**KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, GHANA**

**INSTITUTE OF DISTANCE LEARNING**

**ENVIRONMENTAL SCIENCE**



# PATTERNS OF WOODY PLANT SPECIES RICHNESS, DIVERSITY AND STRUCTURE ALONG A DISTURBANCE GRADIENT IN THE ATIWA RANGE FOREST RESERVE, EASTERN REGION, GHANA

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**JULY, 2011**

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**A THESIS PRESENTED TO THE DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY, COLLEGE OF SCIENCE, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF SCIENCE IN ENVIRONMENTAL SCIENCE**

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**JULY, 2011**

## DECLARATION

I hereby declare that the work now submitted as a thesis for the award of Master degree in Environmental Science, is the result of the research I conducted. References made to the work of other authors have dully been acknowledged.

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# DEDICATION

I dedicate this work to my niece Anita Kpontsu

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To God is all the glory!

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# ABSTRACT

The Atiwa Range Forest Reserve is one of the biodiversity hotspots in Ghana, but no comprehensive study has been carried out to assess the role of human disturbance on plant biodiversity in the area. The study was therefore, carried out to determine the effects of human disturbance on the patterns of woody plant species richness, diversity and structure in the forest. The study was carried out in three forest stands with varying human disturbance (Non-disturbed, moderately disturbed and heavily disturbed forests), within thirty 50 m × 50 m plots (10 plots in each forest stand). A total of 142 woody species belonging to 114 genera and 51 families were identified in three forest stands in the forest reserve. Trees constituted the most dominant woody plant species identified in the forest with *Cedrela odorata, Allamblakia floribunda and Albizia zygia* being the overall dominant species identified.

In all the life forms, species richness decreased from the non-disturbed forest through moderately disturbed forest to the heavily disturbed forest. Tree diversity declined significantly with increasing disturbance. Liana diversity also differed significantly between the non-disturbed forest and heavily disturbed forest, and the moderately disturbed forest and heavily disturbed forest. For shrubs, the non-disturbed forest was significantly more diverse than the heavily disturbed forest while diversity between the other forest pairs did not vary significantly. The mean basal area of trees in the non-disturbed forest was higher than those of the other forest blocks. The mean liana basal area decreased with increasing disturbance. Plant densities also differed significantly among the forest stands. The pattern of plant density for both trees and lianas was similar to that of basal area of trees. The diameter distribution pattern for trees was irregular in all the forest types and that for lianas in the non-disturbed and moderately disturbed forests followed the inverted J shape. Canopy cover of trees was high in the non-disturbed forest than in disturbed forests. The disparity in the forest areas under studied is due to frequent human disturbances going on in the forest, thus compromising the ‘health’ of the Atiwa Range Forest Reserve.

# CHAPTER ONE

## 1.0 INTRODUCTION

### 1.1 Background of Study

Forests are integral part of Ghana's natural heritage. The sector provides livelihoods for many forest-fringe communities and employments both direct and indirect to people (Banahene, 1997; ITTO, 2006). Forests provide potential habitat for invertebrates wildlife and soil micro-organisms that have not been well studied to date. Forests provide recreational, aesthetic and educational opportunities for people in Ghana. Forest reserves provide reference sites for objective assessment of the sustainability of forest management practices (Norton, 1991) and are essential for practicing adaptive resource management (Walters and Holling, 1990). It also provides many ecosystem services many of which are vital to the survival of man on earth.

West African mountain forests are especially rare and important to protect because they contain unique ecosystems with exceptional species richness and high levels of endemism (RAP, 2007). Knowing species richness patterns is crucial to provide insights to environmental planners, nature reserve designers, ecologists, and botanists (Sang, 2009). The structure of plant community in many natural ecosystems is largely determined by the disturbances, which occur quite frequently (White, 1979; Vogl, 1980; Armesto and Pickett, 1985). An understanding of species distribution patterns and the resulting spatial patterns of biodiversity is fundamental to the study of not only evolutionary biology but also of conservation biology (Sang, 2009).

Atiwa forest has an excellent natural wealth and its plant communities are classified by botanist as upland evergreen forest (RAP, 2007). Over the last 90 yrs, Atiwa has been recognized as an important reservoir of biodiversity and has been officially classified in various way: as a

National Reserve in 1926, a Special Biological Protection Area in 1994, a Hill Sanctuary in 1995 and as one of Ghana's 30 Globally Significant Biodiversity Area (GSBAs) in 1999. Unfortunately, unregulated, illegal logging poses a serious threat to the survival of many parts of the Atiwa forest (RAP, 2007).

## 1.2 Problem Statement and Justification

In spite of the important roles forests play in the life of mankind, man continues to destroy it through diverse anthropogenic activities such as fires (Veblen and Lorenz, 1987) animal grazing (Carabelli *et al*., 2006), cutting mature trees for timber, collection of fuel wood (Terborgh, 1992), farming and small scale mining. Disturbances created by these activities influence forest dynamics and tree density (Hubbell *et al*., 1999). They also impact negatively on the forest leading to its destruction and loss of biodiversity (Nepstad *et al*., 1999). Atiwa Forest Reserve which is one of the floristically and biodiversity endowed forests in Ghana and has a distinctive vegetation, has not been spared from this menace. There are many reports of threats to this unique forest by illegal logging and farming activities (RAP, 2007). Despite these alarming reports, there is little information on the extent to which the human activities have affected the integrity of the forest. Additionally, the exact effects of the disturbances on various aspects of biodiversity in the area are unknown.

Such information are necessary in developing proper strategies aimed at conserving disturbed forests. They form the basis for monitoring the state of reserves (Tilman, 1988; Ssegawa and Nukunu, 2006) and projecting changes in vegetation cover. Thus, the outcomes of this study would be important to the management of the Atiwa Forest Reserve for making informed decisions about conservation of the forest.

## 1.3 Aim of the study

The main aim of the study was to determine the effects of anthropogenic disturbances on the patterns of plant species richness, diversity and structure.

The specific objectives were to:

- identify plant species within three forest blocks which differ by the degree of disturbance they experience (i.e. non-disturbed, moderately disturbed and heavily disturbed forests).
- determine plant species diversity within the forest blocks.
- determine the structure of the forest by measuring plant height, diameter at breast height, basal area and density, and canopy cover within the forest blocks.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

### 2.1 Forest biodiversity in Ghana

Biological diversity is the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems (De Laat, 2010). Biodiversity is a very complex and multifaceted term and many scientists in various ways have defined the term and each definition reveals a new dimension and emphasizes a different aspect to suit the work at hand (Nangendo, 2000). Everyone, from farmers to different companies such as, relies on sustainable, healthy and well managed forests. This is because these natural resources are fundamental to Ghana's social and economic development and therefore must be protected and sustainably managed.

According to Allotey (2007), Ghana is part of the Upper Guinea forest ecosystem region of West Africa, which contains exceptionally diverse ecological communities of forest habitat providing refuge to numerous endemic species. This area is one of the world's 25 biological richest and most endangered terrestrial eco-regions but a variety of socio-economic factors have led to forest fragmentation which threatens the variability of biodiversity in the region (Allotey, 2007).

### 2.2 The current state of forest in Ghana

Ghana was richly endowed with forest resources which were vital for the development and future prosperity (Boon *et al* 2009). The degradation of forests and the loss of biodiversity in the country have increased sharply in recent decades (Dixon *et al.*, 1996). Ghana's total forest zone is currently estimated at 81,342 km$^2$ and accounts for about 40% of the total land area, out of which about 17,845 $km^2$ are known to be under reservation. The reserved forests are made up of 11,590 $km^2$ of production forests; 4,323 $km^2$ of protection forests; and about 1,980 $km^2$ of game production reserves (Siaw, 2001). Ghana, like many tropical countries, continues to lose its remaining closed forests at an alarming rate. According to Allotey (2007), the area of undisturbed forest has reduced to less than 25% of its original value and now exists in fragmented patches estimated to be about 20 to 524 $km^2$.

Biodiversity in confined areas (reserves) are in very good state, but in some reserves and off-reserve areas, the conditions are at a reasonable to a deplorable situation. Some biodiversity elements (particular species) of the forests have been noted to have declined in their species richness, density, diversity etc (Bakarr *et al*., 2001). Land use and land use systems have put great pressure on biodiversity in the forest in the country. Land use is series of operations on land, carried out by humans with the intention to obtain products and/or benefits through using land resources such as settlement citing, traditional farming practices of food and cash crops with the use of fire and Land use systems such as shifting cultivation, mono cropping, land rotation, fallow etc (De Bie, 2000) are some of the major activities that put pressure on forest biodiversity. However, the pressures to accommodate ever-expanding human population needs to which the forest is exposed in most tropical countries occur also in Ghana and serious problems have arisen (Hawthorne and Jongkinds, 2006).

Habitats are also being degraded through activities such as misapplication of chemicals, misuse of fire and over harvesting of genetic resources. Forest resources are over exploited through logging, excessive cutting of trees in stressed environments for fire wood as energy source and harvesting of other non timber products. These are some of the effects of the pressure these ecosystems are made to experience on daily basis. Records do indicate the existence of relatively undisturbed forests harboured abundant biodiversity (Alpert, 1993), which protected fragile soils

(UNEP, 2002; FAO, 2007), and regulate the supply of scarce water resources (Glantz and Katz, 1985). However, deforestation and global climate change impacts are significantly causing a rapid loss of biodiversity in the country. The forests are now characterised by excessive harvesting of logs, a reduction in standing volumes of species, species depletion and loss of biodiversity. Allotey (2007) stated in his study that about 14% of the total permanent forest reserves in Ghana are now without adequate forest cover. National parks and other protected areas of Ghana's territory, contain some of the richest biodiversity, but are assigned for timber production. If managed effectively, these forests could maintain their biodiversity values including viable populations of large forest-dwelling species, such as elephants, bongos, and primates; some of which are rare, threatened or endangered.

Ghana's rural population in 1997 was 63.1% of a total population of 18.3 million with an annual rate of change (1995-2000) of 2.3 % (FAO, 2003). The major employment sectors in Ghana are agriculture, services and industrial sectors. About 40 % of total income for all Ghanaians is derived from agriculture (Siaw, 2001). The economic value of Ghana's forest resources lies in the revenues derived mainly from exploitation of its wealth of commercial timbers and the considerable volume of commercial woods and other non-timber forest products (NTFPs). According to Siaw (2001), Ghana's forestry sector contributes 6% of Ghana's energy requirements derived from its forest resources. This is because the majority of rural dwellers burn wood fuel for cooking. Underlying these deforestation driving forces are forest policy failures, unrealistic forest fee regimes, external prices of timber, weak institutional structures, and population pressures (FAO, 2001).

