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Tree Species Composition of Kakum Conservation Area in Ghana

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Abstract: Vegetation assessment was carried out in a rainforest to document tree species composition and vegetation dynamics after logging operation. The study took place at Kakum Conservation Area, Ghana. Satellite images for logging period and after logging were acquired, processed and analysed. Trees in quadrats that were systematically distributed on transects were enumerated. Comparatively, the open canopy area had reduced while the closed canopy area had increased in size inside the forest. The farm areas at the peripheries had increased while those in the reserve area had been eradicated. In total 1,064 individual trees comprising 97 different species were enumerated. Tree species such as *Carapa procera*, *Celtis mildbraedii*, *Diospyros sanza-minika*, *Aulacocalyx jasminflora* and *Dacryodes klaineana* were relatively dense representing about 2% to 9% of the species present in the forest. The following species were examples of trees with higher relative dominance: *Celtis mildbraedii* (10%), *Trichilia prieuriana* (5%), *Tabernaemontana africana* (9%) and *Panda oleosa* (7%). The diversity of all trees was 3.9 (Shannon). The general conclusion is that the implementation of conservation rules has enhanced regeneration of many tree species. It is recommended that forest areas under convalescence must be put under strict conservation.

Keywords: Forest, Conservation, Tree Regeneration, Forest Canopy, Rainforest

1. Introduction

The loss of tropical forest is occurring at a rate of 9.4 million ha per year [1]. Particularly in West Africa, the forest cover has decreased by 1.5% per year from 1990 to 2000, with most recent surveys (in 2000) estimating forest cover at 850,790 km^2 [1]. The reduction of the forest cover often results in the fragmentation of large forest blocks [2]. Human activities that impact on tropical forest habitats can be classed broadly as agriculture, forestry, mining and human activities causing changes in climate indirectly leading to large scale forest disturbance [3]. Yet it is impossible to attribute the responsibility to the different factors since each is inevitably linked. For example, while timber operations may harvest relatively few trees (typically less than 10% of the canopy level trees) the timber operators construct roads and open areas up for agriculture and provide economic incentives for immigration to regions which increases human population, leading to forest degradation [4]. It has been estimated that 8% of the world's tropical forests was lost in the decade between 1980 and 1990 [5]. The rain forest of Africa originally covered 3,620,000km^2 prior to agricultural clearing but habitat alterations by people have drastically reduced the remaining area of forest [4].

Within Africa, tropical forests and animals they support are increasingly threatened by accelerating rates of forest conversion and degradation and by commercial and subsistence hunting and logging [6]. The West African lowland moist forests are among the most depleted forests in the tropics which may be as a result of the historically close links of these countries with Europe, by official policies and by high population densities [7]. Of the original moist forest zone of 31.3 million ha from Guinea to Ghana at the turn of the 20th century, some 8.7 million ha has remained by the end of the century. This is about a quarter and includes highly depleted forest areas still classified as forest but biologically not functioning as such [7]. Forestry has been put at par with mining activities, and the forest has been exploited as a non-renewable natural resource. Ghana has not been spared from this deforestation menace where the forest cover at the beginning of the 20th century was 2.1 million ha but has been reduced to 1.6 million ha at an annual rate of 2.19% [8].

Early silvicultural practices dealt a big blow to the forests of West Africa. At the beginning of the 20th century, foresters assumed that moist tropical forest could be managed in a sustainable fashion similar to European forests. On the basis of this assumption, too much forest has been lost as a consequence of opening up forests for exploitation. In 1945, the Tropical Shelter-wood System which involves the cutting of vines and the poisoning of unwanted species of medium-sized trees was introduced to manage the forests of Ghana and Nigeria. As a result, many valuable secondary species were destroyed. Between 1958 and 1970, 188 tons of sodium arsenate was used in Ghana to poison trees, and an area of 2,590 km² was managed under this system [9]. The system was abandoned when it was realized that natural regeneration under this system did not meet expectations [4].

Traditionally, conservation efforts have concentrated on protecting plant and animal populations through the establishment of national parks in pristine or semi-pristine habitats. Within the countries of Africa with closed canopy forest, an average of 3.2% of each country's area has been protected in national parks or similar protected areas [10]. The level of protection for biodiversity within different regions is clearly limited and constantly changing. The investment of different countries in national parks is dynamic, making it difficult to interpret the significance. As new parks are being created in some countries, in other countries parks are being degraded or even degazetted. For instance, in the northern part of Tai National Park (Cote d'Ivoire), 770km^2 (i.e., 21% of the total park area) was temporarily ceded for exploitation and is now heavily impacted [11]. Similarly, Bia National Park in Ghana was gazetted in 1974 to include 306km^2, but was reduced in size to 230km^2 in 1979 and further reduced to 77.7km^2 in 1980. The area excised from the park was re-classified as a Game Production Reserve or Resource Reserve, and has been largely opened up for timber production [4]. In contrast, the 360km^2 contiguous Kakum and Assin Attandanso Forest Reserves were re-gazetted as a National Park and Resource Reserve respectively in Ghana, and timber extraction was stopped in 1990. After a preliminary survey to establish the park, no comprehensive tree inventory has been conducted to document tree species composition and structure. With regards to the present rate of deforestation in Ghana and the other countries of Upper Guinea, the need to obtain information on species and population dynamics is very critical to the formulation of informed conservation and management plans. This study therefore, aims to assess the plant species composition, structure and dynamics of the vegetation after logging period (about 20 years).

