

# The Contribution of Hemispherical Photographs to Understand Natural Forest Regeneration in the AKAK Forest Area

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## Abstract

Examining the contribution of hemispherical photographs in the understanding of Natural forest regeneration is very important in estimating the future forest structure, composition and to enforce conservation regulations. This study sets out to examine the interaction between stump sprouting, LAI, site and canopy openness for the entire AKAK forest area and for the logging compartments; 2013, 2015 and 2017 respectively. 49 sprouted stump were identified randomly. 20 m × 20 m plots were demarcated along a canopy gaps for each sprouted stump, the plots were established in such a manner that the sprouted stumps will be in the middle. For each of the selected 49 sprouted stump, indirect measurements of canopy cover were performed in the 49 plots of 20 m × 20 m (0.04 ha), giving a total of 1.96 ha of land covered. Galaxy S3 smartphone with a built-in Infinix ZERO 4 fish-eye lens with 198° view angle equidistant projection was used to take photos. The fish-eye lens was mounted on the phone camera and photograph were taken at a fixed height of 1.3 m. Results revealed that, the combine Principal Component Factor Analysis (2013, 2015 and 2017) of the correlation matrix for Sprout, Years, LAI 4%, LAI 5%, Canopy and Site openness, shows that factor 1 explained 62.6% of total variance while factor 2 explained 17.9% together explain 80.05% Communalities. For the year 2013, 2015 and 2017 respectively shows that there is a very strong correlation ( $p < 0.000$ ) between LAI (4 and 5) and (canopy and site openness). This there is a very strong highly significant interaction ( $p < 0.0005$ ) between LAI4 and LAI5.

## Keywords

Hemispherical Photographs, Natural Forest Regeneration, AKAK Forest

## 1. Introduction

Sustainable management of natural forests depends on their ability to regenerate, understanding natural regeneration processes and the distribution of recruits is of paramount importance in estimating the future forest structure, composition and to enforce conservation regulations (Ceccon et al., 2006; Schaafsma et al., 2011). The failure of a species to regenerate will ultimately result in its (local) extinction (Denslow, 1980). Information on forest recovery is crucial for future ecological monitoring and understanding the dynamics of ecological recovery in this forest ecosystem. Different tree species have developed different regeneration strategies over millions of years of evolution (Brokaw, 1985). Regeneration from sprout-origin contributes to sustaining predisturbance species composition (Dietze & Clark, 2008). Several studies have shown that sprouts can constitute the majority of the dominant trees within the regenerating cohort after harvesting, although the capacity to sprout varies by species and site conditions (Boring et al., 1981; Beck & Hooper, 1986; Arthur et al., 1997). Several studies have documented the major contribution of sprouts as a regeneration source within upland and bottomland forests (Beck & Hooper, 1986; Arthur et al., 1997; Dietze & Clark, 2008; Johnson & Deen, 1993). Silvicultural practices, such as the retention of over story trees after harvesting, have been found to have few effects on sprout production but potentially affect sprout survival and growth rates (Dey et al., 2008; Keyser & Zarnoch, 2014). Forest regeneration in the tropics occurs in gaps formed by selective logging and windfalls. In high species diversity forest, species are competing for scarce gap resources, in which some species are successful than others, this may be due to the nature and requirements of the seed and the seedling. However, large gaps formed by intensive logging will affect the composition and structure of the forest. The size of the gap plays a significant role in species diversity, composition and regeneration of natural forests. Gaps in forest landscapes assume a wide range of sizes from the openings created by the deaths of single branches or trees. Canopy structure can be measured by a characteristic descriptor, such as tree height, stocking rate, canopy cover, and light transmittance although, leaf area index is the variable most commonly used to quantify forest canopy. Also cover photography is a technique that measure canopy (foliage and crown) cover. Hemispherical photography (HP), implemented with cameras equipped with “fisheye” lenses, is a widely used method for describing forest canopies and light regimes. A promising technological advance is the availability of low-cost fisheye lenses for smartphone cameras. Smartphone HP is a cheaper and faster but still adequate operational alternative to traditional cameras for describing forest canopies and light regimes. The analysis of the light intercepted by the tree crowns has been the basis for various ecological studies, especially for the dynamics of the vegetation growing under canopy cover (Coates et al., 2003; Duchesneau et al., 2001; Pacala et al., 1996). HP is now considered the most widely used ground-based method for describing both canopy