## 2.3 Threats facing forest biodiversity in Ghana

Every forest has its own threats that it faces. Threats of a particular forest might be different from the other due to several factors such as; population density in the forest catchment area, invasive alien species, specific resource that is present in the forest etc. The biodiversity of Ghana forests is under threat due to the quest for socio-economic development, especially urbanization, industrialization and tourism (Allotey, 2007). Logging, mining, hunting, and human population growth are placing extreme stress on tropical forests and are thereby threatening many species (Bakarr *et al*., 2001; Poorter *et al*., 2004; Ernst and Rodel 2005; Ernst *et al*., 2006; McCullough *et al*., 2007; Hillers *et al*., 2008). Although these activities have a devastating effect on biodiversity, we should not forget that many species will sooner or later come back to the regenerating forests. In Ghana, one of Africa's core forest regions, 94% of the forest reserves are in an alarming state, as a result of unsustainable harvesting in the past decades while the remaining forests are extremely patchy and/or degraded (De Laat, 2010).

The total conserved area is about 15 million hectares. It is estimated that 20,000 hectares per annum of the conserved area is lost to agriculture, or through bush fires and other human activities (Siaw, 2001). In densely populated communities, the populace encroach the reserves to graze animals or obtain fruits and dead wood for fuel. Mining for minerals is also a major threat to forests lands rich in mineral. Collection of firewood and burning of charcoal are major sources of income for members of some communities. Trees and shrubs harvested for these purposes are not replaced. This leads to environmental degradation and loss of genetic resources. Economic trees, shrubs and grasses go up in flames every year due to bushfires. According to Dwumfour, (1994), an assessment by FAO indicated that about 50% of Ghana's vegetation cover fell victim to bush fires, 35% of standing crops (cocoa, oil palm etc.) and cereals (sorghum, millet, maize) were also destroyed in the same year. If the current trend continues unchecked, most parts of country especially Northern Ghana will easily turn to a desert.

Many years ago, forest product gathering, which is for a subsistence society, has been a major form of land use. This has become significantly commercialised since demand for these forest products has risen sharply with the increase in population. Therefore, Ghana experiences levels of resources utilization that far exceeds the productive capacities of the exploited species to sustain exploitation. A number of mushroom species and African snail, which used to constitute a major protein source in the past, have become increasingly scarce. Rattan and cane species used in the rattan/cane craft are becoming rare (Dwumfour, 1994).

De Laat (2010) stated some of the causes of threats to biodiversity in his study as deforestation due to expansion of farm land into forest areas, use of wrong farming practices that reduce productivity and threaten biodiversity, farmers do not have encouragement for planting and managing trees on farms, insufficient information about alternative, tree-based income opportunities for farmers among government, extension service providers, and NGOs. Wildlife is declining in farm areas due to overhunting and loss of habitat. In Ghana, meat from wild animals is a major source of protein and hunting is important for rural subsistence. In many areas over hunting has contributed to sharp decline in species numbers and diversity. Hunting both within and outside wildlife and forest reserves threatens several species, particularly primates, with local extinction. Desertification is largely brought about through deforestation resulting from farming practices and fuel wood collection and is a major concern in the semi-arid parts of the country. Degradation and loss of habitat on farm land as a result of mining activities, represents a serious threat to forest in certain areas, several of which are of high conservation interest.

## 2.4 Disturbances in forest ecosystems

Disturbance is any relatively discrete event in time that disrupts ecosystem, community or population structure and changes resources, substrate availability or the physical environment (Hill and Hill, 2001). Disturbance could be as a result of human activities or natural causes. These forms of disturbances severely threatened biodiversity (Todaria *et al.,* 2010). Natural disturbance varies in spatial extent, temporal frequency and magnitude (Hill *and Hill*, 2001). Natural disturbance can be in the form of fire, wind, etc among these, wind is the major agent of natural disturbance that renews and modifies forests. Collection of leaf litter for animal bedding and composting, grazing and collection of fuel wood, harvesting of trees for timber, collection of raw materials for local industries etc (Todaria *et al.,* 2010) are all forms of human disturbances. These human disturbances do not only influence the soil nutrient and water conditions but also influence climatic conditions of an area. At high levels of disturbance, due to human impacts like deforestation, all species are at risk of going extinct (Lalfakawma *et al.,* 2009). Comparing natural disturbances with human disturbances, repetitive process of the former have more effect on diversity, structure and species richness of plants in forests than the later. Ecologists think that if human effects were eliminated, the forest would return to its natural state (Bunnell and Chan-McLeod, 1997).

Forest resources are the main source of livelihood of the people living in forest communities (they harvest and sell these resources for money). This coupled with the increasing population trend over the past few years, has led to the massive exploitation of natural forests (Todaria *et al.,* 2010). According to Pitchairamu *et al*. (2008), more and more species are threatened due to land-cover and land-use changes all over the world understanding the impact of disturbance on vegetation and the resilience of plant communities to disturbance is imperative to environmental management (Speed, 2010).

## 2.5 Human activities causing biodiversity loss in tropical forest ecosystems

### 2.5.1 Habitat destruction

Habitat destruction has been one of the primary threats to the world's biodiversity (Pimm and Raven, 2000). It alters or eliminates the conditions needed for plants and animals to survive. Some of the factors responsible for habitat loss include mining, logging, slash-and-burn agriculture, etc.

### 2.5.2 Mining

Despite the significant contribution of mining to the economies of many nations, its activities result in the destruction of fauna and flora habitats, changes in topography, hydrology and landscape stability (see Boateng, 2009). Vegetation clearance during mining presents one of the most significant threats to the conservation of biodiversity (Sarma, 2005; Adjei, 2007; Valerie, 2007). It is estimated that, about 40 % of the global terrestrial vegetation had been exchanged for mineral exploration, exploitation, and infrastructural developments (Noble *et al*., 1996). In Ghana, 22,000 hectares of the existing forest cover are lost annually as a result of mining and other anthropogenic disturbances (Hawthorne, 1990). Apart from exposing the soil to higher temperatures, vegetation clearance depletes the soil of nutrients required for vegetation growth (Lu *et al*., 2002), destroys key ecological processes and promotes forest and habitat fragmentation into isolated, smaller habitat patches (Saunders *et al*., 1991).

### 2.5.3 Logging

Logging activities may result in the disappearance of species thus reducing species diversity and the potential of the forest (Abdullhadi and Surkardjo, 1981). Uncontrolled logging has considerable impacts on biodiversity conservation, forest structure and species composition and may lead to loss and fragmentation of forests (Foaham and Jonkers, 1992). Several studies have reported declines in numbers of large tree species after logging (Okali and Ola-Adams, 1987; Primack and Lee, 1991). Even when there is a minimum of mechanization and relatively little incidental damage during extraction (Ganzhorn *et al*., 1990), there are declines in over storey tree size, increased abundance of a few small-stemmed species, and a decrease in larger commercial species even several decades after a logging event. In other cases, the overall number of tree species remains the same but species composition changes in favour of pioneer species (Primack and Lee, 1991). Logging reduces canopy cover and produces large amounts of litter fall and other dead phytomass. This fuel material renders fragments more susceptible to human-induced forest burning (Cochrane and Schulze, 1999, Nepstad *et al*., 1999), which is often triggered by ignition sources in adjacent cattle pastures, slash-and-burn plots, and commercial crops (Holdsworth and Uhl, 1997; Gascon *et al.,* 2000; Barlow and Peres, 2004).

### 2.5.4 Slash-and-burn agriculture

The practice of slash-and-burn agriculture consists of clearing plots from the forest and allowing the cut vegetation to dry, then burning, and finally planting crops in the ashes (Sponsel, 2005). Lands are used for a few years and then are gradually abandoned to natural vegetation for fallow periods of up to 20 or more years. According to Sponsel (2005) slash-and-burn is practiced by 240 to 500 million people on nearly one-half of the land area of the tropics and requires as much as 15-30 hectares to feed one person due to the lengthy fallow period generally required. In the past, slash-and-burn agriculture created little or no concerns as human populations were generally low. In recent years, however, the practice has become unsustainable in the light of the vast areas of land required by the exploding human populations. Slash-and-burn agriculture accounts for half the world's rainforest destruction (Colchester and Lohmann, 1992).

Forest burning depletes the soil seed bank (Cochrane and Schulze, 1999) and increases rates of seedling, sapling, and adult mortality due to lethal thermal stress and competition with lianas, vines, and early successional species (Kauffman, 1991; Holdsworth and Uhl, 1997; Peres, 1999; Perez-Salicrup, 2001). Fire frequency and intensity is often cited as an important predictor of forest diversity in different tropical dry forest regions of the world (Swaine, 1992; Fensham, 1995). Fires in tropical dry forests lower species diversity by selecting for fire resistant species or early successional plants, and destroy understory shrubs and lianas that make up a significant proportion of all woody plants in tropical dry forests (Swaine *et al*., 1990; Medina, 1995).

### 2.5.5 Plant invasion

Though plant invasion in itself is not a human cause, certain human activities of man promote the colonization and subsequent establishment of invasive alien species. Plant invasion is increasingly being recognized as a major threat to both natural and human-exploited ecosystems worldwide (Soule, 1990; Westman, 1990). Invasive plants disrupt ecosystems, compete with native species and cause economic losses (Hobbs and Humphries, 1995; Vitousek *et al*., 1996; DiTomaso, 2000; Levine *et al*., 2003; Dukes and Mooney, 2004; D'Antonio and Hobbie, 2005). In Ghana invasive plants together with other anthropogenic disturbances have been implicated for reducing the original stretch of tropical forest in the country by about 90 % (CSIR, 2002). Invasive plants can alter plant community structure and ecosystem function (Vitousek *et al*., 1987).

### 2.5.6 Overexploitation of species

Many tropical forests are undergoing drastic long-term and deleterious changes due to overhunting of large mammals (Redford, 1992), thus creating an 'empty forest' of herbivores and carnivores. According to Dirzo and Miranda (1990, 1991), even though defaunated forests may show higher density of understorey species, plant diversity is lower than in forests that are not defaunated. Herbivory therefore promotes diversity (Wells, 1971). Eliminating herbivores, therefore will shift the competitive balance in favour of some plants over others, and also reduce overall floristic diversity. Hunting for bush meat has recently caused the extinction of one non-human primate subspecies, Miss Waldron's colobus (*Piliocolobus badius waldroni*) (Oates *et al*., 2000), and the endemic Togo mouse (*Leimacomys buettneri*) may also be extinct (Kingdon, 1997). Overexploitation of certain plant species is also driving those plants species into extinction in certain areas. For example *Milicia sp* and *Nauclea diderrichii* are heavily overexploited in Ghana (Hawthorne, 1995a,b) and will soon become extinct unless current rates of exploitation are reduced.

## 2.6 Patterns of Species Richness of plants in the forest

Species richness is the number of species present within an area. Plant species richness is applicable as a measure of biodiversity for the characterization of ecosystem quality (Kibet, 2011). Species richness often varies from one forest to another depending on a number of factors. Maximum number of species richness has been obtained in intermediately disturbed forest type in some studies (Huston and DeAngelis, 1994; Sang, 2009; Todaria *et al* 2010). On the other hand, other studies have reported of higher species richness in undisturbed stands in relation to other forest types (Rao *et al*., 1990; Muhanguzi *et al.,* 2007). Whatever be the case, it is clear that species richness is negatively affected by intensive disturbance as observed by (Todaria *et al.*, 2010). The occurrence of higher species richness at intermediate disturbance level has been explained by the presence of intermediate resource levels which many species make use of (Tilman, 1982). It was also explained by Todaria *et al.* (2010) that mild disturbance provides greater opportunity for species turnover, colonization and persistence of high species richness.

