ISSN 2056-5879

EVALUATION OF MOUNTAIN SOILS FOR SUSTAINABLE AGRICULTURE AND FOOD SECURITY IN NIGERIA: THE CASE OF OBUDU

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ABSTRACT

The study investigated the fertility status of Obudu Mountain soils as an instrument for sustainable agriculture and food security in Nigeria. Data for this study were obtained from direct field measurements, topographic maps and laboratory analysis of the area. Twelve soil samples were collected from six topographic gradients (2.5, 27.5, 22.5, 17.5, 12.5 and 7.5 percentages) located within the study area. The soil samples were collected with a soil auger at depths of 0-15 and 15-30cm, parceled, labeled and taken to the laboratory for analysis of selected soil fertility parameters. The different topographic gradients were deduced from the topographic map of the area and ground-truthed with an abney level. Using international guidelines for rating soil fertility indicators, the study shows that most of the indicators were low. It is concluded that soil fertility in the area is low and this has implication for sustainable agriculture and food security in the area. Therefore, there is need for increased use of organic matter and no-till-practice to boost the soil fertility of the area.

Keywords: Agriculture, food security, mountain, soils, Obudu.

INTRODUCTION

The world population grew to 7.06 billion in mid-2012 after having passed the 7 billion mark in 2011 with developing countries accounting for 97 per cent of this growth (Population Reference Bureau, 2013). This large absolute increase in human number raises concerns on the ability of the present agricultural production systems and governance structures to provide sufficient food for the population. Soil Science Society of Nigeria cited by Essoka (2011) observed that in Nigeria the problems of food insecurity can be traced to factors such as climate change, rising cost of inputs, and degradation of soil resources. The declining soil fertility is an indication that this vital resource base is under severe pressure.

The problem of soil degradation has become endemic in critical ecosystems. Farmers in marginal ecosystems like mountains often over plough the soil, denying the soils fallow periods needed to regenerate. This has led to soil crisis and as every traditional farmer knows, a soil crisis means a food crisis (Miles, 1990). And when a country cannot feed a large proportion of her population, national development is likely to be threatened. This goes to attest that achieving adequate food security is arguably a necessary first step towards the alleviation of poverty and hunger and sustainable economic growth which are vital components of national development. Food and Agriculture Organization of the United Nation (FAO 2009a) defined food security as condition when all people, at all times, have

ISSN 2056-5879

physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life.This definition identifies four fundamental pillars of food security: food availability, food access, utilization, and stability.

These pillars are especially important in mountain areas where the fragile environment negatively influences food availability and access. Other factors, such as the relative isolation of mountain regions and the inadequate access the people have to infrastructure and social services, make them more vulnerable to external shocks (FAO 2002; Huddleston et al 2003). About 40 percent of the mountain population in developing and transition countries, or nearly 300 million people, are estimated to be vulnerable to food insecurity. Of these, nearly 90 percent live in rural areas and almost half of these are likely to be chronically hungry (FAO 2002). The problem of food insecurity remains pervasive in developing countries. In Nigeria, food insecurity is common, Essoka (2011) citing Abulu reports that a large proportion of Nigerians experience food insecurity especially with regards to availability, access, stability and utilization.

To stem these tides, it is important that the land resources of marginal ecosystems like mountains be evaluated. It is through the assessment of soil capability that sustainable agriculture and food security can be guaranteed. Sereke (2002) argued that to maintain sustainable agriculture, land use planning should be undertaken by investigating the soils and classification carried out at both local and regional levels. When soil assessment is conducted, constraints of the land discovered, and corrected land use planning becomes a tool for economic growth, development and environmental stability (Essoka, 2008). However, when such evaluations are conducted and left in technical form it becomes meaningless to farmer. This explains why interpretation of the data needs to reveal the deficiencies or adequacy of particular nutrient elements for sustainable soil fertility management. When the quality of the soil is known, appropriate management practices can be put in place to ensure good crop yields and by extension food security. In Cross River State about 43 % of her landscape is made up of Mountains (CRMLH, 2000). This explains why evaluating the fertility status of such environments pertinent.

The objectives of this paper was to evaluate selected soil chemical properties, their fertility status, rate them based on established indicators for tropical regions and ascertain the implications of the present soil quality to food security and national development in Nigeria using the Obudu Mountain.

MATERIALS AND METHODS

Study area

The study area is the Obudu Mountains located in the Obanliku Local Government Area of Cross River State, south-south Nigeria. It lies between longitude 9^{o} $22^{'}$ $00^{''}$ and 9^{o} $22^{'}$ $45^{''}$ E, and latitude 6^{o} $21^{'}$ $30^{''}$ and 6^{o} 22' $30^{''}$ N, with an approximate area of $104sqm^2$, and a height of about 1576m above sea level (Ekwueme, 2003). Obudu Plateau is bounded in the north by Benue State, northeast by the Republic of Cameroon, and to the southeast by Boki Local Government Area in Cross River State of Nigeria.