characteristics and forest light regimes (Chianucci & Cutini, 2013; Promis et al., 2011). Today, another potential technological advance in this field is the availability of low-cost fisheye lenses for smartphone and tablet cameras (Korhonen, et al., 2006) and (Tichý, 2015). The history of HP in forestry provided by (Hall et al., 2003) provides a vivid account of the rapid evolution of the use of HP in forestry. Little is known about the overall contributions hemispherical Photographs to understand natural forest regeneration. In the Akak forest area, given the fact that data on the contribution of hemispherical Photographs to understand natural forest regeneration is scanty, this research will examine the interaction between stump sprouting, LAI, site and canopy openness for the entire AKAK forest area and for the logging compartments; 2013, 2015 and 2017 respectively.

## 2. Material and Methods

### 2.1. Location of the Study Area

The Akak forest area is located between latitude 5°20' - 5°25'N longitude and 9°12' - 9°30'E latitude, in the Eyumojock subdivision, Manyu Division, Southwest Region of Cameroon as shown in **Figure 1**. Vegetation consists of semi deciduous lowland rainforest of the Guineo-Congolian type (Kenfack et al., 2006). Precipitation is unimodal, with an annual average around 4100 mm (Nchanji & Plumptre, 2003) and a three-month dry season from December to February (Groenendijk, 2015). The topography is relatively flat. Although human intervention through the establishment of large plantations of cash crops (Palm oil, coffee), as well as natural factors such as elephant disturbance and windfalls have created large gaps in these forests. Logged forest sites are located in the “heart” of the MPL (Mukete Plantations Limited) and the forests of this area have undergone logging both formal and informal from 1995 to date.

### 2.2. Data Collection of Hemispherical Photos

49 sprouted stump were identified randomly as shown in **Figure 2** (Fuashi et al., 2020; Ayamba et al., 2019). 20 m × 20 m plots were demarcated along a canopy gaps for each sprouted stump, the plots were established in such a manner that the sprouted stumps will be in the middle. For each of the selected 49 sprouted stump, indirect measurements of canopy cover were performed in the 49 plots of 20 m × 20 m (0.04 ha), giving a total of 1.96 ha of land covered. Galaxy S3 smartphone with an built-in Infinix ZERO 4 fish-eye lens with 198° view angle equidistant projection was used to take photos as shown in **Figure 3** (Bianchi et al., 2017). The fish-eye lens was mounted on the phone camera and photograph were taken at a fixed height of 1.3 m (Bianchi et al., 2017) as shown in **Figure 3**. The smartphone was held by hand, keeping it leveled and pointing upward as best as we could (Bianchi et al., 2017). Pictures were taking using the automatic exposure with good contrast between sky and canopy (Hale et al., 2009). Pictures

