Micro-Climate Implications of Forest Conversion for Floral Diversity in a Humid Forest Region of South Eastern Nigeria

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Received: June 27, 2011 Accepted: July 25, 2011 Published: March 1, 2012
doi:10.5539/jgg.v4n1p283 URL: http://dx.doi.org/10.5539/jgg.v4n1p283

Abstract

The study assessed the potential impact of forest conversion for micro-climate as well as the implications of micro-climate alteration for floral diversity in a humid forest region of South Eastern Nigeria. The measurement of possible micro-climate condition was taken at two sites including forest under-storey and the nearest open space, cleared but under three year fallow, while the number of trees, shrubs and herbs was documented and species diversity index determined. Three climate parameters were taken into consideration: rainfall, temperature and relative humidity. Results showed that the quantity of rain in open space was higher than in the forest under-storey, implying exposure to possible accelerated runoff, loss of valuable top soil and alteration of floral diversity. Mean daily temperature was lower under forest cover than open space, but with a higher range in the under-storey. At the same time, difference between maximum and minimum temperature was lower in the forest under-story. Relative humidity was higher in forest under-storey than open space; being highly variable between morning and evening in the open space. The conversion of forest has implications for traditional livelihood, which is dependent on forest products. This was expressed in the variation in the floral diversity across the land cover types. Strategies for alternative livelihoods should be explored for local communities.

Keywords: Forest conversion, Micro-climate, Agro-forestry, Floral diversity, Traditional livelihood, Nigeria

1. Introduction

The significance of forests for global to local scale climate modification cannot be over-emphasized. The Cross River rain forest south – eastern Nigeria, recognized as one of the near pristine ecosystem, is in many places, under increased human threat of conversion and fragmentation. This is a particularly common in the Oban group forest reserve where this study was conducted. Many of the conversions here arise from slash and burn subsistence agriculture and the quest for economic expansion through plantation agriculture. These activities no doubt, have the potential to alter the local (micro) climate regime, with regional to global extension and backwash. The knock-on effects on the local plant growth and diversity cannot be overemphasized.

In Ekong Anaku area, which forms the immediate focus for this study, as elsewhere, there is a natural forest, which has its established micro-climate; with floral adaptation to the micro-climatic fluxes. Micro-climate as considered here is, is line with the meteorological glossary's definition recorded in BBC Weather, (2007), as the physical state of the atmosphere, close to a very small area of the earth surface, often in relation to living matter and pertains to a short period of time. It is the climate near the surface of the earth where plants and animals are

characterized by intensity of changes with time and elevation (Geiger *et al.*, 2009; Rosenberg, 1974). In this rainforest region, the high and dense vegetation forms an almost unbroken surface. This makes the micro-climate at the top and in the canopy different from the forest floors and the non-forested areas (Geiger *et al.*, 2009). Meteorological variables are therefore subject to vertical changes near the ground and horizontal variation within short distances.

Variable vegetation thus causes variation in micro-climate across landscape. The main reason is the variation in the ability of different surfaces to distribute the components of the energy balance. Under forest cover, incoming and outgoing radiation is reduced, while the albedo coefficient in evergreen forest with close canopy is always low compared to degraded forest (Stanhill, 1970; Oguntoyinbo, 1970; Geiger *et al.*, 2009). Forest clearing alters this arrangement such that the magnitude of the components of net radiation changes result in greater penetration of solar radiation by day and increased outgoing radiation by night, hence high diurnal range and variability of temperature (Rosenberg, 1974). This is dependent on the size of clearing and proximity to forest stand (Geiger *et al.*, 2009). Thus microclimate of forest edge is different from those of forest floor and clear area farther away from the forest stand.

In addition, forest conversion alters the rate of water availability to the soil. Under forest cover, the soils in the forest receive lower rainfall but are continually damp due to the canopy cover. Forest conversion alters this by making precipitation readily available to the soil, altering the soil moisture content and holding capacity (Ghuman and Lal, 1987). As soils, which were not directly exposed to the impact of rainfall and solar radiation, suddenly face the vagaries of these weather elements, soil moisture initially increases and is constantly dissipated by solar radiation. This, with time, changes the soil physical properties, increasing erosion and reducing the retention capacity and infiltration. The changes that ensue thereafter do not favour original floral species, hence changes in species composition (Glambulluca *et al.*, 2003).

