KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF SCIENCE

DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY

IMPACT OF LAND USE CHANGES ON DIVERSITY, COMMUNITY STRUCTURE AND NATURAL REGENERATION OF WOODY PLANT SPECIES IN A MOIST SEMI-DECIDUOUS FOREST

A THESIS SUBMITTED TO THE DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY IN PARTIAL FULFILMENT OF THE REQUIREMENTS OF MASTER OF SCIENCE DEGREE IN ENVIRONMENTAL SCIENCE

BY

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DECLARATION AND CERTIFICATION

I hereby declare that this submission is my own work towards the Master of Science (M.Sc.) Degree, and that, to the best of my knowledge it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgment has been made in the text.

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ABSTRACT

The diversity, community structure and natural regeneration of woody plant species were assessed in twenty four 50m × 20m sampling plots. Within each of these plots, two 5m × 5m sub-plots were established for the assessment of regeneration species. These plots were established to represent the various land use forms in the study area. Land use change had significant impact on tree and liana diversity in the study (trees: $p < 0.001$; lianas: $p < 0.001$). With regard to trees the differences existed among all the habitats except between the secondary forest and logged forest. On the other hand, differences occurred between all the pairs of habitats except for the abandoned mine site and abandoned farm area pair. The mean canopy cover differed significantly ($p < 0.001$) among all the habitats. The difference in the mean canopy cover existed among all the habitats except between the secondary forest and the illegally logged forest. Whereas mean rank density differed significantly ($p < 0.001$), there was no significant difference in the mean diameter at breast height (dbh) ($p = 0.52$) among all the habitats. The Shannon diversity index for saplings differed significantly among the habitats ($P = 0.022$). The difference existed between the abandoned mined site and the rest of the habitats. There was no significant difference between sapling diversity among the other habitats. In the same way, there were significantly lower seedling diversity in the abandoned mined site ($p <0.001$) compared to the other habitats. Land use change had significant impact on the diversity, community structure and natural regeneration capacity of the study area.

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TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

1.1 Background of Study

The diversity of life present on the earth is a critical prerequisite for ecosystem functionality and human well-being. Forests provide suitable habitats to most of these. However, the earth's biological diversity is at an unprecedented rate of change due to complex response to many anthropogenic induced changes (Hooper *et al*., 2005; Vitousek, 1994), to the forests that provide them with natural habitats. There are several reasons why everyone should be deeply concern regarding this change. Apart from ethical, economical, ecological, and aesthetic reasons, the alterations in the world's biological diversity can alter ecosystem services and environmental goods they provide as well as such properties as productivity, decomposition rates, nutrient cycling, and resistance and resilience to disturbances (Spiegelberger *et al*., 2006; Loreau *et al*., 2001). The factors affecting biodiversity are overexploitation, invasion species, habitat fragmentation and loss, and land use changes among others.

Over-exploitation of resources, including over-hunting, leads to the attenuation of the stocks of animal and plant resources which reduces population, affects the genetic diversity and increases the risk of local extirpation and subsequent extinction. The threat of invasive species on native species is increasing considerably (Winterbottom and Eilu, 2006). Exotic species have the ability to out-compete and take the place of native species and thus reduce the species diversity, decrease genetic diversity and increase the homogeneity of the landscape. The transformation of a large expanse of habitat into a number of smaller patches of smaller total area, isolated from each other by a matrix of habits unlike the original has important repercussion on the flora and fauna that originally occupied large continuous areas of natural habitat. The destruction of these natural habitats through direct anthropogenic activities impacts negatively on biodiversity at the ecosystem, species and genetic levels.

Land use changes are often associated with negative impacts globally. It remains the single most leading cause of loss of biodiversity due to the form it usually take as these result in the destruction, conversion and fragmentation of an existing ecosystem (Duraiappah, 2005; Fahrig, 2003). In some cases, there may be a total transformation of one type of land use form into another. The transformation could also be partial in which case the primary status of the use to which a land is put is retained in the latter, for example a natural to exotic vegetation. Throughout the recent past, human population growth accompanied by extensive and intensive land use has increased the pressure on forest habitats which normally results in the break-up of larger continuous habitats into smaller fractions leading to lose of components of their ecological functions. The conversion of natural habitats consequent to land use may totally damage the living conditions of a particular species, alter species composition and initiate species extinction.

Land use change could entail system changes and as well occur in the form of extensificaton and intensification in which case one or more land uses expand at the expense of other land use types or their uses intensified. The root cause of land use change leading to forest degradation and biological diversity loss are multi-faceted but can be categorized as demographic, economic, politics, policies, institutional, infrastructure, and socio-cultural (William, 2003; Wood *et al*., 2000). In several ways, a combination of these factors alter resource use patterns which in turn determine land use change leading to forest encroachment and finally habitat destruction. In effect, the community structure of the forest is greatly altered which impacts significantly on species diversity. Also, natural regeneration, the process of re-growing or reproducing new individual plants in the community; an important process to maintain the stable structure of the plant species in a community, is affected directly or indirectly by some of these factors. The issue of regeneration is mainly important for those forests which are under particular anthropogenic pressures such as felling tree, grazing and trampling among others.

1.2 Problem Statement/Purpose of Study

Forests generally provide a variety of flora and fauna with habitats and are also the sources and sinks for most of the biochemical and energy flows that maintain the biosphere and geosphere as well as trace gas emissions and hydrological cycle (William, 2003). Tropical forests in particular harbour most of the world's biodiversity and thus make them very important to the extent that biodiversity provides not only environmental goods for economic development and food security among others but also environmental services for proper ecosystem functioning and socio-cultural benefits (Oduro, 2002).

Another very important factor worth mentioning is the characteristic nature of tropical forests which makes any form of its alteration topical. Tropical forests are extremely high in biodiversity, have many rare species as well as large numbers of endemic species. The plants and animal species of tropical forests are very vulnerable to fragmentation or destruction of their habitats. Despite these characteristic features, they are the most affected by anthropogenic activities.

Human-induced habitat loss represents the largest current threat to biodiversity, accompanied by fundamental changes in ecological functioning. During the past decades human population growth and intensification of land use increased the pressure on forest habitats. Land cover changes, such as conversion of forest and woodland areas to agricultural land, continues at an increasing rate. The high tree diversity of West Africa, as a natural resource and a basic foundation of the livelihood of the region's inhabitants, is declining in many places. Prominent among such factors as over exploitation, plant invasion as well as habit fragmentation and loss that affect biodiversity is land use change.

1.3 Justification

Land use change has been identified to have significant impart on forest cover and species diversity in forest biomes. They reduce forest cover leading to loss of habitats and change in species diversity. There is a dramatic constriction on suitable species and natural forest habitats in areas that previously were not in danger and may be threatened due to human developments in respect to land use activities in the face of increasing rate of human population growth.

Understanding the impacts of land use changes on biodiversity is of critical importance for developing appropriate conservation plans and management guidelines for sustainable development. Specifically, the kind of relationship that exists between anthropogenic impacts and species inhabiting a particular landscape will inform the conservation and management approaches that can be used. Chown *et al*. (2003) opine that if species diversity and anthropogenic influence shows a positive relationship, conservation conflicts are probable to increase because the intensified human demand for resources places species and their habitats at greater risk. This will mean that conservation efforts should focus on those areas that human activities are already high so as to counterbalance imminent conflicts between biodiversity protection and development. On the other hand, Luck *et al*. (2004) indicated that a negative relationship between biodiversity and anthropogenic activities suggests that the focus should be on those areas with low human disturbance because they harbour greater diversity and therefore protecting those areas may be more cost-effective.

Further studies into the different and complex response of species to human disturbances are urgently needed to define effective and efficient strategies for conservation. To that end assessment of the land use impact on the structure, diversity and natural regeneration of forests is a very important undertaking.

Biodiversity assessment, monitoring and reporting are important activities aimed at guiding sustainable forest management. Though there are conceptual and practical difficulties, monitoring of biological diversity and of the changes that might have occurred as a result of anthropogenic activities is important in assessing the effectiveness of management and the cumulative changes brought about by change in land use activities.

1.4 Main Objective

The main objective of the study was to determine the impact of land use changes on the diversity, community structure, and natural regeneration of woody plant species in a moist semi-deciduous forest at Akyempim in the Tarkwa-Nsuaem Municipality in the Western Region of Ghana.

1.5 Specific Objectives

The specific objectives of the study were to:

i. Identify woody plant species within the secondary forest under different land use forms.

ii. Determine the structure of the vegetation of the secondary forest with different land use forms.

iii. Determine the natural regeneration capacity of the secondary forest with different land use forms.

CHAPTER TWO

LITERATURE REVIEW

2.0 General Introduction

Human-induced habitat loss currently represents the largest threat to biodiversity (Gaston, 2005), accompanied by fundamental changes in ecological functioning (Laurance and Luizao, 2007; MEA, 2005). During the past decades human population growth and intensification of land use has increased the pressure on forest habitats (Poorter and Bongers, 2004; Wilkie and Laporte, 2001). Land cover changes, such as conversion of forest and woodland areas to agricultural land, continues at an increasing rate (FAO, 2006). The high tree diversity of West Africa, as a natural resource and a basic foundation of the livelihood of the region's inhabitants, is declining in many places (Balmford *et al*., 2001).

The use to which man puts land normally leads to destruction, conversion, and/or fragmentation of an existing system. This makes land use the strong force leading to a substantial loss of biodiversity (Duraiappah, 2005; Fahrig, 2003). The conversation of natural habitats into land use area may totally damage the living conditions of particular species, alter species composition and start species extinctions. The increasing demand of area for land use often causes the break-up of larger habitats into smaller fractions, which may lose parts of their ecological functions.

Land use changes are often associated with negative impacts globally. It remains the single most leading cause of loss of biodiversity due to the form it usually take as the destruction, conversion and fragmentation of an existing ecosystem (Duraiappah, 2005; Fahrig, 2003).

2.1 Tropical Forests

In recent times much interest has been shown in tropical forests both for their high biodiversity and the rate at which they are being destroyed. The deforestation of tropical forests is in many ways, a replay of the fate of temperate forests centuries earlier (Fine, 2002). Tropical forests were considered to be biotic museums where the vast inventory of biodiversity had accumulated partly as a result of the absence of disturbances. Ecosystem stability was believed to be a function of ecosystem maturity or complexity however, human activity introduces unpredictable change in conditions to mature and complex forests believed to be adapted to constant conditions making tropical forests appeared fragile (Lugo, 1995).

The tropical dry forests are among the most endangered ecosystems in the world with less than 0.1% of the original dry forest of Pacific Mesoamerica under protection (Murphy and Lugo, 1986). Throughout Mexico and Central America in particular, the principal cause of tropical dry forest conversion has been deforestation for the development of cattle pastures (Maas, 1995). Apart from reduction in species diversity (Guevara *et al.*, 1992), other ecological consequences subsequent to conversion of tropical forest conversion include: (a) vegetative cover reduction (b) water cycle disruption (c) soil nutrients and status alterations and (d) soil compaction (Johnson and Wedin, 1997; Maas, 1995; Garcia-Oliva *et al.*, 1994).

Studies (elsewhere) have shown that domestic livestock grazing in native ecosystems results in alterations in plant species composition, disruption of ecosystem function, alteration of ecosystem structure, and changes in faunal diversity (Stern, Quesada and Stoner, 2002).

2.2 The Nature of Ghana's Forests

Two main forest zones are found in Ghana: the savannah woodlands and the tropical high forest in the north and in the south respectively. However, the coastal areas around Accra are mainly made up of coastal thicket, and mangrove vegetation. The high forest zone of Ghana harbour over 2,100 plant species out of which 23 are endemic (Oduro, 2002; Hall and Swaine, 1981) whereas 730 tree species have been recorded from the closed forests (Hawthorne, 1989).

In terms of floral species richness, the Wet Evergreen Forest is floristically the richest on one hand and the drier Southern Marginal Forest is the poorest on the other hand. The Moist Evergreen and Moist Semideciduous Forest types are the most important for commercial timber species. The main timber species in the deciduous forests are *Triplochiton scleroxylon* (Wawa), *Mansonia altissima* (Mansonia), *Nesogordonia papaverifera* (Danta) and *Khaya ivorensis* (Mahogany); and in the evergreen forests *Guarea cedrata* (Guarea), *Tieghemella heckelii* (Makore), *Tarrietia utilis* (Niangon) and *Uapaca spp* (Assam).

The forest zones of Ghana are known to have more plant species endemism and diversity than the savanna areas. There are approximately 19 plant species, mostly in the forest vegetation, considered endemic in Ghana. There also exist a decreasing trend in plant species endemism and diversity within the various forest types from the Wet Evergreen (WE) through Moist Evergreen (ME), Upland Evergreen (UE), Moist Semi-Deciduous (MSD), Dry Semi- Deciduous (DSD), and Southern Marginal (SM) to the South-East Outliers (SO), (Hall and Swaine, 1981). Each of these classified sub-zones of the forest is associated with a well-defined plant species, corresponding rainfall and soil conditions. Some of these are briefly reviewed below:

2.2.1 Wet Evergreen

In Ghana, this is the only real rainforest and it epitomizes the heaviest area of rainfall. The community of this forest type is the most diverse in terms of flora composition in Ghana however; it contains not many of the significant commercial timber species (Wagner, Cobbinah and Bosu, 2008). There are multistory stands as well as nutrient-poor soils. This forest type contributes about 3.3% to the total forest area in Ghana. Among the four main forest types in Ghana it has the lowest tree height. This rather lower average tree height may be related to high rainfall and associated nutrient leaching. Common tree species in this forest include *Dacryodes klaineana, Strombosia glaucescens, Diospyros sauza-minaka, Dialium aubrevillei, Heritiera utilis and Lophira alata.*

2.2.2 Moist Evergreen

Though similar to the wet evergreen forest in the areas of rainfall and floristic composition, this forest type tends to have a few more deciduous species and significantly more economic species (Wagner *et al*., 2008). For example, *Triplochiton scleroxylon*, one of the most commercial timber species occurs in this forest type. This forest type represents about 8.2% of the total forest area. The heights of trees in this forest zone tend to be lower than the moist semi-deciduous trees but higher than the wet evergreen forest.

2.2.3 Moist Semi-Deciduous

Forests of this nature are characteristically abundant throughout West Africa and in Ghana particularly, it is the most extensive closed canopy forest type in Africa (Hall and Swaine, 1981). Structurally; it has the tallest trees and several canopy layers with discontinuous upper canopy because of the presence of a few emergent species. Most of the country's timber species such as *Celtis mildbraedii, Entandrophragma utile, Guibourtia ehie, Khaya anthotheca, Khaya ivorensis, Nesogordonia papaverifera, Pericopsis elata, Terminalia ivorensis*, and *T. scleroxylon* are obtained from this forest type (Wagner *et al*., 2008).

2.2.4 Dry Semi-Deciduous

This forest type constitutes the transition zone between the higher rainfall types and the Guinea savannah. It covers about 26% of the forest area. Comparatively, trees in this forest type attain intermediate height. It has a well developed vertical crown structure with multiple canopy layers (Wagner *et al*., 2008).

