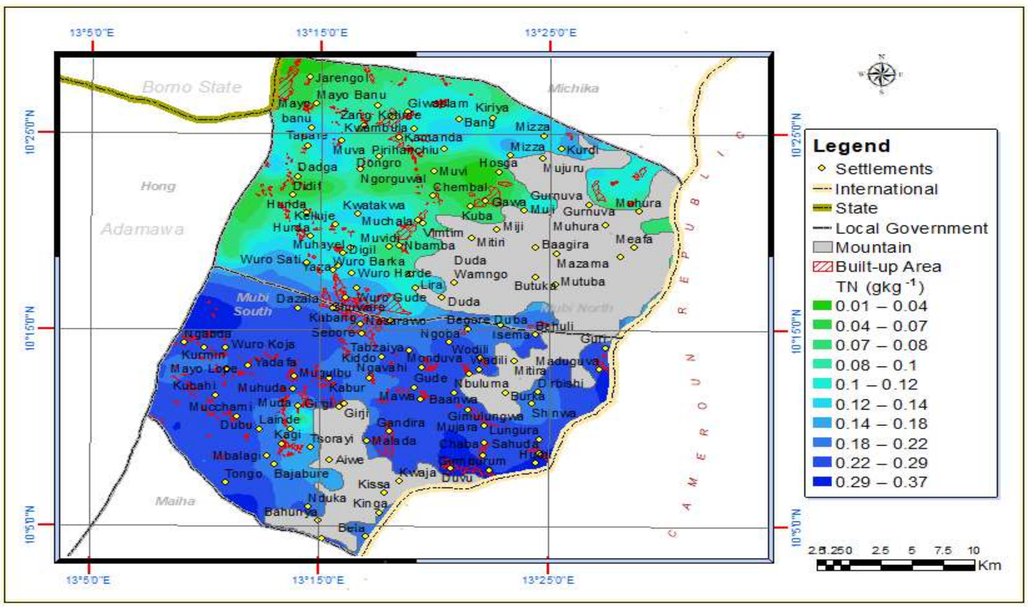

Figure 4. Spatial Distribution of Total Nitrogen in the study area

Available phosphorus

Spatial distribution of available phosphorous in the study area is presented in figure 5. The map shows that available P concentration was generally low in all the investigated soils with ranged values of 6.49-10.89 mg/kg which is within the range of 5-10 mg/kg defined [5] and [17]. However, the North-eastern part of the area (Kurdi and Mahura, Maduguva) and the Southeastern (Shinwa, Sahuda, Huda etc) the Ap is more than the other areas. The high AvP spatial variation in the area may be attributed to the spatial variation of organic carbon and the variability of iron and aluminium content. Moderate concentration of available P was recorded out at North-western part of the area and at Nduka and Bajabure areas of the Southern part respectively. Similarly, low available P was recorded at the western and eastern parts of the area. Average P content of 12.81 Mg kg^{-1} (at Madanya site) and 45.12 Mg kg^{-1} (at Gella site) were observed. Low AvP has been reported in Savannah soils [18]. The P variation was perhaps due to OM rates in the soils, which probably lead to P additions within the top surface soil depths. In addition, the low soil pH might have also reduced the available P due to P-fixation in the soils [19]. The increase of

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available phosphorus can be explained in terms of the activities of iron, aluminium and manganese at low pH [20]. When the soil pH is low, activities of iron, aluminium and manganese are significantly form complexes with the soluble forms of phosphorus thus fixing the element. With lime application, the pH is increased and the iron and aluminium which dominate the soils become less active, thus releasing the soluble phosphate ions in form of the diphosphates and monophosphate. This result is similar to [21], reduction in soil acidity leads to phosphorus availability. Maximum P uptake by plant occurred when soils were limed to pH between 5 and 6. The available phosphorus content of the study area generally falls within the low to medium range based on the classification of [22].