2. Materials and Methods

2.1. The Study Area

Kakum Conservation Area (KCA) is located on longitude 1°30' W and 1°51' W and latitude 5°20'N and 5°40'N and is made up of the 210 km^2 Kakum National Park (KNP) and its twin 150 km^2 Assin Attandanso Resource Reserve (AARR). The Kakum forest and Assin Attandanso forests was legally regazetted as a national park and resource reserve respectively in 1991 under the wildlife reserves regulations (L.I 1525) under the administrative jurisdiction of the Wildlife Division of the Forestry Commission [12].

Timber exploitation started in the two reserves in 1936 with mahogany (*Khaya ivorensis*) being the principal species logged. Other timber species were included for exploitation from the 1950s until 1989 when the two reserves were transferred from the Forestry Department to Wildlife Department. As a result of an initial faunal survey the Kakum forest reserve was designated as a national park and Assin Attandanso forest reserve as a resource reserve in 1991 under Wildlife reserves regulations 1971, L.I. 710 as amended by Wildlife Reserves Regulations 1991, L.I 1525.

The Kakum and Assin Attandanso forests were demarcated between 1925 and 1926 and put into reserve and managed as forest reserves in 1931 and 1937 respectively as a source of timber production and protection of the watersheds of the Kakum and other rivers which supply water to Cape Coast and its surrounding areas by the then Governing Council of the Gold Coast. The conservation area has gone through a long period of disturbance as a result of commercial and subsistence hunting on one hand and logging on the other. Prior to timber exploitation, the reserve was more or less a virgin forest since there was no evidence that farming might have taken place in the reserve for any considerable length of time [13]. It has however been alleged that the local people mined gold and clay several years before the area was reserved [14].

The two reserves contained a good stock of economic and other tree species of both local and international importance for timber, which resulted in division of the reserves into concessions. All the traditional states leased portions of their forests to timber concessionaires. Hence at the time of converting the reserves into a conservation area, both reserves were held by the concessionaires as shown in Table 1 and Figure 1.

Table 1. *Areas of timber operation by various concession owners prior to the conversion of forest reserves into Kakum Conservation Area.*

Concessionaire	Area (km²)	Period of Lease	Name of reserve
S.K. Owusu Timbers	36.06	1/11/1971-31/12/1996	Kakum
Pan Sawmills Ltd.	60.32	24/8/1959-23/8/2004	Kakum
Takoradi Veneer and Lumber Co.	109.43	21/8/1988-20/9/2093	Kakum
Ghana Prime-wood Product Ltd	134. 62	1/7/1969-30/6/1994	Assin Attandanso
Gabrah Brothers Ent. Ltd	6.86	1/2/1986-31/1/1996	Assin Attandanso
R. T. Brisco/T. V. L. C	12.22	20/9/1948-19/9/1988	Assin Attandanso

Source: [15]