2.3 Characteristics of Tropical Forests

Mature forests often have several distinct vertical layers. These include: forest floor, herb layer, shrub layer, understory, canopy and emergent. The species composition of a forest is often unique to that forest, with some forests consisting of many hundreds of species of trees while others consist of just a handful of species. Forests constantly change and progress through a series of successional stages during which species composition changes within the forest. These different layers provide a mosaic of habitats and enable animals and wildlife to settle into various pockets of habitat within the overall structure of a forest. Tropical forests differ in structure and species composition. However, they have certain distinct features distinguishing them from the temperate forests (Riswan and Hartanti, 1995).

2.3.1 Forest Species and Ecosystem

In terms of forest species, tropical forest are characterized by: (a) high biodiversity – have extremely rich flora and fauna species, (b) many rare species – individual species, particularly trees, are usually represented by few individuals per unit area, (c) large number of endemic species – many of the flora and fauna species have localized distributions (d) very slow migration rates of both plants and animals and are therefore very susceptible to habitat fragmentation or destruction, and (e) an ecosystem stability that mainly depends on a high level of species diversity (Riswan and Hartanti, 1995).

In terms of the forest ecosystem, tropical forests have some distinctive peculiarities: (a) there are stable, dynamic and complex ecosystems with a balance between the biological and physicochemical components, (b) the soils are largely poor in the major plant nutrients, particularly phosphorus and potassium, and (c) a major part of the nutrient capital is in the biomass rather than in the soils, and an almost closed nutrient cycle with a little loss in the drainage water (Riswan and Hartanti, 1995; Golley *et al.*, 1975).

2.3.2 Structure of Tropical Forests

Different authors express contrasting views on the forces that structure tropical rain-forest plant communities and other species-rich biotic communities. On one hand, local community structure is considered to be the deterministic result of inter specific interactions and differences in niche requirements among species (Wright, 2002; Hubbell, 2001; Tilman, 1997). On the other hand, local communities are considered to be controlled by dispersal-dependent sampling of the regional species pool (Hubbell, 2001; Cornell and Lawton, 1992). Interestingly, Hubell (2001) considers both factors.

Furthermore, other authors (Liyun *et al.*, 2006) consider species diversity, seral stage, and the community stability as the essential parameters for proper characterization of a community. Species diversity directly controls community structure, and it is the biological basis for the maintance of ecosystem functions (Zhang *et al.*, 2004; Tilman and Downing, 1994). The diversity of species is not only an important index in describing a community but it also indicates the type of community, the stage of community development and community stability (Liyun *et al.*, 2006). Species richness is a simple interpretable indicator of biological diversity (Peet, 1974). Several changes in the environment affect the processes that can influence biological diversity. The altitude and climatic variations such as temperature and rainfall can affect the diversity of a particular area (Sharma *et al*., 2009). Also, differences in altitude and slope affect the species richness (Ellu and Obua, 2005). Normally, species richness decreases along a vertical gradient and it is mainly as a result of decline in temperature (Qi-Jing, 1997). However, Dolezal and Srutek (2002) reported that species richness and diversity have no well-defined correlation to altitude but tended to increase with the degree of tree/shrub canopy closure.

2.3.3 Flora Diversity

Plant diversity in the tropical forests is heterogeneous in terms of species richness and endemism patterning. Towards the equator there is an obvious increase of species diversity. Barthlott *et al*. (2007) noted that species richness is strongly correlated to perhumid conditions, historic climate stability, and highly structured vegetation. On the other hand, lowest species numbers are usually recorded in perarid to arid desert regions (Barthlott *et al*., 2007). Species richness may also be connected to palaeo-climatic fluctuations (Linder, 2001). The diversity of abiotic factors, commonly referred to as geodiversity, affect species diversity to a great extent. Geodiversity is a mainspring for habitat differentiation of communities and may account for the higher biodiversity in abiotically heterogeneous areas (Barthlott *et al*., 1999). There are many life forms that characterize tropical forests and two of such that are of great importance to this work are trees and climbers.

2.4 Importance of Tropical Forests

The tropical forests contain most of the world's biodiversity. The importance of tropical forests is therefore a function of its biological diversity. Broadly, the benefits derived from the tropical forests can be divided into food security and others such as environmental goods and economic value, environmental services and ecological importance, and socio-cultural importance (FAO, 2008; Oduro, 2002).

2.4.1 Biodiversity for Human Food Security

Biodiversity guarantees an incessant supply of food and energy. Through the role it plays in ecosystem functions and services, biodiversity builds the basis for agricultural production, the origin of all crops and domesticated livestock, and their variety (FAO, 2008). Agriculture production directly depends on such ecosystem services as pollination and biological pest control provided by biodiversity. Over 100,000 animal species play vital roles as agents in the pollination of animal pollinated crops and well over 90% potential crop-insect-pest are controlled by natural enemies living in areas adjacent croplands (FAO, 2008). Indirectly, intact ecosystems contribute to agricultural systems as it holds up soil fertility, nutrient supply, water cycle and quality. It also helps in the prevention of such environmental hazards as soil erosion, flood and drought.

2.4.2 Others

There are other benefits derived from tropical forests. These include environmental goods and economic value, environmental services and ecological value as well as socio-cultural values. A lot of the plants and animals from the forest are essential commercial trade products. There are other valuable non-timber forest products including but not limited to fruits, nuts, gums, dyes, latexes, oils, resins and drugs which are obtained from tropical forest (Riswan and Hartanti, 1995). In Ghana, for instance, the forestry sector contributes about 11% of the national foreign exchange earnings and the timber industry in particular contributes 6% of GDP whilst providing employment opportunities to about 104, 0000 people and livelihood for about two million of the population (Gene-Birikorang *et al*., 2001; Appiah, 1998;).

Tropical forests provide invaluable environmental services and contribute greatly in the maintenance of local, regional and global natural ecosystems (Oduro, 2002). However, the ecosystem services they provide does not depend so much on the absolute number of species present but on the diversity of the functions performed by different members of the ecological community. Ecosystem biodiversity influence climate at local, regional and global levels. For instance, radiation from the sun, evapotranspiration, air temperature, fire regime and carbon sequestration, all of which affect climate, are influenced by the type and distribution of habitats and functional diversity of terrestrial plants (MEA, 2006).

Local communities of all cultures around tropical forests normally have special traditional knowledge in their way of life. People place cultural, spiritual, religious, and aesthetic values on biodiversity (MEA, 2005; Biggs *et al*., 2004). These values are expressed in the form of sacred species, ecosystems and landscapes by the traditional communities whereas in the urban and developed communities, these are expressed in the form of protected areas and heritage sites. In Ghana for example, stools which are the symbol of Asante Chieftaincy, are normally carved with specific sacred-tree woods and also drums are made from specific woods and animal skins (Oduro, 2002). A lot of religions attach spiritual values to ecosystems or their components and therefore loss or damage to these ecosystems can harm social relations by impeding religious and social ceremonies that bind them (MEA, 2005, 2003).

2.5 Factors Affecting Biodiversity

The factors that affect biodiversity are many. Chief among these are land use changes, overexploitation, invasive species, and habitat fragmentation and loss. These are briefly reviewed in this section.

2.5.1 Land Use Change

The modification of an existing natural environment by anthropogenic activities, normally leading to the destruction, conversion and fragmentation of the system, represents the key driver leading to a considerable loss of biodiversity (Duraiappah, 2005; Fahrig, 2003). Converting natural habitats into land use areas may totally destroy the living conditions of a particular species, alter species composition, and initiate species extinctions. Furthermore rising demands for land, most often than not, leads to the breakup of lager habitats into smaller fractions which may lose parts of their ecological functions. The root cause of land-use change leading to forest degradation and subsequently biodiversity loss may be categorized as demographic, economic, policies, institutional, politics, infrastructure, and socio-cultural factors (William, 2003;

Wood, 2000) which either independently or in complex combination, may have altered resource use pattern that have resulted in change in land use (Sabellek, 2010).

The gravity of the impact of any of these land use categories on the biological diversity, for the most part, depends on the extent of habitat modifications through removals, displacements and introduction of species (Ayensu *et al.*, 1996). The kind of technologies employed in any one particular land use form may bring about changes in the diversity of biological resources. Both conventional and modern technologies are implicated in this. The main categories of land use in Ghana with important impact on biodiversity and forest resources are mining, logging, agriculture, gathering, settlement, tourism, transportation and energy (hydro-electric impoundments and fuelwood) (Ayensu *et al.*, 1996).

2.5.1.1 Mining

Mining activities require large concessionary areas for the tailings dam, plant site and feed stockpile, siting of mines, heap leach facilities, open pits and mine camps which could have both direct and indirect impact on the natural forest habitat. Over the years, mining activities have resulted in substantial disturbance of surface soils in the mining areas, destruction of vegetation and the pollution of water and air (Ayensu *et al.*, 1996). Generally, mining leads to rapid environmental degradation and more particularly activities of large-scale mining continue to reduce the vegetation of an area to levels that are destructive to biodiversity (Akabzaa and Darimani, 2001).

Surface mining leads to deforestation as a result of clearing considerable areas of land and vegetation which has long-term effects even with replacement of top soil for re-aforestation after mine decommissioning (Akabzaa and Darimani, 2001). New species that might be introduced have the potential to influence species diversity in the area. Suitable habitats for birds and other animals are not only significantly destroyed but also excessive noise associated with mining activities can frighten animals, interfere with their mating processes and also cause abortions, therefore negatively affecting the animal population.

Furthermore, mining projects are usually sited in remote areas and are as such associated with the construction of substantial physical and social infrastructure including roads, schools, hospitals, electricity and water supplies (Akabzaa and Darimani, 2001). The development of these infrastructure impacts negatively on biodiversity as clearing of forest for space normally leads to the removal and destruction of suitable natural habits. Also, large scale mining could lead to displacement, relocation and resettlement of communities (Akabzaa and Darimani, 2001). This has an associated impact, usually negative, on forest areas as demand for new land areas to meet the needs of these communities increase.

2.5.1.2 Logging

Examined at the community and regional scales, there appears to be a simplifying and homogenizing effect of logging on tropical forest diversity (Bawa and Seidler, 1998). The direct effects of logging in a primary tropical forest are significant changes to the physical structure of the forest. The canopy cover of an area can be reduced to about 50% as a result of removal of about 3.3% of trees in that area (Bawa and Seidler, 1998). Gullison and Hardner (1993) also documented a 4-5% damage to basal area consequent to the removal of merely 0.12 mahogany trees per hectare.

Another major effect of logging operations is the changes in species abundance and species composition. Many studies have reported a decline in a number of large tree species subsequent to logging (Bawa and Seidler, 1998; Primack and Lee, 1991; Okali and Ola-Adams, 1987). Even when mechanization is small and there is comparatively little incidental damage during extraction (Ganzhorn *et al.*, 1990), there are declines in overstory tree size, increased abundance of a few small-stemmed species, and a decrease in larger commercial species. In other cases, the number of tree species generally remains unchanged however, species composition changes favourably towards pioneer species (Primack and Lee, 1991).

Generally, the pattern of change in tropical forest biodiversity after logging tends towards a local rise in the abundance and diversity of particular species (Bawa and Seidler, 1998). Such rise is observed basically in the abundance and diversity of those species adapted to gap environments and disturbed habitats and of those able to use a variety of resources. A regional decline in species richness may be due to a the loss or shrinking geographic range of such species adapted to comparatively constant conditions of forest interior and those dependent upon a narrow range of resources (Bawa and Seidler, 1998).

2.5.1.3 Agriculture

Agriculture may disturb or destroy the balance of an ecosystem either through disruptive practices on existing farmland or by converting uncultivated land to farmland. Activities associated with agricultural production that may affect biodiversity vary widely in their intensity and effects.

Cultivation of crops and livestock farming has a direct impact on biodiversity resulting from fragmentation and conversion of native habitats. The advent of modern technology into land use practices leads to intensification of land use and to larger homogenized cultivated areas such as plantations and extended croplands (Sabellek, 2010). The destruction of habitats for cropland results directly in biodiversity loss. Poorter and Bongers (2004) documented an approximate 50% of natural areas in the Western African forests already converted to cultivated land. The application of agrochemicals to increase crop yield, may also have negative effects and consequently alter species composition of adjacent ecosystems.

2.5.1.4 Gathering

This land use form is predominant in rural areas and it involves the collection of wild plant and animal produce normally for use or gain. It was a subsistence activity but has increasingly become commercial with urbanization and it is feared it may lead to the endangering of some species (Ayensu *et al.*, 1996). For instance an estimated 90% of Ghanaians use chew sticks collected from the forests. Many plant and animal species have been extensively and intensively gathered to the point of becoming scarce which is indicated by scarcity in the rural areas and by price trends in urban markets.

2.5.1.5 Tourism

Tourism has been given considerable publicity in recent times as an industry which could contribute significantly to the country's gross domestic product. Even though there is no documented evidence that suggest a serious impact of tourism on land use in Ghana (Ayensu *et al.*, 1996), the potential impact of tourism on the environment in general and specifically on biodiversity can not be overlooked. The natural and cultural environment upon which the industry thrives is consequently destroyed by same if proper planning and management is not in place.

2.5.2 Plant Invasion

Non-native species are rare in undisturbed tropical forests but readily invade disturbed ones, usually dominating and even cause irreparable change to the ecosystem (Fine, 2002). They have the potential to alter ecosystem structure and function dramatically. Invasive species are able to exert strong competitive effects on the growth, reproduction and resources allocation on native species, and finally take their place, thus reducing the species diversity, decreasing genetic diversity and increasing the homogeneity of the landscape (Winterbottom and Eilu, 2006; Levine *et al.*, 2003). The extensive and dense rhizome system of some invasive species plays crucial roles in the competitive exclusion of native species from invaded communities.

Another effective way of suppressing native vegetation is the ability of invasive species to form homogenous strands or to grow very fast and tall (Hejdea *et al.*, 2009). However, individual plants of some invading species form clusters leading a spatial pattern of invading populations leaving space for native species to survive in the community after invasion (Hejda and Pysek, 2006).

2.5.3 Overexploitation

The main driver of over exploitation of forest is the ever increasing rate of population growth. As the human population grows, there is an increase demand of forest resources to meet developmental and livelihood needs of the populace. NTFPs play a significant and often critical role in providing subsistence and cash income to a large part of the world's poor population. Three basic reasons can be identified for the engagement of the poor in NTFP extraction; (a) NTFP extraction usually requires very little capital investment, (b) forests are geographically remote from the centers of economic and political power (i.e. tropical forests tend to be occupied by the poorest, most economically marginalized segments of the society) and (c) the absence of alternative income sources (Winterbottom and Eilu, 2006).

Over-exploitation occurs for various reasons (Winterbottom and Eilu, 2006). Whilst in some cases some species are harvested because of their food value, others are because of their commercial value or because they are used in popular medicine. In still other cases, overexploitation is due to the pet and skin trade, whether to private or public collection.

In some cases it is related to destructive extraction practices, such as the use of explosive or toxic substances.

Over-exploitation of resources may lead to the depletion of stocks of animal and plant resources, lowering population, affecting the genetic diversity and increasing the risk of local extirpation and subsequent extinction (Winterbottom and Eilu, 2006).

2.5.4 Habitat Fragmentation and Habitat Loss

Habitat fragmentation involves three factors, which have important repercussion on the species of the flora and fauna that originally occupied large continuous areas of natural habitat (Gehring and Swihart, 2003; Schmiegelow and Monkkonen, 2002).