The pattern of species richness along a disturbance gradient may vary from one life form to another. Whereas tree species richness peaked at undisturbed level, that of herbs peaked at disturbed forest (Pitchairamu *et al*., 2008). Lalfakawmaet *et al*. (2009) also recorded higher tree and shrub species richness in an undisturbed stand than in a disturbed stand. However, the number of herbaceous species richness remained higher in the disturbed stand compared to the undisturbed stand. Most studies on lianas have reported of increasing species richness along an increasing disturbance gradient (see Addo-Fordjour *et al*., 2009a,b). On the contrary, a few studies have recorded relatively higher species richness of lianas in undisturbed forest sites (Addo-Fordjour *et al*., 2009a,b). While higher species richness of trees in the undisturbed forest was attributed to absence of human disturbance (harvesting of trees) that of herbs in the disturbed forest has been explained by their ability to reach maturity quickly; the so-called opportunistic, pioneer species, frequently disturbed areas (Hill and Hill, 2001).

It is also reported that the regional patterns of species richness are consequences of many interacting factors, such as plant productivity, competition, geographical area, historical or evolutionary development, regional species dynamics, regional species pool, environmental variables and human activity (Woodward, 1988; Palmer, 1991; Eriksson, 1996; Zobel, 1997). According to Latham and Ricklefs (1993) fewer samples exist for temperate undisturbed forests than for tropical forests, possibly because most of the former were altered or destroyed before scientific interest in species richness arose, or because species inventory in temperate forests provides a smaller payoff in new scientific knowledge. The species richness results of Dalberg *et al*. (2005) compared to other records underlines the fact that Africa's forest ecosystems are relatively poor in plant species richness than other continents (Richards 1973). Lianas comprise widely varying proportions of the plant species in tropical forest often matching the number of tree species (Gentry and Dodson 1987), whereas they typically represent a trivial fraction of the species richness in temperate forests (Latham 1993). This variation between the temperate and tropical forests can be associated with differences in climate, soils and landscape (Cowling *et al*., 1992; Richards *et al*., 1997; Goldblatt 1997).

## 2.7 Diversity of plants along disturbance gradients

Plant diversity is the range of different plants that occur at a place. Patterns of plant diversity are important for prioritising conservation activities (Sang, 2009). Species diversity just like species richness also varies from one forest to another depending on a number of factors. Frequent and less severe disturbances have often been shown to increase diversity. In fact, many studies have found that the highest diversity occurs at intermediate frequencies of disturbance. Other authors like Grime (1979), Huston (1979), Armesto and Pickett (1985) also reported the same trend of diversity in the intermediately disturbed forest. This higher plant diversity in intermediately disturbed forest was explained by Connell, (1978) that intermediate, in terms of intensity and frequency, promotes higher species diversity. Also, at intermediate levels of disturbance, diversity is thus maximized because both competitive and opportunistic species can coexist. On the contrary, Rao *et al*. (1990) reported a peak in diversity in an undisturbed area and it was argued that the type of disturbance that went on in the forest might be responsible for the low diversity in the disturbed forests. Similar results were obtained by Sang (2009) and Muhanguzi *et al*, (2007), who explained that past harvesting and farming activities were responsible for reducing diversity in the disturbed forests.

The difference that exists between the various life forms does not only represent habitat diversity of different sites; it also reflects the adaptation of species to different environments and the large-scale influences on plant (Condit *et al.*, 2002; Zhang, 2005). Whitmore (1974) stated that tropical rain forest species diversity is not open to any single or simple explanation, but is due to a complex interplay of factors that must be resolved indivnidually for any particular forest.

### 2.8 The structure of forests

Forest structure was defined as the physical and temporal distribution of trees in a stand (Oliver and Larson, 1990). However, this description of forest structure is commonly based on the aggregation of individual plant measures (e.g. density, tree diameter at breast height distribution etc). The work of Pereira *et al*. (2001) recorded highest canopy cover in an undisturbed area while light intensity on the forest floor was high in the disturbed forest. The works of Rao *et al*. (1990) and Sang (2009) followed the same trend. The decrease in canopy cover and increased light intensity in the disturbed forest was attributed to the direct removal of trees and creation of gaps. The study of Todaria *et al*. (2010) recorded higher density of shrubs and herbs in undisturbed stand while maximum herb and shrubs species richness was recorded in the moderately disturbed forest. Similar results were previously reported by other authors (Kumar and Ram, 2005; Bhuyan *et al.*, 2003; Mishra *et al*, 2004). The higher herb and shrub species richness and density in moderately disturbed stand indicate that openings of canopies favour herb and shrub growth which gives overall stability to the forest ecosystem. On the other hand, openings in disturbed forests permit much light to reach the forest floor which favours the growth and development of herbaceous species. This may hamper tree diversity as the herbs suppress tree regeneration and seedling development due to competition. In many of these systems either increasing or decreasing disturbance changes overall community structure (Lalfakawma *et al.*, 2009).

Plant density and basal area of mature trees decline with an increase in disturbance intensity. Other plant structural attributes such as density, height and canopy cover have all been found to decrease with increasing disturbance (Dumbrell *et al*, 2008; Lalfakawma *et al*., 2009). Clearly, human disturbance causes disruption of forest structure and changes community composition which ultimately leads to disruption of tree population structure. Muhanguzi *et al.*, (2007) also explain that the effects on forest structure and composition caused by heavy forest disturbance (such as heavy mechanical logging) results in the destruction of both mature trees and young stock and the alteration of certain environmental conditions which hinder forest regeneration.

# CHAPTER THREE

## 3.0 MATERIALS AND METHODS

### 3.1 Study area

The study was conducted in Atiwa Range forest Reserve, which falls under Atiwa Municipal Area (political administration) and Begro Forest District (forestry administration) of the Ashanti region of Ghana (See Figure 1).

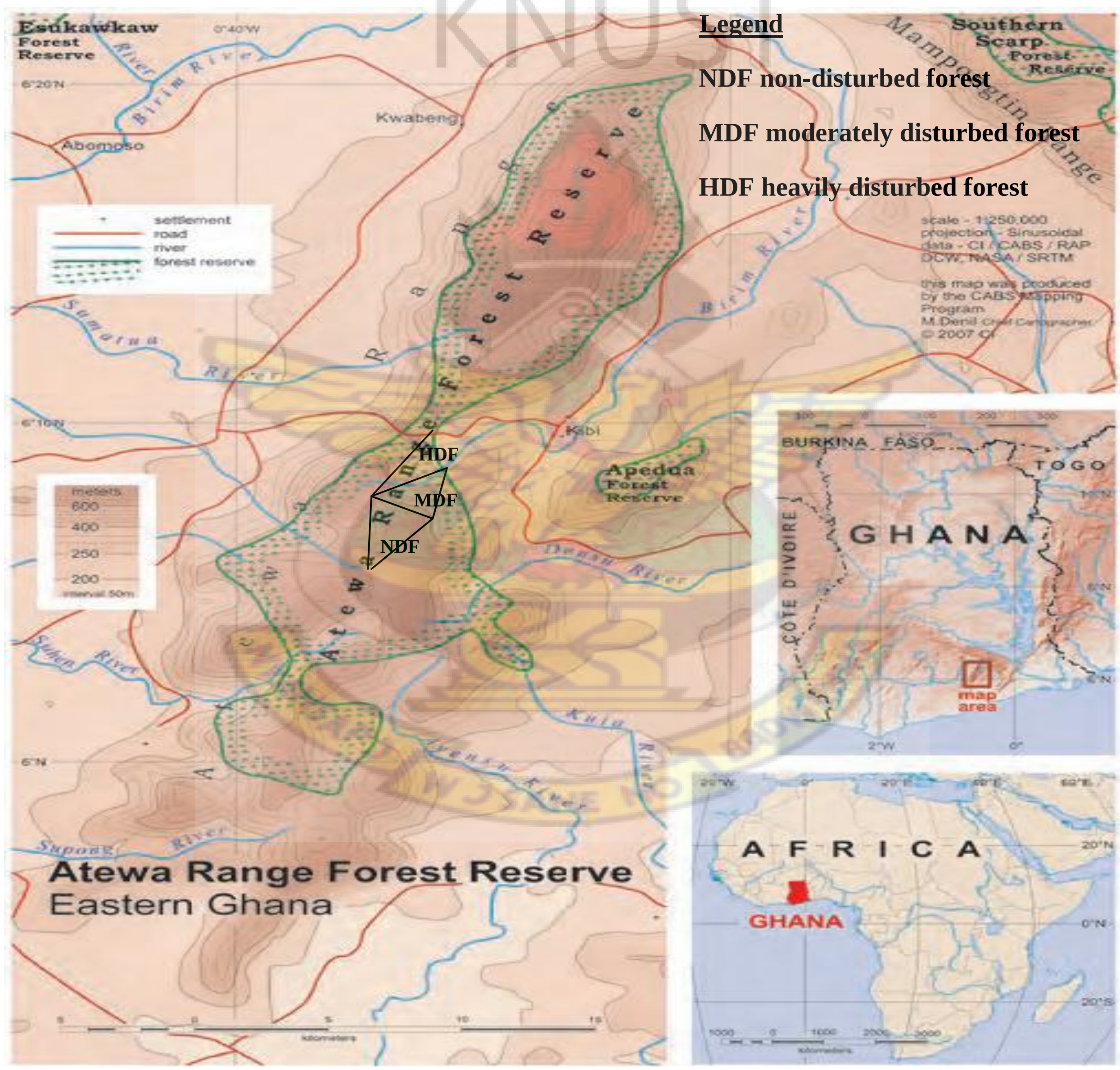


Fig: 1. Map of the Atiwa Range Forest Reserve (Source: Rapid Assessment Program, 2007)

Atiwa forest is unique because it is an Upland Evergreen forest which has excellent biological resources as well as rich bauxite deposits. It is one of the largest forests in Ghana and covers 23,665 ha of land (RAP, 2007). The unique floristic composition of the Upland Evergreen Forest is generated by the misty conditions on top of the plateaus (Swaine and Hall, 1977). The flora is very rich and contains a number of very rare species. It is also recognized as a nationally important reserve because it provides the headwaters of three river systems, the Ayensu River, the Birim River and the Densu River. The forest reserve, keeps the soil in place so that it does not clog the waterways of its head waters (Ayensu River, Birim River and Densu River), absorbs rainfall, filters and slowly releases water into the rivers and streams for us and all of the animals to drink. It produces and cleans the air we breathe and provides wood and other products for our homes. It is a source of both traditional and modern medicines and provides a home to many animal and plant species. It influences the climate of the Kibi region, including when the rain comes and how long the dry season will last (RAP, 2007). Together with the highly degraded Tano Ofin, the Atewa Range is one of only two reserves in Ghana where Upland Evergreen Forest occurs (Hall and Swaine, 1981, Abu-Juam *et al*., 2003).

