Effect of Mining Activities on Vegetation Composition and nutrient status of Forest Soil in Benue Cement Company, Benue State, Nigeria

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***Abstract*— *Mining is essential in the economic development plan of any country endowed with mineral resources. This is due to both internal and external economic benefits that are made available to countries that are involved in the extraction of mineral resources. Internally, there is creation of employment and revenue generation among others while externally; a substantial foreign exchange is available to such countries. However, looking at the socio-economic importance of the industry, most countries lose sight of the ensuing effect that might accrue to an area as a result of mining activities. This study sought to provide an empirical data to ascertain whether or not mining activities has affected tree diversity of the area in general and on vegetation and soil nutrients in particular. In the study diversity indices (Shannon, margalef and Pielou's evenness) all indicated higher values for adjacent site 5 km away from the factory. Soil health indicators investigated revealed significant differences except Potassium, with adjacent site having higher mean values. This study has indicated that tree diversity was higher in the adjacent site and also that soil 5 km away from the factory was healthier than soil within factory site. Construction of shield over factory site is suggested.*

Keywords*— *Mining activities, Forest soil, nutrient status, Ecological indices, Soil health.

I. INTRODUCTION

Mining is any activity that involves excavating the earth surface for the purpose of exploiting its mineral wealth. This could be for local economic and industrial development or for export purposes (David, 2002). If properly coordinated, its positive socio-economic impact cannot be overemphasized as it provides natural resources for consumption, offers employment, as well as a source of revenue and foreign exchange. It also leads to the development of some socio-economic infrastructures like roads, schools, hospitals, among others (Hilson, 2002). The industry has been, and in many cases remains important to the socio-economic development of many developed and industrialized countries such as Australia, Canada, Sweden, and the United States. Various cities and regions have built their wealth and industrial development at least in part, on mining. Historical examples include Monterrey in Mexico and Colombia among others (Akande and Idris, 2005; Singh, 2007).

In developing countries also, mining will continue to provide technological development and employment. Large-scale mineral exploitation has contributed over 90% of all foreign exchange earnings, 60% of Gross National Product, 50% of total government revenue and 30% of total employment in some Southern African Countries (Olaleye *et al*., 2010). Similarly, small scale-mineral exploitation provides a source of livelihood for those in rural and semi-urban Africa. The exploitation of mineral resources has assumed prime importance in several developing countries including Nigeria which is endowed with abundant mineral resources; this has contributed immensely to the socio-economic status of the country (Adekoya, 2003).

However, if mining activities are not properly organized, it can result to various environmental problems. The industry's operations ranging from prospecting to excavation are seen to be causing several environmental problems ranging from erosion, pollution, formation of sinkholes, soil nutrients loss, bio-diversity loss, heavy metal and organic contamination of groundwater and surface water (Kiranmay, 2005). He also asserted that mining causes massive damage to landscape and biological community as plant communities get disturbed and subsequently become impoverished thus presenting a very rigorous condition for its growth. Dumping of mine products will result into destruction of surrounding vegetation, and severe soil and water pollution.

Soil is a natural medium or only slightly disturbed materials that took centuries to develop under permanent forest cover.

A succession of genetic soil layer is present, ranging from the very important surface organic layer down to the mineral parent material (Ibanga *et al*., 2008). It is a mixture of minerals, organic matter, gases, liquids, and countless organisms that together support plant life. It is a medium for plant growth; a means of water storage, supply and purification, it is a habitat for organisms all of which modify the soil.

Soil Nutrients play a vital role in enhancing the growth of forest because plants require essential soil nutrients such as nitrogen, calcium, potassium, phosphorus, among others which are assimilated from the soil to complete their vegetative and reproductive life circles (Julio and Carlos, 1999). Other essential elements such as carbon, hydrogen and oxygen are readily available to plants because they are freely obtained from carbon dioxide and water and converted to carbohydrates during photosynthesis (Olaleye *et al*., 2010).