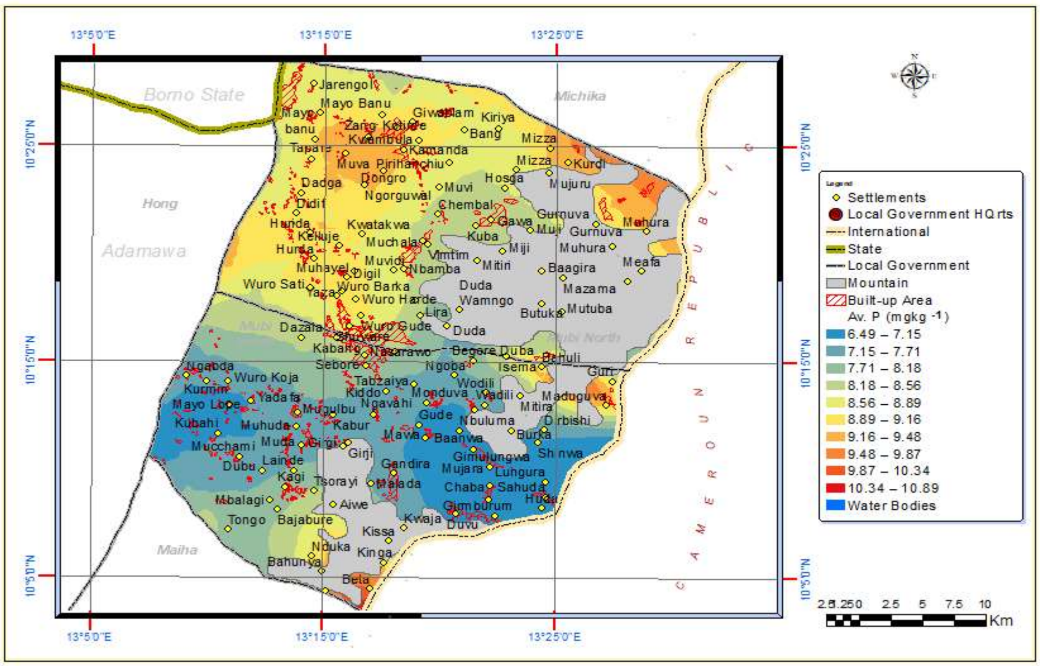

Figure 5. Spatial Distribution of Available Phosphorous in the study area

Potassium

In figure 6 spatial distribution of potassium content in the studied area is presented. High concentration of potassium was recorded having values varied from 0.62-1.08 cmo/kg which is > critical high value of > 0.6 cmol/kg described by [5] and [17] where found at the western part of the area which includes Ngabda, Kurmin, Mayo-lope and Yadafa settlements. Western, eastern and North-central parts were recorded with moderate in concentrations. Low concentration of potassium having values ranged from 0.22-0.55 cmol/kg within defined rating (0.2 -0.6 cmol/kg) of [5] and [17] was recorded at the extreme North, North-central, North-east, North-west, South-west and South–eastern parts of the area respectively. This finding agreed with the result of [8] who reported moderate to high K with values varied from 1.12-9.52 cmol/kg with a mean value of 2.83 cmol/kg in the Mubi soils. In addition, low K content with < 0.2 cmol/kg defined as low [5] and [17] is observed at the extreme north of the investigated parts of Giwabilam, Kiriya and Bang of the studied area respectively. According to the reports of [23] and [24] K is generally considered adequate in most savannah soils and therefore requires no additional K fertilization. However,

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soils can supply some K for crop production, but when the supply from the soil is not adequate, thus K must be supplied in a fertilizer program [25].