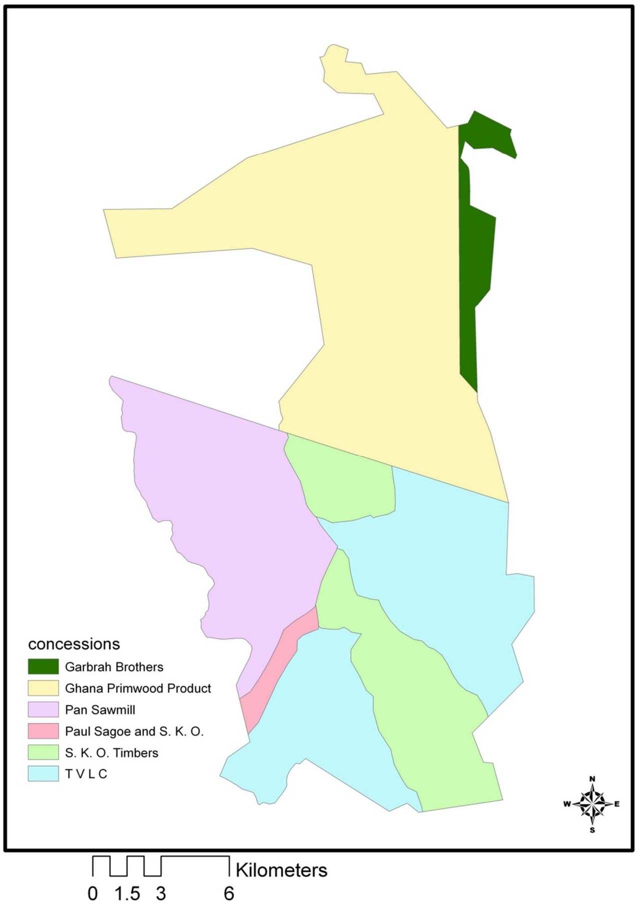

Figure 1. Map of Kakum and Assin Attandanso forest reserves showing areas occupied by the different concession owners before converting into a conservation area.

2.2. Vegetation Assessment Procedure

Satellite images were obtained from Landsat TM and ETM for 1986 and 2002 to represent the vegetation structure for the logging and conservation periods respectively. The scenes were path 195 Row 56 with a resolution of 30 meters. These images were processed to evaluate the dynamics of the canopy structure of the Kakum Conservation Area.

2.3. Plot Demarcation and Enumeration

To equalize sampling effort, the entire conservation area was divided into eight blocks (Plots A-H) of approximately 45km² each. These were Adiembra (A), Aboabo (B), Ahomaho (C), Afiaso (D), Kruwa (E), Antwikwa (F), Briscoe II (G) and Abrafo (H) protection camps. Each block was identified by the name of the nearest protection camp. In each block, two transects were laid at random at least 4km apart. Each transect was straight and run for a length of 4km long. Wooden beacons were placed at 100m intervals to indicate the distance covered during the census. Navigation was by compass and a Geographical Positioning System (GPS) to reach the starting point of each transect. Transects which followed compass lines were measured with a GPS and laid out with minimal cutting and disturbance [16]. A one minute of latitude or longitude grid consisting of cells, each was placed at random over the map of the study site. The intersections of the lines then formed the mid-point of each transect, and two transects chosen at random were laid in each block. Along each transect, 10 rectangular, 20 m by 10 m plots were demarcated one kilometre apart, in each forest block. Plots were measured using a 20-metre long nylon rope. Red ribbons were tied at the borders of the plot and any border tree with the greater part falling within the plot was enumerated.

The 3-person enumeration team was made up of a recorder, a tree spotter and an assistant. The main duty of the recorder was to record all information about any of the trees including identification and measurements. The tree spotter identified, measured and provided the information to the recorder while the assistant helped in measurements and specimen collection.

Moving in a clock-wise direction within a plot, all trees with girth at breast height (1.30m from the ground) equal to or greater than 31cm (>31cm, gbh), were identified, measured and recorded. The girth at breast height of each sampled tree was measured over bark with linear tape. However, there were some reasons to deviate sometimes from this standard "breast height" and execute the girth/diameter measurements at another position on the sample tree. These were as follows:

- Sample trees with buttresses: the stem diameter was measured approximately 30 cm above the buttress.
- Sample trees with aerial or stilt roots: the stem diameter was measured at 1.3m above the beginning of the stem.
- Forked trees were regarded as two sample trees if the fork was below 1.3m.

The girth values (gbh) were converted to diameter at breast height (dbh) values by using the formula:

$$D = \frac{C}{3.142} \qquad (1)$$

Where, D = diameter

C = girth

Tree height was defined as the total length from the ground up to the tip of the tallest vertical branch of the sample tree. As the measurement of the tree height is very time consuming, mostly not very accurate and also not very important to increase the precision of floral information, it was replaced with estimation of stem height in meters. An assistant stood at the foot of the sample tree and held a 2m-long ranging pole in his hand (when he lifted up the ranging pole while holding it on one end the upper part of the ranging pole shows the length of 4m). Relative to this given length, the total height of the sample tree was estimated.

The local name or common name of the tree species, girth at breast height, and estimated height were called out by the men who identified and measured trees to the recorder. To ensure that the right information had been recorded, the recorder in turn calls back the same information to the source. All trees were identified to species level. Specimens of unidentified trees were collected and sent to the Resource Management Support Centre's Herbarium in Kumasi (Ghana) for identification. Nomenclature was after [17].

2.4. Data Analysis

The plant community parameters were calculated as follows:

$$\text{Density} = \frac{\text{Total number of trees in all plots}}{\text{Total Sampled Area}} \quad (2)$$

$$\text{Relative Density} = \frac{\text{Number of particular species capturedx100}}{\text{Total number of captures of all species}} \quad (3)$$

$$\text{Relative Dominance} = \frac{\sum\text{Basal area for all trees of a particular species}}{\sum\text{Basal area for all trees pooled}} \text{X100} \quad (4)$$

Statistical analysis involved the use of Paleontological Statistics software package for education and data analysis, PAST [18], and Microsoft Excel. The Kruskal-Wallis test was used to evaluate statistical differences in medians of three or more variables while the Mann-Whitney U test was used to test the differences in densities of species between two variables.