Vegetation, which refers to the plant cover of the earth, displays patterns that reflect a wide variety of environmental characteristics as well as temporal aspects operating on it (Kumi-Boateng and Issaka, 2012). This is due to the fact that it supports critical functions in the biosphere by regulating the flow of numerous bio-geochemical cycles like that of water, carbon, and nitrogen; it is also of great importance in local and global energy balance. Removal of vegetation cover strongly affects soil characteristics, including soil fertility, chemistry and texture (Adewoye, 2005; David and Mark 2005).

Although vegetation is of high environmental and biological importance, it is often under intense human pressure in mining areas especially where surface mining and illegal small scale mining activities are prevalent, resulting into changes in land-use/land-cover of mine areas. Directly or indirectly, mining has been seen to be a major factor responsible for vegetation loss in mining areas the world over (Adewoye, 2001; David and Mark 2005). Directly, it is caused by vegetation clearance for various mining activities and indirectly, with dust pollution as volume of dust is discharged into the air during the process of quarrying. This eventually gets deposited on the leaves of plants and flowers as well as the soil supporting the plants. The overall effect of this is that the photosynthetic and fruiting ability of the plants is impaired. When calcium, surphur-dioxide among other chemical constituents enter the plants through the stomata pores it leads to the destruction of chlorophyll and disruption of photosynthesis in plants subsequently leading to stunted growth or death (Ujoh and Alhassan, 2014).

Irrespective of the socio-economic importance of mineral resources, Aigbedion and Iyayi (2007) stated that the three stages of mineral development (i.e exploration, mining and processing), have caused different types of environmental damages, which include ecological disturbance, destruction of natural flora and fauna, soil nutrient loss, land degradation and water, among others. According to Olaleye (2010), the scale of operations involved in each stage of mineral development however determines the intensity and extent of soil degradation and vegetation loss. For example, recent environmental impact studies of limestone mining in Sagamu, Ogun State, Nigeria, has also revealed a decline in kola nut output from the plantations within a few kilometers radius of the mine (Adekoya, 2003; Tolulope, 2004; Aigbedion and Iyayi, 2007).

According to Aigbedion and Iyayi (2007) A similar situation exists in all the limestone and marble quarries in differing proportions at Ewekoro, Nkalagu, Ashaka, Kalambaina, Okpilla, and Jakura among others. On the discovery of limestone traces in Mbayion, Gboko Local Government Area, Benue State of Nigeria in 1960, a cement plant was established within the region which commenced operation in 1980. Subsequently, in 2004 with Dangote Industries Plc. as the new management of the company, an aggressive upgrading and rehabilitation of the plant was carried out. This has subsequently transformed the company into a new state-of-the-art cement factory with two 1.4 million tonnes lines (Vetiva Research, 2010). Due to increase in quarrying activities caused by the upgrade of the processing plant within the study area, the natural vegetation belt of the area which is characterized with the presence of tall grasses and tall trees is being threatened as it has to be cleared to give room for mining activities The consequences of vegetal deterioration within the study area are however enormous with various environmental and economic implications as agriculture is the main source of income for the people living within the study area. Against this backdrop, the assessment of the effect of mining within the area especially as it affects forest soil and vegetation becomes necessary.

II. MATERIALS AND METHODS

2.1 Study area

The study was conducted in Mbayion in Gboko Local Government Area of Benue State, which is located in the Northern part of the State. It is situated between latitudes 07° 08' and 07° 31' N of the equator and longitudes 08° 37' and 09°10' E of the Greenwich Meridian. It is made up of five (5) Districts namely: Mbatyiav, Mbayion, Mbatyerev, Yandev and Ipav. Mbayion which is the study area, is situated between latitudes 7016' and 7028'N of the equator and longitudes 8048' and 9000'E of the Greenwich Meridian. It shares common boundaries with Takar Local Government in the North, Yandev in North-East, Ipav in South-East, Ushongo Local Government in the South, Mbatiav in South-West and Mbatierev District in the North-Western part of the Local Government as shown in Fig.1 and 2.