The area is situated within the tropics but it has a climate that is likened to temperate region with mean daily temperatures range between $15^{0}C$ and $22^{0}C$. It has a mean annual rainfall of about 4300mm with highest rainfall of about 76.2cm usually recorded in August while the

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lowest of 0.76cm is usually recorded in December (Mabogunje, 1983). The Obudu Plateau is part of the Precambrian Basement Complex of Nigeria (Ekwueme, 2003). It is a giant spur forming the western prolongation of the Cameroon Mountains into the Cross River plains of southeastern Nigeria.

Field procedures

The Obudu mountain was stratified into the traditional three slope segments; the shoulder slope (Shs), middle slope (Ms), and the toe slope (Lts) using topographic map of the area. These broad slope units were further subsumed into six slope positions; summit, shoulder, base, toe, middle toe and lower toe positions. An abney level was employed to confirm the various topographic positions along the soil catena from the summit to the lower toe slope.

Soil samples collection

Soil samples were collected from the median point of each of the landforms (slope positions), for instance, at the summit slope which ranges from 0-5 percentage data representing the summit slope was obtained from slope gradient point of 2.5 percentages, for the shoulder slope a sample was collected at slope gradient of 27.5 percentages. Soil samples were also collected at the base, toe, middle toe and lower toe slopes representing slope gradients of 22.5 percent, 17.5 percent, 12.5 percent and 7.5 percent, respectively.

Transect placement and sampling intervals along transects were determined subjectively to capture the full range of soil variability within landforms as described by Young *et al*, (1992). Soil samples were taken with a soil auger at 0-15 and 15-30 cm depths of the soil. These layers are considered the most productive soil layers that exert the greatest effect on crop yield and geomorphologic processes are enacted within such layers (Aweto and Enaruvbe 2010). All samples were assumed to be independent of one another.

LABORATORY METHODS

The Walkley and Black method as outlined by Juo (1979) was used to determined organic carbon. While organic matter in the soil was digested by potassium dichromate ($K_2Cr_2O_7$) and using concentrated sulphuric acid to raise the temperature of the reaction. 1gm of the finely ground air dried sieved soil sample was weighed into 250ml Erlenmeyer flask. To it, 10mls of $INK_2Cr_20_7$ was added followed with 20ml-distilled water. The excess dichromate was back titrated using ferrous ammonium sulphate with barium diphenylamine sulphate as indicator. Available phosphorus by Bray No. I method (Bray and Kutz 1945). Exchangeable cations were extracted with NH_4OAC (pH 8.2); potassium and sodium were determined by the flame photometry while calcium and magnesium contents were measured by EDTA titration method.

RESULTS AND DISCUSSION

Descriptive statistics of sampled soils in the Obudu Mountains

Table 1 is the descriptive statistics of soil properties analyzed. Using Aweto (1982) soil coefficient of variability classification, (little variation ≤ 20%, moderate variability 20 to 50 % and highly variable ≥ 50 %), most of the fertility properties of the soils were moderately variable except Calcium which had a high coefficient of variation (57.1 %) for subsoil. Organic matter, calcium potassium and sodium on the other hand showed high coefficient of variation at the subsoil layers (50.0; 78.6; 50.0 and 88.9 %). The variation of organic matter and other nutrient parameters at both depths may not be unconnected to the agricultural and geomorphological processes in the area. These processes go to explain the poor crop yields in the area. The critical limit for available phosphorus is 8ppm (Udo and Ogunwale, 1986; Enweozor *et.al*. 1989) for tropical soils. By this standard, available phosphorus is deficient in the agricultural fields of the Obudu Mountain. Essoka (2007) attributed the low available Phosphorus in the area to Kaolinitic minerals that dominate the area.