Maps were processed using Arc Map (version 9.3) mapping software developed by Environmental Systems Research Institute (ESRI) (1999-2008). The satellite images after acquisition were processed using IDRISI Kilimanjaro and CHIPS software by first presenting a false colour composite for visual interpretation. An unsupervised classification was performed using five categories and later reduced to three, closed canopy forest, opened canopy forest and farms. The images were later smoothened with 5x5 filter kernel. Areas covered by the three categories of the canopy structures were calculated.

The diversity indices were calculated using Shannon, Simpson, Menhinick, Margalef, Fisher alpha and Beger-Parker. Kruskal-Wallis test was conducted to test the hypothesis that the tree densities occurring in the various blocks were the same. The satellite image of the canopy of coverage of the KCA for 1986, when the timber operation was in progress; and 2002, that is, 13 years after logging were used to evaluate the dynamics of the canopy coverage.

3. Results and Discussions

3.1. Forest Structure, Tree Species Composition, Relative Density, Relative Dominance and Vegetation Dynamics of KCA

The general structure of the forest vegetation has three major storeys: (i) lower storey comprising of the undergrowth and trees less than 10m high, (ii) the canopy layer involving trees from 10m to 20m, and (iii) the upper layer ranging from trees of 20m to 40m and the emergent layer of 50m and above. The study indicated that the number of trees reduced with increasing height classes at an exponential rate of -0.5158, and this explains about 71% of the relationship as shown in Figure 2 ($y = 651.86^{e-0.5158x}$, $R^2 = 0.7082$). This represents a forest undergoing natural regeneration after selective logging ban about 20 years (Figure 2).

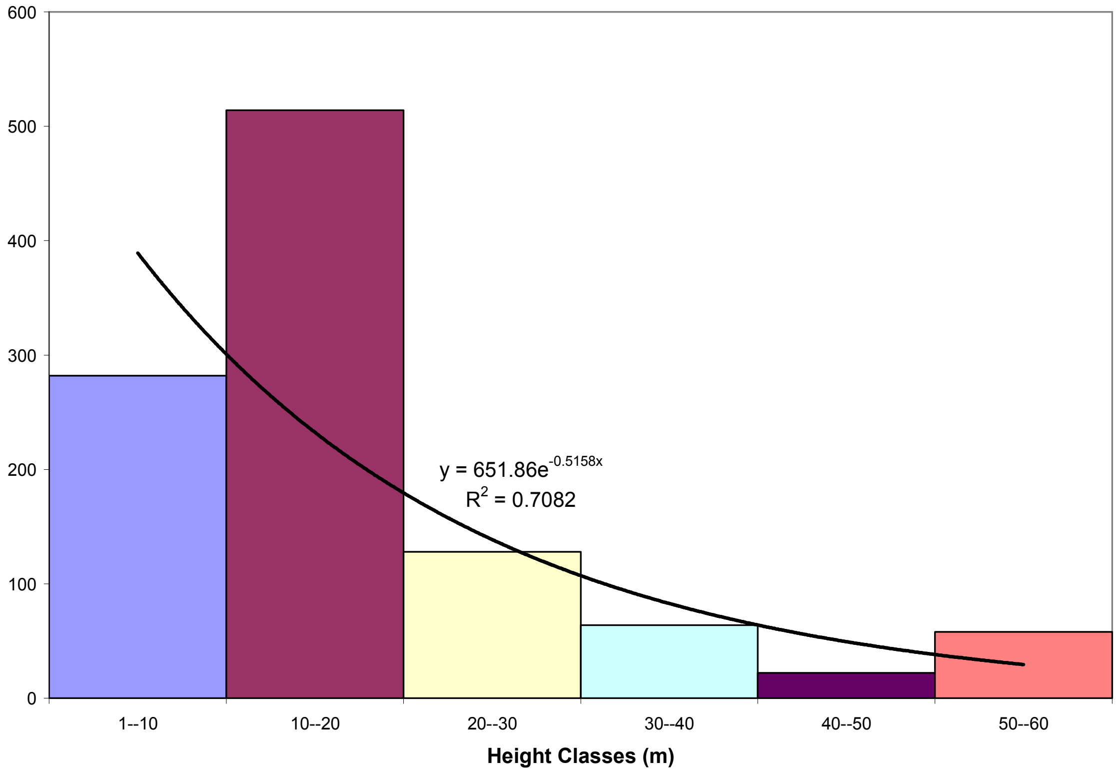

Figure 2. *Height classes of trees in relation to number of trees enumerated at KCA.*

In total 1,064 individual trees comprising 97 different species were enumerated within 62 plots. The results of diversity of trees are presented in Table 2.