2.2 Soils and Vegetation

The predominant factors that have influenced the distribution of soils within the study area are relief and vegetation cover. Within the area, the predominant soil is tropical ferruginous soils; coarse loamy soils; laterite soils as well as sandy soils (Benue State Economic Empowerment and Development Strategy (BENSEED), 2004). According to BENSEED (2004), the presence of clay soils near streams and valleys, are however mixed with a reasonable amount of sandy soil and as such, most parts of the area is adequately drained and free from water. With respect to vegetation, the area belongs to the Guinea Savanna belt which is made up of a lot of grasses interspersed with trees. Trees grow side by side with tall grasses giving the area a luxuriant vegetation cover (Ibanga *et al*., 2008). This vegetation belt serves as a transitional belt between the tropical rain forest in the South and the open grassland in the North of Nigeria. Within this vegetation belt, several grain and root crops are produced in commercial quantities and the study area is known for the cultivation of crops like maize, guinea corn, millet, rice, yam, cassava among others. Tree crops like oranges, mangoes among others are also produced commercially in Gboko local government (Ministry of Information and Orientation, 2012).

2.3 Method of Data Collection

2.3.1 Soil and Vegetation composition Sampling procedure and Data Collection

To assesses vegetation composition, two areas were purposely selected:- vegetation within the cement factory and vegetation within the adjacent site 5km away. Plot of size 100m x 100m (1 hectare) were demarcated. This was further demarcated to sub-plots size of 20m x 20m from which 5 sample plots were randomly selected for the study. Tree species found within sample plots were recorded under the following parameters:- diameter at base (db), diameter at breast height (dbh), and total height.

For soil analysis, 6 plots of size measuring 10m x 10m were laid within the cement factory and the adjacent forest to collect soil samples. Four auger points per site were drilled at random to a depth of 0-45cm, using soil auger in four directions on a transect line, for site 1, site 2, site 3, site 4, for both the soil within and outside the factory. The soil samples from the four auger points per location were poured together and mixed thoroughly in a polythene bag. An appreciable quantity was poured into a polythene bag, labeled and taken to the laboratory for analysis.

2.4 Data Analysis

2.4.1 Data Analysis for Vegetation Cover

Floristic compositions in the two sites were estimated using diversity indices such as species richness, diversity and evenness. Species richness was computed using Margalef (1951) as cited by Spellerberg (1991) and Magurran (2004). It is measured by the formula:

$$D = \frac{(S-1)}{\ln N}$$

Where, **D** = species richness index (Margalef index), **S** = number of species and **N** = the total number of individuals.

Species diversity was estimated using Shannon- wiener diversity index as cited by Spellerberg (1991); Turyahabwe and Tweheyo (2010); Ruszazyk *et al*;(1992) cited by Radha *et* al; (2016).

Shannon- wiener diversity index equation is stated as:

$$H' = -\sum_{i=1}^{s} p_i \ln p_i$$

Where H′ = species diversity index, **pi** = the proportion of individuals or the abundance of the i^{th} species expressed as a proportion of the total abundance. The use of natural logs is usual because this gives information in binary digits.

Species evenness was estimated using Pielou's evenness (equitability) index (Pielou, 1975) cited by Turyahabwe and Tweheyo (2010) as followed:

$$J' = \frac{H'(observed)}{H_{\max}}$$

J′ = Pielou's evenness index. Where **H′** (observed) / $\mathbf{H_{max}}$, where $\mathbf{H_{max}}$ is the maximum possible diversity, which would be achieved if all species were equally abundant (=**Log S**)

The indices were computed for all plant species in various growth forms (trees, sapling, shrubs and herbs) in each plot of vegetation location.

2.4.2 Data analysis for soil sample

Soil P^H was determined using p^H Meter, Available phosphorus was determined using the method of Liu. (Liu, 2000).Total nitrogen was determined using Micro kjeldahl Method, Potassium determined using Flame photometry and organic carbon determined using wet oxidation Method (Black and Walkley, 1934). Paired test was used to analyzed soil variables such as Soil P^H , soil organic carbon and organic matter, soil Nitrogen, soil Phosphorus and Potassium. The level of significance in each case was set at $P< 0.05$.