A scenario of forest conversion as on-going has the potential of altering the micro-climate with knock-on effects on the plant communities and the people's livelihood standards. Studies of this nature have not been conducted for this region (Oban group reserve). Most importantly the connection between the microclimate alteration and variation in floral diversity associated with forest conversion has not been determined. Where forest clearing is for agricultural plantation as in the case with the Ekong Anaku scenario, there is the potential for a more permanent alteration of the micro-climate. This is on the grounds that such monocultures are under a management regime that requires the constant clearing of undergrowth, with little canopy provided by the plantation crops. At the same time, most monocultures are characterized by plants that are of pure stand. Thus, although many studies have linked micro-climate alteration to forest conversion, the potential implication for agriculture and species composition within the Ekong Anaku area of Oban forest reserve remains to be investigated.

2. Materials and Methods

2.1 Study Area

The study focuses on the micro-climate implications of converting a humid forest into agricultural plantation in Ekong Anaku. An oil palm plantation has been ear - marked for Ekong Anaku. The plantation called Real Oil Palm Project involves the conversion of quite a substantial proportion of an intact forest into a monoculture. It also involves the establishment of an oil processing factory, which will definitely generate gaseous emissions into the atmosphere. What becomes of the existing micro-climate and associate ecological implications, form the main crux of this study.

Ekong Anaku, within the Oban group forest of the Cross River rainforest south-eastern Nigeria (Figure 1) is located specifically as 05°16'30"N and 08°33'40"E. It is within the rainforest, which is of interest to the Cross River National Park. However, being not only in the buffer zone of the national park but mostly in community and public (government) forest reserve, strict adherence to conservation ethics appears to be an illusion as slash and burn agriculture is widely a major forest degradation phenomenon.

In 2003, part of this government and community forest reserve was sold to large scale oil palm plantation firm-Real Oil Palm Plantation. Real oil palm plantation in Ekong Anaku occupies an approximate areal coverage of 97sqkm. Apart from the biodiversity implication of the widespread forest conversion associated with the development, the potential micro-climate implications of converting this forest to monoculture are expectedly monumental.

From the regional perspective, Ekong Anaku falls within humid tropics with an average total annual rainfall above 2900mm, short dry season of 2 to 3 months (December-February) and double maxima regime. Mean

monthly temperature is about 27°C with monthly range of about 4°C. The mean daily and monthly totals of hourly sunshine duration are 3.93 and 120 hours respectively. Generally, hours of sunshine are much lower than the maximum possible for this latitude, with lower incidence of solar radiation characteristic of the wet season (Illeoje, 1978). This is lower under forest cover than where cleared and this affects the plant photosynthetic processes, hence species variation.

Relative humidity is generally high throughout the year but definitely varies between forested areas and open space (Illeoje, 1978. The high humidity contributes to the generally high and equable temperature.

2.2 Method of Study

The study was an experimental field survey. Three micro-climate parameters and two land cover types were taken into consideration. The climatic elements included: rainfall, temperature and relative humidity. The land cover types were forest cover and cleared forest under 3 year fallow. Trees, shrubs and herbs were enumerated from the land covers.

Three plots of different sizes were selected for the each land use (main sites). This gave a total of 6 plots. In each land cover four (4) sample plots of 15x15m each were carved out. Out of these, sub-plots of 10 x 10m and 5 x 5m were carved out from each plot.

The major plot was used to enumerate the tree species, while the 10x10m plots were used to enumerate shrubs and the 5x5m for herbal species. The 15x15m plots were purposively selected, but the lower order plots were selected from the main plot through the simple random sampling technique.

Field meteorological instruments used were: manual rain gauge and the Kestrel Model 4000 weather tracker. For the floral diversity assessment, data collection involved enumeration and documentation (inventory) of the identified species of interest.

The period for the study was for ten days. Readings were taken twice a day and averages calculated as representing mean daily readings.