Firstly, fragmentation results in the breaking of large continuous area into smaller patches leading to a net habitat loss. Consequently, the amount of resources and shelter available to wild species will decline. This may further result in a general decline in the populations that can be hosted.

Secondly, fragmentation results in a substantial increase in edges (Sih *et al.*, 2000). Edges come along with distinct micro-climatic conditions from the core areas that might become less appropriate for species. Furthermore, the edges results in increase rates of predation by favouring generalist predator immigration (Schmiegelow and Monkkonen, 2002) which in turn greatly affects the number of individual resident species.

Thirdly, habitat fragmentation leads to geographic isolation of “islands” of habitat among a matrix of urban or agricultural land-uses. The mobility of certain organisms might be restricted as a result (Andreassen *et al.*, 1996) and thus isolate some populations. Small isolated populations may however be threatened by inbreeding, creating serious problems for their survival and could eventually lead to population extinction in the case of severe inbreeding (Templeton *et al.*, 1990; Schmitt and Seitz, 2002).

2.6 Natural Regeneration

Natural regeneration refers to the process by which trees and woodlands are established from seeds produced and germinated *in situ*. This process normally relates to the restocking of existing woodland however, it also includes the natural colonisation of previously unwooded sites. Natural regeneration can conserve local genotypes and also create more structural diversity within a particular site in which circumstance natural regeneration may be more desirable than planting (Harmer and Gill, 2000). Seedlings may be present before harvesting of the mature and the presence of such advance regeneration is the most reliable indicator that natural regeneration will be successful and sites with trees which fruit frequently are known to have the potential to form advance regeneration (Harmer and Gill, 2000). Species with shade tolerant seedlings are established more readily underneath a canopy than light demanders which only grow well if the canopy density is low (Harmer and Gill, 2000).

2.6.1 Factors Affecting Natural Regeneration

2.6.1.1 Agriculture

Abandoned agricultural lands are usually invaded by non-native (exotic) grasses, which constrain or arrest succession of tree species because of recurrent fires (Hooper, Lengendre, and Condit, 2004). Grass competition can prevent many tree species from regenerating, especially small-seeded species, thus affecting plant community composition. Recovery of mature-forest species composition on heavily used sites can be very slow because intensive land use (often coupled with fire) eliminates tree regeneration from the seed bank and root sprouts leaving seed dispersal as the critical mechanism for forest regeneration (Guariguata and Ostertag, 2001). Weed competition in the ground layer reduces resource availability to tree seedlings throughout early stages of succession. Seasonal changes may cause variation in this competition. In northern Thailand for instance, Hardwick (1999) found that weeds compete with seedlings for light throughout the rainy season but protect seedlings from excessive light during the hot dry season.

Studies have shown that in deforested sites formerly covered by dry evergreen forests, very few of the original species will be restored through natural regeneration (Thongvichit and Sommum, 2003). Species formerly found in the uppermost succession level do not recover easily. It is difficult and requires a long period of time to bring the forests back to their original status. For instance studies conducted in former dry evergreen forest areas that were cut over, converted to farms, and then abandoned for 18 years showed that the trees that regenerated naturally were pioneer species common to secondary forests (Thongvichit and Sommum, 2003). Consequent to the destruction of the genetic pool, the original appearance of the dry evergreen forest was altered.

2.6.1.2 Logging

A lot of shade-tolerant species need increase of light at a certain age so that these suppressed seedlings can reach the canopy. Gaps in forests canopy consequent to logging or natural occurrence complement these light needs. In the understory, light conditions are different in the forest stand and the gap centre, the gap having naturally more light. This light increase brings about accelerated height growth of seedlings (Yirdaw, 2002; Otsamo, 2000). This may cause density of ground vegetation to increase more in large gaps or selection-felled gaps than in small or naturally formed gaps, throughout the first year of the gap formation. Research on forest regeneration after logging showed that; (a) the quality of regeneration can be improved by optimizing the pattern of exploitation and thereby enhancing the forests of the future and (b) the diversity, economic value, and vegetation structure of natural regeneration is more vigorous in small rather than large gaps (Oduro, 2002).

2.6.1.3 Human-Induced Fire Disturbance

Traditionally, fires have been employed as an agricultural tool for swidden cultivation however it is currently widely employed in forests to stimulate growth of the ground vegetation for cattle grazing. There are three main forms of fire that affect forests; (1) ground fires, with slow burning of organic matter on the ground; (2) surface fires, including rapid burning of litter, herbs and shrubs; and (3) crown fires, resulting in the burning of tree crowns in the woody vegetation. In terms of intensity and frequency fire can be classified as frequent low-intensity, infrequent low-intensity, and infrequent high-intensity surface fires (Kiianmaa, 2005).

Fires can severely impact soil moisture in several ways, especially if organic matter is burned at the soil surface; (a) reduce the infiltration rate and increase the surface run-off and further increase the erosion, (b) damage moisture storage especially on coarser soil, where organic matter provide much of the storage capacity, and (c) affect infiltration by forming a water-repellent layer on the soil (Kiianmaa 2005).

Different forest types respond distinctly to fire that alters the balance between tree species and controls the survival of seedlings. However, forest stands that are often burned and whose tree seedlings are destroyed, mature trees are not replaced resulting in a sparse, open canopy, absent understory and a ground layer consisting of fire-resistant grasses (Kiianmaa, 2005).

2.6.2.4 Seed Dispersal

Wind or animal can be agents of seeds dispersal. Wind dispersal follows the downwind direction, whereas animal dispersion can proceed towards any direction from the mother tree. Comparatively, wind-dispersal has a smaller dispersal area than animal dispersal. Generally, animal-generated stands have greater tree species richness than the wind-generated ones and represent a greater proportion of the total population of the area. However, it has been observed that wind dispersed seeds are more uniformly and densely distributed than the animal dispersed ones (Kiianmaa, 2005). Hunting can cause the populations of seed dispersing animals, especially large mammals as well as birds, bats and civets, to diminish or disappear (Kiianmaa, 2005). In severe situations, wind-dispersed species become more common.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

The study was carried out in the Subri Forest in the Tarkwa-Nsuaem Municipality of the Western Region of Ghana. The Tarkwa-Nsuaem Municipal lies between latitudes 4^0 N and $5^0$40” N and longitudes $1^0$45” W and $2^0$10” W. The total land area of the district is about 9,235km^2 and it shares boundaries with districts such as Mpohor-Wassa East to the east, Nzema East to the west, Wassa Amenfi to the north and, Mpohor-Wassa East and Ahanta West to the south.

The area lies within the southeastern limb of the Ashanti Trend, a noticeable northeast trending greenstone belt that stretches well over 240 km within the Man Shield of the West African Craton. The belt takes the form of a synclinorium developed within lower Proterozoic sedimentary and volcaniclastic rocks of the Birimian and the Tarkwaian Groups. The Birimian consists of an assemblage of turbiditic sedimentary (phyllites, schists and greywackes), and volcaniclastic rocks deposited in shallow marine basins separated by a sub-parallel series of north-east trending volcanic belts. The area is characterized by an undulating terrain with a magnificent drainage system.

The area falls within the equatorial climatic zone, basically the tropical rain forest zone of Ghana. The district has a bi-modal rainfall regime with a mean annual rainfall ranging between 1,500mm and 1,933mm. Relative humidity for the area ranges from 70% to

90% with daily temperature ranging between 20^0C and 40^0C whereas the mean monthly temperature ranges from 24^0C to 30^0C.

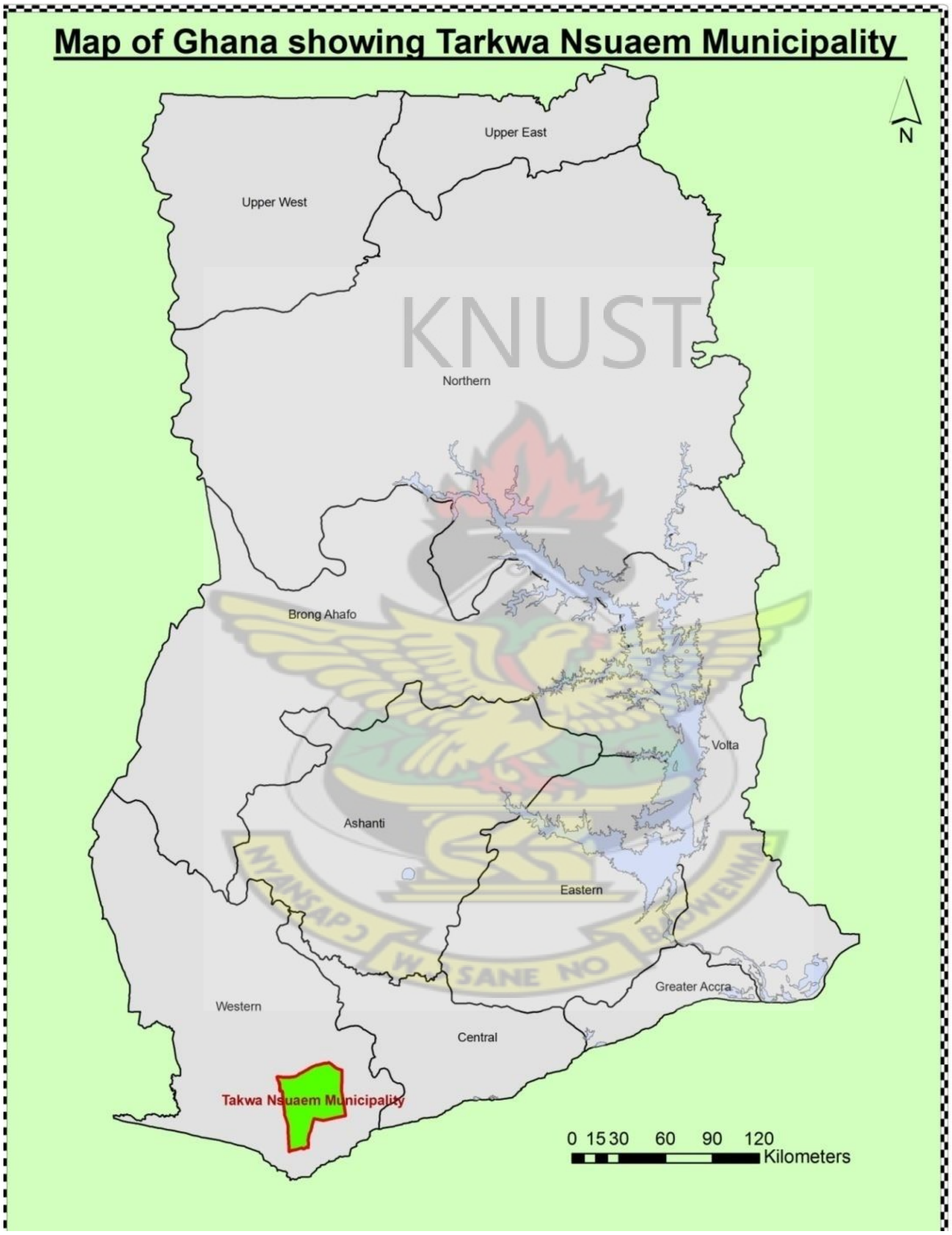

Fig. 1. Map of Ghana showing Tarkwa Nsuaem Municipality

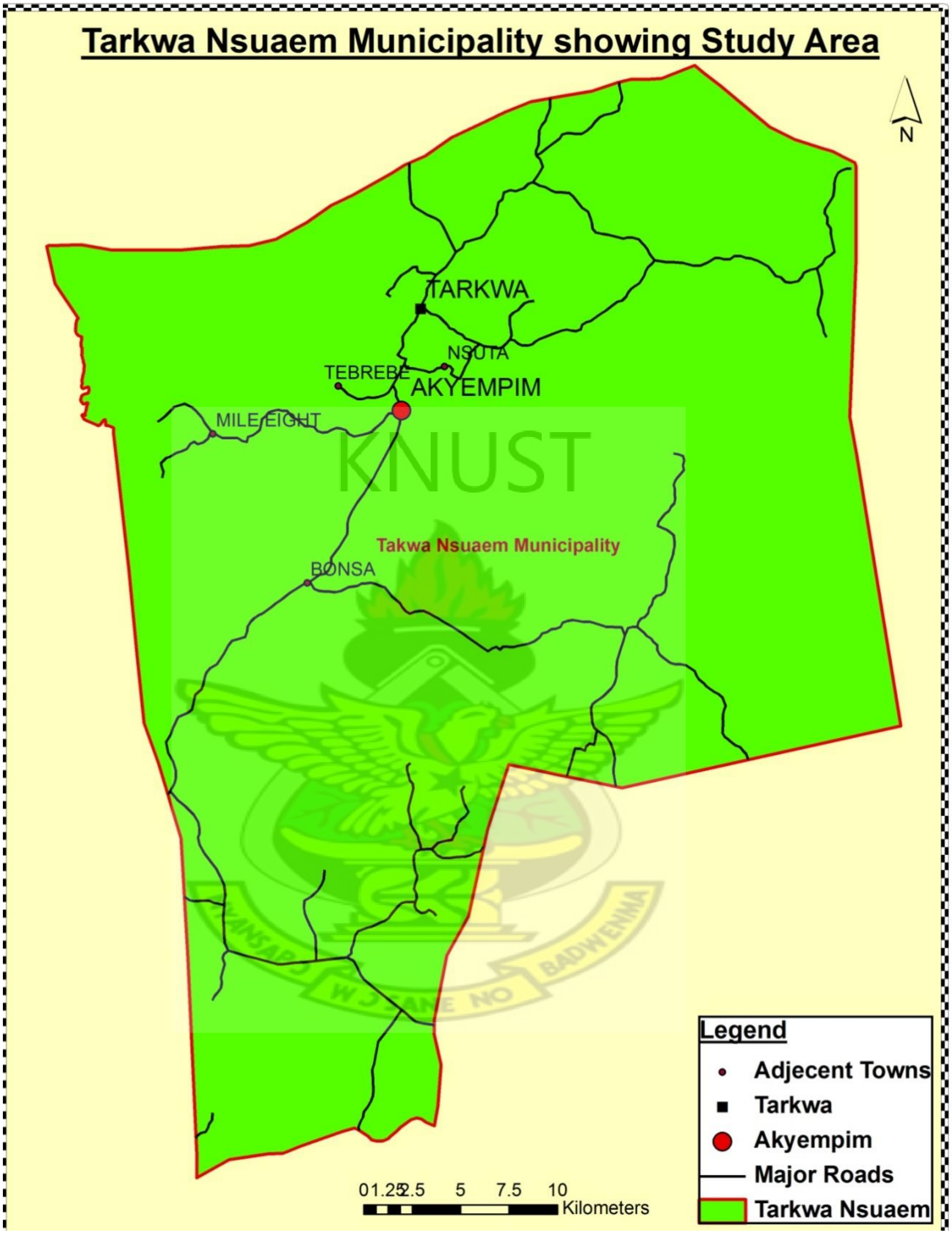

Fig. 2. Map of Tarkwa Nsuaem Municipality showing Akyempim, the study area.

The district contains a very high percentage of the closed forests in Ghana and also accounts for a high percent of gold production, cocoa production, standing commercial timber and, almost all the manganese and bauxite production in the country. Until the advent of heavy mining activities, the economic activities in the district have been subsistence and commercial farming.