III. RESULTS AND DISCUSSION

In this study, a total of 27 tree species representing 13 families were encountered. Out of this number 12 tree species were recorded in the factory site and 15 tree species were recorded in the adjacent site as presented in Table 1. A total of 53 individuals were recorded in the study with 23 encountered in the factory site and 30 encountered in adjacent site. Our result presented in table 2 also shows that adjacent site recorded the higher species richness (D= 4.248) while factory site recorded a lower value (D= 3.683). Species richness is the number of species in an area, and in this study, the adjacent plot 5 kilometers away from the factory was more diverse. This could be as a result of cement dust inhibiting certain plant species from thriving.

Shannon diversity index was higher in off-site ($H^1 = 2.464$) while factory site recorded ($H^1 = 2.415$). Shannon Diversity index has been reported to fall between 1.5 and 3.5, and that it rarely surpasses 4.5, where a value near 4.6 indicates that numbers of individuals are distributed evenly (Radha *et al*., 2016). Species evenness value indicates that factory site recorded the higher value (0.9325) while the adjacent site recorded low (0.7834). However, since species evenness ranges from one to zero, where 1 indicates complete evenness and 0 no evenness, the two sites from our result, shows no evenness in species composition.

Overall tree population was observed to be more in the adjacent plot in comparison with plots within the cement factory. Dust deposit on leaves of plants is cable of blocking the stomata pore thereby hindering transpiration resulting to decrease in biomass production. It may lead to reduction in growth for certain species that could not survive. Leaves and bark injuries caused by dust deposit have been reported by Farmer *et al*.,(1991), which has led to alteration of tree community composition and structure. Natural regeneration becomes difficult for many forest trees due to hard crust formed on the forest floor by dust deposit. Sometimes the crust is so heavy and hard that young plants are smothered. Table 1 show that trees in diameter classes 61 and above were lacking in the adjacent plot, while they were visible within these class ranges in the factory site. Trees within these dbh classes are mature and useable by the local population. These trees are extracted by individuals without restriction unlike the ones within the factory which are protected.

Table 3 shows the mean values of soil nutrients indicators between soil within the cement factory and from adjacent plot 5km away from the cement factory. Soil within the cement factory recorded mean values of 6.21 for soil P^H , 0.70 for Organic Carbon, 1.22 for Organic Matter content, 0.10 for Nitrogen, 3.38 for Phosphorus, 3.23 for Calcium, Magnesium 1.58, Potassium 0.26 and Sodium 0.67. Mean values for same soil parameters from the adjacent plot, 5km away from factory recorded 6.45 for P^{H}, 0.79 for Organic Carbon, 1.39 for Organic matter, Nitrogen 0.16, Phosphorus 3.92, Calcium 3.98, Magnesium 1.83, Potassium 0.29 and Sodium 0.80.

T-test shows that all soil parameters investigated in the two locations were significantly different from each other except soil Phosphorus.

3.1 Soil health and determinants

The concerns on the sustainability of forestry and agricultural systems have increased recently because the world population is ever increasing and so is the demand for food. To feed seven billion people while sustaining the environment is a big challenge for the present generation. Sustainable forestry and agriculture aims at meeting the needs of the present without compromising the productive potential for the next generations. Sustainable yields can only be reached with the maintenance or recovery of the soil health. Thus, a healthy soil has been defined as "The continued capacity of soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain biological productivity, promote the quality of air and water environments, and maintain plant, animal and human health " (Doran and Safley, 1997).

To assess the sustainability of a production system, changes in chemical, physical, and biological properties, and the effects on the soil's capacity to support plant growth and exert environmental functions, must be monitored (Doran and Safley, 1997).

Soil health definition cannot be generalized for all kinds of soil and soil-use as criticized by Sojka and Upchurch (1999). Thus, indicators of soil health must be selected according to soil use and management, soil characteristics and environmental circumstances. Parameters investigated in this study were chemical properties of soil in the two locations it is important to discuss the general and most used chemical indicators of soil health. Chemical attributes of soil health are correlated with the capacity to provide nutrients for plants and/or retaining chemical elements or compounds harmful to the environment and plant growth. Soil pH, cation exchange capacity (CEC), and organic matter and nutrient levels are the main chemical attributes used in soil health assessment, especially when considering the soil capacity for supporting high yield crops (Kelly *et al*., 2009), although our study did not examine soil CEC.