Table 2. *Diversity indices of trees enumerated at KCA.*

Type of Index	Index	Lower Limit	Upper Limit
Taxa	97	-	-
Individuals	1064	-	-
Dominance	0.03152	0.02962	0.03574
Shannon	3.884	3.766	3.897
Simpson	0.9685	0.9642	0.9704
Menhinick	2.974	2.514	2.820
Margalef	13.77	11.62	13.06
Fisher alpha	25.95	20.72	24.16
Berger-Parker	0.08553	0.0731	0.1034
Equitability	0.8491	0.8444	0.8716

The mean density of trees enumerated in all the forest blocks were presented as number of trees per 0.20 ha as follows: Aboabo, 50 (SD=16.74), Abrafo, 51 (SD=17.18), Adiembra, 60 (SD=15.81), Afeaso, 37 (SD=13.51), Antwikwa, 56 (SD=6.25), Briscoe II, 57 (SD=15.67), Homaho, 92 (SD=20.79) and Kruwa, 41 (SD=12.57). The densities of trees in all the eight blocks were found to differ significantly (H=19.28, DoF=7, p=0.007). This could be attributed to a combination of factors such as logging history, past silviculture, edaphic factors, etc. The details of the relative species densities and relative dominance of the enumerated species have been presented in Table 3.

It was found that tree species such as *Carapa procera, Celtis mildbraedii, Diospyros sanza-minika, Aulacocalyx jasminflora, Dacryodes klaineana, Funtumia elastica, Myrianthus arboreus, Diospyros gabunensis, Nesogordonia papaverifera, Cola gigantean*, etc. were dense in the conservation area representing about two to nine percent of the species present in the forest. Tree species with higher relative density were not necessarily of higher relative dominance as the latter deals with diameter of the particular species. The following species were among others, examples of trees with higher relative dominance (Table 3): *Celtis mildbraedii* (10%), *Trichilia prieuriana* (5%), *Tabernaemontana africana* (9%) and *Panda oleosa* (7%).

Table 3. *Tree species composition, relative density and relative dominance enumerated in KCA.*

Family	Scientific Name	Local Name	Relative Density	Relative Dominance
Meliaceae	*Carapa procera*	Kwakuobese	8.6	1.90
Ulmaceae	*Celtis mildbraedii*	Esa	7.4	10.36
Ebenaceae	*Diospyros sanza-minika*	Osonoafe	4.8	0.38
Rubiaceae	*Aulacocalyx jasminflora*	Asabine	4.5	0.44
Burseraceae	*Dacryodes klaineana*	Adwea	4.0	0.03
Apocynaceae	*Funtumia elastica*	Fruntum	3.7	0.01
Cecropiaceae	*Myrianthus arboreus*	Nyankomabere	3.5	0.05
Ebenaceae	*Diospyros gabunensis*	Kusibire	3.4	0.82
Sterculiaceae	*Nesogordonia papaverifera*	Danta	3.0	0.05
Sterculiaceae	*Cola gigantea*	Watapuo	2.9	0.15
Sterculiaceae	*Triplochiton scleroxylon*	Wawa	2.9	0.14
Sterculiaceae	*Sterculia rhionpetala*	Wawabima	2.8	0.36
Meliaceae	*Trichilia prieuriana*	Kakadikro	2.8	5.03
Apocynaceae	*Tabernaemontana africana*	Oboonawa	2.5	9.17
Olacaceae	*Strombosia pustulata*	Afena	2.3	0.02
Meliaceae	*Trichila monadelpha*	Tanro	1.9	0.01
Sterculiaceae	*Cola chlamydantha*	Tananfre	1.8	0.05
Chrysobalanaceae	*Parinari excelsa*	Afam	1.7	1.28
Combretaceae	*Terminalia superba*	Ofram	1.6	0.36
Malvaceae	*Desplatsia chrysochlamys*	Osonowesamfe	1.5	0.17
Meliaceae	*Entandrophragma angolense*	Edinam	1.5	0.63
Euphorbiaceae	*Drypetes aubrevillei*	Duamako	1.3	0.14
Leguminosae	*Parkia bicolor*	Asoma	1.2	0.04
Pandaceae	*Panda oleosa*	Kokroboba	1.1	7.29
Leguminosae	*Piptadeniastrum africanum*	Dahoma	1.1	0.20
Meliaceae	*Guarea cedrata*	Kwabohoro	1.0	0.01
Leguminosae	*Baphia pubescens*	Odwenkobire	0.9	0.14
Malvaceae	*Mansonia ultissima*	Oprono	0.9	0.02
Caesalpiniaceae	*Afzelia africana*	Papao	0.8	0.31
Euphorbiaceae	*Discoglypremna caloneura*	Fetefre	0.8	0.56
Apocynaceae	*Funtumia africana*	Okae	0.8	0.60
Sapotaceae	*Gluema ivorensis*	Nsudua	0.8	0.08
Lecythidaceae	*Petersianthus macrocarpus*	Esia	0.8	7.30
Violaceae	*Rinorea oblongifolia*	Mpawoutuntum	0.8	0.06
Violaceae	*Rinorea welwitschii*	Apose	0.8	1.85
Leguminosae	*Daniellia ogea*	Hyedua	0.7	4.71