3.2 Sampling Design and Species Identification

Four land use forms, namely; secondary forest (SF), illegally logged forest (ILF), abandoned farmland (AF) and abandoned mine sites (AMS) were identified and used for the study. Twenty four 50m × 20m sampling plots were established to represent the various land use forms in the study area. In each of the land use forms, six (6) of such sampling plots were established for the species identification. All trees and shrubs with dbh (diameter at breast height) $\geq$ 5 cm were identified. All trees with dbh $\geq$ 5 cm were examined for the presence of lianas. The diameter of the lianas was determined at 1.3m from the rooting base (Addo-Fordjour *et al*., 2009).

Within each of these plots, two 5m × 5m plots were established for the sampling of regeneration species. All woody saplings and seedlings (< 2m high with dbh < 5cm) were identified and counted. Most of the trees were identified in the field by observing bark layers and outer appearance. Slash was also made by striking the bark downwards and slightly inwards to the tree by a sharp cutlass to reveal important features including exudate, texture, colour and smell. Crown, bole and buttresses of trees were also examined in the identification process. Identification was done with the assistance of a plant taxonomist aided by field guides. Field press was used to keep specimens of species which were not easily identified on the field for their subsequent identification off the field. Voucher specimens are kept at the KNUST herbarium.

3.3 Determination of the Structure of the Vegetation in the Areas with Different Land Use Forms.

The dbh of trees, shrubs and liana was measured using a diameter tape. The main trunk of trees with more than one stem was measured at the narrowest point below the branches. Very huge trees or those with high buttresses were measured at about 30 cm above the convergence of the protrusions of the buttresses on the bole. The percentage canopy cover of each plot was determined by a spherical densiometer. At each plot, four readings from the four cardinal directions were taken at two different points. The mean of all the readings for the plots in the forest with different land use forms was calculated and used as the percentage canopy cover of the forest with that particular land use form. Tree density per hectare was standardized by converting density per plot area to density per hectare.

3.4 Data Analysis

Data was organized using the excel spread sheet and also used for the calculation of the various parameters. The Shannon-Wiener index of diversity (H') and Pielou's eveness index (J') were computed to evaluate the species diversity of the study area. The Shannon-Weiner's index was chosen not only because it incorporates both species richness and the evenness of species abundance but also it is suitable for both large and small sample sizes. It is given by the expression; $H' = -\Sigma p_i \ln p_i$

where p_i is the proportion of the individuals in the ith species.

However the calculated value of H' alone does not show the degree to which each factor contributes to diversity and so a separate measure of evenness (J') was calculated:

$J' = H'/H_{max}$

where H' is the Shannon index and $H_{max} = \ln S$ (species richness).

The important value (IV) was computed to analyze the relative importance of each species in the study area. It is given by

IV = RD + RF + RBA

where RD is the relative density, RF the relative frequency and RBA relative basal area.

One-way analysis of variance was performed at 5% significant level to determine the impact of land use changes on the diversity, community structure, and natural regeneration of woody plant species in the study area. The Kruskal Wallis ANOVA was used where the data was not normally distributed. All analyses were conducted with the Eleventh Edition of the GenStat software.

CHAPTER FOUR

RESULTS

4.1 Species Richness

A total of 185 adult plant species were identified in the study area. These belonged to 50 families, 142 genera, and three life forms (Table 2). Fabacea, Euphorbiaceae, Apocynaceae and Malvaceae were the most species rich families.

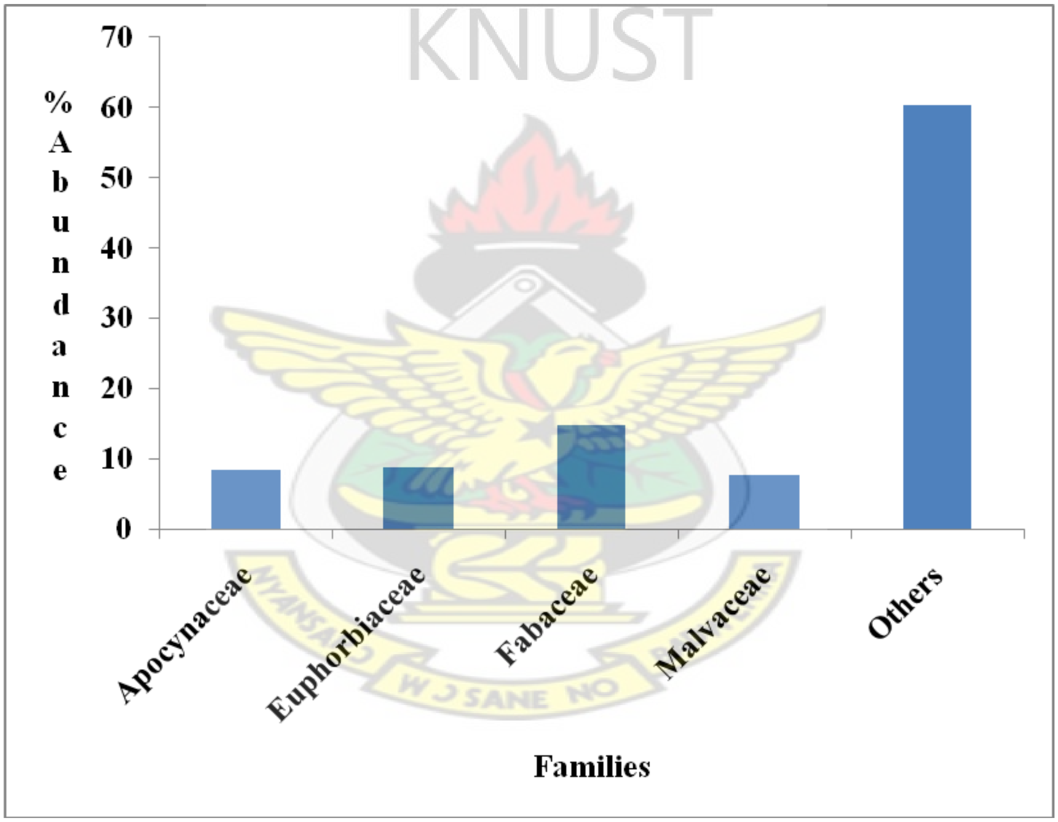

Fig. 3. Family abundance of plant species in the study area.

These families together contributed 39.6% of all the species recorded in the study (Figure 3). The most dominant adult plant species identified in the study area were

Macaranga barteri, *Anthocleista vogelii*, *Tabernaemontana Africana*, *Griffonia simplicifolia*, *Funtumia africana*, *Culcasia angolensis* and *Macaranga hurifolia*.

Table 1. Plant species richness and abundance in the various land use forms

Parameters	**SF**	**ILF**	**AF**	**AMS**
Tree				
Species Richness	31.0^{a}	21.5^{b}	8.7^{c}	7.0^{c}
Species Abundance	68.0^{a}	45.5^{b}	13.8^{c}	14.7^{c}
Liana				
Species Richness	9.67^{a}	4.67^{b}	1.33^{c}	0.17^{c}
Species Abundance	18.67^{a}	8.50^{b}	2.50^{c}	0.17^{c}

Parameters in the same row that have different superscripts are significantly different at α = 5 % *(i.e.* $p > 0.05$*).*
SF = Secondary Forest; ILF = Illegally Logged Forest; AF = Abandoned Farmland; AMS = Abandoned Mined Site.

Species richness and abundance of trees and lianas varied across the habitats. Generally, plant species richness and abundance decreased from the secondary forest through the illegally losgged forest and the abondaned farmland to the abandoned mined site. There is no significant difference between plant species richness and abundance between abandoned farmland and abandoned mined site however these differed significantly between the secondary and illegally logged forests.

4.2 Forest Structure

There were a total of 1,149 individuals of woody species (excluding saplings and seedlings). Trees were more abundant (896 individuals) compared with lianas (200 individuals) and shrubs (53 individuals). In terms of species richness, the secondary forest ranked highest (147 species) and the abandoned mined site ranked least (25 species). Tree density was greatest in the secondary forest (673/ha) than in the illegally logged forest (463/ha), abandoned farmland (188/ha) and abandoned mined site (168/ha). The density of lianas also followed a similar trend – 228, 88, 15 and 2/ha in the secondary forest, illegally logged forest, abandoned farmland and abandoned mined site respectively. However the density of shrub differed from that trend: it was highest in the illegally logged forest (50/ha) compared with the abandoned farmland (28/ha) and the secondary forest (12/ha). Shannon-Wiener diversity index was greater in the secondary forest (H′= 4.28) compared to the illegally logged forest (H′= 3.98) and the abandoned farmland (H′= 3.08).

Land use change had significant impact on tree and liana diversity in the study (trees: $p < 0.001$; lianas: $p < 0.001$). With regard to trees the differences existed among all the habitats except between the secondary forest and logged forest. On the other hand, differences occurred between all the pairs of habitats except for the abandoned mined site and abandoned farm area pair with regards to liana diversity. Generally the species were evenly distributed. However, lianas were more evenly distributed (average E = 0.9) than trees (average E = 0.84) and shrubs (average E = 0.65).

The average diameter at breast height (dbh) of all the species identified in the study area was highest in the abandoned farmland (16.87 cm) and least in the abandoned mined site (5 cm). Whereas mean rank density differed significantly ($p < 0.001$), there was no significant difference in the mean diameter at breast height (dbh) ($p = 0.52$) among all the habitats. However, a variance in the dbh existed between the abandoned farmland and the abandoned mined site. With regards to density, no difference existed between the illegally logged forest and the rest of the habitats but on the other hand, a difference existed between the secondary forest and both the abandoned farmland and the abandoned mined site.

The mean canopy cover differed significantly ($p<0.001$) among all the habitats. The difference in the mean canopy cover existed among all the habitats but between the secondary forest and the illegally logged forest.

Table 2. Summary characteristics of floristic composition and structure of the secondary forest in the study area.

Parameters	SF	ILF	AF	AMS
Liana				
Species richness	34	16	5	1
Total number of individuals	137	53	9	1
Average dbh (cm)	4.27	4.92	2.72	5
Average basal area (cm^2)	93.38	124.92	10.47	19.64
Density (ha^{-1})	228.33	88.33	15	1.67
Shannon diversity index	2.97	2.5	1.52	0
Pielou's evenness	0.84	0.9	0.95	0

Table 2. ***cont.***

Parameters	SF	ILF	AF	AMS
Shrub				
Species richness	2	5	5	-
Total number of individuals	6	30	17	-
Average dbh (cm)	18.25	5.32	5.6	-
Average basal area (cm^2)	55.88	60.48	25.59	-
Density (ha^{-1})	11.67	50	28.33	0
Shannon diversity index	0.41	1.32	1.00	0
Pielou's evenness	0.59	0.73	0.62	0
Tree				
Species richness	111	75	30	24
Total number of individuals	404	278	113	101
Average dbh (cm)	17.25	17.03	17.7	12.62
Average basal area (cm^2)	1589.5	1513.45	1795.18	715
Density (ha^{-1})	673.33	463.33	188.33	168.33
Shannon diversity index	3.95	3.69	2.78	2.81
Pielou's evenness	0.84	0.85	0.82	0.88
Combined				
Species richness	147	93	40	25
Total number of individuals	548	338	139	102
Average dbh (cm)	14.04	14.9	16.87	12.54
Average basal area (cm^2)	1238.17	1246.18	1498.57	686.45
Density (ha^{-1})	304.44	187.78	77.22	56.67
Average canopy cover	76.29	79.99	71.13	-
Shannon diversity index	4.28	3.98	3.08	2.84
Pielou's evenness	0.86	0.88	0.83	0.88

dbh = diameter at breast height, SF = secondary forest, ILF = illegally logged forest, abandoned farmland, AMS = abandoned mined site.

Table 3. A comparison of the structural attributes of the habitats in the study area

Parameter	Mean/Mean Rank				*p*	*lsd*
	SF	ILF	AF	AMS		
Canopy Cover	76.3^{a}	80.0^{a}	7.1^{b}	0.00^{b}	<0.001	17.4
Density*	20.92^{a}	16.08^{a}	6.17^{b}	6.83^{b}	<0.001	
Dbh	15.0^{ab}	14.9^{ab}	24.6^{bc}	11.1^{a}	0.052	9.70

**Mean rank*

Means in the same row that have different superscripts are significantly different at α = 5 % *(i.e. p > 0.05)*

Table 4. A comparison of the diversity of trees and lianas among the habitats of the study area.

Parameter	**Mean**				***p***	***lsd***
	SF	**ILF**	**AF**	**AMS**		
Tree SDI	2.982^{a}	2.597^{a}	1.928^{b}	1.805^{b}	<0.001	0.5247
Liana SDI	2.035^{a}	1.340^{b}	0.208^{c}	0.000^{c}	<0.001	0.4319
Combined SDI	2.508^{a}	1.968^{b}	1.068^{c}	0.902^{c}	<0.001	0.3796
Evenness	0.873^{a}	0.865^{a}	0.920^{a}	0.865^{a}	0.755	0.1234

Means in the same row that have different superscripts are significantly different at α = 5 % *(i.e. p > 0.05)*

4.3 Dominance of Plant Species

Macaranga barteri was found to be the most dominant specie in terms of important value in all but one (abandoned mined site) of the habitats. The five most dominant species in the secondary forest habitat are *Macaranga barteri, Anthocleista vogelii, Gilbertiodendron splendidum, Alchornea cordifolia* and *Grifonia simplicifolia* contributing 19.15% of the overall important value of the habitat. In the abandoned farmland, *Macaranga hurifolia*, *Ceiba pentandra*, *Anthocleista nobilis*, *Anthocleista vogeli* and *Macaranga barteri* were the five most dominant species in terms of important value, representing 30.94% of the total. The dominance of *Macaranga barteri*, *Musanga ceropoides*, *Tabernaemontana africana*, *Funtumia africana* and *Discoglyprema caloncomba* ranked highest and represented a 22.28 % of important value of all the species identified in the illegally logged forest. In the abandoned mined site, *Terminalia superba*, *Ceiba pentandra*, *Recinodendron heudolotii*, *Trema orientalis* and *Musanga ceropoides* contributed 54.01% to the important values out of the 21 species for which the value was determined.

4.4 Natural Regeneration of Woody Plant Species

The natural regeneration status of species in the study area was completely based on the population size of seedlings and saplings of woody plant species. There were 160 regeneration woody species (sapling and seedlings) out of which 60 species were absent in the adult tree population in the study area (Appendix III). Also there were 91 non-regenerating species in the study area (Appendices I & III).

Generally the population of seedlings was higher (498 individuals) than that of the saplings (328 individuals) in the study area. Comparatively, the population of the regeneration species was highest in the illegally logged forest (234 seedlings and 103 saplings) compared to the secondary forest (126 seedlings and 129 saplings), abandoned farmland (120 seedlings and 87 saplings), and the abandoned mined site (18 seedlings and 9 saplings). In all the habitats but the secondary forest, seedling population was higher than the population of saplings.

Table 5. Summary characteristics of natural regeneration of woody species in the sudy area.

Parameters	SF	ILF	AF	AMS
Sapling				
Species richness	48	54	27	6
Total number of individuals	129	103	89	9
Density (ha^{-1})	215	171.67	148.33	15
Shannon diversity index	3.34	3.64	2.86	1.68
Pielou's evenness	0.86	0.91	0.87	0.94
Seedling				
Species richness	43	51	46	11
Total number of individuals	126	234	120	18
Density (ha^{-1})	210	390	200	30
Shannon diversity index	3.14	3.4	3.44	2.2
Pielou's evenness	0.84	0.86	0.9	0.92

In terms of sapling population, the secondary forest ranked highest whereas the illegally logged forest ranked highest in terms of seedling population and the abandoned mined site ranked lowest in both cases (Figure 4). Natural regeneration was lowest in the abandoned mined site: regeneration species were found on only two out of the six plots established in this area.