Chemical attributes have been correlated with plant yields and thus the variations of a particular indicator are easily interpreted, and allow a quick improvement of the soil chemical properties by liming and/or fertilization. These soil chemical indicators can also be useful in considering the soil's capacity for sustaining forest production and sustainability, maintaining nutrient cycling, plant biomass and organic matter (Schoenholtz *et al*., 2000). Idowu *et al*. (2008) concluded that the most important chemical parameters to be assessed were pH, available N, P, K, Mn.

Soil organic carbon is also a key attribute in assessing soil health, generally correlating positively with crop yield (Bennett *et al*., 2010). The soil organic carbon affects important functional processes in soil like the storage of nutrients, mainly N, water holding capacity, and stability of aggregates (Silva and Sá-Mendonça, 2007). In addition, the soil organic carbon also affects microbial activity. Hence, a key component of soil fertility, especially in tropical conditions, which interacts with chemical, physical, and biological soil properties and must be considered in assessments of soil health.

Nitrogen is the most required plant nutrient, which is found in several chemical forms in soil (Cantarella, 2007), resulting in a very dynamic behavior. Soil nitrogen has been assessed mainly as mineral N, especially nitrate, organic N or potentially mineralizable N, as stored in the soil organic matter. Despite the importance in plant nutrition and environment, the use of nitrogen as parameter for assessing soil health is subjected to factors that affect its dynamics in soil, like climatic conditions, turning inadequate the diagnosis of the real availability for plants, based on soil chemical analysis (Cantarella, 2007).

Phosphorus (P) is also a key nutrient for agricultural yields and is essential in assessments of soil health. Along with nitrogen, P is the main nutrient that limits the agricultural yields, especially in highly weathered, oxidic soils, where the major part of the total soil P is fixed in clay minerals and oxides. The available P in the soil solution is present as orthophosphates, but the microbial P and organic-P are also stocks that can rapidly become available. Procedures for assessment of P availability have been well established (Pankhurst *et al*., 2003; Zhang *et al*., 2006a).

Soil chemical parameters have been traditionally used for assessment of potentially available nutrients for crops, and are based on worldwide well established analytical methodologies. Among them, organic matter, pH, and available nutrients and also some potential hazardous chemicals have been used to establish levels of soil health.

IV. CONCLUSION

In this study biodiversity indices and some chemical soil health indicators were employed to investigate the effects of mining activities on soil nutrient status and vegetation composition within the cement factory and 5 km away from the factory. The study revealed that the adjacent site which was 5 km away from the factory has a higher level of biodiversity than the factory site indicating low plant population and low number of species. All the diversity indices used in the study indicated higher values for the adjacent site. The study further proved that all the Soil health indicators investigated were significantly different from the two sites with the adjacent plot recording higher mean values, except Potassium. Our results suggest that soil chemical properties and vegetation composition and structure are being impaired by mining activities. This may have negative effects on vegetation and soils within close range to the factory, thereby effecting rural livelihood.

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Table.1:. Species composition in dbh classes within factory site(A) and adjacent site (B)

DBH Classes	site A	site B
>20	0	0
21-40	11	22
41-60	6	11
61-80	2	0
81>	1	0
Number of Species	12	15

Table.2:result of Species Diversity within site A and site B

Variables	Site A	Site B
Number of species	12	15
Number of individuals	23	30
Shannon H	2.415	2.464
Evenness	0.9325	0.7834
Margalef	3.683	4.248

Table.3: Result of means and T-test values of soil nutrients indicators within factory and adjacent site

Variables	Mean values		SE	Prob. at 5% level	Paired
	site A	site B			T-test
p^H	6.21	6.45	-	0.001	15.24*
OC	0.70	0.79	0.01772	0.007	5.192*
OM	1.22	1.39	0.01855	0.001	-9.274*
N	0.10	0.16	0.003614	0.016	-4.040*
P	3.38	3.92	0.18055	0.040	-2.991*
Ca	3.23	3.98	0.10851	0.002	-6.986*
Mg	1.58	1.83	0.02939	0.001	8.437*
K	0.26	0.29	0.00490	0.005	-5.715^{ns}
Na	0.67	0.80	0.0235	0.003	6.487*