The data collected were presented in tabular format based on daily means. The data were subjected to both descriptive and inferential statistics. In the former, measures of central tendency (mean and percentages) and measures of dispersion (standard deviation) were used. Inferential statistics involved the use of independent t-test, to determine the level of difference in the sample mean between the different land covers under study.

Data analysis also involved tabulation of species composition and frequency of occurrence per plot for each land cover type. In addition, species diversity index for each land cover was determined. Species diversity was evaluated using Simpson's index of diversity.

The Simpson's diversity index is given as

$$D = {}^{s}\sum P_i^2 \text{ (Simpson 1949 in Kell and Maxted, 2001)} \quad (1)$$

Where P_i = Proportion of species in relation to the total number of individual species.

The values obtained from the Simpson diversity index as represented in formula (1), usually show lower values representing higher diversity, with 1 representing no diversity (Kell and Maxted, 2001). Because this is neither intuitive nor logical, the problem was overcome by subtracting the value of D from 1 given the formula $D = 1 {}^{s}\sum P_i^2$ ----- (1) (Kell and Maxted, 2001).

3. Results and Discussions

3.1 Microclimatic Variation

The data generated from the field are as presented in tables 1, 2 and 3. In table 1, which represents rainfall data, 5 days were characterized by no rainfall. During the days with marginal rainfall, 55.5 percent of the rain fell in open space implying that in the forested areas, most of the rain must have been intercepted by the forest canopy, becoming readily available for evaporation. The rest that finds it way into the forest under storey becomes available for infiltration. This enriches the soil moisture and contributes to the constant evaporation and its cooling effect in the forest understorey. It should be noted that although more rainfall reaches the ground in open space than forest understorey, the effectiveness may be reduced. As noted by Lal and Cummings (1979), while fluctuation in maximum and minimum soil and air temperature and relative humidity may be enhanced by deforestation, rainfall effectiveness is decreased because of run off and rapid evaporation, thus aridization of the micro-climate.

In table 2, it is observed that the mean daily temperature for forest cover was generally lower than mean daily for open space. On the other hand the range was higher for forest cover (8.5°C) as against 4.8°C in open space. This implies that mean daily temperature was more stable but constantly higher in open space. The generally high range is in conformity with Rosenberg (1974) that whether the surface is bare or vegetated, the greatest durinal range in temperature is experienced at any level near the surfaces, while the intensity of these changes varies with time.

However, in terms of the difference between maximum and minimum temperature, the variation was lower under forest cover, implying a more equally daily temperature conditions in this environment. The case for open space conforms with Lal and Gummings (1979) that deforestation of tropical rainforest leads to drastic change in microclimate by eliminating the buffering effects of vegetation cover, thus accentuating the extremes.

It most noted that measurements for this study were restricted to air temperature. However according to Lal (1995), though deforestation correspondingly increases air temperature and evaporation, the most drastic effect perhaps is on soil temperature. The soil maximum temperature can be as high as 5-20°C at 1 to 5cm depth on cleared land on a sunny day compared to the area under forest cover. Because of the high soil evaporation that results thereafter, the soil moisture content of the surface layer is also lower in cleared that in forested soils. At the onset of clearing is the increase in soil wetness, but increasing human activities alter the soil physical properties such that there are species alterations.

For relative humidity (Table 3) it is observed that this was higher under forest cover than in open space. In the open, this was highly variable between the mornings and evenings that readings were taken, being higher during the day. The result as shown in table 3 confirm with Ghummanard and Lal 91987) for South Central Nigeria, that day time relative humidity under forest cover changes very little, while that in cleared forest is usually lower and alters widely.

The standard deviation and t test analysis results are presented in table 4. From the table it is observed that the standard deviation for rainfall and relative humidity in open space was higher than under forest cover, while standard deviation for temperature was higher under forest cover. This confirms that on the average, daily temperature was constantly higher while this varies remarkably under forest cover from day to day. As mean rainfall in open space was higher, it also deviated remarkably from the mean, implying that forest canopy moderated through fall, which appeared in the under-storey as rain. The higher relative humidity under forest cover as seen table 3 did not synchronize the standard deviation. This implies that the relative humidity under forest was rather stable during the period of study. In all, rainfall and relative humidity were more stable under forest cover and being more unstable in open space. Though this stability in temperature in open space could favour some crops that require fairly stable mean daily temperature during growth, it may not favour some of the forest valuable trees that are adept at surviving under the fluctuating mean daily temperature.