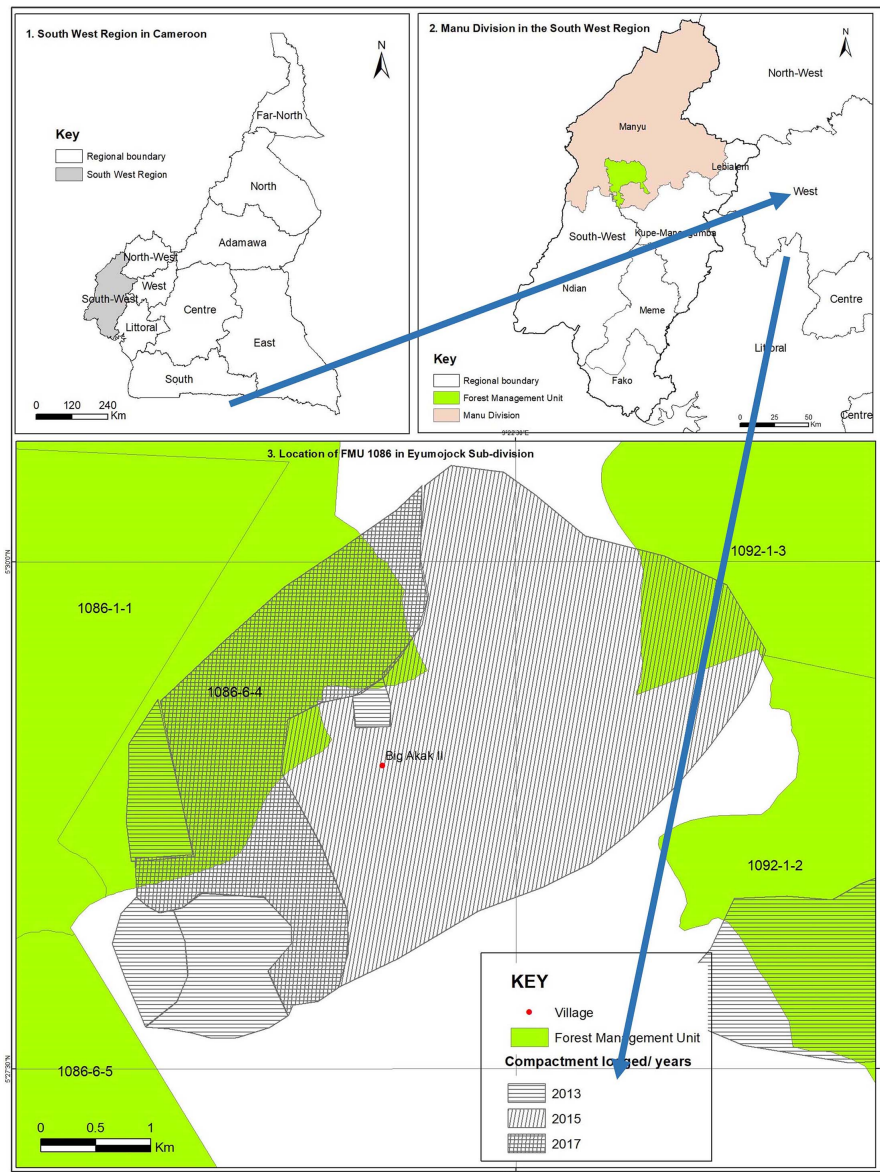


Figure 1. Map of Akak forest area, adapted from: National Institute of Cartography, 2019.