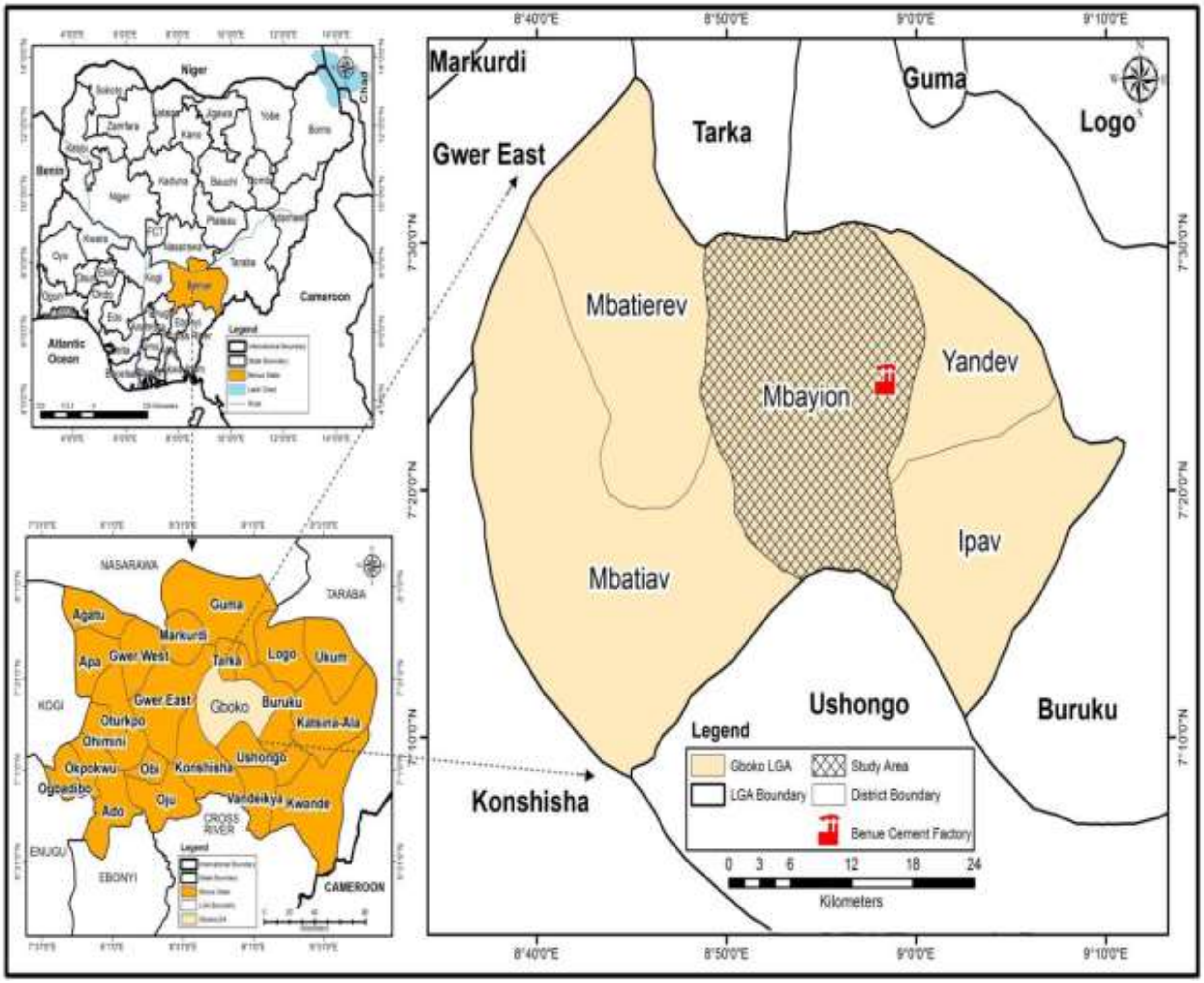

Fig.1: Gboko LGA Showing Study Area

Source: Modified from the Administrative Map of Gboko LGA, 2014.