### 3.2 Data collection

Total of thirty (30) main plots were established in the forest for the collection of data. The study was carried out in three forest types based on different levels of disturbance intensity. These were the non-disturbed forest (NDF), moderately disturbed forest (MDF) and the heavily disturbed forest (HDF). The non-disturbed forest is categorized as a primary forest because it was the part of the forest that has not undergone any major form of human disturbance. This is partly due to low accessibility to it by the local community as it is very far (about 10 km) from them. The moderately disturbed and heavily disturbed forests which are part of a secondary forest in the forest range, has undergone various degrees of human disturbances. The moderately disturbed forest was relatively less disturbed with human disturbances in the form of illegal logging activities that had taken place. On the other hand, recent disturbances in the form of logging, removal of non-timber products and farming activities have characterised the heavily disturbed forest. These forest types (NDF, MDF and HDF) were selected in areas with approximately equal topography so as to eliminate their effects on plant moderately disturbed forest was relatively less disturbed with human disturbances in the form of past composition and structure as stated in (Addo-Fordjour *et al.*, 2009b). Ten (50 m x 50 m) plots were randomly demarcated in each forest block for sampling.

On each plot, all woody plant species were identified and quantified. Height and diameter were also determined. As stated by Addo-Fordjour *et al.,* (2009b), all shrubs with DBH (Diameter at Breast Height) ≥ 5 cm were identified and their DBH measured with a diameter tape. The heights of all trees were determined with a clinometer. All trees with DBH (≥ 10 cm) were examined for the presence of lianas with DBH ≥ 1 cm. The percentage canopy cover of each plot was determined by a spherical densitometer. On each plot four readings from the four cardinal directions was taken at four different points. The average of all readings for the 10 plots in each habitat (40 readings) was calculated and used as the percentage canopy cover of that habitat (Anning *et al*., 2008).

Identification was performed by a plant taxonomist aided by manuals and Floras (Hawthorne, 1990; Arbon- nier, 2004; Poorter *et al.*, 2004; Hawthorne and Jongkind, 2006). Identification of the species was confirmed at KNUST herbarium, Kumasi and the Forestry Commission herbarium, Kumasi. Field work was conducted from $4^{th}$ to $28^{th}$ January, 2011.

### 3.3 Data analyses

One-way ANOVA was used in testing the differences in plant densities between the habitats. The analyses were performed using Genstat software at a significance level of 5%. The diversity of plant species in the forest types was quantified using the Shannon-Wiener species diversity index (Gimaret-Carpentier *et al*., 1998; Blanc *et al*., 2000; Parthasarathy, 2001; Addo-Fordjour *et al*., 2009b). Importance value index of the species were calculated as the sum of the species relative density; relative frequency, relative basal area and relative dominance (see Addo-Fordjour *et al.*, 2009b).

# CHAPTER FOUR

## 4.0 RESULT

### 4.1 Species richness and diversity of the forest

A total of 142 woody species were identified in three habitats of Atiwa range forest reserve (Table 1). The plants belonged to 51 families and 114 genera. Trees were the most dominant woody species identified in the forest. One hundred and four tree species were identified which represents 73.2% followed by lianas thirty-two species; (23.3%) and then shrubs (5 species; 3.5%).

**Table 1. List of plant species identified in Atiwa Range Forest Reserve**

| Species | Family | Life form |
|---|---|---|
| *Acacia kamerunensis* | Fabaceae | Liana |
| *Acacia pentagyna* | Fabaceae | Liana |
| *Adenia rumicifolia* | Passifloraceae | Liana |
| *Afzelia Africana* | Fabaceae | Tree |
| *Agelaea nitida* | Connaraceae | Liana |
| *Alafia barteri* | Apocynaceae | Liana |
| *Alafia whytei* | Apocynaceae | Liana |
| *Albizia adianthifolia* | Fabaceae | Tree |
| *Albizia glaberrima* | Fabaceae | Tree |
| *Albizia zygia* | Fabaceae | Tree |
| *Alchornea cordifolia* | Euphorbiaceae | Shrub |
| *Alchornea floribunda* | Euphorbiaceae | Shrub |
| *Allanblackia floribunda* | Guttiferae | Tree |
| *Alstonia boonei* | Apocynaceae | Tree |
| *Anthocleista nobilis* | Loganiaceae | Tree |
| *Antiaris toxicaria* | Moraceae | Tree |
| *Antrocaryon micraster* | Anacaardiaceae | Tree |
| *Asclepia sp.* | Asclepiadaceae | Liana |
| *Baphia pubescence* | Papilionaceae | Tree |
| *Berlinia confusa* | Caesalpiniaceae | Tree |
| *Blighia sapida* | Sapindaceae | Tree |
| *Blighia unijugata* | Sapindaceae | Tree |
| *Blighia welwitschii* | Sapindaceae | Tree |
| *Bombax buonopozense* | Malvaceae | Tree |
| *Bridelia grandis* | Euphorbiaceae | Tree |

*Table 1 Cont'd.*

| **Species** | **Family** | **Life form** |
|---|---|---|
| *Bussea occidentalis* | Caesalpiniaceae | Tree |
| *Calycobolus Africana* | Convolvulaceae | Liana |
| *Calycobolus heudelotii* | Convolvulaceae | Liana |
| *Canarium schweinfurthii* | Burseraceae | Tree |
| *Cedrela odorata* | Meliaceae | Tree |
| *Ceiba petandra* | Malvaceae | Tree |
| *Celtis adolfi-fiderici* | Ulmaceae | Tree |
| *Celtis mildbraedii* | Ulmaceae | Tree |
| *Celtis zenkeri* | Ulmaceae | Tree |
| *Chrysophyllum subnudum* | Sapotaceae | Tree |
| *Cissus debilis* | Vitaceae | Liana |
| *Cleistopholis patens* | Annonaceae | Tree |
| *Cola caricifolia* | Sterculiaceae | Tree |
| *Cola lateritia* | Sterculiaceae | Tree |
| *Cola nitida* | Sterculiaceae | Tree |
| *Combretum smeathmannii* | Combretaceae | Liana |
| *Combretum sp.* | Combretaceae | Liana |
| *Corynanthe pachyceras* | Rubiaceae | Tree |
| *Cyathea manniana* | Cyatheaceae | Tree |
| *Dacryodeo klaineana* | Burseraceae | Tree |
| *Dalbergia hostiles* | Fabaceae | Liana |
| *Dalbergia saxatilis* | Fabaceae | Liana |
| *Dalbergiella welwitschii* | Fabaceae | Liana |
| *Delonix regia* | Caesalpiniaceae | Tree |
| *Dichapetalum sp.* | Dicharpitalaceae | Liana |
| *Diospyros kamerunensis* | Ebenaceae | Tree |
| *Diospyros sanza-minika* | Ebenaceae | Tree |
| *Discoglypremna caloneura* | Euphorbiaceae | Tree |
| *Distemonanthus benthamianus* | Caesalpiniaceae | Tree |
| *Drypetes pellegrinii* | Euphorbiaceae | Tree |
| *Elaeis guineensis* | Palmaceae | Tree |
| *Entandrophragma angolense* | Meliaceae | Tree |
| *Erythroxylum mannii* | Erythroxylaceae | Tree |
| *Ficus capensis* | Moraceae | Tree |
| *Ficus exasperata* | Moraceae | Tree |
| *Funtumia Africana* | Apocynaceae | Tree |
| *Funtumia elastica* | Apocynaceae | Tree |
| *Gongronema latifolium* | Asclepiadaceae | Liana |
| *Griffonia simplicifolia* | Fabaceae | Liana |
| *Guarea cedrata* | Meliaceae | Tree |
| *Hannoa klaineana* | Simaroubaceae | Tree |
| *Harungana madagascariensis* | Guttiferae | Tree |

***Table 1 Cont'd.***

| **Species** | **Family** | **Life form** |
|---|---|---|
| *Hippocratea Africana* | Celastraceae | Liana |
| *Holarrhena floribunda* | Apocynaceae | Tree |
| *Hugonia sp.* | Linaceae | Liana |
| *Hymenostegia afzelii* | Cesalpiniaceae | Tree |
| *Hymenostegia aubrevillie* | Cesalpiniaceae | Tree |
| *Irvingia gabonensis* | Irvingiaceae | Tree |
| *Klainedoxa gabonensis* | Irvingiaceae | Tree |
| *Landolphia dulci-barteri* | Apocynaceae | Tree |
| *Landolphia owariensis* | Apocynaceae | Tree |
| *Lannea welwitschii* | Anacardiaceae | Tree |
| *Leptoderris micrantha* | Fabaceae | Liana |
| *Leptoderris miegi* | Fabaceae | Liana |
| *Leptoderris sp.* | Fabaceae | Liana |
| *Lovoa trichilioides* | Meliaceae | Tree |
| *Macaranga barteri* | Euphorbiaceae | Tree |
| *Macaranga heterophylla* | Euphorbiaceae | Tree |
| *Macaranga huricifolia* | Euphorbiaceae | Tree |
| *Macaranga spinosa* | Euphorbiaceae | Tree |
| *Magaritaria discoredes* | Phyllanthaceae | Tree |
| *Maranthes robusta* | Chrysobalanaceae | Tree |
| *Marratis fraxinea* | Marattiacea | Tree |
| *Milicia excela* | Moraceae | Tree |
| *Milicia regia* | Moraceae | Tree |
| *Milletia chrysophylla* | Fabaceae | Liana |
| *Morinda lucida* | Rubiaceae | Tree |
| *Motandra guineensis* | Apocynaceae | Liana |
| *Musanga cecropioides* | Moraceae | Tree |
| *Myrianthus arboreus* | Cercropiaceae | Tree |
| *Neuropeltis sp.* | Convolvulaceae | Liana |
| *Pachypodanthum staudtii* | Annonaceae | Tree |
| *Panda oleosa* | Pandaceae | Tree |
| *Parkia bicolor* | Mimosaceae | Tree |
| *Parquetina nigreesens* | Asclepiadaceae | Liana |
| *Paulinia pinnata* | Sapindaceae | Liana |
| *Pentaclethra macrophylla* | Mimosaceae | Tree |
| *Petersianthus macrocarpus* | Lecythidaceae | Tree |
| *Piper guineensis* | Papilionoidae | Liana |
| *Piptadeniastrum africanum* | Mimosaceae | Tree |
| *Placodiscus boya* | Sapindaceae | Shrub |
| *Pouteria altissima* | Sapotaceae | Tree |
| *Psychotria sp.* | Apocynaceae | Shrub |
| *Psydrax subcordata* | Rubiaceae | Tree |
| *Pycnanthus angolensis* | Myristicaceae | Tree |