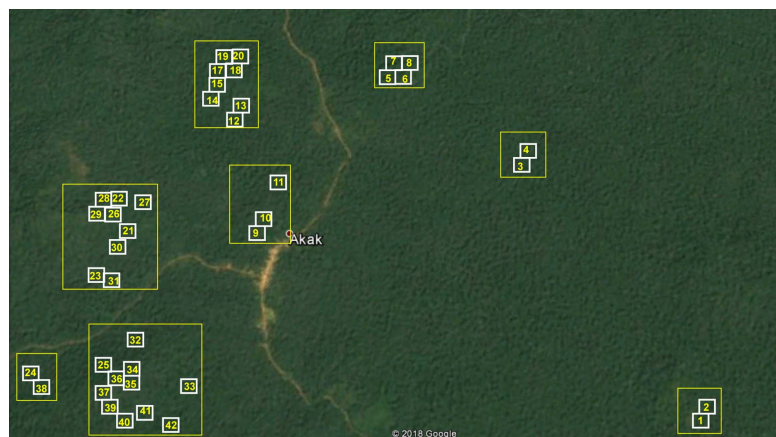
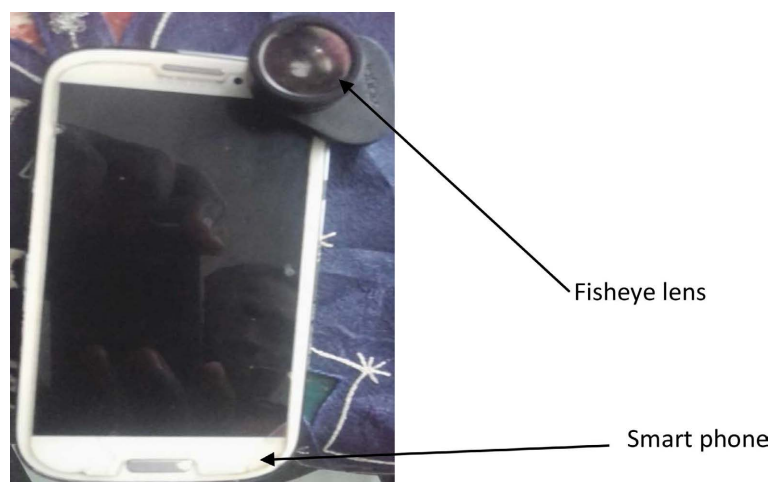


Figure 2. The distribution of sampling plots.

were taken immediately after reaching the point (Planchais & Pontailier, 1999). The smartphone pictures had pixel dimensions of  $3.1341 \times 1.624$ . The smart phone was used because smartphone hemispherical photographs is comparable to hemispherical photographs using traditional cameras (Tichý, 2015) and it take only diagonal photographs which is suitable for rectangular or square plots following the definition of (Schneider et al., 2009). Four pictures were taken per plot randomly as shown in Figure 4, two pictures taken at north-south direction and the other two pictures east-west direction with the aid of a compass (Bianchi et al., 2017). Photographs were taken at each sampled plots (that was average time the team spent on each plot), trying to catch the best backlighting conditions. A total of 196 images (pictures) were taken in February - April 2018, on 49 plots of  $20 \text{ m} \times 20 \text{ m}$  in size. Hemispherical photos were taken under completely overcast sky conditions and when the sun was under the skyline in order to minimize glare from Sunlight (Bianchi et al., 2017). Fieldwork took place the whole day resulting in different time of hemispherical photographs acquisition (Bianchi et al., 2017).



**Figure 3.** Fisheye lens mounted on a smart phone.

To calculate canopy characteristics, 196 images collected were imported in the Gap Light Analyser (GLA). This software transforms the colours of the images to black and white, in order to quantify the pixels before calculation of canopy openness, leaf area index and site openness (Frazer et al., 2000).

### 2.3. Image Processing in Gap Light Analyser

Before the pictures were processed, GLA software was downloaded on the desktop. A folder was created on the desktop to store the 196 images collected from the field. The images were uploaded in to the GLA application and process. Before processing began, Geographic north and polar projection distortion on the configuration menu of the GLA software were selected as the geographic parameters of the images. Geographical North was used because our



**Figure 4.** Hemispherical photographs.

camera was aligned using a compass northward (Frazer et al., 2000), and polar projection distortion was used because it is the specification of the camera lens (Herbert, 1987).

Still in the configuration menu, the image was registered using “register the image” selection, and the cross-hair cursor was dragged from west to east of the image which created a symmetrical circle around the image. During image registration, the box for “fix the registration for subsequent image” was checked since all our images were taken using the same lens.

After the image was registered, a second working image opened. The threshold button in the image menu was clicked to slide the cursor till we had an accurate representation of the sky and shadow for both first and second working image. This was done to ensure that both dark and light areas of the original image had similar representation in either directions (Frazer et al., 2000).

In the menu bar the registered image was calculated for canopy only since the research is focused on canopy characteristics.