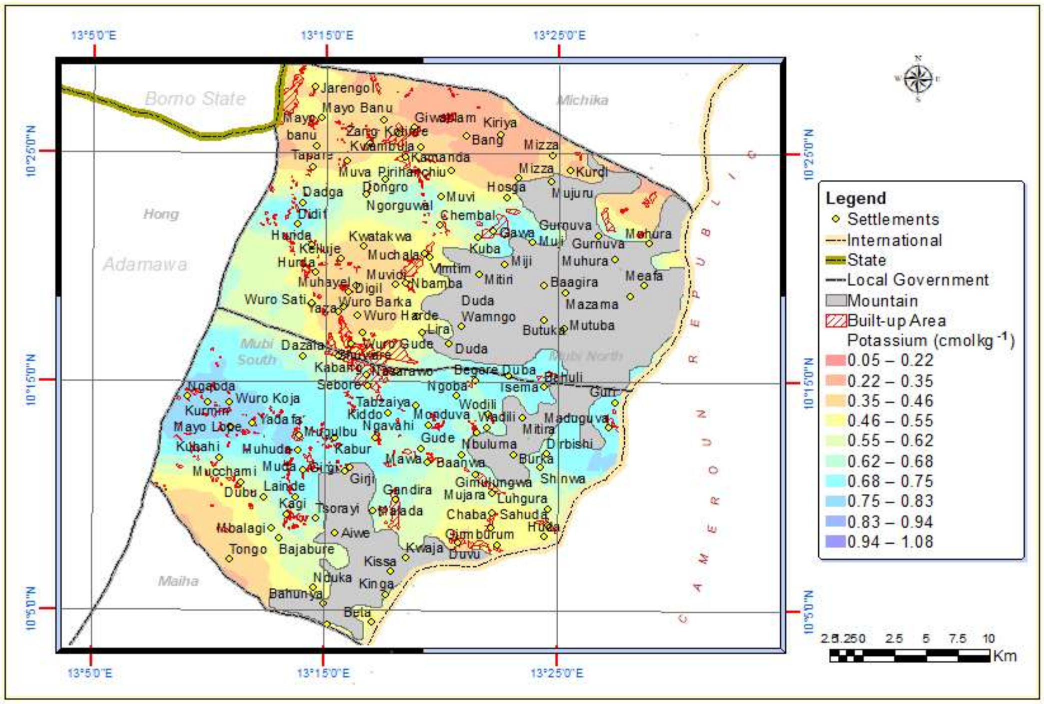

Figure 6. Spatial Distribution of Potassium in the study area

Organic carbon and Organic matter

Spatially distribution of organic carbon is presented in figure 7. Low content of organic carbon was recorded with values ranged from 0.06- 1.88 g/kg which is < 5 g/kg low level defined by [5] was found in all part of the study area. However, more amount can be observed at the western, eastern, extreme north (Kamanda and Mizza settlements) and north-western parts while less amount can be located at the southern area (Lainde and Bajabure settlements), north-central and North-west settlements of the map (Barka, Muvi, Chambal, Husga, Kiriya, Didif, Mayo-Bani) and Meafa area at the north-eastern part of the studied area. This low OC content might be attributed to scanty vegetation and high decomposition rate of savanna climate. This assertion agreed with report of [26] who linked low OC of Savanna soil to insufficient vegetation coupled with intensity of temperature.

Similarly the OM content as was presented on figure 8 respectively. Moderate content of OM was recorded with considerable value ranged from 2.16-2.82 % found at South-eastern (Mujara, Chaba, Sahuda, Huda,etc) and South-western (Wuro koja, Yadafa, Mahuda, Muchamm, Dubu) and central parts of the study area. This low OM has made the savanna soils susceptible to major chemical, physical and biological limitations which reduce crop yield [7].