The five most abundant regeneration species were *Penianthus zenkeri*, *Griffonia simplicifolia*, *Milletia zechiana*, *Baphia nitida* and *Rinorea oblongifolia* (Appendix III).

Griffonia simplicifolia (39 individuals), *Penianthus zenkeri* (34 individuals) and *Milletia zechiana* (23individuals) were the most abundant seedling species whereas *Lannea welwithschii* (21 individuals), *Rinorea oblongifolia* (21 individuals) and *Baphia nitida* (20 individuals) were the most abundant sapling species (Appendix III). Generally, the Shannon diversity index showed a rather low diversity of natural regeneration species however, the species were almost evenly distributed (Table 5).

The Shannon diversity index for saplings differed significantly among the habitats (P = 0.022). The difference existed between the abandoned mined site and the rest of the habitats. There was no significant difference between sapling diversity among the other habitats. In the same way, there were significantly lower seedling diversity in the abandoned mined site (p <0.001) compared to the other habitats.

Table 6. A comparison of the diversity of seedlings and saplings among the habitats in the study area.

Parameter	Mean					
	SF	ILF	AF	AMS	*p*	*lsd*
Sapling SDI	1.98^a	1.82^a	1.41^a	0.38^b	0.022	1.066
Seedling SDI	1.87^a	2.10^a	1.85^a	0.43^b	<0.001	0.761

Means in the same row that have different superscripts are significantly different at α = 5 % *(i.e. p > 0.05)*

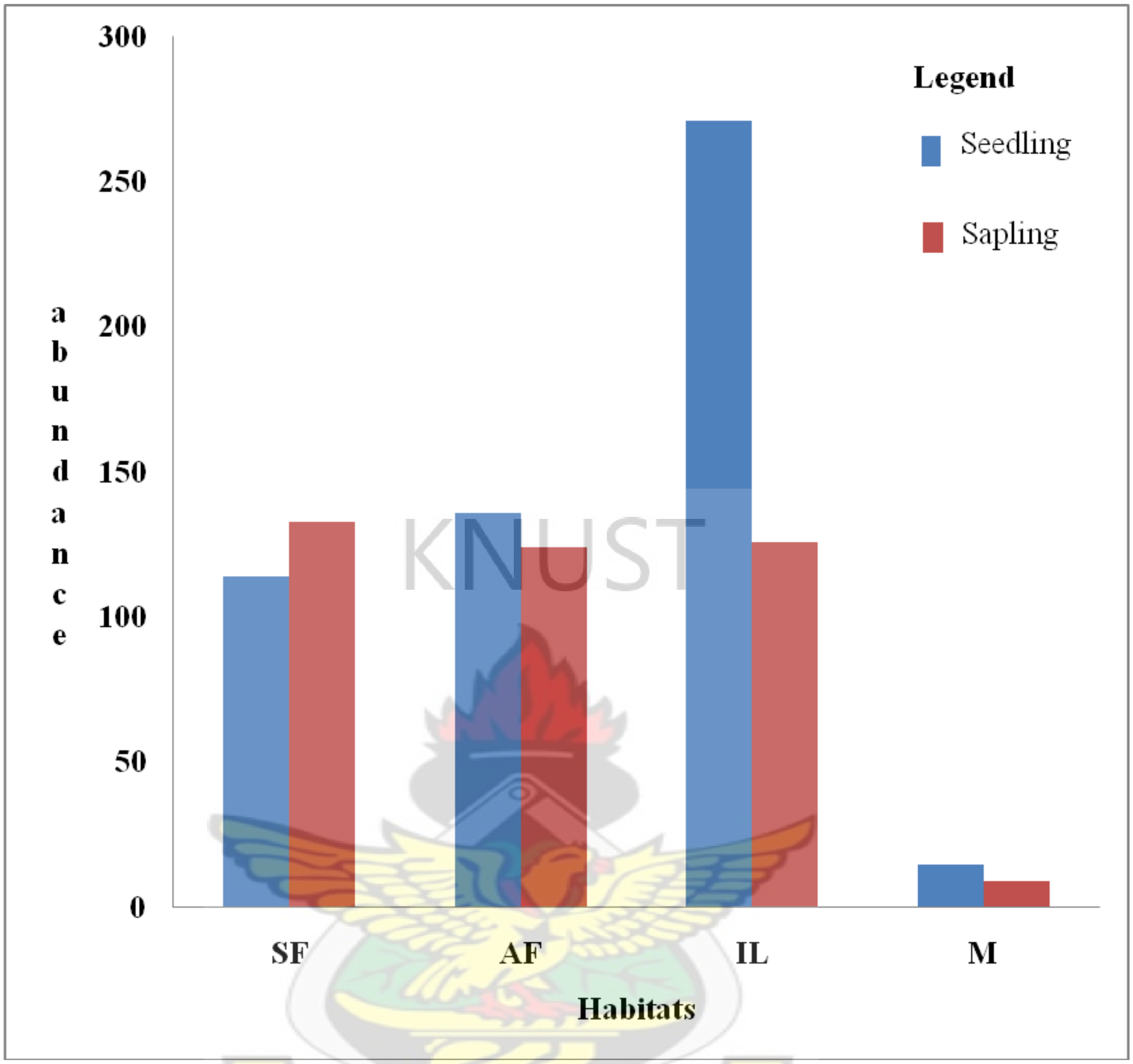

Fig. 4. Abundance of the natural regeneration species in the various habitats in the study area.

CHAPTER FIVE

DISCUSSION

5.1 Introduction

Despite the importance of studies of this kind in the conservation of plant species, and the management of forest ecosystems as a whole, only few research works (Hall and Swaine, 1981; Addo-Fordjour *et al*., 2009) in this regard have been carried out in forests of Ghana. This together with the lower diameter cut off point of ≥ 5 cm (compared to the standard ≥ 10 cm) used makes it difficult for the present study to be compared with a wide range of other similar studies in Ghana.

5.2 Species Richness, Abundance and Dominance.

Although the use of lower diameter cut off point allows for the inclusion of more species, the number of species (77 species/ha) recorded in this study was comparatively lower compared to other studies conducted in Ghana and beyond. For instance, Parthasarathy (2001) also recorded 125 species/ha even at a higher diameter cut-off point of ≥ 30cm in a tropical evergreen forest in Senegaltheri of the Western Ghats in India. On the other hand, the species richness recorded in the work of Addo-Fordjour *et al*., (2009) in a disturbed semi-deciduous forest in Ghana were much lower (48 species /ha) as compared with the results of this study. It is however, only fair to add that the study by Addo-Fordjour *et al*., (2009) was conducted at a higher diameter cut-off point (≥ 10 cm) as compared with diameter cut-off point (≥ 5cm) in the current study which might have affected the number of species recorded in both studies.

Interestingly, the general species richness (all life-forms put together) decreased with increasing intensity of disturbance represented by the various land use forms (SF > ILF > AF > AMS). This finding is in conformity with that of earlier studies (Addo-Fordjour *et al*., 2009). The pattern of species richness across various land form uses was non-uniform with respect to the different life-forms.

Whereas, trees and lianas exhibited the same pattern as the general species richness mentioned above, shrubs did not give any specific pattern in relation to disturbance intensity related to land use forms. This shows that different life-forms may respond to disturbances in different manner. Like species richness, the overall plant diversity (expressed by the Shannon diversity index) varied across the land use forms, decreasing with increasing intensity of disturbance. The diversity pattern in trees was similar to that of lianas, decreasing with increasing disturbance intensity. However, the diversity pattern of shrubs failed to depict this usual trend. Therefore, different plant life-forms may have different responses to disturbances.

The results of this study are indicative of a decreasing trend of species diversity as human interference in a particular habitat become more extensive and intensive. These patterns in species richness and diversity may be indicative of the fact that anthropogenic activities such as logging, agriculture, mining, harvesting of wood for fuel, and collection of other non-timber forest products affect plant species richness and diversity.

Species abundance of trees and lianas also varied across the habitats, showing that different land use forms have different effects on plant diversity. Generally, plant specie abundance decreased with increasing disturbance intensity associated with the landforms. There is no significant difference between plant species abundance between the abandoned farmland (AF) and abandoned mined site (AMS) however; these differed significantly between the secondary forest (SF) and the illegally logged forest (ILF).

Plant dominance was measured in terms of the important value of the species. Generally, increasing disturbance increased the dominance of a few species. This trend was observed in the contribution of the important values of five species to the overall values across the respective habitats used in the study. The results showed that, the important values of the five most dominant species increased steadily from 19.15% in the secondary forest, 22.28% in the illegally logged forest, and 30.94% in the abandoned farmland to 54.01% in the abandoned mined site.

5.3 Forest Structure

The role of human activities on forest structure was evident from the data gathered in this study. The overall plant density decreased across the habitats, along increasing disturbance gradient. The densities of trees and lianas followed the same trend. While this trend is typical of trees, it is unusual for lianas considering many studies which have reported that lianas increase in abundance with disturbance (Bongers *et al.*, 2005; Hegarty and Caballe, 1991). The diversity of plant species also showed a decreasing trend in response to increasing disturbances across the various habitats.

Consistent with the study by Addo-Fordjour *et al*. (2009) trees constituted the predominant life form in all the different land use forms. *Grifonia simplicifolia* and *Macaranga hurifolia* were the most dominant species recorded in this study. They were widely distributed in all the habitats except the abandoned mined site. The absence of these lianas in the abandoned mined site may be attributed to lack of available tree supports for their development. The presence of these species in almost all the habitats with different land form uses may be attributed to their wider range of ecological adaptations (Addo-Fordjour *et al.,* 2008). *Grifonia simplicifolia* has been reported as showing plasticity to different habitats, and also as the commonest climbing plant in the forest Ghana (Addo-Fordjour *et al*., 2008, 2009; Swaine *et al*., 2005).

5.4 Natural Regeneration

The density values of seedlings and sapling are measured as the regeneration ability of the species (Dhaulakhandi *et al*., 2008). High seedling population as reported in this study is indicative of a good natural regeneration potential of the forest. This may present an excellent opportunity for more seedling survival and subsequent transition to adult plants from the sapling stage. Even though some adult plants are not regenerating as portrayed by the results in this study, it is however important to consider that some regeneration species are absent in the adult species. This may be pointing to a future forest whose characteristics may be different from the one currently under study to the extent of the survival rate of the regeneration species currently reported under the present conditions. This could also mean that anthropogenic disturbance may have changed the natural conditions that favour certain indigenous species and thus may now not be regenerating. By extension, other non-indigenous species (absent in the adult species) could now be favoured by the new condition consequent to the disturbances attended to anthropogenic activities.

The densities of seedlings and saplings of woody plant species did not vary significantly among the habitats studied. This may give an indication that conditions for regeneration did not vary much in those habitats. In that case, the different land use forms have not had differential effects on natural regeneration in the respective habitats. However, natural regeneration in the abandoned mined site was poor. The occurrence of good regeneration ability indicates appropriateness of species to the environment. In considering the factors that cause successful regeneration of plant species, Good and Good (1972) identified components such as "the ability to initiate new seedlings, ability of seedlings and saplings to survive, and ability of seedlings and saplings to grow". The mining activities might have altered the habitat to the extent that it could not support natural regeneration well.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Trees formed the dominant life form of the three woody plant habits identified in the study area. Fabaceae was the most species rich family in the study area. The dominant species were *Grifonia simplicifolia* and *Macaranga hurifolia.* In terms of species richness, the secondary forest ranked highest whereas the abandoned mined site ranked the least. The densities of trees and liana followed a similar pattern.

The study showed that land use change had significant impact on diversity, community structure. The impact was greatly observed in the abandoned mined sites and the abandoned farmlands as the diversity, structural and natural regeneration attributes measured least in these areas. Mining activities impacted negatively on natural regeneration in the habitat. There was no significant difference in the diversity, structural attributes and regeneration potential of the secondary forest and the illegally logged areas.

6.2 Recommendations

Steps should be taken by the relevant government agencies and institutions as well all major stakeholders to ensure that mining companies comply with the regulations regarding the decommissioning phase of their undertakings. For instance the assisted natural regeneration could be employed using both native and non-indigenous species to enhance the natural process of regeneration.

Best farming practices especially agroforestry should be employed where practicable to reduce the negative impact of farming on the status of diversity of the forests.

Further studies should be carried out on the impact land use changes may have on the condition of the soil and belowground biodiversity as well as on adjoining aquatic habitats.

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APPENDIX I

List of plant species (excluding saplings and seedlings) identified in the study area.

Species	Family	Habit/Life Form
Acacia kamerunensis	Fabaceae	Liana
Acacia mangium	Fabaceae	Liana
Acacia pentagyna	Fabaceae	Liana
Acridocarpus smeathmanii	Fabceae	Liana
Adenia lobata	Passifloraceae	Liana
Agelaea sp.	Connaraceae	Liana
Aidia genipiflora	Rubiaceae	Tree
Alafia adianthifolia	Fabaceae	Tree
Alafia barteri	Apocynaceae	Tree/Liana
Alafia whytii	Apocynaceae	Tree
Albizia zygia	Fabaceae	Tree
Alchornea cordifolia	Euphorbiaceae	Tree/Shrub/Liana
Allanblackia floribunda	Fabaceae	Tree
Alstonia boonei	Apocynaceae	Tree
Amphima pterocarpoides	Fabaceae	Tree
Anthocleista nobilis	Loganiaceae	Tree
Anthocleista vogelii	Loganiaceae	Tree
Anthonotha sassandraensis	Caesalpinniaceae	Tree
Antiaris toxicaria	Moraceae	Tree
Antrocaryon micraster	Anacardiaceae	Tree
Baphia nitida	Fabaceae	Tree
Baphia pubescens	Fabaceae	Tree
Berlinia confusa	Fabaceae	Tree
Berlinia tomentella	Fabaceae	Tree
Blighia sapida	Sapindaceae	Tree
Blighia unijugata	Sapindaceae	Tree
Blighia welwitschii	Sapindaceae	Tree
Bombax buonopuzense	Malvaceae	Tree
Bridelia atroviridis	Euphorbiaceae	Tree
Bridelia grandis	Euphorbiaceae	Tree
Byttneria catalpifolia	Sterculaceae	Tree
Calamus deeratus	Palmaceae	Tree
Calancoba gilgiana	Flacourtiaceae	Tree
Calycobolus africanus	Convolvulaceae	Liana
Calycobolus heudelotii	Convolvulaceae	Tree/Liana
Canarium schweinfurthii	Burseraceae	Tree
Carapa procera	Meliaceae	Tree
Ceiba pentandra	Malvaceae	Tree

Appendix I contd.