Canopy characteristics included:

1) Leaf area index (LAI) that can be simply defined as the amount of leaf surface area per unit ground area. It describes the photosynthetic and transpirational surface of plant canopies. Here, calculated effective leaf area index integrated over the zenith angles  $0^\circ - 60^\circ$  (referred as LAI 4 in the GLA software) were used.

$$\text{LAI} = \text{leaf area/ground area, m}^2/\text{m}^2.$$

2) Canopy openness that is a percentage of open sky seen from beneath a forest canopy, or called “a frog perspective”.

$$CO = \sum_Z (G_Z W_Z) \times 100$$

where CO represents canopy openness,  $Z$  represents the different intervals of zenith angle,  $G_Z$  is the gap fraction of interval  $Z$ , and  $W_Z$  the weighting factor for interval  $Z$ .

3) Site Openness is the percentage of the total sky area that is found in overlapping gaps in the canopy and mask for each sky region.

$$SO = \sum_Z (G_Z W_Z) \times 100$$

where SO represent canopy openness,  $Z$  represents the different intervals of zenith angle,  $G_Z$  is the gap fraction of interval  $Z$ , and  $W_Z$  the weighting factor for interval  $Z$ .

The result was transfer to minitab for further analysis.

## 2.4. Data Analysis

All statistical analyses were done using Minitab Version 17 Statistical Package (Minitab Inc., PA, USA). The significance level ( $\alpha$ ) was set at 0.05.

The field data were imported into QGIS 2.8 to digitise the coordinates of the sprouted stumps. Baseline information from the Cameroon official forest data and the Cameroon atlas were collected before any data manipulation commenced. After digitizing was completed, a quality check was performed to ensure that no points or lines were missing. To ensure correct display of data, all of the shape files were projected to UTM 84, zone 32 N.

Multivariate factor analysis without rotation was done to explore relationships among the variables. Two factors were extracted and their contribution to explaining the resulting data patterns was determined by the percent variation and communality. This was followed by applying the Spearman rank correlation.

The relationship between canopy characteristics and LAI was determined using Spearman Rank correlation and  $\alpha = 0.05$ . The relationship between all parameters was established through Multivariate Factor analysis based on the correlation matrix.

## 3. Results

### 3.1. The Interaction between Stump Sprouting, LAI, Site and Canopy Openness for the Entire AKAK Forest Area

The combine Principal Component Factor Analysis (2013, 2015 and 2017) of the Correlation Matrix for Sprout, Years, LAI 4%, LAI 5%, Canopy and Site openness, shows that factor 1 explained 62.6% of total variance while factor 2 explained 17.9% (Table 1).

Factor 1 and factor2 together explain 80.05% Communalities. This means that natural forest recovery in the Akak forest area can be explained 80.05% by the variables listed (Table 1).

**Table 1.** The relationship amongst Sprout, Years (2013, 2015 and 2017), Canopy openness, Site openness, LAI 4%, LAI 5%.

Variables	Factor 1	Factor 2	Communalities
Year	-0.014	-0.737	0.544
Sprout	0.074	-0.728	0.536
Canopy openness	-0.974	0.001	0.948
Site openness	-0.974	0.001	0.948
LAI 4%	0.953	0.015	0.908
LAI 5%	0.972	0.033	0.946
Variance	3.7534	1.0749	4.8283
% Var	0.626	0.179	0.805

### 3.2. The Relationship between Stump Sprouting, LAI, Site and Canopy Openness for the Logging Compartments; 2013, 2015 and 2017 Respectively

Factors 1 and 2 together explain 96.5% Communalities (**Table 2**) in 2013. This means that natural forest recovery in the forest compartment logged in the year 2013 in the Akak forest area can be explained 96.5% by the variables listed (**Table 2**).

**Table 2.** Relationship amongst Sprout, Years, Canopy openness, Site openness, LAI 4% and LAI 5% for logged compactment 2013.