Family	Scientific Name	Local Name	Relative Density	Relative Dominance
Euphorbiaceae	*Uapaca guineensis*	Kuntan	0.7	0.03
Rutacee	*Zanthoxylum gilletii*	Okuo	0.7	0.69
Moraceae	*Antiaris toxicaria*	Kyenkyen	0.6	2.91
Euphorbiaceae	*Bridelia atroviridis*	Opamkotokrodu	0.6	0.51
Moraceae	*Milicia excelsa*	Odum	0.6	4.49
Sterculiaceae	*Sterculia oblonga*	Ohaa	0.6	0.98
Sapindaceae	*Blighia sapida*	Akye	0.5	0.19
Leguminosae	*Bussea occidentalis*	Kotoprepre	0.5	0.07
Malvaceae	*Celba pentandra*	Onyina	0.5	0.96
Sterculiaceae	*Cola caricifolia*	Ananseaya	0.5	0.10
Sterculiaceae	*Cola nitida*	Bese	0.5	0.45
Leguminosae	*Crudia gebonensis*	Samantaa	0.5	0.02
Moraceae	*Ficus sur*	Nwadua	0.5	0.15
Simaroubaceae	*Hannoa klaineana*	Fotie	0.5	0.03
Guttiferae	*Pentadesma butyracea*	Abotoasabie	0.5	0.91
Moraceae	*Treculia africana*	Ototim	0.5	0.20
Annonaceae	*Xylopia quintasii*	Obaa	0.5	0.20
Sapotaceae	*Aningeria robusta*	Asanfina	0.4	2.43
Leguminosae	*Dialium guineense*	Asenaa	0.4	0.15
Euphorbiaceae	*Uapaca corbisieri*	Kuntanmiri	0.4	0.09
Verbenaceae	*Vitex microntha*	Otwentrowanini	0.4	0.06
Capparaceae	*Buchholzia coriacea*	Konini	0.3	0.04
Ulmaceae	*Celtis philippensis*	Premprensa	0.3	0.03
Sapotaceae	*Chrysophyllum africanum*	Sutabene	0.3	1.36
Leguminosae	*Distemonanthus benthamianus*	Bonsamdua	0.3	0.09
Irvingiaceae	*Irvingia gabonensis*	Abesebuo	0.3	0.02
Pandaceae	*Microdesmis keayana*	Ofema	0.3	6.79
Cecropiaceae	*Myrianthus libericus*	Nyankomanini	0.3	0.00
Rubiaceae	*Nauclea diderrichii*	Kusia	0.3	5.48
Rubiaceae	*Oxyanthus unilocularis*	Kwaetawa	0.3	0.18
Sapotaceae	*Tieghemella heckelii*	Baku	0.3	0.18
Mimosaceae	*Albizia zygia*	Awienfoosamina	0.2	0.98
Annonaceae	*Annickia polycarpa*	Duasika	0.2	0.02
Olacaceae	*Coula edulis*	Bodwue	0.2	0.25
Meliaceae	*Entandrophragma cylindricum*	Penkwa	0.2	2.32
Meliaceae	*Entandrophragma utile*	Efobrodedwo	0.2	0.03
Bignoniaceae	*Kigelia africana*	Nufuten	0.2	0.16
Irvingiaceae	*Klainedoxa gabonensis*	Kroma	0.2	0.02
Anacardiaceae	*Lannea welwitschii*	Kumanini	0.2	0.02
Euphorbiaceae	*Macaranga barteri*	Opam	0.2	0.01
Myristicaceae	*Pycnanthus angolensis*	Otie	0.2	0.18
Mimosaceae	*Albizia adainthifolia*	Pampena	0.1	0.01
Apocynaceae	*Alstonia boonei*	Nyamedua	0.1	0.00
Anacardiaceae	*Antrocaryon micraster*	Aprokuma	0.1	0.27
Leguminosae	*Baphia nitida*	Odwen	0.1	0.01
Leguminosae	*Cylicodiscus gabunensis*	Danya	0.1	0.16
Leguminosae	*Cynometra ananta*	Ananta	0.1	0.11
Meliaceae	*Entandrophragma candolai*	Penkwa-akoa	0.1	3.05
Guttiferae	*Garcinia kola*	Tweapeakoa	0.1	0.52
Sapotaceae	*Chrysophyllum albidum*	Akasa	0.1	0.57
Ulmaceae	*Holoptelea grandis*	Nakwa	0.1	0.04
Leguminosae	*Hymenostegia afzelii*	Takrowa	0.1	0.29
Sapindaceae	*Lecaniodiscus cupanioides*	Dwindwira	0.1	0.22
Guttiferae	*Mammea africana*	Bompagya	0.1	2.44
Lecythidaceae	*Napoleonaea vogelii*	Obua	0.1	0.70
Olacaceae	*Ongokea gore*	Bodwe	0.1	0.03
Euphorbiaceae	*Ricinodendron heudelotii*	Wama	0.1	0.09
Sapotaceae	*Synsepalum msolo*	Asaba	0.1	0.18
Combretaceae	*Terminalia ivorensis*	Emire	0.1	2.40
Meliaceae	*Trichilia tessmannii*	Tanronini	0.1	0.24
Leguminosae	*Xylia evansii*	Samantaa	0.1	0.20