***Table 1 Cont'd.***

| **Species** | **Family** | **Life form** |
|---|---|---|
| *Raphiostylis sp.* | Icacinaceae | Liana |
| *Ricinodenderon heudelotii* | Euphorbiaceae | Tree |
| *Rauvolfia vomitoria* | Apocynaceae | Tree |
| *Ricinodendron heudelotii* | Euphorbiaceae | Tree |
| *Rinorea oblongifolia* | Violaceae | Tree |
| *Rubiaceae sp.* | Rubiaceae | Shrub |
| *Salacia Africana* | Celastraceae | Liana |
| *Salacia owabiensis* | Celastraceae | Liana |
| *Salacia sp.* | Celastraceae | Liana |
| *Scottellia klaineana* | Flacourtiaceae | Tree |
| *Sterculia rhinopetala* | Sterculiaceae | Tree |
| *Sterculia tragacantha* | Sterculiaceae | Tree |
| *Strombosia glaucescens* | Olacaceae | Tree |
| *Tabernaemontana Africana* | Apocynaceae | Tree |
| *Tabernaemontana crassa* | Apocynaceae | Tree |
| *Tectona grandis* | Lamiaceae | Tree |
| *Terminalia ivorensis* | Combretaceae | Tree |
| *Terminalia superba* | Combretaceae | Tree |
| *Tetracera sp.* | Ulmaceae | Tree |
| *Trema orientalis* | Cannabaceae | Tree |
| *Tricalysia discolor* | Rubiaceae | Tree |
| *Trichilia prieuriana* | Meliaceae | Tree |
| *Trichilia tessmannii* | Meliaceae | Tree |
| *Triplochiton scleroxylon* | Sterculiaceae | Tree |
| *Turraeanthus africanus* | Meliaceae | Tree |
| *Vitex ferruginea* | Verbenaceae | Tree |
| *Voacanga Africana* | Apocynaceae | Tree |
| *Xylia evansii* | Mimosaceae | Tree |
| *Xylopia aethiopica* | Annonaceae | Tree |
| *Xylopia staudtii* | Annonaceae | Tree |
| *Xylopia villosa* | Annonaceae | Tree |
| *Zanthoxylum gilletii* | Rutaceae | Tree |

There were more families in the non-disturbed forest (40 families) in relation to the other forest types (26 and 20 families in the moderately and heavily disturbed forests respectively). Four families namely, Apocynaceae, Fabaceae and Euphorbiaceae were the most species rich families in all the forest block. In addition, Moraceae was a species rich family in the heavily disturbed forest.

Shannon Wiener diversity index for trees varied significantly across the three forest blocks (d.f. = 2; P ≤0.001). Tree diversity was significantly higher in the non-disturbed forest than the moderately disturbed forest, which in turn was higher than that of the heavily disturbed forest. Furthermore, tree diversity in the non-disturbed forest was significantly higher than that of the moderiately disturbed forest as against heavily disturbed forest. Though liana diversity also differed significantly between the forest blocks (d.f. = 2; p ≤ 0.001), the differences existed between non-disturbed (mean = 1.98)) and highly disturbed (mean = 0.88) forests, and moderately disturbed (mean = 1.69) and highly disturbed forests (mean = 0.88). With regard to shrubs, the non-disturbed forest was significantly more diverse than the heavily disturbed forest whereas diversity between the other forest pairs did not vary significantly (d.f. = 2; p = 0.035).

**4.2 Structure of the forest**

*Alchornea cordifolia* was the most dominant species recorded for shrubs in the three forest blocks (Table 2). This species was more dominated in the HDF (7.36) than in the MDF (3.41) and in the NDF (1.54). The MDF and HDF recorded *Cedrela odorata* (60.89 and 60.24) respectively as the most dominant tree species while the NDF recorded *Allamblankia floribunda* (30.20). The MDF recorded *Griffonia simplicifolia* (12.50), as the most dominant liana species followed by NDF; *Acacia kemerunensis* (8.35) then HDF; *Parquetina nigreecens* (7.49). Ten tree species, 3 liana species and 2 shrubs were common to the entire three habitats. In all the life forms, species richness decreased from the non-disturbed forest (86 tree, 29 liana and 12 shrub species) through the moderately disturbed forest (40 trees, 17 liana and 10 shrub species) to the heavily disturbed forest (21 tree, 13 liana and 9 shrub species).

The average canopy cover was higher in the non-disturbed forest (89.6%) as compared to moderately disturbed (68.3%) and heavily disturbed (42.2%) forests (Table 3). The differences between all the pairs were significant with respect to the three forest bocks (d.f. = 2; $p \leq 0.001$). The NDF had the greatest density for all the woody species (trees 114/ha, lianas 71.60/ha and shrub 5.6/ha). The MDF and HDF followed the same trend as the NDF; (trees 86.40/ha, lianas 51.20/ha, shrubs 6.4/ha) and (tree 48/ha, liana 14.40/ha, shrub 2.8/ha) respectively. The average DBH for trees was high in the NDF (28.01), followed by MDF (27.64) and HDF (22.10). For lianas, the MDF recorded the highest average DBH (3.15) whereas HDF and NDF had 2.95 and 2.90 respectively. The HDF recorded the highest DBH for shrubs (7.84) than the IDF (7.24) and NDF (7.04).

The diameter distribution of trees in all the forest types did not follow the inverted J curve (Figure 2). However, the abundance of trees in the various diameter classes decreased with increasing disturbance in almost all cases. The diameter class distribution of lianas in the non-disturbed forest followed the same trend as that of the trees. However, that of the moderately disturbed forest depicted the inverted J curve (Figure 3). Small size lianas (1-4 cm diameter) were absent in the heavily disturbed forest.

