KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

INSTITUTE OF DISTANCE LEARNING

COLLEGE OF SCIENCE

DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY

RATE OF TIMBER PRODUCTION IN BIBIANI ANHWIASO BEKWAI DISTRICT IN THE WESTERN REGION OVER A PERIOD OF ELEVEN YEARS (2002-2012) AND ITS IMPLICATION ON SUSTAINABLE FOREST MANAGEMENT

THIS THESIS IS PRESENTED TO THE DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY IN PARTIAL FULFILLMENT FOR THE REQUIREMENT FOR THE AWARD OF MASTER OF SCIENCE IN ENVIRONMENTAL SCIENCE

BY

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OCTOBER, 2015

DECLARATION

"I declare that I have wholly undertaken this study reported therein under the supervision of Dr. Ebenezer J. D. Belford and that except portions where references have been duly cited, this thesis is the outcome of my research".

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ACKNOWLEDGEMENT

‘‘It never happens without help’’. - Tom Clancy

I thank God Almighty for his inexplicable grace, empowerment and granting me the ability, strength and wisdom throughout this study. I wish to acknowledge with thanks, the guidance, support and encouragement I received from many people whose contributions in diverse ways enabled me to complete this study.

First and foremost, I would like to thank my supervisor Dr. Ebenezer J. D. Belford**,** Lecturer at the Department of Theoretical and Applied Biology of Kwame Nkrumah University of Science and Technology for his immense help, support, advice, encouragement and critical insightful contributions towards this study regardless of his busy schedules.

I also extend my heartfelt appreciation to Mr. Yahanes Dissou Arthur, a Lecturer at the University of Education Winneba (UEW), Northern Campus for the help accorded me in analyzing the data of this thesis. I thank Mr. Solomon Nyamaah, a Range Supervisor with the Forest Services Division, Bibiani and Messrs Johannes Vidufe Aborgeh and Elorm John Amengor, National Service Personnel for their assistance on the field. I also thank Mr. Tony Adams Tulasi of Kwame Nkrumah University of Science and Technology for the insightful contributions towards this study.

I thank my wife Christiana and children (Gifty, Hannah, Gideon, Princess, Solomon, Lucky and David) for their inspiration and prayers. I am also grateful to my brothers and sisters for their encouragement.

ABSTRACT

Timber production data are very essential for sustainable management of forest resources. In Ghana and most developing countries the rate of timber harvesting is increasing alarmingly, leading to depletion and degradation of forest resources. In a bid to investigate the rate of depletion of timbers in Ghana, the rate of timber harvesting in the On and Off reserve areas in the Bibiani Anhwiaso Bekwai Forest District of the Western Region, was evaluated over the period 2002 to 2012. Sampling in the On and Off reserves was conducted during an eight months period in 2013. A total of 57 different indigenous hardwood species in 22 families were identified to be harvested from both On and Off reserve areas. The data obtained from the Forest Services Division official records (monthly and annual report files) were on the species, volume and number of different economic timber species exploited on monthly basis from 2002 to 2012. The number and volume of timber species harvested from the forest reserves (On reserve) was higher and significantly different ($p<0.05$) than those harvested from the Off reserve areas over the period of eleven years. The total number of stems (trunk) exploited from the forest ecosystem of the district during the period of eleven years was 18,885 with an estimated volume of 211,719.215m^3. There was a significant difference ($p<0.05$) in timber logging between the years 2002 to 2012. In the Off-reserves, 22 species out of 57 sampled were harvested whilst in the On reserve 56 species were harvested. The age of the timber trees harvested ranged from 4 to 190 years. The trend revealed that economic timber species were disappearing from the forest. *Celtis zenkeri*, *Triplochiton scleroxylon*, *Piptadeniastrum africanum*, *Celtis mildbreadii* and *Ceiba pentandra* were the most exploited species. The New National Forest Plantation Development Program has not been able to meet its intended target, introduced to bridge the gap between rates of extraction and planting. Only 1163.77 hectares were planted out of the total target of 2164.80 hectares during the period 2010 - 2013. The principles for achieving the goals of Sustainable Forest Management (SFM) and urgent conservation measures must be monitored to mitigate the consequences of forest degradation in Ghana.

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LIST OF ABBREVIATIONS

AAC	Annual Allowable Cut
ANOVA	Analysis of Variance
ASNAPP	Agribusiness in Sustainable Natural African Plant Products
BAB	Bibiani Anhwiaso Bekwai
CBD	Conservation on Biological Diversity
COP5	Fifth Conference of Parties
COP7	Seventh Conference of Parties
°C	Degree Celsius
EOEA	Executive Office of Environmental Affairs
ERP	Economic Recovery Program
FAO	Food and Agriculture Organization
FC	Forestry Commission
FIG	Figure
FOE	Friends of the Earth
FSD	Forest Services Division
GEO	Green Earth Organization
GPS	Geographic Positioning System
Km	Kilometer

KWC	Kumasi Wood Cluster
LTEM	Long Term Ecological Monitoring
m	Meter
m^3	Cubic meter
MAI	Mean Average Increment
MCPFE	Ministerial Conference on the Protection of Forest in Europe
NGO	Non-Governmental Organization
NNFPDP	New Nation Forest plantation Development Program
NTFP	Non Timber Forest Product
OR	Off Reserve
PEBLDS	Pan European Biological and landscape Diversity Strategy
PSP	Permanent Sample Plot
R	On Reserve
RMSC	Resources Management Support Center
RUDEYA	Rural Development and Youth Association
SFM	Sustainable Forest Management
SFMP	Sustainable Forest Management Partnership
SPP	Species
SPSS	Statistical Package for Social Sciences
Sq km	Square Kilometer
TUC	Timber Utilization Contract
UNEP-WCMC	United Nations Environment Programme's World Conservation Monitoring Centre
UNESCO	United Nations Educational Scientific and Cultural Organization
USD	United State of America Dollar

WATC	WassaAmenfi Traditional Council
WG	Working Group on Forest Certification
WTS	Wood Tracking System

CHARPTER ONE

1.0 INTRODUCTION

1.1 Background

At the beginning of the twentieth century, the forest area of Ghana covered about 34 percent of the total land. Forest reservation started in Ghana in 1927 by the Colonial administration and ensured the reservation of 11 percent of the Country's total land area.