The t test results as shown in table 4 indicate that significant variation existed in the mean values of the parameters between forest cover and open space. This is because the calculated values are greater than table values at 0.05 significance level.

These results confirm the assertion that forest conversion alters the micro-climate, sometimes drastically. The higher standard deviation of relative humidity and rainfall are in line with Lal (1995) that deforestation eliminates the buffering affects of vegetation and accentuate the extremes. This is applicable to mean daily maximum and minimum temperature, whose range was equally high, though more stable, in the open space on the average. Forest cover in this case also buffers the extreme heat and cold by reducing the net radiation reaching the forest floor, but the absorption of leaf reduces extreme cold. The higher average daily temperature in open space confirms that deforestation increases air temperature (Ghuman and Lel, 1987).

The increase in rainfall as observed implies higher soil moisture at the beginning of forest clearing: Continuous rain and human activities result later to compaction, which reduces the infiltration rate of the soil, hence low retention capacity and rapid surface runoff. This reduced rainfall effectiveness (Ghuman and Lal, 1992) leads to soil fertility loss with high implication for agricultural productivity and the growth of original floral species that are of socio-economic value to the forest dependent communities. In addition, increase in mean daily temperature and extreme conditions imply agricultural impacts as well as alteration of indigenous plant species with the proliferation of the exotic.

The summary of the species distribution and composition as presented in table 5 shows that trees species were generally more abundant and this was more in the 3 year fallow. However, in terms of the number of individual species, herbs were more abundant followed by trees. The herbal species were still more abundant in the 3 year fallow and high forest, being the least abundant in herbs.

3.2 Species Diversity

The results of the Simpson's diversity index are as shown in table 6. Based on Simpson's diversity index, areas under high forest have higher tree species diversity. The lowest diversity of trees is in the 3 year fallow. In another development, the diversity of shrubs and herbs vary between land cover. The highest diversity of shrubs is in the 3 year fallow, while the highest herb diversity is equally in three year fallowed. The result confirm the prediction that disturbance can increase diversity (Sheil, 2001).

4. Conclusion

The potential impact of forest conversion on micro-climate in the Ekong Anaku area as a result of planned plantation agriculture implies a major modification of the floral diversity. This area is originally rich in such diversity and these are adept at being sustained by the existing forest micro-climate. The alteration of the micro-climate and the colossal impact it could have on biodiversity that are valuable source of local economies imply the shift in the people's economic activities such as collection of non-timber forest product. This means an attempt at such collection could push the people far into the forest frontier, which is either a distance away or under a different jurisdiction such as the National park protected area. Conflict arising from such attempts could be envisaged and a shift in economic venture is eminent.

High temperatures occasioned by forest clearing are injurious to locally cultivated crops and may affect also the yield of other valuable forest product. Increase air temperature translates to high soil temperature and many of the forest species are known to perform poorly under such conditions.

On this basis, clear cutting of the forest is not advisable. Oil palms are possible to co-exist with other trees species. Selective clearing and planed tree planting are thus encouraged where the forest have already been cleared.

Shelterbelts and reforestation efforts should be designed by competent Forestry and Land use experts such that crop lands, water catchments and dwelling places could be protected from the risk of deforestation and micro-climate alteration.