Table 1: Descriptive statistics of selected sol parameters in an agricultural field of Obudu Mountain

Topsoil

	Org. M. (%)	**Avail. P (ppm)**	**Ca cmol/kg-^{1}**	**Mg cmol/kg-^{1}**	**K cmol/kg-^{1}**	**Na cmol/kg-^{1}**
Standard Error	0.1	0.3	1.0	0.2	0.0	0.1
Minimum	3.0	3.3	3.4	1.0	0.1	0.4
Maximum	0.9	5.4	10.1	2.9	0.4	0.7
Range	0.6	2.0	6.7	1.9	0.3	0.4
CV	30.8	20.5	57.1	33.3	33.3	33.0
Skewness	-1.7	-0.5	2.3	0.9	-0.1	-0.3

Subsoil

	Org. M. (%)	**Avail. P (ppm)**	**Ca cmol/kg-^{1}**	**Mg cmol/kg-^{1}**	**K cmol/kg-^{1}**	**Na cmol/kg-^{1}**
Standard Error	0.2	0.5	1.8	0.2	0.1	0.3
Minimum	0.2	2.2	2.1	0.9	0.2	0.3
Maximum	1.7	5.1	14.0	2.2	0.6	2.4
Range	1.5	2.8	11.9	1.3	0.4	2.1
CV	50.0	34.3	78.6	29.4	50.0	88.9
Skewness	-0.7	0.0	1.9	-0.6	0.7	2.0

Source: Field survey by authors (2014)

Fertility indicator of sampled soils in the Obudu Mountains

The mean values of each soil sampled at depth of 0-15 and 15-30 cm are presented in table 2 while the guidelines for rating the fertility status of tropical soils are contained in table 3. These guidelines are based on international rating for tropical soils (ILACO, 1985 and Landon, 1991). The qualitative ratings of the Obudu Mountain soils arising from the comparison between soils data derived in the field (table 2) and established critical limits (table 3) are presented in table 4. From table 3, the values quoted as 'very low' are critical levels below which the crops are expected to exhibit deficiency symptoms.

Table 4 revealed that soils in the Obudu Mountains are low in fertility elements. Organic matter was observed to be low in the six sample positions. This is informed by the high rates of soil erosion and high tropical temperature. The area is a high rainfall region and this mean high soil nutrient wash downward by runoff. Similarly, total nitrogen was low across the different slope positions. Possible reasons for these low values could be due to the dynamic

ISSN 2056-5879

nature of TN being highly susceptible to leaching since the area experiences high rainfall (4300mm mean annual rainfall). In addition, intensive land use, seasonal burning of vegetal cover, and poor agricultural practices observed in the slopes of the Mountain could also explained the low values of total nitrogen recorded.

Available phosphorus in the different topographic positions was low. It had mean values of 4.05, 2.8, 4.68, 4.83, 2.95, 2.95 and 4.8 ppm compared to the recommended levels of 8pp by Udo and Ogunwale (1986) for tropical soils. Essoka (2008) attributed the low values to the kaolinitic composition of the minerals in the area. More so, lateritic soils and soils with pH values lower than 5.5 are common in the Obudu Mountains (Amuyou 2012) this could be another reason for the low values of available P since monocalcium phosphate solubility is increased at low pH. This degree of phosphate solubility is influenced by changes in soil pH (Olaitan and Lombin, 1988) and it could be the reason for the low values of P content in the soils of Obudu Mountain region.

The reserve of Ca, Mg and K stored at the soils exchange sites determine the soil reaction and their subsequent availability to crops. Their quantities (leachable with IN NH4OAc/ethanol, pH 8.2) are often used as a measure of actual soil fertility. Exchangeable cations attained adequate quantity in the lower toe slope position, Mg and K exhibited moderate values in most of slope gradients. However, Ca has low mean values in other slope positions.

Table 2: Values of soil fertility parameters in the Obudu Mountains

	Org.C (%)	**Org. M (%)**	**Total N. (%)**	**Avail. P Ppm**	**Ca cmol/kg-^{1}**	**Mg cmol/kg-^{1}**	**K cmol/kg-^{1}**	**Na cmol/kg-^{1}**
0-15	0.98	1.69	0.102	5.4	3.94	1.62	0.60	0.49
15-30	0.40	0.69	0.056	2.7	2.10	2.99	0.32	0.21
	(0.69)	(1.19)	(0.079)	(4.05)	(3.02)	(1.30)	(0.46)	(0.35)
0-15	0.33	0.57	0.050	0.36	10.6	2.90	0.39	0.18
15-30	0.12	0.21	0.051	2.24	14.0	1.9	2.45	0.60
	(0.22)	(0.67)	(0.050)	(2.80)	(12.3)	(2.40)	(1.41)	(0.39)
0-15	0.79	0.37	0.090	4.80	4.20	1.75	0.55	0.32
15-30	0.99	1.71	0.119	4.56	4.55	1.86	0.70	0.30
	(0.89)	(1.54)	(0.104)	(4.68)	(4.37)	(1.80)	(0.62)	(0.31)
0-15	0.88	1.52	1.110	5.1	3.70	1.88	0.38	0.29
15-30	0.99	1.21	0.199	4.56	4.55	1.86	0.70	0.30
	(0.93)	(1.61)	(0.114)	(4.83)	(4.12)	(1.87)	(0.54)	(0.29)
0-15	0.74	1.30	0.069	3.4	3.38	1.15	0.69	0.35
15-30	0.64	0.11	0.058	2.50	2.95	1.15	0.31	0.19
	(0.70)	(1.20)	(0.063)	(2.95)	(3.16)	(1.15)	(0.50)	(0.27)
0-15	0.81	1.40	0.077	4.6	3.80	1.71	0.72	0.40
15-30	0.90	1.56	0.098	5.0	5.60	2.24	0.85	0.61
	(0.85)	(1.48)	(0.087)	(4.80)	(4.70)	(1.97)	(0.78)	(0.50)