Species	Family	Habit/Life Form
Celtis mildbraedii	Ulmaceae	Tree
Chrysophyllum subnudum	Sapotaceae	Tree
Cissux adenopum	Vitaceae	Liana
Cissux debilis	Vitaceae	Liana
Cissux producta	Vitaceae	Liana
Cleidion gabonicum	Euphorbiaceae	Tree
Cleistopholis patens	Annonaceae	Tree
Clerodendron sp.	Verbenaceae	Liana
Coelocaryon oxycarpum	Myristicaceae	Tree
Cola caricifolia	Malvaceae	Tree
Cola chlamydantha	Malvaceae	Tree
Cola lateritia	Malvaceae	Tree
Cola millenii	Malvaceae	Tree
Cola nitida	Malvaceae	Tree
Combretum micranthum	Combretaceae	Liana
Comnbretum sp.	Combretaceae	Liana
Culcasia angolensis	Araceae	Tree
Culcassia saxatilis	Araceae	Tree
Cussonia bancoensis	Araliaceae	Tree
Cuviera nigrescens	Rubiaceae	Tree
Dacryodes klaineana	Bursearaceae	Tree
Dialium aubrevillei	Fabaceae	Tree
Dialium dinklagei	Fabaceae	Tree
Diospyros gabunensis	Ebenaceae	Tree
Diospyros kamerunensis	Ebenaceae	Tree
Diospyros sanza-minika	Ebenaceae	Tree
Diospyros viridicans	Ebeneceae	Tree
Discoglyprema caloneura	Euphorbiaceae	Tree
Distemonanthus benthamianus	Fabaceae	Tree
Dracaena mannii	Dracaenaceae	Tree
Drypetes principum	Euphorbiaceae	Tree
Elaeis guineensis	Aracaceae	Tree
Enantia polycarpa	Annonaceae	Tree
Entandrophragma angolense	Meliaceae	Tree
Erithrina vogelii	Fabaceae	Tree
Erythrina mildbraedii	Fabaceae	Tree
Erythrophleum ivorense	Fabaceae	Tree
Ficus capensis	Moraceae	Tree
Ficus exasperate	Moracea	Tree
Ficus sur	Moraceae	Tree/Shrub

Appendix I contd.

Species	Family	Habit/Life Form
Ficus variifolia	Moraceae	Tree
Funtumia africanus	Apocynaceae	Tree
Funtumia elatica	Apocynaceae	Tree
Gilbertiodendron splendidum	Fabaceae	Tree
Glyphaea brevis	Malvaceae	Tree
Gongronema latifolium	Asclepiadaceae	Liana
Griffonia simplicifolia	Fabaceae	Liana
Guarea thompsonii	Meliaceae	Tree
Hallea ledermannii	Rubiaceae	Tree
Hannoa klaineana	Simaroubaceae	Tree
Harungana madagascariensis	Guttiferae	Tree
Heritiera grandis	Ulmaceae	Tree
Homalium stipulaceum	Flacourtiaceae	Tree
Hypselodelphys violaceae	Marantacdeae	Tree/Shrub
Icacina mannii	Icacinaceae	Liana
Illegera pentaphylla	Hernandiaceae	Liana
Iodes sp.	Icacinaceae	Liana
Irvingia gabonensis	Irvingiaceae	Tree
Irvingia wombulu	Irvingiaceae	Tree
Khaya ivorensis	Meliaceae	Tree
Kigelia africana	Bignoniaceae	Tree
Klainedoxa gabonensis	Irvingiaceae	Tree
Landolphia hirsuta	Apocynaceae	Liana
Landolphia micrantha	Apocynaceae	Liana
Landolphia owariensis	Apocynaceae	Liana
Landolphia sp.	Apocynaceae	Liana
Lanneae welwitschii	Anacardiaceae	Tree
Leptoderris sp.	Fabaceae	Liana
Macaranga barteri	Euphorbiaceae	Tree
Macaranga hurifolia	Euphorbiaceae	Tree/Liana
Maesobotrya barteri	Euphorbiaceae	Tree
Maesopsis eminii	Rhamnaceae	Tree
Maniophyton fulvum	Euphorbiaceae	Liana
Mareya micrantha	Euphorbiaceae	Tree
Margaritaria discoidea	Euphorbiaceae	Tree
Margaritaria discoides	Euphorbiaceae	Tree
Microdemis puberula	Pandaceae	Tree
Milicia excels	Moraceae	Tree
Milletia chrysophylla	Fabaceae	Liana
Milletia sp.	Fabaceae	Liana

Appendix I contd.

Species	Family	Habit/Life Form
Milletia zechiana	Fabaceae	Tree
Monodora myristica	Annonaceae	Tree
Monodora tenuifolia	Annonaceae	Tree
Morinda lucida	Rubiaceae	Tree
Motandra guineensis	Apocynaceae	Liana
Musanga cecropioides	Cecropiaceae	Tree
Myrianthus arboreus	Cecropiaceae	Tree
Myrianthus libericus	Cecropiaceae	Tree
Napoleonaea vogelii	Lecythidaceae	Tree
Nesogordonai papaverifera	Malvaceae	Tree
Newbouldia laevis	Bignoniaceae	Tree
Oxyanthus speciosus	Rubiaceae	Tree
Parinari exelsa	Chrysobalanaceae	Tree
Parkia bicolor	Fabaceae	Tree
Persea americana	Lauraceae	Tree
Petersianthus macrocarpus	Leccythiadaceae	Tree
Phylocosmos africanus	Ixonanthaceae	Tree
Picralima nitida	Apocynaceae	Tree
Piper guineensis	Piperaceae	Tree/Liana
Piptadeniastrum africanum	Fabaceae	Tree
Placodiscus bancoensis	Sapindaceae	Tree
Pouteria sp.	Sapotaceae	Tree
Protomegabaria splendidum	Euphorbiaceae	Tree
Psedospondias macrocarpa	Anacardiaceae	Tree
Psydrax subcordata	Rubiaceae	Tree
Pycnanthus angolensis	Myristicaceae	Tree
Rauvolfia vomitoria	Apocynaceae	Tree
Rhodognaphalon brevicuspe	Apocynaceae	Tree
Ricinodendron heudelotii	Malvaceae	Tree
Rinorea oblongifolia	Violaceae	Tree
Rothmania longiflora	Rubiaceae	Tree
Salacia owabiensis	Celastraceae	Liana
Salacia sp.	Celastraceae	Liana
Schumanniophytum problematicum	Rubiaceae	Tree
Scottellia klaineana	Flacourtiaceae	Tree
Secamone afzelii	Asclepiadaceae	Liana
Smilax kraussiana	Smilacaceae	Liana
Spathodea campanulata	Bignoniaceae	Tree
Spondianthus preussii	Euphorbiaceae	Tree
Spondias mombin	Anacardiaceae	Tree

Appendix I contd.

Species	Family	Habit/Life Form
Sterculia oblonga	Malvaceae	Tree
Sterculia rhinopetala	Malvaceae	Tree
Sterculia tragacantha	Malvaceae	Tree
Strombosia glaucesens	Olacaceae	Tree
Symphonia globulifera	Guttiferae	Tree
Tabernaemontana africana	Apocynaceae	Tree
Tabernaemontana spp.	Apocynaceae	Tree
Terminalia ivorensis	Combretaceae	Tree
Terminalia superba	Combretaceae	Tree
Tetracera affenis	Dilleniaceae	Liana
Treculia africana	Moraceae	Tree
Tricalysia pallens	Rubiaceae	Tree
Trichilia prieureana	Meliaceae	Tree
Trichilia tessmanii	Meliaceae	Tree
Trichillia monadelpha	Meliaceae	Tree
Trilepisium madagascariense	Moraceae	Tree
Turraenthus africanus	Meliaceae	Tree
Uapaca corbisieri	Euphorbiasceae	Tree
Vitex feruginea	Verbenaceae	Tree
Vitex grandifolia	Verbenaceae	Tree
Voacanga africana	Apocynaceae	Tree
Xylopia aethiopica	Annonaceae	Tree
Xylopia staudtii	Annonaceae	Tree
Zanthoxylum gilletii	Rutaceae	Tree

APENDIX II

Important value of adult woody species identified in the study area.

Species	SF				AF				IL				AMS			
	RBA	**RF**	**RD**	**IV**	**RBA**	**RF**	**RD**	**IV**	**RBA**	**RF**	**RD**	**IV**	**RBA**	**RF**	**RD**	**IV**
Acacia kamerunensis	0.01	0.44	0.19	**0.64**	-	-	-	-	-	-	-	-	-	-	-	-
Accia mangium	-	-	-	-	-	-	-	-	-	-	-	-	5.33	2.38	4.21	**11.93**
Acacia pentagyna	*0.*01	0.44	0.19	**0.64**	-	-	-	-	1.24	1.14	1.25	**3.63**	-	-	-	-
Adenia lobata	0.01	0.44	0.38	**0.83**	-	-	-	-	0.02	1.71	1.56	**3.29**	-	-	-	-
Agelaea sp.	0.01	0.87	0.38	**1.26**	-	-	-	-	0.002	0.57	0.31	**0.882**	-	-	-	-
Aidia genipiflora	0.69	0.44	0.38	**1.51**	-	-	-	-	-	-	-	-	-	-	-	-
Alafia barteri	0.01	0.87	0.76	**1.64**	-	-	-	-	0.06	2.29	3.43	**5.78**	-	-	-	-
Alafia whytii	-	-	-	-	-	-	-	-	0.06	0.57	0.31	**0.94**	-	-	-	-
Albizia adianthifolia	1.03	0.44	0.19	**1.66**	-	-	-	-	0.53	1.71	1.25	**3.49**	-	-	-	-
Albizia zygia	0.18	0.44	0.38	**1.00**	-	-	-	-	0.87	1.71	1.56	**4.14**	-	-	-	-
Alchornea cordifolia	3.75	2.17	1.33	**7.25**	0.03	1.67	1.02	**2.72**	0.09	2.29	2.18	**4.56**	0.12	7.14	4.21	**11.47**
Allanblackia flori.	*0.*04	0.44	0.57	**1.05**	-	-	-	-	0.54	1.14	0.62	**2.30**	-	-	-	-
Alstonia boonei	3.62	0.87	0.76	**5.25**	0.09	3.33	2.04	**5.46**	0.76	1.14	1.25	**3.15**	1.82	4.76	4.21	**10.79**
Amphima pterocar.	0.39	0.44	0.19	**1.02**	2.483	1.667	1.02	**5.17**	-	-	-	-	-	-	-	-
Anthocleista nobilis	0.33	0.44	0.38	**1.15**	9.54	5	5.10	**19.64**	0.34	1.14	1.25	**2.73**	2.87	7.14	6.32	**16.33**
Anthocleista vogelii	5.84	0.44	6.06	**12.34**	0.51	1.67	12.24	**14.42**	-	-	-	-	-	-	-	-
Anthonotha saxa.	0.03	0.44	0.38	**0.85**	-	-	-	-	-	-	-	-	-	-	-	-
Antiaris toxicaria	6.14	0.44	0.38	**6.96**	-	-	-	-	1.95	0.57	0.31	**2.83**	-	-	-	-
Antrocaryon micra.	0.07	0.44	0.38	**0.89**	-	-	-	-	-	-	-	-	-	-	-	-
Baphia nitida	0.05	0.44	0.19	**0.68**	-	-	-	-	0.02	0.57	0.31	**0.90**	-	-	-	-
Baphia pubescens	0.10	0.44	0.19	**0.73**	-	-	-	-	-	-	-	-	-	-	-	-
Berlinia confusa	0.08	0.44	0.19	**0.71**	-	-	-	-	2.17	0.57	0.31	**3.05**	-	-	-	-
Berlina tomentella	2.19	0.87	0.38	**3.44**	0.18	1.67	1.02	**2.87**	0.02	0.57	0.31	**0.90**	-	-	-	-
Blighia sapida	0.67	0.44	0.19	**1.30**	-	-	-	-	0.65	0.57	0.31	**1.53**	-	-	-	-
Blighia unijugata	0.29	0.44	0.38	**1.11**	-	-	-	-	0.81	1.14	0.62	**2.57**	-	-	-	-
Blighia welwitschii	-	-	-	-	-	-	-	-	1.37	0.57	0.31	**2.25**	-	-	-	-

Appendix II contd.

Species	SF				AF				IL				AMS			
	RBA	**RF**	**RD**	**IV**	**RBA**	**RF**	**RD**	**IV**	**RBA**	**RF**	**RD**	**IV**	**RBA**	**RF**	**RD**	**IV**
Bombax buonopo.	0.02	0.44	0.19	**0.65**	4.24	3.33	2.04	**9.61**	-	-	-	-	0.76	2.38	1.05	**4.19**
Bridelia atroviridis	-	-	-	-	0.23	1.67	2.04	**3.94**	1.29	1.71	1.56	**4.56**	-	-	-	-
Bridelia grandis	3.25	0.44	0.38	**4.06**	-	-	-	-	-	-	-	-	-	-	-	-
Table 3 contd.																
Byttneria catalpi.	-	-	-	-	-	-	-	-	0.05	0.57	0.94	**1.56**	-	-	-	-
Calamus deeratus	0.002	0.44	0.19	**0.82**	-	-	-	-	-	-	-	-	-	-	-	-
Calancoba gilgiana	-	-	-	-	-	-	-	-	0.06	0.57	0.31	**0.94**	-	-	-	-
Calycobolus africanus	0.05	1.30	1.52	**2.87**	-	-	-	-	0.01	0.57	0.31	**0.89**	-	-	-	-
Calicoblus heudelottii	0.52	1.74	3.41	**5.67**	-	-	-	-	-	-	-	-	-	-	-	-
Canarium schewein.	0.18	1.30	0.76	**2.24**	0.06	1.67	1.02	**2.75**	0.08	1.71	0.94	**2.73**	-	-	-	-
Carapa procera	-	-	-	-	-	-	-	-	0.08	1.14	0.62	**1.84**	-	-	-	-
Cassia leucucefera	-	-	-	-	-	-	-	-	-	-	-	-	4.78	2.38	8.42	**15.58**
Ceiba pentandra	0.22	0.87	0.38	**1.47**	14.65	3.33	4.08	**22.06**	-	-	-	-	16.7	7.14	9.47	**33.32**
Celtis mildbraedii	0.45	0.44	0.95	**1.84**	6.72	1.67	1.02	**9.41**	2.34	0.57	0.31	**3.22**	-	-	-	-
Cercamoni afzelii	-	-	-	-	2E-04	1.67	1.02	**2.69**	-	-	-	-	-	-	-	-
Chrysophyllum subnu.	0.38	0.44	0.57	**0.39**	-	-	-	-	-	-	-	-	-	-	-	-
Cissux adeopum	0.003	0.44	0.19	**0.633**	-	-	-	-	-	-	-	-	-	-	-	-
Cissux debilis	-	-	-	-	-	-	-	-	0.005	0.57	0.62	**1.2**	-	-	-	-
Cissux producta	0.19	0.87	0.57	1.63	-	-	-	-	-	-	-	-	-	-	-	
Cleidion gabonicum	0.01	0.44	0.19	**0.64**	-	-	-	-	-	-	-	-	-	-	-	-
Cleistopholis patens	1.01	1.74	1.14	**3.89**	-	-	-	-	1.54	1.14	0.94	**3.62**	-	-	-	-
Clerodendron sp.	-	-	-	-	-	-	-	-	6E-04	0.571	0.312	0.884	-	-	-	-
Coelocaryon oxycar.	1.83	1.30	0.95	**4.08**	-	-	-	-	-	-	-	-	-	-	-	-
Cola caricifolia	0.05	0.87	0.38	**1.30**	-	-	-	-	0.05	0.57	0.31	**0.93**	-	-	-	-
Cola chlamydantha	0.49	0.44	1.14	**2.07**	-	-	-	-	-	-	-	-	-	-	-	-
Cola latericia	0.19	0.44	0.19	**0.82**	-	-	-	-	-	-	-	-	-	-	-	-
Cola millenii	-	-	-	-	-	-	-	-	0.05	0.57	0.31	**0.93**	-	-	-	-
Cola nitida	1.76	1.30	0.76	**3.82**	-	-	-	-	-	-	-	-	-	-	-	-

Appendix II contd.