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Table 1. Forest Micro-Climate for Ekong Anaku-Rainfall (mm)

Days	Date	Rainfall (Mm) Daily		Daily Total	Daily Mean
		Open Space	Forest Cover		
1	12/11/04	9.4	9.2	18.6	9.3
2	13/11/04	22.2	11.3	33.5	16.8
3	19/11/04	1.8	1.3	3.1	1.55
4	20/11/04	0	0	0	0
5	21/11/04	0	0	0	0
6	22/11/04	23.2	2.1	47.3	23.7
7	23/11/04	0	0	0	0
8	24/11/04	5.5	3.8	9.3	4.65
9	25/11/04	0	0	0	0
10	26/11/04	0	0	0	0
Total		62.1	49.7	111.8	56.0
Average Daily		6.21	4.97	11.18	5.6

Source: Author's Field Survey

Table 2. Forest Micro-Climate (Temperature) for Ekong Anaku-Temperature (℃)

Date/ Day	12/11/04 1	13/11/04 2	19/11/04 3	20/11/04 4	21/11/04 5	22/11/04 6	23/11/04 7	24/11/04 8	25/11/04 9	26/11/04 10	Total	Daily mean
Temperature (℃)	℃	℃	℃	℃	℃	℃	℃	℃	℃	℃		
	Forest Cover											
Maximum	32	32.8	28	30	31	28	31	30	29.5	29.5	301.8	30.1
Minimum	23	20.5	27.5	27.5	26	18.5	20	25	27.5	30.5	246	23.6
										20.5	236	
Daily temp. (Mean)	27.5	25.5	27.8	28.8	28.5	23.3	25.5	27.5	28.5	30.0	272.9	27.3
Date/ Day	12/11/04 1	13/11/04 2	19/11/04 3	20/11/04 4	21/11/04 5	22/11/04 6	23/11/04 7	24/11/04 8	25/11/04 9	26/11/04 10	Total	Daily mean
Temperature (℃)	℃	℃	℃	℃	℃	℃	℃	℃	℃	℃		
	Open Space											
Maximum	35	33.5	31.5	34.5	30.5	34.5	36	34.4	35	34	339	33.9
Minimum	25.5	20.5	25	24	25	25	26	23.5	25	21.5	241	24.1
Daily temp. (Mean)	30.5	26.7	28.3	29.3	27.8	29.3	31.0	29.0	30.0	27.8	290	29.0

Average mean daily = 28.2

Source: Author's Field Survey

ISSN 1916-9779 E-ISSN 1916-9787

Table 3. Forest Micro-Climate for Ekong Anaku – Relative Humidity (%): (Derived from Dry and Wet Bulb Field Thermometer Reading)

Days	Date	Under forest cover			Open space		
		Dry	Wet	R.H%	Dry	Wet	R.H%
1	12/11/04	28.8	26.5	83	30.5	27.1	76
2	13/11/04	30.5	25.3	85	26.5	17.9	41
3	19/11/04	26.2	25.7	86	27.5	25.8	87
4	20/11/04	26.9	25.6	90	28.5	26.2	83
5	21/11/04	26.8	25.5	89	27.2	26.7	81
6	22/11/04	26.1	25	91	27.5	25.2	82
7	23/11/04	27.8	25	90	27.6	26.1	88
8	24/11/04	27.1	25.8	90	28.5	24.8	73
9	25/11/04	28.3	25.7	75	28.7	26.5	83
10	26/11/04	27.5	25.8	86	28.9	28.2	28
Mean		27.6	25.6	86.5	28.1	25.5	72.2

Source: Author's Field Survey

Table 4. Showing Analysis Result for Forest Cover and Open Space

Parameter	Location and Result		T statistics		
	Forest cover std dev.	Converted forest (std. dev.)	Cal	Df	Table value
Mean rainfall	6.67	7.58	3.88	18	1.73
Mean temperature	8.47	1.27	-2.33	18	1.73
Mean relative humidity	5.37	16.89	2.55	18	1.73

Source: Author's Field Survey

Table 5. Percentage composition of species and frequency per land use

Land Cover	Composition by species						Composition by individual plant					
	Trees		Shrubs		Herbs		Trees		Shrubs		Herbs	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Forest cover	24	42.2	24	45.2	17	51.5	130	24.7	253	59.7	578	30.7
3 year fallow	33	57.8	29	54.8	16	54.5	396	74.3	171	42.3	1307	69.3
Total	57	100	53	100	33	100	526	100	424	100	1885	100

Source: Author's Field Survey

Table 6. Simpson's Diversity Index

Simpson Diversity Index	
Forest cover	Cleared forest under 3 year Fallow
Trees	
0.855	0.515
Shrubs	
0.773	0.880
Herbs	
0.675	0.774