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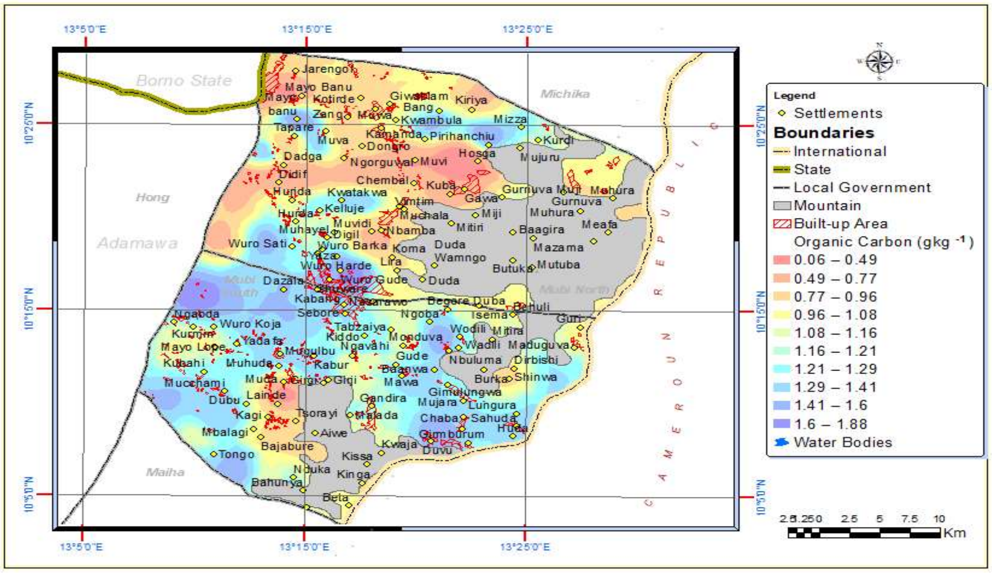

Figure 7. Spatial Distribution of Organic Carbon in the study area

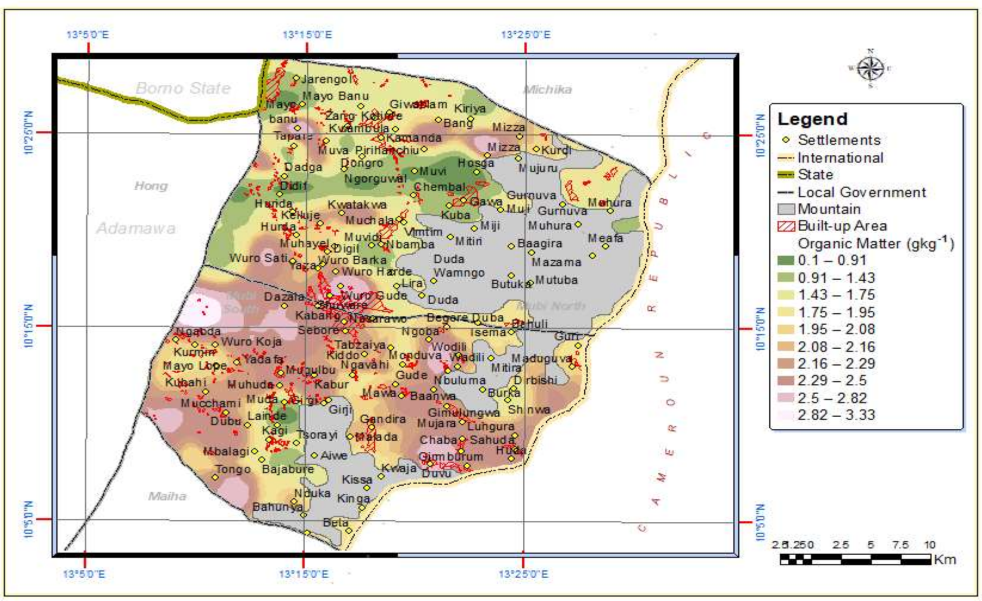

Figure 8. Spatial Distribution of Organic Matter in the study area

Calcium

Moderate calcium content in the study is shown in figure 9 with the considerable values ranged from 5.11-10.4 cml/kg which are within the moderate limit of 4-10 cmol/kg defined by [5] and [17] where observed at north-northeastern part (Muvi and Chambal) parts of the area. This may be a result of abundant biological activities as well as plant and animal residues at the topsoil than the subsoil of the studied sites as