Note: Org. C = Organic Carbon; Org. M = Organic Matter; Total N = Total Nitrogen; Avail. P = Available phosphorous; Ca = Calcium; K= Potassium; Mg = magnesium; Na=sodium; values in parentheses show the mean.

Source: Field survey by authors (2014)

Table 3: Guidelines for rating soil fertility indicators (ILACO, 1985 and Landon, 1991)

	Ca cmol/kg-1	**Mg cmol//kg-1**	**K cmol/kg-1**	**Total N. (%)**	**Avail. P ppm**	**Org. M (%)**	**C/N**
Very High	>20	>8	>1.2	>0.300	-	>60	
High	10-20	3-8	0.6-1.2	0.226-3.00	>50	4.3-6.0	
Medium	5-10	1.5-3	0.3-0.6	0.126-0.225	15-50	2.1-4.2	
Low	2-5	0.5-1.5	0.2-0.3	0.050-0.125	<15	1.0-2.0	
Very low	<2	<0.5	<0.2	<0.050	-	<1.0	

Note: **Available P does not have very low or very high levels**.

Table 4: Qualitative rating of soil fertility in the Obudu Mountains

Slope positions	Org. C	OM	TN	AV.P	Ca	Mg	K	Na
Summit	-	Low	Low	Low	Low	Medium	Medium	-
Lower toe	-	Low	Low	Low	High	Medium	Very high	-
Middle toe	-	Low	Low	Low	Low	Medium	High	-
Toe	-	Low	Low	Low	Low	Medium	Medium	-
Base	-	Low	Low	Low	Low	Medium	Medium	-
Shoulder	-	Low	Low	Low	Low	Medium	High	-

Source: Analysis by authors (2014).

Food security implications of Obudu Mountain soils

The Obudu Mountains soils are problem soils with different proportion of constraints as shown by the varying fertility levels. Similar observations were made by Oluwolafe (2004) about the Jos Plateau. Inappropriate land use is a major cause of declining soil quality in such environments. This is made worst by the continuous stress on the limited land resources due to population pressure and climatic variability. Excessive rainfall will mean removal of soil nutrients through leaching, gullying and this will have negative impact on crop production. On the other hand, high temperature with little rainfall is likely to encourage laterization of soil. All of these have significant impact on food security since food security is directly related to the ability of land to support the population.

Poor soil fertility affects food security, and the livelihood portfolio of mountain communities. When crops yields are low, peasant farmers who largely depend on farm produce as is the case with most rural communities in Nigeria would not be able to achieve food stability, availability and access to food will be limited. As it stands, communities of the Obudu Mountains depend mostly on lowland communities of Utanga and Amana for their food needs.

The investment of the Cross River State Government in the tourism sector of the Obudu plateau has attracted more middle income and low income earners to the area; this mean more stomach to feed. This explains the urgent need to employ sound soil management practices to boost food production in the area to avert the problem of food insecurity. In addition, diversification of income sources will increase purchasing powers of the people as well as give them options to look for other rewarding ventures to bring food to households.

ISSN 2056-5879

Efforts to restore productivity of a degraded land must be coupled with efforts to recognize productive capacity of soil resources. Restoring the soil quality for crop production through the appropriate soil management and conservation techniques is important for national development, especially Nigeria that is highly vulnerable to food insecurity. It is therefore, important for Nigeria to develop spatial databases about the extent of soil degradation, its biophysical, economic and social impacts of mountain soils. We can not continue to plan without facts 51 years after Stopler's (1962) thesis recognized Nigeria as a country that plans without facts.

CONCLUSION

Mountain soils of the Obudu region are poor in fertility nutrients. This study has shown that with this knowledge we can adopt soil management techniques that will ensure sustainable agriculture and food security in mountain communities of Nigeria. No nation can achieve comprehensive national development when a large proportion of her citizens are vulnerable to food insecurity. In Nigeria, most rural mountain people engage in some form of agriculture as the main source of their livelihood. Hence, the must be a total land resources assessment of the country which is a precursor to national development planning.

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