Species	SF				AF				IL				AMS			
	RBA	**RF**	**RD**	**IV**	**RBA**	**RF**	**RD**	**IV**	**RBA**	**RF**	**RD**	**IV**	**RBA**	**RF**	**RD**	**IV**
Combretum micra.	0.09	0.87	0.38	**1.34**	-	-	-	-	-	-	-	-	-	-	-	-
Combrtum sp	0.003	0.87	0.38	**1.253**	0.006	1.67	1.02	**2.696**	0.02	1.14	1.56	**2.72**	-	-	-	-
Cussonia bancoensis	-	-	-	-	-	-	-	-	0.43	0.57	0.31	**1.31**	-	-	-	-
Cuviera nigrescens	0.01	0.44	0.19	**0.64**	-	-	-	-	-	-	-	-	-	-	-	-
Dacryodes klaineana	2.26	0.87	1.52	**4.65**	-	-	-	-	-	-	-	-	-	-	-	-
Dialium aubrevillei	0.08	0.87	0.38	**1.33**	-	-	-	-	-	-	-	-	-	-	-	-
Dialium dinklagei	-	-	-	-	-	-	-	-	1.32	0.57	0.31	**2.2**	-	-	-	-
Diospyros gabunensis	-	-	-	-	-	-	-	-	0.02	0.57	0.31	**0.9**	-	-	-	-
Diospyros kameru.	0.12	1.3	0.76	**2.18**	-	-	-	-	-	-	-	-	-	-	-	-
Diospyros sanza.	0.23	0.44	0.38	**1.05**	-	-	-	-	-	-	-	-	-	-	-	-
Diospyros viridicans	0.01	0.43	0.19	**0.63**	-	-	-	-	-	-	-	-	-	-	-	-
Discoglypremna calo.	0.26	0.44	0.19	**0.89**	5.48	1.67	2.04	**9.19**	6.86	2.29	1.56	**10.7**	-	-	-	-
Distemonanthus benth.	0.06	0.44	0.19	**0.69**	-	-	-	-	1.87	1.14	0.62	**3.63**	-	-	-	-
Dracaena mannii	-	-	-	-	0.06	1.67	1.02	**2.75**	-	-	-	-	-	-	-	-
Drypetes principum	1.05	0.87	1.33	**3.25**	-	-	-	-	-	-	-	-	-	-	-	-
Elaeis guineensis	3.62	1.30	1.52	**6.44**	-	-	-	-	-	-	-	-	-	-	-	-
Enantia polycarpa	0.01	0.44	0.19	**0.64**	-	-	-	-	-	-	-	-	-	-	-	-
Entandrophragma ang.	0.21	1.30	0.76	**2.27**	-	-	-	-	0.31	0.57	0.31	**1.19**	0.31	2.38	1.05	**3.74**
Erythrina mildbraedii	-	-	-	-	-	-	-	-	0.31	0.57	0.31	**1.19**	-	-	-	-
Erythrina vogelii	0.22	0.44	0.19	**0.85**	-	-	-	-	-	-	-	-	-	-	-	-
Erythrophleum ivo.	3.41	0.44	0.19	**4.04**	-	-	-	-	-	-	-	-	-	-	-	-
Ficus capensis	0.20	0.44	0.19	**0.83**	-	-	-	-	3.21	1.14	0.62	**4.97**	1.59	2.38	1.05	**5.02**
Ficus exasperata	-	-	-	-	-	-	-	-	0.4	0.57	0.31	**1.28**	-	-	-	-
Ficus sur	-	-	-	-	0.39	3.33	3.06	**6.78**	0.09	0.57	0.31	**0.97**	-	-	-	-
Ficus varifolia	0.04	0.44	0.19	**0.67**	0.25	3.33	3.06	**6.64**	0.40	0.57	0.31	**1.28**	3.11	4.76	2.11	**9.98**
Funtumia africana	1.43	2.17	1.71	**5.31**	1.03	3.33	5.10	**9.46**	1.93	3.43	5.61	**10.97**	-	-	-	-
Gilbertiodendron splen.	7.56	0.44	1.52	**9.52**	-	-	-	-	-	-	-	-	-	-	-	-
Glyphaea brevis	0.02	0.44	0.19	**0.65**	-	-	-	-	-	-	-	-	-	-	-	-

Appendix II contd.

Species	SF				AF				IL				AMS			
	RBA	**RF**	**RD**	**IV**	**RBA**	**RF**	**RD**	**IV**	**RBA**	**RF**	**RD**	**IV**	**RBA**	**RF**	**RD**	**IV**
Gongronema latifolium	0.004	0.87	0.38	**1.254**	-	-	-	-	0.16	1.14	0.62	**1.92**	-	-	-	-
Griffonia simplicifolia	0.28	2.61	4.36	**7.25**	0.004	1.67	1.02	**2.694**	0.07	2.29	3.43	**5.79**	-	-	-	-
Guarea thompsonii	0.12	0.44	0.19	**0.75**	-	-	-	-	-	-	-	-	-	-	-	-
Hallea ledermannii	0.66	0.44	1.14	**2.24**	-	-	-	-	-	-	-	-	-	-	-	-
Hannoa klaineana	4.1	1.3	1.33	**6.73**	-	-	-	-	-	-	-	-	-	-	-	-
Harungana mada.	-	-	-	-	-	-	-	-	0.04	0.57	0.31	**0.92**	2.24	9.52	5.26	**17.02**
Heritiera utilis	0.46	0.44	0.19	**1.09**	-	-	-	-	-	-	-	-	-	-	-	-
Holoptelea grandis	0.94	0.44	0.19	**1.57**	-	-	-	-	0.02	0.57	0.31	**0.9**	-	-	-	-
Homalium stipula.	-	-	-	-	-	-	-	-	3.25	0.57	0.31	**4.13**	-	-	-	-
Hypselodelphys viola.	0.75	0.44	3.79	**4.98**	-	-	-	-	-	-	-	-	-	-	-	-
Icacina mannii	0.004	0.44	0.38	**0.824**	-	-	-	-	-	-	-	-	-	-	-	-
Illegera pentaphylla	0.03	0.87	0.38	**1.28**	-	-	-	-	-	-	-	-	-	-	-	-
Irvengia gaboneensis	0.49	0.44	0.19	**1.12**	10.79	1.67	1.02	**13.48**	-	-	-	-	-	-	-	-
Khaya ivorensis	0.01	0.44	0.19	**0.64**	-	-	-	-	0.03	0.57	0.31	**0.91**	-	-	-	-
Kigelia africana	0.03	0.44	0.19	**0.66**	-	-	-	-	-	-	-	-	-	-	-	-
Landolphia hirsuta	0.08	0.44	0.38	**0.9**	-	-	-	-	-	-	-	-	-	-	-	-
Landoliphia micrantha	0.003	0.44	0.19	**0.633**	-	-	-	-	-	-	-	-	-	-	-	-
Landolphia owariensis	0.002	0.44	0.19	**0.632**	-	-	-	-	-	-	-	-	-	-	-	-
Landolphia sp.	9E-04	0.435	0.189	**0.625**	-	-	-	-	-	-	-	-	-	-	-	-
Lannea welwitschii	0.31	0.87	0.38	**1.56**	0.2	1.67	1.02	**2.89**	0.66	1.14	1.25	**3.05**	-	-	-	-
Leptoderris sp.	-	-	-	-	-	-	-	-	0.01	0.57	0.31	**0.89**	-	-	-	-
Macaranga barteri	5.91	1.74	13.45	**21.1**	3.42	5	5.1	**13.52**	5.09	3.43	11.53	**20.05**	0.72	2.38	2.1	**5.21**
Macaranga hurifolia	0.28	1.3	0.76	**2.34**	6.3	6.67	10.2	**23.17**	1.83	2.29	2.49	**6.61**	-	-	-	-
Maesobotrya barteria	0.08	0.87	0.57	**1.52**	-	-	-	-	0.02	0.57	0.31	**0.9**	-	-	-	-
Maesopsis eminii	1.06	0.87	0.57	**2.5**	-	-	-	-	0.63	0.57	0.31	**1.51**	-	-	-	-
Manniophyton fulvum	0.04	0.87	2.27	**3.18**	-	-	-	-	0.02	1.71	1.25	**2.98**	-	-	-	-
Mareya micrantha	0.1	0.44	0.38	**0.92**	-	-	-	-	0.49	0.57	0.94	**2**	-	-	-	-
Margaritaria discoi.	0.03	0.44	0.19	**0.66**	-	-	-	-	2.58	1.14	1.56	**5.28**	1.42	4.76	2.11	**8.29**

Appendix II contd.

Species	SF				AF				IL				AMS			
	RBA	RF	RD	IV	RBA	RF	RD	IV	RBA	RF	RD	IV	RBA	RF	RD	IV
Microdesmis puberula	0.55	1.3	1.14	**2.99**	-	-	-	-	-	-	-	-	-	-	-	-
Milicia excelsa	0.05	0.87	0.38	**1.3**	-	-	-	-	5.1	1.14	1.25	**7.49**	-	-	-	-
Milletia chrysophylla	0.02	0.87	0.57	**1.46**	-	-	-	-	0.01	0.57	0.31	**0.89**	-	-	-	-
Milletia sp.	-	-	-	-	-	-	-	-	0.07	0.57	0.96	**1.6**	-	-	-	-
Milletia zechiana	-	-	-	-	0.06	1.67	1.02	**2.75**	-	-	-	-	-	-	-	-
Monodora myristica	0.01	0.44	0.19	**0.64**	-	-	-	-	0.07	0.57	0.31	**0.95**	-	-	-	-
Monodora tenuifolia	-	-	-	-	-	-	-	-	0.12	0.57	0.62	**1.31**	-	-	-	-
Morinda lucida	0.15	0.44	0.19	**0.78**	-	-	-	-	0.37	1.14	0.62	**2.13**	0.08	2.38	1.05	**3.51**
Motandra guineensis	0.005	0.87	0.57	**1.45**	-	-	-	-	-	-	-	-	-	-	-	-
Musanga ceropioides	4.04	1.3	1.71	**7.05**	7.56	1.67	1.02	**10.25**	7.73	2.29	2.8	**12.82**	11.28	9.52	7.37	**28.51**
Myrianthus arboreus	4.3	1.3	0.57	**6.17**	1.41	3.33	2.04	**6.78**	0.57	1.71	1.25	**3.53**	-	-	-	-
Myrianthus libericus	0.06	0.44	0.19	**0.69**	-	-	-	-	0.26	1.14	0.62	**2.02**	-	-	-	-
Napoleonaea vogelii	0.06	0.87	0.38	**1.3**	-	-	-	-	-	-	-	-	-	-	-	-
Nesogordonia papa.	-	-	-	-	-	-	-	-	0.29	1.14	0.62	**2.05**	-	-	-	-
Newbouldia laevis	-	-	-	-	0.13	1.67	1.02	**2.82**	-	-	-	-	-	-	-	-
Oxyanthus speciosus	0.03	0.44	0.38	**0.85**	-	-	-	-	-	-	-	-	-	-	-	-
Parinari exelsa	0.67	0.44	0.19	**1.3**	-	-	-	-	-	-	-	-	-	-	-	-
Parkia bicolor	0.95	0.87	0.38	**2.2**	0.6	1.67	1.02	**3.29**	2.9	1.14	0.62	**4.66**	-	-	-	-
Persea americana	0.18	0.44	0.19	**0.81**	3.19	1.67	4.08	**8.94**	-	-	-	-	-	-	-	-
Petersianthus macro.	-	-	-	-	1.68	1.67	2.04	**5.39**	5.86	1.71	1.25	**8.82**	-	-	-	-
Phylocosmos afri.	0.01	0.44	0.19	**0.64**	-	-	-	-	-	-	-	-	-	-	-	-
Picralima nitida	0.04	0.44	0.19	**0.67**	-	-	-	-	-	-	-	-	-	-	-	-
Piper guineensis	0.06	1.74	1.9	**3.7**	0.01	1.67	2.04	**3.72**	0.01	2.29	1.25	**3.55**	-	-	-	-
Piptadeniastrum afr.	0.03	0.44	0.19	**0.66**	-	-	-	-	1	1.71	1.25	**3.96**	-	-	-	-
Placodescus banco.	0.56	0.44	0.38	**1.38**	-	-	-	-	-	-	-	-	-	-	-	-
Pouteria sp.	0.4	0.44	0.19	**1.03**	-	-	-	-	-	-	-	-	-	-	-	-
Protomegabaria splen.	0.22	0.44	0.57	**1.23**	-	-	-	-	-	-	-	-	-	-	-	-

Appendix II contd.

Species	SF				AF				IL				AMS			
	RBA	RF	RD	IV	RBA	RF	RD	IV	RBA	RF	RD	IV	RBA	RF	RD	IV
Psydrax subcordata	0.1	0.44	0.19	**0.73**	-	-	-	-	-	-	-	-	-	-	-	-
Pychnanthus angolen.	4.31	0.87	0.38	**5.56**	0.25	3.33	3.06	**6.64**	0.74	1.14	0.62	**2.5**	-	-	-	-
Rauvolfia vomitoria	0.17	0.87	0.95	**1.99**	1.15	5	4.08	**10.23**	0.53	2.29	2.49	**5.31**	0.42	4.76	2.11	**7.29**
Rhodognaphalon brev.	0.2	0.44	0.19	**0.83**	8.84	1.67	1.02	**11.53**	3.65	0.57	0.94	**5.16**	-	-	-	-
Ricinodendron heudo.	0.24	0.44	0.19	**0.87**	-	-	-	-	4.65	1.14	0.62	**6.39**	20.67	4.76	5.26	**30.7**
Rinorea oblongifolia	0.1	1.3	1.14	**2.54**	-	-	-	-	0.05	0.57	0.31	**0.93**	-	-	-	-
Rothmania longiflora	0.04	0.44	0.19	**0.67**	-	-	-	-	-	-	-	-	-	-	-	-
Salacia owabiensis	0.01	0.44	0.38	**0.83**	-	-	-	-	0.01	1.14	0.62	**1.77**	-	-	-	-
Salacia sp.	0.07	1.3	0.57	**1.94**	-	-	-	-	-	-	-	-	-	-	-	-
Schumaniophyton pro.	-	-	-	-	-	-	-	-	0.02	0.57	0.31	**0.9**	-	-	-	-
Scottellia klaineana	0.08	0.44	0.19	**0.71**	-	-	-	-	-	-	-	-	-	-	-	-
Secamone afzelii	9E-04	0.435	0.189	**0.625**	-	-	-	-	-	-	-	-	-	-	-	-
Smilax kraussiana	-	-	-	-	-	-	-	-	0.01	0.57	0.31	**0.89**	-	-	-	-
Spathodea campa.	-	-	-	-	-	-	-	-	-	-	-	-	0.61	2.38	1.05	**4.04**
Spondianthus preussii	0.03	0.44	0.19	**0.66**	-	-	-	-	-	-	-	-	-	-	-	-
Spondias mombin	-	-	-	-	0.02	1.67	1.02	**2.71**	-	-	-	-	-	-	-	-
Sterculia oblonga	-	-	-	-	-	-	-	-	0.29	0.57	0.31	**1.17**	-	-	-	-
Sterculia rhinopetala	1.16	0.44	0.57	**2.17**	-	-	-	-	1.38	0.57	0.31	**2.26**	-	-	-	-
Sterculia tragacantha	0.12	0.87	0.57	**1.56**	0.27	3.33	2.04	**5.64**	0.54	1.14	1.56	**3.24**	-	-	-	-
Strombosia glaucesens	0.54	0.87	0.57	**1.98**	-	-	-	-	-	-	-	-	-	-	-	-
Symphonia globulifera	0.61	0.44	0.57	**1.62**	-	-	-	-	-	-	-	-	-	-	-	-
Tabernaemontana afri.	0.68	1.74	2.27	**4.69**	-	-	-	-	1.91	2.29	8.1	**12.3**	-	-	-	-
Terminalia ivorensis	-	-	-	-	1.89	3.33	2.04	**7.26**	-	-	-	-	-	-	-	-
Terminalia superba	2.87	0.87	0.95	**4.69**	5.17	3.33	3.06	**11.56**	2.06	0.57	0.62	**3.25**	20.25	4.76	15.79	**40.8**
Tetracera afenis	0.02	0.44	0.57	**1.03**	-	-	-	-	-	-	-	-	-	-	-	-
Thelpyteris micro.	-	-	-	-	-	-	-	-	-	-	-	-	0.48	2.38	1.05	**3.92**
Treculia africana	-	-	-	-	-	-	-	-	3.41	0.57	0.31	**4.29**	-	-	-	-

Appendix II contd.