Variable	Factor 1	Factor 2	Communality
Sprout	0.682	-0.731	0.998
Canopy openness	-0.977	-0.103	0.965
Site openness	-0.977	-0.103	0.966
LAI 4%	0.938	0.235	0.935
LAI 5%	0.977	0.078	0.961
Variance	4.2081	0.6164	4.8245
% Var	0.842	0.123	0.965

Factors 1 and 2 for 2015 together explain 96.2% Communalities. This means that natural forest recovery in the forest compartment logged in the year 2015 in the Akak forest area can be explained 96.2% by the variables listed above (**Table 3**).

**Table 3.** The relationship amongst Sprout, Years, Canopy openness, Site openness, LAI 4% and LAI 5% for logged compactment 2015.

Variable	Factor 1	Factor 2	Communality
Sprout	0.143	-0.990	1.000
Canopy openness	0.978	0.060	0.960

**Continued**

Site openness	0.978	0.061	0.960
LAI 4%	-0.966	-0.012	0.934
LAI 5%	-0.978	-0.012	0.956
Variance	3.8225	0.9867	4.8093
% Var	0.765	0.197	0.962

Factors 1 and 2 in 2017 together explain 96.1% Communalities. This means that natural forest recovery in the forest compartment logged in the year 2017 in the Akak forest area can be explained 96.1% by the variables listed above (**Table 4**).

**Table 4.** The relationship amongst Sprout, Years, Canopy openness, Site openness, LAI 4%, LAI 5% for logged compactment 2017.

Variable	Factor 1	Factor 2	Communality
Sprout	0.562	-0.827	1.000
Canopy openness	0.972	0.136	0.962
Site openness	0.972	0.136	0.962
LAI 4%	-0.961	-0.093	0.932
LAI 5%	-0.968	-0.115	0.951
Variance	4.0647	0.7424	4.8071
% Var	0.813	0.148	0.961

For the year 2013, 2015 and 2017 respectively shows that there is a very strong correlation between LAI (4 and 5) and (canopy and site openness) (**Table 5**).

**Table 5.** The (P value) for the relationship amongst canopy openness and site openness with LAI4/5.

	Canopy openness		Significant code	Site openness		Significant code
	Rho	P value		Rho	P value	
Year-2013						
LAI4	-0.728	<0.003	**	-0.714	<0.004	**
LAI5	-0.932	<0.0005	***	-0.922	<0.0005	***
Year-2015						
LAI4	-0.899	<0.000	***	-0.899	<0.000	***
LAI5	-0.886	<0.000	***	-0.886	<0.000	***
Year-2017						
LAI4	-0.911	<0.000	***	-0.911	<0.000	***
LAI5	-0.960	<0.000	***	-0.960	<0.000	***

Very significant\*\*\*, Very significant\*\*, significant\*.

There is a very strong highly significant interaction ( $p < 0.0005$ ) between LAI4 and LAI5. This means that as LAI4 increases so to LAI5 also increases (**Table 6**). There is no significant correlation between sprouting with other variables (LAI, canopy and site openness) (**Table 6**).

**Table 6.** The (P value) for the relationship amongst: Sprout, Years, Canopy openness, Site openness, LAI 4%, LAI 5%.

	Sprout	Years	Canopy openness	Site openness	LAI 4%
Years	0.078				
	0.593				
Canopy openness	0.050	0.132			
	0.735	0.366			
Site openness	0.048	0.132	1.000		
	0.744	0.366	0.0005		
LAI 4%	-0.070	0.002	-0.865	-0.864	
	0.631	0.987	0.0005	0.0005	
LAI 5%	-0.058	-0.078	-0.907	-0.906	0.919
	0.695	0.593	0.0005	0.0005	0.0005

#### 4. Discussion

##### The interaction between stump sprouting, LAI, site and canopy openness for the entire AKAK forest area.

A large number of specialized studies have used Hemispherical Photographs in a wide array of fields related to forestry, including forest ecology (light regime Canham et al., 1990; seedling regeneration Nicotra et al., 1999; spring phenology White, 1991) and canopy openness (Machado & Reich, 1999). Hemispherical photography can provide an accurate measure of understory light conditions (Becker et al., 1989; Rich et al., 1993) as there is apparently is a strong relationship between canopy openness and LAIs. In our studies canopy openness/site openness and LAIs had a very strong negative correlations meaning the opening in the Akak forest area is relatively low, this could be due to the hyper selective logging practiced in this area.