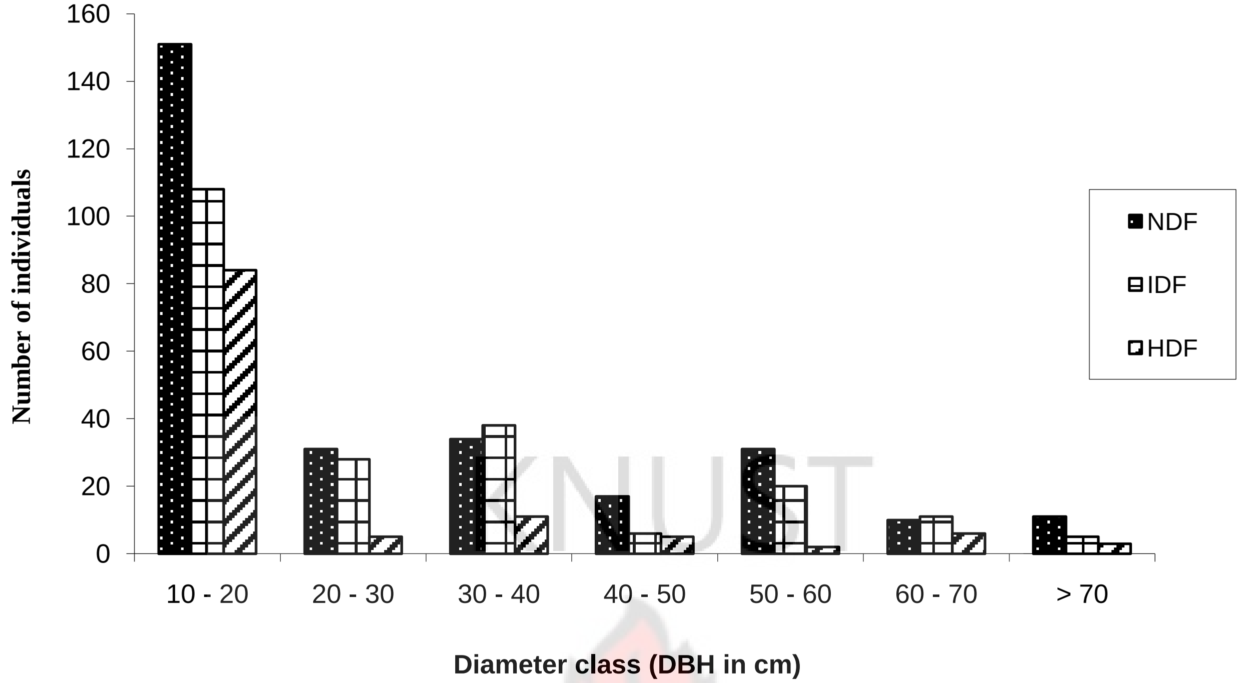


**Figure 2. Diameter distribution of trees (≥ 10cm) in Atiwa forest**

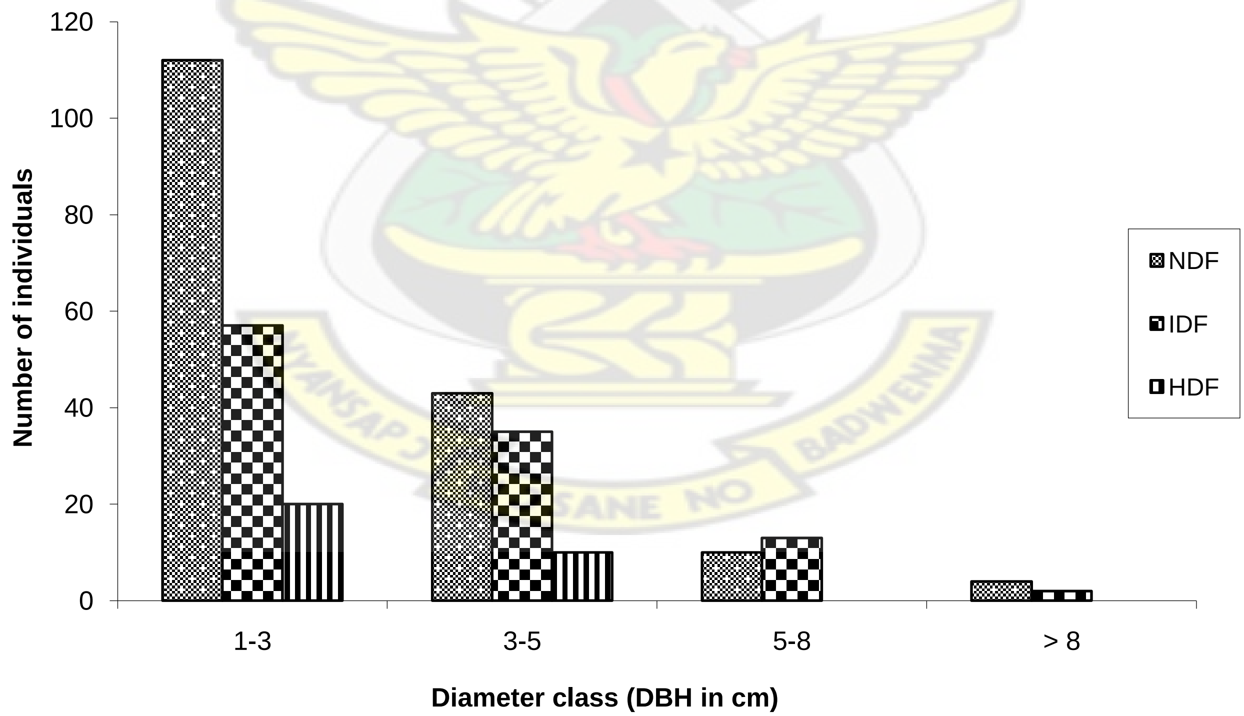


**Figure 3. Diameter class distribution of lianas (≥ 1cm) in Atiwa forest**

**Table 2.** **Dominance of woody plant species within the forest types of the Atiwa range forest reserve**

| | NDF | | | | IDF | | | | HDF | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species** | **RD** | **RF** | **RBA** | **IV** | **RD** | **RF** | **RBA** | **IV** | **RD** | **RF** | **RBA** | **IV** |
| *Acacia kamerunensis* | 4.05 | 4.24 | 0.06 | **8.35** | 4.46 | 4.23 | 0.10 | **8.79** | - | - | - | - |
| *Acacia pentagyna* | 1.58 | 1.70 | 0.01 | **3.29** | 2.68 | 3.52 | 0.10 | **6.30** | 1.37 | 1.33 | 0.03 | **2.73** |
| *Adenia rumicifolia* | 1.35 | 2.12 | 0.08 | **3.55** | 0.30 | 1.41 | 0.007 | **1.78** | - | - | - | - |
| *Afzelia africana* | 0.45 | 0.85 | 1.09 | **20.9** | - | - | - | - | - | - | - | - |
| *Agelaea nitida* | - | - | - | - | 0.30 | 0.70 | 0.004 | **1.00** | - | - | - | - |
| *Alafia barteri* | 0.90 | 2.12 | 0.01 | **3.03** | 1.19 | 1.41 | 0.03 | **2.63** | - | - | - | - |
| *Alafia whytei* | 0.45 | 0.42 | 0.002 | **0.87** | 1.19 | 0.70 | 0.004 | **1.93** | - | - | - | - |
| *Albizia adianthifolia* | 2.48 | 2.97 | 1.95 | **7.40** | 5.36 | 0.70 | 8.48 | **14.54** | 2.05 | 1.33 | 4.84 | **8.22** |
| *Albizia glaberrima* | 0.23 | 0.42 | 0.04 | **0.69** | 0.30 | 0.70 | 0.31 | **1.31** | - | - | - | - |
| *Albizia zygia* | 2.03 | 2.12 | 5.61 | **9.76** | 5.36 | 5.63 | 4.90 | **15.89** | 6.85 | 10.67 | 5.66 | **23.18** |
| *Alchornea cordifolia* | 0.68 | 0.85 | 0.01 | **1.54** | 2.68 | 0.70 | 0.03 | **3.41** | 0.68 | 6.67 | 0.01 | **7.36** |
| *Alchornea floribunda* | - | - | - | - | 0.30 | 0.70 | 0.003 | **1.00** | - | - | - | - |
| *Allanblackia floribunda* | 0.68 | 0.85 | 1.49 | **30.2** | - | - | - | - | - | - | - | - |
| *Alstonia boonei* | 1.35 | 2.54 | 2.41 | **6.30** | 0.89 | 2.11 | 0.60 | **3.60** | 0.68 | 1.33 | 3.95 | **5.96** |
| *Anthocleista nobilis* | - | - | - | - | 0.30 | 0.70 | 0.46 | **1.46** | 2.05 | 1.33 | 0.63 | **4.01** |
| *Antiaris toxicaria* | 0.45 | 0.85 | 0.72 | **2.02** | - | - | - | - | - | - | - | - |
| *Antrocaryon micraster* | 0.90 | 1.69 | 3.63 | **6.22** | - | - | - | - | - | - | - | - |
| *Asclepia sp.* | 0.68 | 0.42 | 0.02 | **1.12** | 0.60 | 0.70 | 0.004 | **1.30** | - | - | - | - |
| *Baphia pubescence* | - | - | - | - | 0.30 | 0.70 | 0.08 | **1.08** | - | - | - | - |
| *Berlinia confusa* | 0.23 | 0.42 | 0.06 | **0.71** | - | - | - | - | - | - | - | - |
| *Blighia sapida* | 0.68 | 1.27 | 0.62 | **2.27** | 0.60 | 1.41 | 0.15 | **2.16** | - | - | - | - |
| *Blighia unijugata* | - | - | - | - | 0.30 | 0.70 | 0.04 | **1.04** | 0.68 | 1.33 | 0.12 | **2.13** |
| *Blighia welwitschii* | - | - | - | - | 0.30 | 0.70 | 0.08 | **1.08** | - | - | - | - |
| *Bombax buonopzense* | - | - | - | - | - | - | - | - | 0.68 | 1.33 | 0.01 | **2.02** |
| *Bridelia grandis* | 0.23 | 0.42 | 0.05 | **0.70** | - | - | - | - | - | - | - | - |

RD = Relative density, RF = Relative frequency, RBA = Relative basal area, IV =Important value

**Table 2 *Cont'd.* Dominance of woody plant species within the forest types of the Atiwa range forest reserve**

| | NDF | | | | IDF | | | | HDF | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species** | **RD** | **RF** | **RBA** | **IV** | **RD** | **RF** | **RBA** | **IV** | **RD** | **RF** | **RBA** | **IV** |
| *Bussea occidentalis* | 0.68 | 0.85 | 0.14 | **1.67** | - | - | - | | - | - | - | - |
| *Calycobolus africana* | 2.48 | 1.27 | 0.07 | **3.82** | - | - | - | | - | - | - | - |
| *Calycobolus heudelotii* | 2.48 | 2.12 | 0.03 | **4.63** | - | - | - | | - | - | - | - |
| *Canarium schweinfurthii* | 1.13 | 1.27 | 0.82 | **3.22** | 1.49 | 1.41 | 0.51 | **3.41** | - | - | - | - |
| *Cedrela odorata* | - | - | - | - | 16.10 | 5.63 | 38.75 | **60.48** | 21.92 | 10.77 | 27.55 | 60.24 |
| *Ceiba pentandra* | 2.48 | 2.54 | 8.88 | **13.9** | 0.89 | 1.41 | 9.00 | **11.30** | 3.42 | 4.00 | 6.76 | **14.18** |
| *Celtis adolfi-fiderici* | 0.68 | 0.42 | 9.27 | **10.37** | - | - | - | | - | - | - | - |
| *Celtis mildbraedii* | 1.80 | 1.69 | 1.68 | **5.17** | 0.30 | 0.70 | 0.08 | **1.08** | - | - | - | - |
| *Celtis zenkeri* | 0.82 | 0.53 | 0.98 | 2.33 | - | - | - | - | - | - | - | - |
| *Chrysophyllum subnudum* | 0.90 | 1.69 | 2.06 | **4.65** | - | - | - | | - | - | - | - |
| *Cissus debilis* | - | - | - | - | 1.49 | 0.70 | 0.02 | **2.21** | - | - | - | - |
| *Cleistopholis patens* | 0.90 | 0.85 | 0.47 | **2.22** | - | - | - | - | - | - | - | - |
| *Cola caricifolia* | 0.23 | 0.42 | 0.04 | **0.69** | - | - | - | - | - | - | - | - |
| *Cola lateritia* | 0.23 | 0.42 | 0.03 | **0.68** | - | - | - | - | - | - | - | - |
| *Cola nitida* | 0.23 | 0.42 | 0.02 | **0.67** | 2.38 | 2.11 | 1.80 | **6.29** | - | - | - | - |
| *Combretum smeathmannii* | 1.13 | 0.85 | 0.007 | **1.99** | 0.60 | 1.33 | 0.001 | **1.93** | - | - | - | - |
| *Combretum sp.* | - | - | - | - | - | - | - | - | 2.05 | 4.00 | 0.02 | **6.07** |
| *Corynanthe pachyceras* | - | - | - | - | - | - | - | - | 0.68 | 1.33 | 1.36 | **3.37** |
| *Cyathea manniana* | 1.80 | 0.42 | 1.52 | **3.74** | - | - | - | - | - | - | - | - |
| *Dacryodeo klaineana* | 0.23 | 0.42 | 0.06 | **0.71** | - | - | - | - | - | - | - | - |
| *Dalbergia hostilis* | 0.45 | 0.42 | 0.002 | **0.87** | - | - | - | - | 1.37 | 1.33 | 0.04 | **2.74** |
| *Dalbergia saxatilis* | - | - | - | - | - | - | - | - | 0.68 | 1.33 | 0.07 | **2.08** |
| *Dalbergiella welwitschii* | 1.35 | 0.42 | 0.01 | **1.78** | | - | - | - | 1.37 | 1.33 | 0.005 | **2.71** |
| *Delonix regia* | - | - | - | - | 1.19 | 0.70 | 2.23 | **4.12** | - | - | - | - |
| *Dichapetalum sp.* | 0.90 | 0.42 | 0.008 | **1.33** | 1.49 | 0.70 | 0.03 | **2.22** | 0.68 | 1.33 | 0.02 | **2.03** |

RD = Relative density, RF = Relative frequency, RBA = Relative basal area, IV =Important value

**Table 2** ***Cont'd.*** **Dominance of woody plant species within the forest types of the Atiwa range forest reserve**

| Species | NDF | | | | IDF | | | | HDF | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **RD** | **RF** | **RBA** | **IV** | **RD** | **RF** | **RBA** | **IV** | **RD** | **RF** | **RBA** | **IV** |
| *Diospyros kamerunensis* | 0.23 | 0.42 | 0.03 | **0.68** | - | - | - | - | - | - | - | - |
| *Diospyros sanza-minika* | 0.68 | 0.42 | 1.67 | **2.77** | - | - | - | - | - | - | - | - |
| *Discoglypremna caloneura* | 1.13 | 0.85 | 0.53 | **2.51** | - | - | - | - | - | - | - | - |
| *Distemonanthus benthamianus* | 0.23 | 0.42 | 0.65 | **1.30** | 0.60 | 0.70 | 1.11 | **2.41** | - | - | - | - |
| *Drypetes pellegrinii* | 0.23 | 0.42 | 0.32 | **0.97** | - | - | - | - | - | - | - | - |
| *Elaeis guineensis* | - | - | - | - | - | - | - | - | 4.11 | 2.67 | 23.00 | 29.78 |
| *Entandrophragma angolense* | 0.68 | 0.42 | 0.49 | **1.59** | - | - | - | - | - | - | - | - |
| *Erythroxylum mannii* | 0.68 | 0.42 | 0.44 | **1.54** | - | - | - | - | - | - | - | - |
| Ficus capensis | 2.93 | 0.85 | 0.12 | **3.90** | 2.68 | 3.52 | 0.57 | **6.77** | 2.05 | 4.00 | 0.48 | **6.53** |
| *Ficus exasperata* | - | - | - | - | 0.30 | 0.70 | 0.10 | **1.10** | 4.11 | 2.67 | 1.64 | **8.42** |
| *Funtumia africana* | 4.95 | 3.39 | 1.57 | **9.91** | 1.19 | 2.11 | 1.82 | **5.12** | 3.42 | 1.33 | 0.12 | **4.87** |
| *Funtumia elastica* | - | - | - | - | 0.30 | 0.70 | 0.06 | **1.06** | - | - | - | - |
| *Gongronema latifolium* | - | - | - | - | 0.30 | 0.70 | 0.001 | **1.00** | - | - | - | - |
| *Griffonia simplicifolia* | 3.60 | 3.39 | 0.04 | **7.03** | 7.44 | 4.90 | 0.16 | **12.50** | 0.68 | 1.33 | 0.01 | **2.02** |
| *Guarea cedrata* | 0.45 | 0.42 | 0.07 | **0.94** | - | - | - | - | - | - | - | - |
| *Hannoa klaineana* | 0.45 | 0.85 | 0.80 | **2.10** | - | - | - | - | - | - | - | - |
| *Harungana madagascariensis* | 0.23 | 0.42 | 0.04 | **0.69** | - | - | - | - | - | - | - | - |
| *Hippocratea africana* | 0.68 | 0.42 | 0.005 | **1.11** | - | - | - | - | 1.37 | 1.33 | 0.007 | **2.71** |
| *Holarrhena floribunda* | - | - | - | - | 0.30 | 0.70 | 0.08 | **1.08** | - | - | - | - |
| *Hugonia sp.* | 0.23 | 0.42 | 0.001 | **0.65** | - | - | - | - | - | - | - | - |
| *Hymenostegia afzelii* | 0.23 | 0.42 | 0.05 | **0.7** | - | - | - | - | - | - | - | - |
| *Hymenostegia aubrevillie* | 0.23 | 0.85 | 0.06 | **1.14** | - | - | - | - | - | - | - | - |
| *Irvingia gabonensis* | 0.33 | 0.42 | 0.10 | **0.85** | - | - | - | - | - | - | - | - |
| Klainedoxa gabonensis | 0.90 | 0.85 | 1.11 | **2.86** | - | - | - | - | - | - | - | - |
| *Landolphia dulci-barteri* | 0.68 | 0.42 | 0.004 | **1.10** | 0.30 | 0.70 | 0.01 | **1.01** | - | - | - | - |