Source: Author's Field Survey

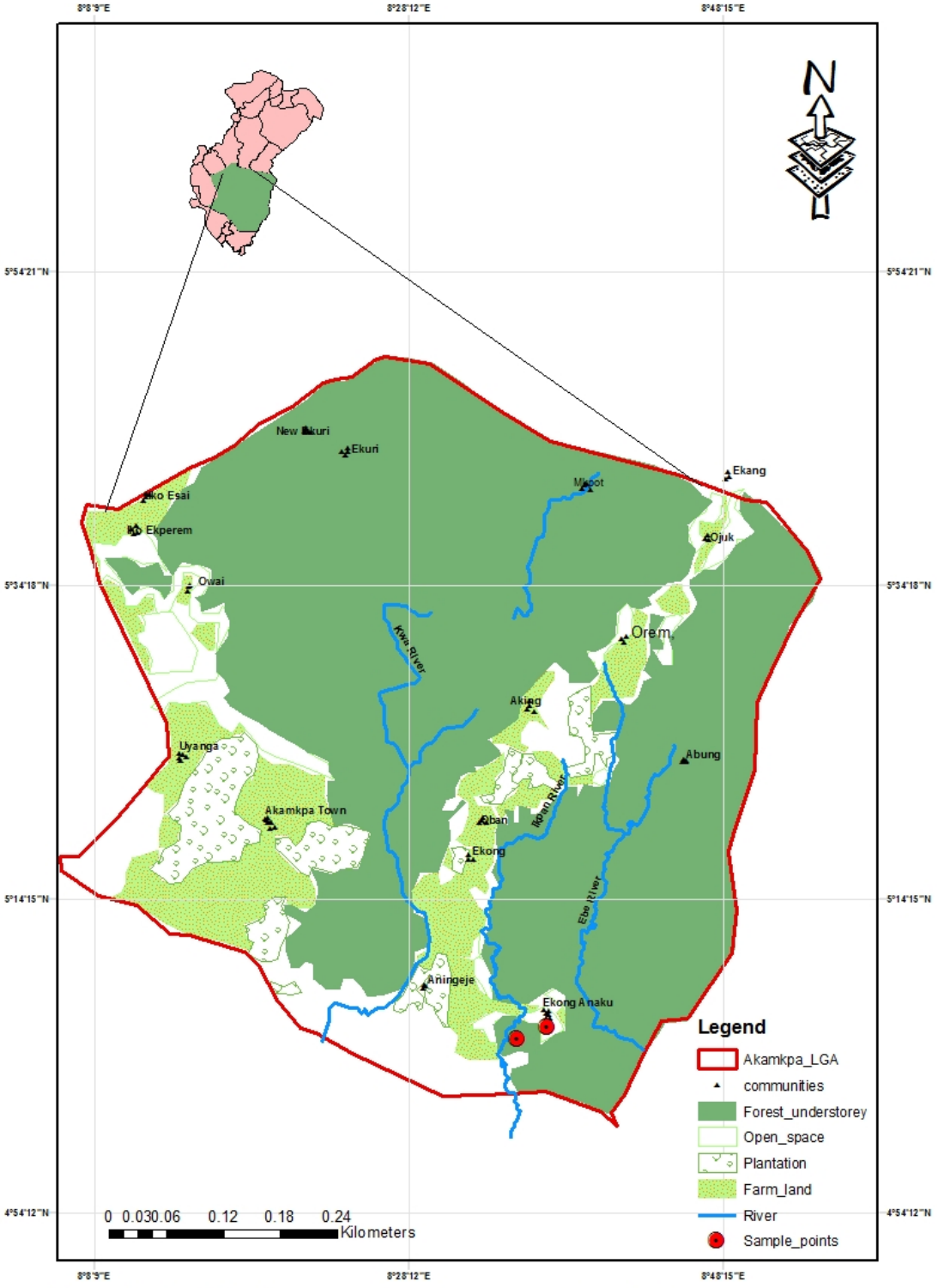

Figure 1. The study area showing sample points

 ISSN 1916-9779 E-ISSN 1916-9787