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was also reported by [27]. In addition, it could be linked to weathering of calcarious parent materials found at north-western part of the investigated area. Low content of calcium was recorded with values varied from 0.25-3.84 cmol/kg which is below the low (< 4 cmol/kg) described by [5] and [17] where identified in some areas of central part (Wuro-gude, Nasrawo) and at the extreme northwestern part (Dazala, Wuro sati Yaza and Kabang) extreme north (Jarengo,Mayo Bani,Giwablam,Kiriya) and northeast (Mahura and Meafa) parts in the studied area. The decreased in Ca content might be affiliated to due to higher proportions of the element being retained in the diverse plant biomass and not being returned to the soil.. According to [19] reported that high tropical rainfall in an open soil leads to serious erosion and nutrient leaching that lead to rapid loss of Ca. This could also be attributed reason of Ca decreased in the areas. Generally, the Ca ranged from moderate to high which may support crop production. This results concord with that of [8] who reported moderate to high Ca content in the investigated soils of the area with varied values of 6.85-19.44 cmol/kg with a mean of 10.43 cmol/kg. Lowest Mg content was recorded at south-eastern (Gimburum, Sahuda, Huda, Chaba, Mujara, Gandira,Mafada) and south-western parts (Tongo, Mbalagi, Muchammi, Bajabure, Kagi Nduka, Beta, Kubahi) of the area.

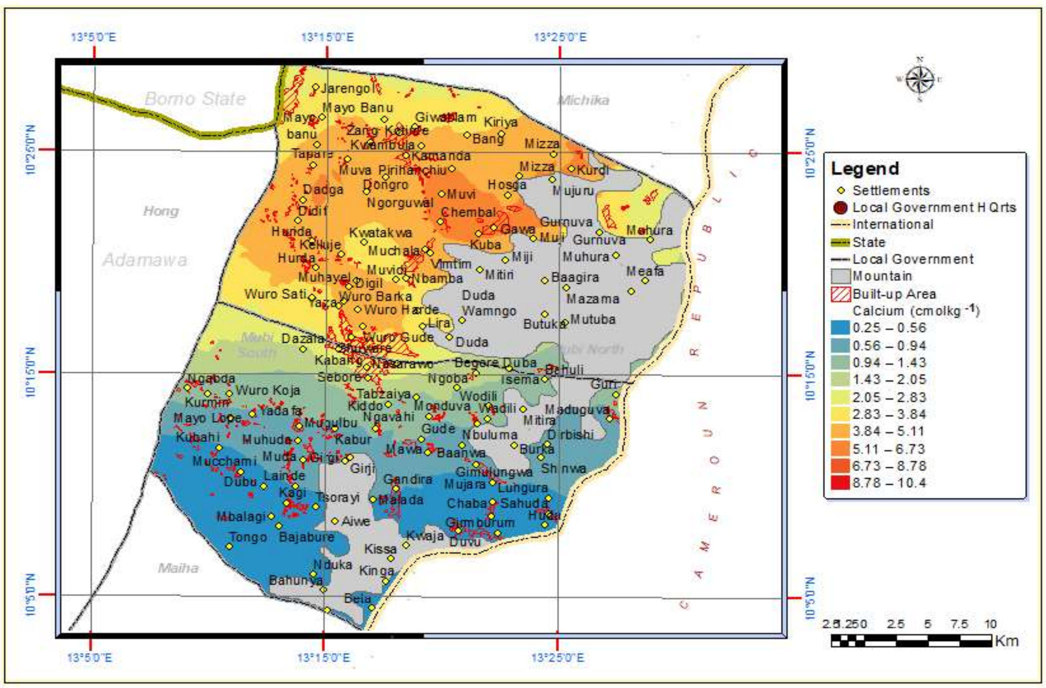

Figure 9. Spatial Distribution of Calcium in the study area

Magnesium

Moderate concentration of magnesium content with ranged values of 3.1-5.51 cmol/kg which are within the rated values of 3-8 cmol/kg defined as moderate by [5] and [17] was recorded at the South-western part of the area (Kurmin, Ngaba, Mayo-lope, Mucchami, Dubu, Tongo, Nduku, Sebore) and at the South-eastern part (Sebore, Baanwa, Mujara, Chaba, Sahuda, Gim burum and Huda) with some patches found at the northern part as shown in figure 10 respectively. This could be linked to