RD = Relative density, RF = Relative frequency, RBA = Relative basal area, IV =Important value

**Table 2** ***Cont'd.*** **Dominance of woody plant species within the forest types of the Atiwa range forest reserve**

| Species | NDF | | | | IDF | | | | HDF | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RD | RF | RBA | IV | RD | RF | RBA | IV | RD | RF | RBA | IV |
| *Landolphia owariensis* | 0.68 | 0.42 | 0.004 | **1.10** | - | - | - | **-** | - | - | - | **-** |
| *Lannea welwitschii* | 2.93 | 0.85 | 3.10 | **6.88** | - | - | - | **-** | - | - | - | **-** |
| *Leptoderris micrantha* | 1.58 | 0.85 | 0.007 | **2.44** | 0.60 | 1.41 | 0.02 | **2.03** | - | - | - | **-** |
| *Leptoderris miegi* | 0.45 | 0.42 | 0.001 | **0.87** | 0.30 | 0.70 | 0.001 | **1.00** | - | - | - | **-** |
| *Leptoderris sp.* | 0.23 | 0.42 | 0.002 | **0.65** | - | - | - | **-** | - | - | - | **-** |
| *Lovoa trichilioides* | 0.45 | 0.42 | 0.72 | **1.59** | - | - | - | **-** | - | - | - | **-** |
| *Macaranga barteri* | 0.68 | 2.97 | 0.40 | **4.05** | 3.57 | 4.23 | 1.48 | **9.28** | 1.37 | 1.33 | 0.29 | **2.99** |
| *Macaranga heterophylla* | - | - | - | **-** | 0.89 | 0.70 | 3.96 | **5.55** | - | - | - | **-** |
| *Macaranga huricifolia* | - | - | - | **-** | 0.60 | 0.70 | 1.20 | **2.50** | - | - | - | **-** |
| *Macaranga spinosa* | 0.23 | 0.42 | 0.61 | **1.26** | - | - | - | **-** | - | - | - | **-** |
| *Magaritaria discoredes* | 0.23 | 0.42 | 0.09 | **0.74** | - | - | - | **-** | - | - | - | **-** |
| *Maranthes robusta* | 0.23 | 0.42 | 0.11 | **0.76** | - | - | - | **-** | - | - | - | **-** |
| *Marratis fraxinea* | 0.27 | 0.42 | 5.10 | **5.79** | - | - | - | **-** | - | - | - | **-** |
| *Milicia excelsa* | 1.13 | 1.27 | 1.67 | **4.07** | 1.19 | 2.11 | 1.30 | **4.60** | 0.68 | 1.33 | 0.23 | **2.24** |
| *Milicia regia* | 1.13 | 0.85 | 1.92 | **3.90** | - | - | - | **-** | 6.85 | 4.00 | 6.64 | **17.49** |
| *Milletia chrysophylla* | - | - | - | **-** | 0.60 | 0.70 | 0.05 | **1.35** | - | - | - | **-** |
| *Morinda lucida* | 0.23 | 0.42 | 0.04 | **1.69** | 3.57 | 2.82 | 6.76 | **13.15** | 6.16 | 6.67 | 3.45 | **16.28** |
| *Motandra guineensis* | - | - | - | **-** | 1.49 | 2.11 | 0.006 | **3.61** | - | - | - | **-** |
| *Musanga cecropioides* | 0.45 | 0.42 | 1.82 | **2.69** | 0.89 | 0.70 | 2.12 | **3.71** | - | - | - | - |
| *Myrianthus arboreus* | - | - | - | - | - | - | - | **-** | 0.68 | 1.33 | 0.14 | **2.15** |
| *Neuropeltis sp.* | 0.45 | 0.42 | 0.002 | **0.87** | - | - | - | **-** | - | - | - | **-** |
| *Pachypodanthum staudtii* | 0.45 | 0.42 | 0.78 | **1.67** | - | - | - | **-** | - | - | - | **-** |
| *Panda oleosa* | 0.68 | 0.42 | 0.18 | **1.28** | - | - | - | **-** | - | - | - | **-** |
| *Parkia bicolor* | 0.23 | 0.42 | 0.08 | **0.73** | - | - | - | **-** | - | - | - | **-** |

RD = Relative density, RF = Relative frequency, RBA = Relative basal area, IV =Important value

**Table 2 *Cont'd.* Dominance of woody plant species within the forest types of the Atiwa range forest reserve**

| | NDF | | | | IDF | | | | HDF | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species** | **RD** | **RF** | **RBA** | **IV** | **RD** | **RF** | **RBA** | **IV** | **RD** | **RF** | **RBA** | **IV** |
| *Parquetina nigrescens* | - | - | - | - | 0.89 | 1.41 | 0.005 | **2.31** | 3.42 | 4.00 | 0.07 | **7.49** |
| *Paulinia pinnata* | 0.45 | 0.85 | 0.003 | **1.30** | 3.27 | 4.93 | 0.03 | **8.23** | 2.05 | 5.33 | 0.02 | **7.40** |
| *Pycnanthus angolensis* | - | - | - | - | - | - | - | **-** | 0.68 | 1.33 | 4.56 | **6.57** |
| *Pentaclethra macrophylla* | 0.45 | 0.85 | 0.73 | **2.03** | - | - | - | **-** | - | - | - | **-** |
| *Petersianthus macrocarpus* | 0.23 | 0.42 | 0.06 | **0.71** | - | - | - | **-** | - | - | - | **-** |
| *Piper guineensis* | 0.23 | 0.42 | 0.001 | **0.65** | - | - | - | **-** | - | - | - | **-** |
| *Piptadeniastrum africanum* | 2.03 | 2.54 | 2.60 | **7.17** | 0.89 | 0.70 | 1.90 | **3.49** | - | - | - | **-** |
| *Placodiscus boya* | 0.23 | 0.42 | 0.86 | **1.51** | - | - | - | **-** | - | - | - | **-** |
| *Pouteria altissima* | 0.23 | 0.42 | 0.07 | **0.72** | - | - | - | **-** | - | - | - | **-** |
| *Psychotria sp.* | 0.23 | 0.42 | 0.71 | **1.36** | - | - | - | **-** | - | - | - | **-** |
| *Psydrax subcordata* | - | - | - | - | 0.60 | 1.41 | 0.24 | **2.25** | - | - | - | **-** |
| *Raphiostylis sp.* | 0.23 | 0.42 | 0.001 | **0.65** | - | - | - | **-** | - | - | - | **-** |
| *Ricinodenderon heudelotii* | 0.68 | 0.42 | 0.004 | **1.10** | - | - | - | **-** | - | - | - | **-** |
| *Rauvolfia vomitoria* | 1.13 | 1.69 | 0.89 | **3.71** | 1.49 | 2.82 | 0.65 | **4.96** | - | - | - | **-** |
| *Ricinodendron heudelotii* | - | - | - | - | - | - | - | **-** | 0.68 | 1.33 | 4.31 | **6.32** |
| *Rinorea oblongifolia* | 0.23 | 0.42 | 0.03 | **0.68** | - | - | - | **-** | - | - | - | **-** |
| *Rubiaceae sp.* | 0.45 | 0.42 | 0.001 | **0.87** | 0.60 | 0.70 | 0.004 | **1.30** | 0.68 | 1.33 | 0.02 | **2.03** |
| *Salacia africana* | 0.23 | 0.42 | 0.002 | **0.65** | 2.68 | 0.70 | 0.03 | **3.41** | - | - | - | **-** |
| *Salacia owabiensis* | 0.23 | 0.42 | 0.002 | **0.65** | - | - | - | **-** | - | - | - | **-** |
| *Salacia sp.* | 2.93 | 0.42 | 0.04 | **3.39** | - | - | - | **-** | - | - | - | **-** |
| *Scottellia klaineana* | 0.23 | 0.42 | 0.24 | **0.89** | - | - | - | **-** | - | - | - | **-** |
| *Sterculia rhinopetala* | 0.68 | 0.85 | 0.10 | **1.63** | - | - | - | **-** | - | - | - | **-** |
| *Sterculia tragacantha* | 0.90 | 1.27 | 0.52 | **2.69** | 1.19 | 2.82 | 0.35 | **4.36** | 0.68 | 1.33 | 0.12 | **2.13** |
| *Strombosia glaucescens* | 0.45 | 0.42 | 1.26 | **2.13** | - | - | - | **-** | - | - | - | **-** |
| *Tabernaemontana africana* | 4.95 | 2.54 | 12.52 | **20.01** | 1.19 | 1.41 | 0.88 | **3.48** | - | - | - | **-** |
| *Tabernaemontana crassa* | 0.68 | 0.85 | 0.15 | **1.68** | 1.19 | 1.41 | 0.77 | **3.37** | - | - | - | **-** |

RD = Relative density, RF = Relative frequency, RBA = Relative basal area, IV =Important value