3.2. Changes in Canopy Area

The result of the analysis of satellite images indicated that in 1986, out of the total canopy coverage of 295.8 km² the opened canopy area was 80.6%, closed canopy area was 18.4% and farms at the peripheries of the conservation area covered 1.03% as shown in Figure 3.

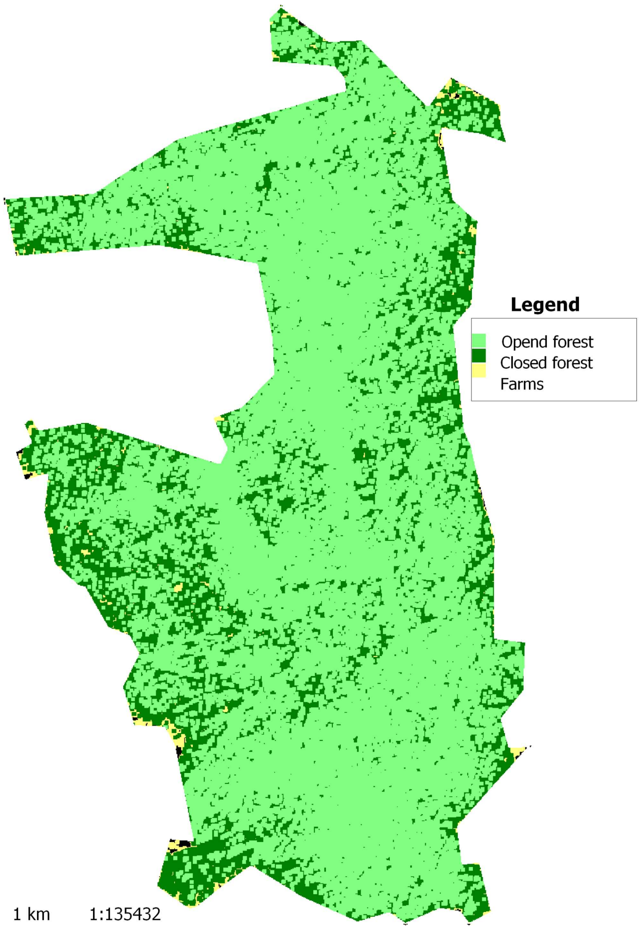

Figure 3. *Satellite image of KCA in 1986 during the period of logging.*

On the contrary, in 2002, out of 302.9 km² the open canopy area was found to be 58.4%, while the closed canopy area was 37.4% and the canopy coverage of the farms around the peripheries of the conservation area was 4.1% as shown in Figure 4.

Comparing the two periods, it could be inferred that the open canopy area had reduced while the closed canopy area had increased in size inside the forest. The farm areas at the peripheries had increased while those in the reserve area had been eradicated (Figure 4). After the status of the area has been changed from logging area to conservation area, all farm activities were ceased in the reserved area. Subsequently, the forms were relocated at the peripheries.