For the variable sprout (this refers to both sprouted and un sprouted stumps), factor 2 is dominating in each case with factor loading of  $-0.731$ ,  $-0.990$  and  $-0.827$  respectively, this means that the number of stumps sprouts in the Akak forest area is relatively low as compared to the observed logged stumps as indicated by a negative signed in all the cases on the variable, therefore the recovery of the original stocking densities is not likely from stump sprouting alone. With regards to variable canopy openness and site openness, factors 1 both for canopy and site openness are dominating, it shows that there is a perfect positive interaction between canopy and site openness which is very significant, this could

mean that the proportion of both canopy and site openness is relatively low in the Akak forest area as indicated by a negative 9.74 on each variable. They have high communalities of 0.948 each meaning the variables have an enormous contribution of 94.8% on forest recovery in the Akak forest area.

**The Relationship between stump sprouting, LAI, site and canopy openness for the logging compartments; 2013, 2015 and 2017 respectively.**

The forest compartment of 2013 had a very strong and very significant correlation between canopy openness and site openness, this means as canopy openness increases so thus site openness increases. The interaction between canopy openness with LAI 4/5 has a strong and very strong negative correlation, this means that as LAIs increases so does canopy openness reduces. For the interaction between LAI 4/5 and site openness has a strong and very strong negative correlation respectively, which is very significant, this means that as LAIs increases so does site openness reduces. The forest compartment of the year 2015 indicates that the interaction between canopy openness with LAI 4/5 has a very strong negative correlation, this means that as LAIs increases so does Canopy openness reduces. For the interaction between LAI 4/5 and site openness has a very strong negative correlation. This means that as LAIs increases so does site openness reduces. The forest compartment of the year 2017 indicates that the interaction between canopy openness with LAI 4/5 has a very strong negative correlation, this means that as LAIs increases so does Canopy openness reduces. For the interaction between LAI 4/5 and site openness has a very strong negative correlation, this means that as LAIs increases so does site openness reduces. While LAI (4 and 5) the first factors both for LAI 4 and LAI 5 (factor loading: 0.953 and 0.972) are dominating. This means that the proportion of LAIs in the AKAK forest area is very high, couple with high communalities values of 90.8% and 94.6% respectively which the variables contribute in Natural forest recovery in the AKAK forest area.

The forest structure has a mosaic of areas, some few opening, and areas similar to small gaps, where low levels of radiation reach the forest floor indicating a continuous canopy. Similar results were obtained from the studies carried by (Kabakoff & Chazdon, 1996) were LAI was negatively correlated with canopy opening in the two forests and also in six sites in a tropical humid forest. In dense tropical forest, the canopy opening is smaller (<10%), while in the seasonal forests canopy opening varies from 33 to over 60% (Kabakoff & Chazdon, 1996).

## 5. Conclusion

The combine Principal Component Factor Analysis (2013, 2015 and 2017) of the Correlation Matrix shows that factor 1 explained 62.6% of total variance while factor 2 explained 17.9%, while for the year 2013, 2015 and 2017 respectively shows that there is a very strong correlation ( $p < 0.000$ ) between LAI (4 and 5) and (canopy and site openness). There is a very strong highly significant interac-

tion ( $p < 0.0005$ ) between LAI4 and LAI5. There is no relationship between sprouting with other variables (LAI, canopy and site openness). The years 2013, 2015 and 2017 show that there is a very strong relationship between LAI (4 and 5) and (canopy and site openness) thus as LAI increases so canopy and site openness reduce.

### Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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