**Table 2 *Cont'd.* Dominance of woody plant species within the forest types of the Atiwa range forest reserve**

| | NDF | | | | IDF | | | | HDF | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species** | **RD** | **RF** | **RBA** | **IV** | **RD** | **RF** | **RBA** | **IV** | **RD** | **RF** | **RBA** | **IV** |
| *Tectona grandis* | - | - | - | - | - | - | - | - | 10.27 | 4.00 | 3.76 | **18.03** |
| *Terminalia ivorensis* | 0.23 | 0.42 | 0.48 | **1.13** | 2.68 | 2.82 | 6.72 | **12.22** | - | - | - | - |
| *Terminalia superba* | 0.90 | 1.27 | 0.51 | **2.68** | 1.49 | 1.41 | 0.40 | **3.30** | - | - | - | - |
| *Tetracera sp.* | 0.45 | 0.42 | 0.002 | **0.87** | 0.30 | 0.70 | 0.005 | **1.00** | - | - | - | - |
| *Trema orientalis* | 0.23 | 0.42 | 0.36 | **1.01** | | | | | | | | |
| *Tricalysia discolor* | 0.23 | 0.42 | 0.04 | **0.69** | - | - | - | - | 2.74 | 2.67 | 0.03 | **5.44** |
| *Trichilia prieuriana* | 0.23 | 0.42 | 0.50 | **1.15** | - | - | - | - | - | - | - | - |
| *Trichilia tessmannii* | 0.90 | 0.85 | 0.78 | **2.53** | 0.30 | 1.41 | 0.10 | **1.81** | - | - | - | - |
| *Triplochiton scleroxylon* | 1.58 | 2.12 | 4.04 | **7.74** | 0.60 | 1.41 | 0.24 | **2.25** | - | - | - | - |
| *Turraeanthus africanus* | 0.45 | 0.42 | 0.09 | **0.96** | - | - | - | - | - | - | - | - |
| *Vitex ferruginea* | 0.45 | 0.42 | 0.67 | **1.54** | - | - | - | - | - | - | - | - |
| *Voacanga africana* | 0.45 | 0.42 | 0.06 | **0.93** | - | - | - | - | - | - | - | - |
| *Xylia evansii* | 0.45 | 0.85 | 4.30 | **5.60** | 0.30 | 0.71 | 0.05 | **1.06** | - | - | - | - |
| *Xylopia aethiopica* | 0.45 | 0.85 | 0.07 | **1.37** | - | - | - | - | - | - | - | - |
| *Xylopia staudtii* | 0.23 | 0.42 | 0.27 | **0.92** | - | - | - | - | - | - | - | - |
| *Xylopia villosa* | 0.23 | 0.42 | 0.04 | **0.69** | - | - | - | - | - | - | - | - |
| *Zanthoxylum gilletii* | 1.35 | 0.42 | 0.04 | **1.81** | - | - | - | - | - | - | - | - |

RD = Relative density, RF = Relative frequency, RBA = Relative basal area, IV =Important value

**Table 3. Summary characteristics of species richness and structure the Atiwa Range Forest Reserve**

| Parameters | NDF | IDF | HDF |
|---|---|---|---|
| **Liana** | | | |
| Species richness | 29 | 17 | 13 |
| Mean species richness/plot | 8.80$^{a}$ | 5.30$^{b}$ | 2.40$^{c}$ |
| Mean DBH (cm) | 2.90 | 3.15 | 2.95 |
| Mean basal area (cm$^2$) | 0.061$^{a}$ | 0.052$^{a}$ | 0.046$^{a}$ |
| Mean density (ha$^{-1}$) | 70.80$^{a}$ | 51.60$^{a}$ | 12.00$^{b}$ |
| **Shrubs** | | | |
| Species richness | 4 | 3 | 2 |
| Mean DBH (cm) | 15.63 | 11.54 | 13.00 |
| Mean basal area (cm$^2$) | 0.07 | 0.04 | 0.05 |
| Mean density (ha$^{-1}$) | 5.6 | 6.4 | 2.8 |
| **Trees** | | | |
| Species richness | 82 | 37 | 19 |
| Mean species richness/plot | 17.64$^{a}$ | 9.55$^{b}$ | 6.30$^{c}$ |
| Mean DBH (cm) | 28.01 | 27.64 | 22.10 |
| Mean basal area (m$^2$/ha) | 10.39$^{a}$ | 7.47$^{a}$ | 2.86$^{b}$ |
| Mean density (ha$^{-1}$) | 113.6$^{a}$ | 87.20$^{a}$ | 43.60$^{b}$ |
| **Combined** | | | |
| Species richness | 115 | 57 | 34 |
| Mean species richness/plot | 26.52$^{a}$ | 14.75$^{b}$ | 8.70$^{c}$ |
| Mean DBH (cm) | 18.45 | 18.70 | 18.10 |
| Mean basal area (m$^2$/ha) | 10.44$^{a}$ | 7.52$^{b}$ | 2.90$^{c}$ |
| Mean density (ha$^{-1}$) | 184.40$^{a}$ | 138.80$^{b}$ | 55.60$^{c}$ |
| Mean canopy cover (%) | 89.61$^{a}$ | 68.30$^{b}$ | 42.16$^{c}$ |

*Means within the same row that have different superscripts are significantly different at $\alpha$ = 5 % (i.e. p = 0.05).*

# CHAPTER FIVE

## 5.0 DISCUSSION

### 5.1 Species richness

Species richness within the non-disturbed forest was higher in relation to the other forests types. This pattern of species distribution is supported by other related studies (Muhanguzi et al., 2007; Rao *et al*., 1990; Grubb, 1977; Connell 1978; Houston, 1979; Pickett, 1980; Armesto and Pickett, 1985). All these studies have related this trend to the influence of human disturbances. Trees constituted the major life form of woody species in the forest. Six hundred and twenty-nine individual trees were recorded on 7.5 hectare of land compared with 312 individual lianas and 18 individual shrubs on the same 7.5 hectare of land**.** The current study confirms the work of other authors that trees constitute the predominant woody life forms in forests (Vordzogbe *et al*., 2005; Anning *et al*., 2008; Addo-Fordjour *et al*., 2009b).There was a decreasing trend in the number of individuals with increasing disturbance (from the non-disturbed forest through the moderately disturbed forest to the heavily disturbed forest). The result of this work proves that the areas that support many species also support many individuals (Muhanguzi *et al*., 2007).

### 5.2 Diversity

Although woody plant species diversity differed significantly across the forest blocks in all the life forms, the extent of influence of the forest blocks and therefore, disturbance on diversity varied. Whereas significant differences existed between all the forest pairs (thus between non-disturbed and moderately disturbed forests, non-disturbed and heavily disturbed forest, and moderately disturbed and heavily disturbed forests) in the case of trees, differences occurred only between some of the forest pairs in the other life forms. This clearly demonstrates the differential effects of human disturbances on different plant life forms. Comparing the result to other related works, Muhanguzi *et al*. (2007) and (Rao *et al.*, 1990) documented a decline in diversity from the undisturbed to the mildly disturbed to highly disturbed forests in a related study conducted in Uganda and India respectively. Some more results of other related works follow the same trend (Grubb, 1977; Connell, 1978; Houston, 1979; Pickett, 1980; Armesto and Pickett, 1985) as in this study.

Ten tree species, three lianas and two shrubs occurred in all the three forest blocks. This may signify their wider range of ecological adaptation (Senbeta *et al.*, 2005; Addo-Fordjour *et al.*, 2008). *Griffonia simplicifolia* was among the lianas that occurred in all the forest types and it has been reported of as the commonest climbing plant in Ghana's forest showing its plasticity to different habitats (Swaine *et al.*, 2005; Addo-Fordjour *et al.*, 2009a).

There were more families in the non-disturbed forest (40 families) in relation to the other forest types (26 and 20 families in the moderately and heavily disturbed forests respectively). Apocynaceae, Euphorbiaceae, Fabaceae and Rubiaceae were the most species rich families in all the forest. The dorminance of Moraceae in some semi-deciduous forests has been reported (Vordzogbe *et al.*, 2005; Anning *et al.*, 2008; Addo-Fordjour *et al.*, 2009b).

## 5.3 Forest structure

The stand structure in the Atiwa range forest reserve was not uniform but varied from one forest block to another mainly due to the influence of anthropogenic disturbance. The effect of disturbance on canopy cover was clearly evident in the study, with canopy cover significantly decreasing with increasing disturbance. This pattern is supported by the work of Pereira *et al*. (2001). The direct removal of trees by logging and farming activities were directly responsible for the decrease in canopy cover in the disturbed areas. The mean tree basal area of the non-disturbed forest was higher than those of the other forest types. In fact, the significant differences that existed between the non-disturbed and heavily disturbed forests on one hand, and moderately disturbed and heavily disturbed forests on the other hand, in terms of mean basal area of trees, clearly demonstrates the effects of human disturbance on this structural attribute of the forest. Although, the mean liana basal area decreased with increasing disturbance, the difference between them was not significant as observed for trees. Thus, disturbance in the forest exerted differential influence on the basal area of trees and lianas. The pattern of plant density for both trees and lianas was similar to that of basal area of trees, once again emphasizing the role of disturbance. Generally, the diameter class distribution for lianas in the non-disturbed and moderately disturbed forests followed the usual inverted J shape pattern that has been observed in other related studies (Parren, 2003; Muthuramkumar and Parthasarathy, 2000). In this case, majority of the lianas were distributed in the lower diameter classes, indicating that the diameter threshold of 1 cm used in the study was appropriate as it included majority of liana individuals. The higher abundance of lianas in small diameter classes may be attributed to their extremely slow stem diameter increment by an inverse resource allocation (Putz, 1983). The paucity at some diameter classes in the heavily disturbed forest suggests that the recruitment process was affected by a combination of certain factors such as deforestation. The absence of large size lianas in the heavily disturbed forest is at least partly due to logging and farming activities in the area. This depicts the negative effects of deforestation on the abundance of large diameter lianas (Addo-Fordjour *et al*., 2008; Addo-Fordjour *et al*., 2009a). The diameter distribution pattern for trees was irregular in all the forest types. Whereas in the moderately and heavily disturbed forests this deviation from the normal inverted J shape pattern could be explained by deforestation (Nord-Larsen and Cao, 2006), it is surprising that the non-disturbed forest showed this pattern.

## 6.0 CONCLUSION

Diversity for all the life forms decreased with increasing disturbance. In the same manner, species richness of all the life forms decreased in response to increasing human disturbance. The average canopy cover decreased with increased disturbance. The average basal area and density of all the life forms and dbh of trees followed the above trend. The highest dbh for lianas was recorded in the moderately disturbed forest than in the non-disturbed and heavily disturbed forests and that for shrubs was higher in the heavily disturbed forest than in the other forest types.

The non-disturbed forest had more matured trees because; there was no disturbance thus making this forest type more diverse and rich in the species identified there. Previous human disturbances in the form of illegal logging led to the loss of diversity and species richness in the moderately disturbed forest while logging, removal of non timber products and farming activities have also influenced the diversity and species richness of the woody species in the heavily disturbed forests. The structure of the moderately disturbed and heavily disturbed forests was affected by cutting down of big and tall tress for timber thereby creating gaps in the forest types.

The findings of the study revealed that human disturbance has influenced the species richness, diversity and structure in the moderately disturbed and heavily disturbed forests of the Atiwa Range Forest Reserve. For Atiwa Range Forest Reserve to maintain its status of being biodiversity rich forests in Ghana, proper management strategies have to be adopted to control the exploitation of forest resources including controlled selective felling. This may reduce the forest degeneration process and enhance it for sustainable forest production.

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