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accumulation of Mg at the downward slope of the area that are leached .The pouches of moderate distribution of magnesium concentration was also recorded at extreme northern part areas like Duba, Bhuli, Mhura. The low accumulation was dominated the extreme north and central part of the area with values < 3 cmol/kg indicated as low by [5] and [17] varied from 0.31-2.7 cmol/kg . This could be ascribed to high leaching effects caused by highland topography. Thus, soil surface that are exposed to erosion may leads soil Mg depletion [28]. In addition, the intensity of cultivation and annual crop harvest with little or no inputs in soils may have accounted for the low Mg status as was also reported by [6]. In addition, low Ca: Mg ratio showed the possibility of deterioration of the structural stability with consequent surface sealing, decreased infiltration, increased runoff and erosion during rainfall. This causes a large separation distance between clay layers and less attraction between them which then causes flocculation and low structural stability of the soil [15].

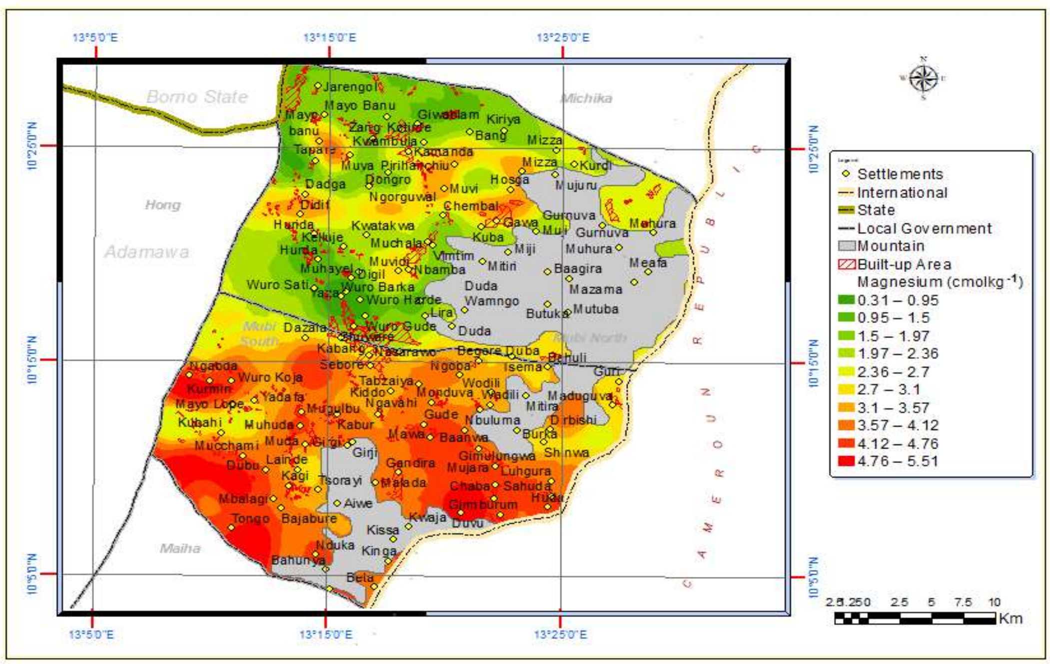

Figure 10. Spatial Distribution of Magnesium in the study area

CONCLUSION

The geospatial distribution of some soil nutrients in Mubi area, North Eastern Nigeria was assessed. The geospatial distribution of the soil nutrients shows widely distribution of the studied nutrients with some wide-ranging variations of values which could be attributed to intrinsic or extrinsic factors. It is therefore recommended that areas with high spatial distribution and concentration of the soils nutrients should be considered for intensive farming with less or no fertilizer application. Also, the maps generated should be used as a guide for future fertilizer application and management considering the pattern within the distribution.

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