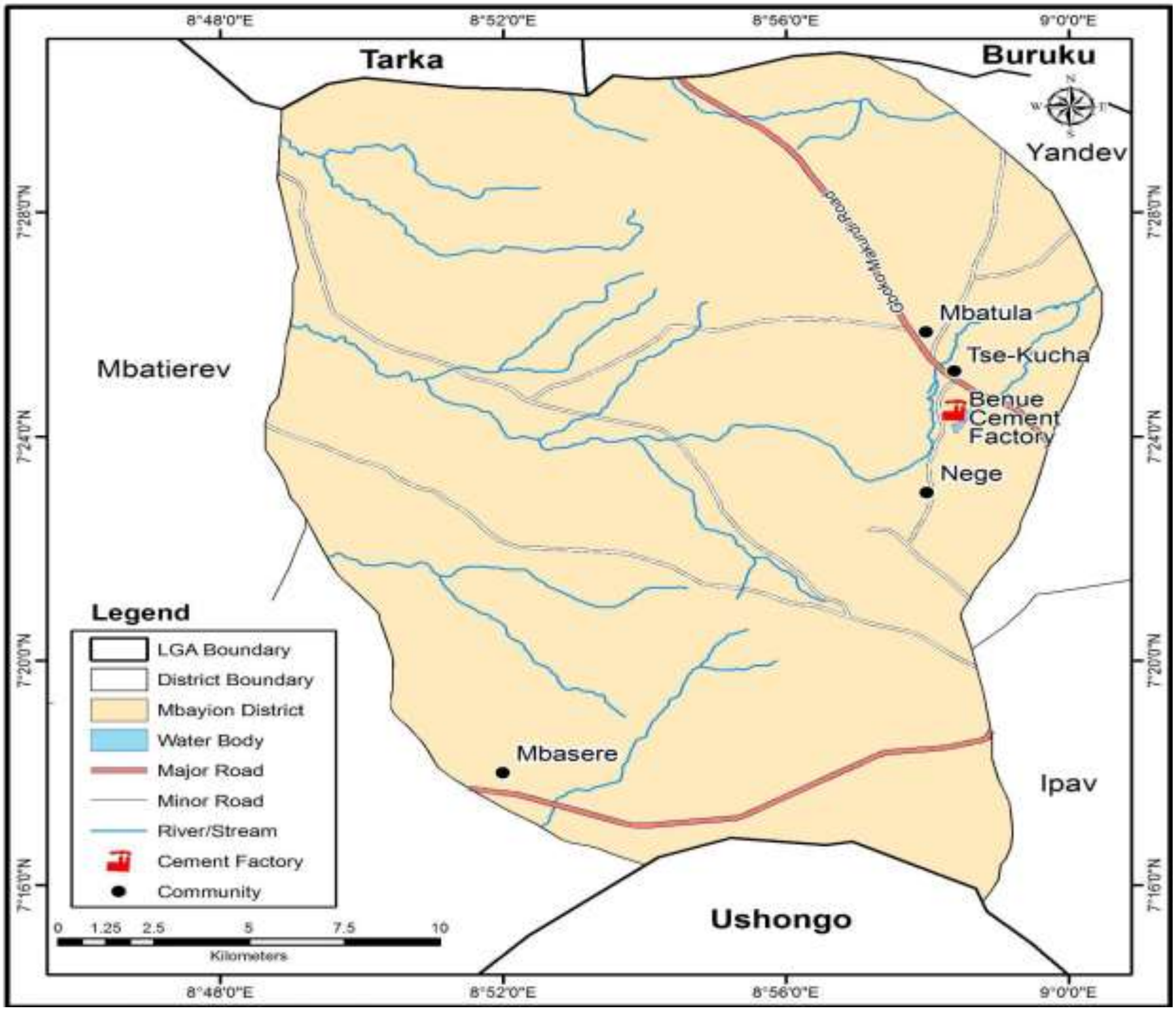

Fig.2: Mbayion District (Study Area)

Source: Modified from the Administrative Map of Gboko LGA/Google Maps, 2014.