Species	SF				AF				IL				AMS			
	RBA	**RF**	**RD**	**IV**	**RBA**	**RF**	**RD**	**IV**	**RBA**	**RF**	**RD**	**IV**	**RBA**	**RF**	**RD**	**IV**
Trema orientalis	-	-	-	-	-	-	-	-	-	-	-	-	4.43	9.52	14.74	**28.69**
Tricalysia pallens	0.04	0.87	0.19	**1.1**	-	-	-	-	-	-	-	-	-	-	-	-
Trichilia monadelpha	1.17	2.17	1.33	**4.67**	0.29	1.67	1.02	**2.98**	1.33	2.29	1.87	**5.49**	-	-	-	-
Trichilia prieuriana	0.2	0.44	0.19	**0.83**	-	-	-	-	-	-	-	-	-	-	-	-
Trichilia tessmannii	0.04	0.44	0.19	**0.67**	-	-	-	-	-	-	-	-	-	-	-	-
Trilepisium madaga.	0.02	0.44	0.19	**0.65**	-	-	-	-	0.35	0.57	0.31	**1.23**	-	-	-	-
Triplochiton sclero.	-	-	-	-	0.82	1.67	1.02	**3.51**	-	-	-	-	-	-	-	-
Turraeanthus africa.	0.99	1.3	2.08	**4.37**	-	-	-	-	0.74	0.57	1.56	**2.87**	-	-	-	-
Uapaca corbisieri	0.89	0.87	0.19	**1.95**	-	-	-	-	-	-	-	-	-	-	-	-
Vitex ferruginea	-	-	-	-	-	-	-	-	0.51	0.57	0.31	**1.39**	-	-	-	-
Voacanga africana	-	-	-	-	-	-	-	-	0.09	0.57	0.31	**0.97**	-	-	-	-
Xylopia aethiopica	0.02	0.44	0.38	**0.84**	-	-	-	-	-	-	-	-	-	-	-	-
Xylopia staudtii	0.01	0.87	0.19	**1.07**	-	-	-	-	-	-	-	-	-	-	-	-
Zanthoxylum gilletii	0.05	0.44	0.19	**0.68**	-	-	-	-	3.57	1.71	1.25	**6.53**	-	-	-	-

SF = secondary forest, ILF = illegally logged forest, AF = abandoned farmland, AMS = abandoned mined site, RBA = relative basal area, RF = relative frequency, RD = relative density, IV = important value.

APENDIX III

List of seedlings and saplings species found in the study area.

Species	Seedling				Sapling			
	SF	**AF**	**ILF**	**AMS**	**SF**	**AF**	**IL**	**AMS**
Acacia pentagyna	1	-	3	-	-	-	-	-
Acridocarpus sp.	1	-	-	-	-	-	-	-
Adenia lobata	1	2	1	-	-	-	-	-
Adianthum sp.	-	-	11	-	-	-	-	-
Aganope sp.	-	-	1	-	-	-	-	-
Agelaea nitida	1	-	-	-	-	-	-	-
Ageleae pentagyna	1	-	-	-	-	-	-	-
Alafia barteri	-	-	5	-	-	-	-	-
Albizia adianthifolia	-	1	1	-	-	1	-	-
Albizia ferruginea	-	1	-	-	-	-	-	-
Albizia zygia	-	17	-	-	-	2	-	-
Alchornea cordifolia	3	4	5	-	-	2	-	-
Alchornea floribunda	-	-	-	1	1	-	-	-
Allanblackia floribunda	-	-	1	-	2	-	-	-
Ancormanis deformis	-	-	2	-	2	-	-	-
Angylocalyx sp.	-	-	5	-	-	-	1	-
Angylocalyx oligophyllus	-	-	-	-	4	-	-	-
Anthocleister nobilis	-	6	-	2	-	-	-	5
Anthocleister vogelii	1	-	-	-	-	-	1	-
Anthonotha sassandraensis	1	-	-	-	1	1	-	-
Antiaris toxicaria	1	1	1	-	1	2	-	-
Antidesma laciniatum	-	-	-	-	-	-	1	-
Baissea breviloba	1	-	2	-	-	-	-	-
Baphia nitida	-	2	11	-	2	3	15	-
Baphia pubescens	1	-	8	-	1	-	3	-
Blighia sapida	-	-	2	-	-	-	1	-
Blighia unijugata	-	1	1	-	-	1	-	-
Bredelia grandis	-	1	-	-	-	2	1	-
Bussea occidentalis	-	-	-	-	-	-	1	-
Caloncoba gilgiana	-	-	-	-	-	-	1	-
Calycobolus africanus	1	-	1	-	-	-	-	-
Calycobolus heudelotii	21	-	-	-	-	-	-	-
Canarium schweinfurthii	-	-	-	-	-	-	1	-

Appendix III contd.

Species	Seedling				Sapling			
	SF	AF	ILF	AMS	SF	AF	IL	AMS
Carpolobia leutea	-	-	-	-	3	-	1	-
Cassia leucucefera	-	-	-	-	-	-	-	1
Ceiba pentandra	-	-	-	-	-	1	-	-
Celtis mildbraedii	1	-	2	-	2	1	1	-
Cercamoni afzelii	-	6	1	-	-	-	-	-
Cercestis afzelii	-	-	2	-	-	-	-	-
Chytranthus carneus	1	-	-	-	-	-	2	-
Chytranthus cauliflorus	-	-	-	-	1	-	-	-
Cissux adenicularus	-	1	-	-	-	-	-	-
Clerodendron capitatum	-	5	-	-	-	-	-	-
Cnestis ferruginea	-	-	-	-	-	-	1	-
Cola chlamydantha	1	-	-	-	1	-	1	-
Combretum micranthum	-	1	-	-	-	-	-	-
Combretum mucronatum	-	-	-	1	-	-	-	-
Copaifera salikounda	-	-	-	-	1	-	-	-
Costus afer	-	-	-	-	1	14	-	-
Culcasia angolensi	-	-	3	-	-	-	-	-
Culcasia saxatilis	1	-	20	-	-	-	-	-
Cyperus sp.	-	5	-	-	-	-	-	-
Dacryodes klaineana	1	-	-	-	8	-	-	-
Dalbergia hostilis	2	-	-	-	-	-	-	-
Desmodium adscendens	-	-	-	-	-	1	-	-
Desplatsia dewevrei	-	-	-	-	1	-	-	-
Dialium dinklagei	-	-	-	-	-	1	1	-
Dichapetallum pallidum	-	-	-	-	1	-	1	-
Dichapetalum sp.	-	-	1	-	-	-	4	-
Diospyros kamerunensis	-	-	-	-	1	-	-	-
Diospyros sanza-minika	1	-	-	-	-	-	-	-
Discoglypremna caloneura	-	-	-	-	1	-	1	-
Distemonanthus benthamianus	-	-	-	-	-	1	-	-
Dracaena mannii	-	-	-	-	-	2	-	-
Drypetes ivorensis	-	-	-	-	-	-	3	-
Enancea polycarpa	-	-	-	-	-	-	1	-
Entandrophragma angolensis	-	-	3	1	-	-	5	-
Ficus varifolia	-	1	-	-	-	1	-	-
Funtumia africana	-	1	-	4	3	-	-	-

Appendix III contd.

Species	Seedling				Sapling			
	SF	AF	ILF	AMS	SF	AF	IL	AMS
Funtumia elastica	-	-	-	-	-	-	1	-
Geophila sp.	4	-	-	-	-	-	-	-
Gilbertiodendron splendidum	-	-	-	-	12	-	-	-
Glyphaea brevis	-	-	-	-	2	-	-	-
Gongronema latifolium	-	3	2	-	-	-	-	-
Greenwayodendron oliveri	-	-	4	-	-	-	-	-
Griffonia simplicifolia	20	5	14	-	-	7	-	-
Harungana madagascriensis	-	-	-	-	-	-	-	1
Heisteria pavifolia	-	-	-	-	3	-	-	-
Hipselodelphys violaceae	-	-	-	-	1	-	-	-
Hunteria spp.	-	-	-	-	1	-	-	-
Icacina mannii	-	-	-	-	1	-	-	-
Iodes sp.	1	-	-	-	-	-	-	-
Lannea welwithschii	-	-	-	-	-	2	1	-
Leptoderris micrantha	2	-	-	-	-	-	-	-
Macaranga barteri	1	4	1	-	1	6	-	-
Macaranga hurifolia	-	-	-	-	-	2	1	-
Manniophyton fulvum	1	-	6	-	-	-	1	-
Mansonia altissima	-	-	1	-	-	-	-	-
Mareya micrantha	-	1	-	-	-	-	-	-
Melastromataceae sp.	-	1	-	-	-	-	-	-
Microdesmis peberula	-	1	5	-	3	-	14	-
Milicia excelsa	-	-	-	-	-	-	-	1
Milletia chrysophylla	2	-	12	-	5	-	-	-
Milletia zechiana	2	4	17	-	1	12	-	-
Monodora myristica	-	-	5	-	7	-	3	-
Monodora tennuifolia	-	-	2	-	1	-	-	-
Morinda lucida	-	1	-	-	-	2	-	-
Motandra guineensis	2	-	3	-	-	-	-	-
Myrianthus arboreus	-	-	1	-	-	-	1	-
Napoleonaea vogelii	-	3	-	-	-	1	1	-
Nauclea diderichii	-	1	-	-	-	2	-	-
Neuropeltis acuminata	1	-	12	-	-	-	-	-
Olyra latifolia	-	-	-	-	-	-	1	-
Oxyanthus sp.	-	-	-	-	-	-	1	-
Oxyanthus speciosus	-	-	-	-	1	-	-	-

Appendix III contd.

Species	Seedling				Sapling			
	SF	AF	ILF	AMS	SF	AF	IL	AMS
Paulinia pinnata	1	4	-	-	-	-	-	-
Persea americana	-	5	-	-	-	1	-	-
Petersianthus macrocarpus	-	2	1	-	1	-	-	-
Phyllanthus muelanianus	-	1	-	-	-	-	-	-
Phylocosmos africanus	1	-	-	-	2	-	-	-
Piper guineensis	2	1	4	-	-	-	-	-
Piptadeniastrum africanum	-	-	-	-	1	-	-	-
Placodescus bancoensis	-	-	-	-	3	-	-	-
Placodiscus oblongifolius	-	-	-	-	-	-	1	-
Pseudospondias macrocarpa	1	1	-	-	2	-	-	-
Psychotria ivorensis	1	3	-	-	-	-	-	-
Psydrax subcordata	-	-	-	-	1	2	-	-
Ptychopetalum anceps	-	-	-	-	-	-	1	-
Pycnanthus angolensis	-	1	5	-	-	2	2	-
Rauvolfia vomitoria	1	2	-	-	-	10	3	1
Ricinodendron heudolotii	-	-	-	1	-	-	-	-
Rinorea illicifolia	-	-	-	-	2	-	-	-
Rinorea oblongifolia	-	-	6	-	18	-	3	-
Rinorea prasina	-	-	12	-	-	-	3	-
Rothmania longiflora	-	1	-	1	1	-	5	-
Salacia elagans	-	-	1	-	-	-	-	-
Sclerodendron capitatum	-	-	-	-	-	6	-	-
Scottelia klaineana	-	-	1	-	1	-	-	-
Secamonii afzelii	-	1	-	-	-	-	-	-
Smilax kraussiana	1	-	2	-	-	-	-	-
Spathodea campanulata	-	1	-	-	-	1	-	-
Sphenocentrum jollyanum	-	-	-	-	3	-	-	-
Spondias mombin	-	1	-	-	-	5	-	-
Stemonocoleus micranthus	-	-	-	-	-	-	1	-
Sterculia oblonga	-	-	-	-	-	-	2	-
Sterculia tragacantha	-	-	-	-	-	7	2	-
Strombosia glaucesens	-	-	-	-	1	-	-	-
Strychnos spinosa	-	-	-	-	-	-	1	-
Tabernaemontana africana	-	-	1	-	1	-	5	-

Appendix III contd.

Species	Seedling				Sapling			
	SF	AF	ILF	AMS	SF	AF	IL	AMS
Terminalia superba	-	-	-	-	1	-	-	-
Tetracera afenis	-	3	-	-	-	-	-	-
Tetrorchidium didymostemon	-	-	1	-	2	-	-	-
Trema orientalis	-	-	-	1	-	-	-	-
Tricalysia pallens	-	-	1	-	-	-	-	-
Trichilia megalantha	-	-	-	-	1	-	-	-
Trichilia monadelpha	4	4	7	-	3	2	3	-
Trichilia prieuriana	1	-	1	-	1	-	-	-
Trichilia tessmannii	-	-	-	-	1	-	-	-
Trclysia pallens	-	1	-	-	-	-	-	-
Trilepisium madascariense	-	1	-	-	-	-	1	-
Triplochiton scleroxylon	-	7	-	-	-	1	-	-
Turraeanthus africanus	1	-	-	-	2	-	6	-
Uvaria afzelia	-	5	-	-	-	-	-	-
Uvaria mokolii	1	-	-	-	-	-	-	-
Voacanga africana	-	-	-	1	-	1	1	-
Xxlopia aethiopica	3	1	-	-	4	-	-	-
Xylopia paviflora	1	-	-	-	-	-	-	-
Xylopia quintasii	-	-	-	-	2	-	-	-
Zanthoxylum gilletii	-	-	1	-	-	-	-	-

SF = secondary forest, ILF = illegally logged forest, AF = abandoned farmland, AMS = abandoned mine site.