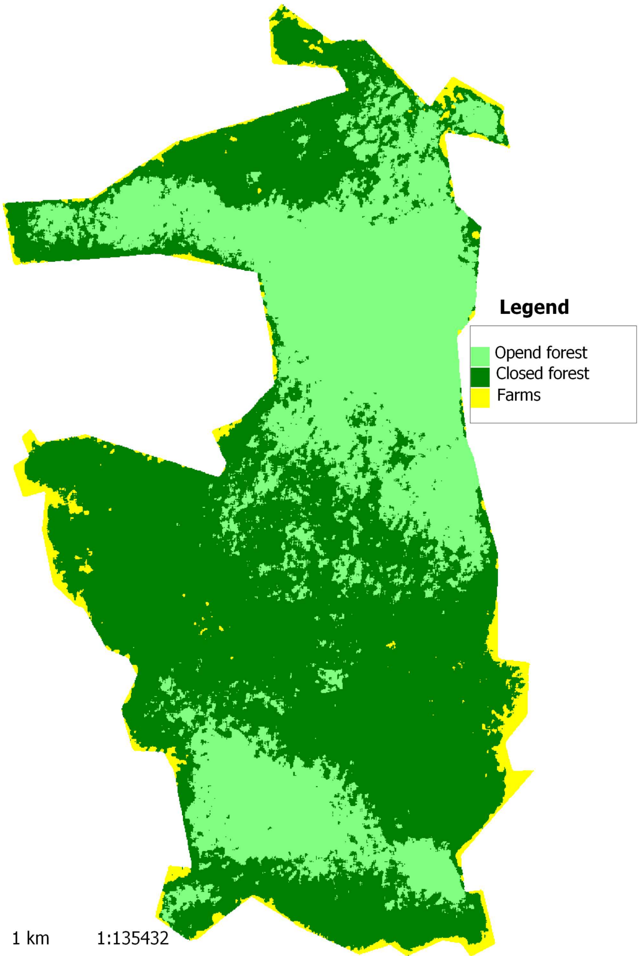

Figure 4. *Satellite image of KCA in 2002, thirteen years after logging.*

3.3. Habitat Structure and Species Composition

The structure of the forest vegetation in KCA conforms to the structure of a normal old-growth rainforest as stated by [19] that in almost every old-growth rain forest free of major external disturbances, small trees greatly outnumber large ones. The overall spatial pattern of tree stems in most rainforests differs little from random [20]; [21]. However, the structure of the forest of Kakum could have resembled young re-growth forest as the last logging activities ended only about 20 years ago (1989) rendered it to lack large diameter trees for the total stem densities of relatively small diameter class to be higher. Therefore, the structure of this could be attributed to the fact that the logging operations were done through systematic selective exploitation. The loggers removed trees within 70cm diameter classes and above at reference height. The systematic selective exploitation was based on the preference by international and national buyer for certain species. It was only the best grade timber trees which were taken. The largest trees were first taken, going progressively down in size until the allowable yield was obtained. The stock was then distributed over each compartment of 65ha or 1.3 square km [7]. The idea was that an even distribution would ensure sufficient seed regeneration and this might have favoured animals that depend on such trees for survival. Past logging operations have a great influence on the variations in structure and composition of the forest as indicated by [19] who stated that differences in forest structure occur at all scales both in the physical environment and in the biological communities.

The vegetation classification used in this study (according to structural complexity) proved to be adequate for a general description of the overall status of the vegetation. After the logging operations during the last decades, the vegetation of the KCA appeared as a mosaic of patches of variable structure. Repeated logging created frequent gaps. At the time this study was carried out, the frequency of occurrence of gaps was high, but not higher than in undisturbed forests where natural gaps constitute 9% of the forest area [22]. What differed most from matured forest, was the high proportion of patches which were in an early phase of successional development of the forest. Patches where the foliage was more evenly distributed along a vertical profile only made up 24% of the surface. This clearly shows that the overall forest condition is critical. [23] defined characteristics for the evaluation of Ghanaian forests based on the vegetation structure. According to their scale ranging from one to six (one - excellent, six – no significant forest left), the score two has to be assigned to the forest of KCA.

With the 97 species belonging to 32 families, the most common families were Leguminosae, Meliaceae, Sterculiaceae, and Euphorbiaceae which contributed 13.2%, 9.3%, 8.2%, 7.2%, and 6.2% respectively to the species composition of the vegetation in KCA. The remaining families contributed from 4.0% to 1.0% species to the ecosystem. There is therefore higher diversity in the phenology of the plants [24], which could imply that at any time there would be fruit available for the frugivorous animals.

4. Conclusions

From the result of the study it could be concluded that the vegetation of KCA is made up of high diverse species of tree composition with diverse dimensional classes. Trees with short height and sizes outnumber the trees with tall heights and large size, which follows the normal structure of a typical healthy rainforest. In other words, the number of trees reduces with increasing height and size (like an invented 'J' shape) which indicates the good health of the forest. The structure of the forest can be classified as the nature of a forest under natural regeneration 20 years after logging. The logging was selective and the target was on few trees classified as 'economic trees' at that time. Trees that were not economic at the time are still growing in the reserve hence a relatively large number of emergent layer trees enumerated. Today, logging of economic trees is not allowed in the conservation area and they continue to contribute to the food production of wildlife such as *Aningeria robusta*, *Chrysophyllum albidum*, *Parkia bicolor* etc.

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