In all, 282 forest reserves and 15 wildlife protected areas, occupying more than 38,000 sq.km or about 16 percent of the total land area were established and gazetted in Ghana. There was an additional 4,000 sq.km of forest outside this gazetted area. The main aim of the reservation programme was to ensure the protection of substantial areas of forest but the process of forest land reservation ignored the traditional tenure system, which led to a negative attitude to reserves among the population, especially in forest fringe communities. This situation was aggravated by a failure to inform forest communities of their usufruct rights and by focusing of forest management on forest protection by the Central Government (Ghana Gazette, 2004).

According to Dei (1990), deforestation has claimed an enormous toll through the ages in environmental damage, economic deterioration and human misery. For various reasons such as logging and clearing for cash crops cultivation, the rainforest in Ghana has been decreasing rapidly and significantly. Since 1981, the annual rate of deforestation in Ghana has been two percent per year or 750 hectares each year. Ghana s tropical forest area is now just 25 percent of its original size. The impact of deforestation is widespread, affecting the livelihoods of local people, disrupting important environmental functions and severely disturbing the biological integrity of the forest ecosystem.

There is a serious concern in the region about climate change, soil erosion and large-scale desertification.

Since the colonial era, the exploitation of timber for commercial purposes has been part of the Ghanaian economy. But it is only since the start of the economic reform program known as Economic Recovery Program (ERP) in 1981 that deforestation has become a serious concern for the environmental balance of the region. Today, timber is Ghana s third most important export commodity after cocoa and minerals. Timber exports have increased in terms of volume and revenue since the start of the ERP, rising from $16 million in 1983 to 100 million in 1988 (Dei, 1992).

Population increase has increased the pressure on forest land for cultivation of arable and tree crops. Sustainable Forest Management (SFM), a system of management that gives room to the judicious harvesting and utilization of forest resources without jeopardizing the future, is the brain behind forest management in developed countries. SFM was defined as the stewardship and use of forests and forestlands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local national, and global levels, and does not cause damage to other ecosystems (Briner, 2004).

The data on the rate of timber production and harvesting in Ghana are deficient due to poor record keeping system and blithe attitude of Ghanaian civil servants. Where these data are available, they are not well studied and analysed. As a result, it has been so difficult to compare the rate of forest harvesting with the regeneration potential of the natural forests. This would have formed the premise on which forestry planning and development should rest like in the developed nations that have committed substantial amount of fund to monitor growth and harvesting in their natural forests and plantations.

Consequently, there is the need to carry out a field research for estimating the rate at which economic tropical hardwood timber species are removed from the tropical forest ecosystem of Ghana. This work therefore, assessed the rate of timber harvesting in the tropical ecosystem of Ghana, using BibianiAnhwiasoBekwai (BAB) Forest District as a case study, and also to find out whether this rate of extraction is in conformity with the Annual Allowable Cut (AAC) set aside by the Forestry Commission, and its consequences on sustainable forest resources management.

1.2 Main Objective

To determine the rate of extraction of timber species in the Bibiani Anhwiaso Bekwai Forest District.

1.3 Specific Objectives

The specific objectives of this project are:

1. To identify and classify tree species extracted from the district over a period of 11 years (2002-2012) and during the year 2013.
2. To determine the age of the trees that are being logged/ exploited during the year 2013.
3. To determine the frequency and abundance of tree species that are being extracted during the year 2013.
4. To compare the rate of extraction between on and off- reserves over a period of 11 years.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Brief Historical Overview and Perspective of Sustainable Forest Management

Sustainable forest management means the environmentally appropriate, socially beneficial, and economically viable management of forests for present and future generations. Forests are essential for human survival and well-being. It is estimated that approximately 60 million indigenous people are almost wholly dependent on forests. About 350 million people depend on forests for a high degree for subsistence and income, and about 1.2 billion people rely on agroforestry farming systems (World Bank, 2004).

Biodiversity can be described as the diversity of life on Earth. In other words, biodiversity is the variety of all living things, the places they inhabit, and the interaction between them. Interactions between the components of biodiversity make the Earth inhabitable for all species, including humans.
Biodiversity is directly responsible for around 40% of the world's economy, particularly in sectors such as agriculture and forestry, and for providing ecosystem services such as clean water and soil fertility. Seventy percent (70%) of the world's poor live in rural areas and depend directly on biodiversity for their survival and well-being.

The General Assembly of the United Nations adopted in December 2007 the most widely, intergovernmental agreed definition of Sustainable Forest Management (SFM): Sustainable forest management as a dynamic and evolving concept aims to maintain and enhance the economic, social and environmental value of all types of forests, for the benefit of present and future generations. It is characterized by seven elements, including: (i) extent of forest resources; (ii) forest biological diversity; (iii) forest health and vitality; (iv) productive functions of forest resources; (v) protective functions of forest resources; (vi) socio-economic functions of forests; and (vii) legal, policy and institutional framework (UN, 2008).

According to Lanly (2013), sustainable forest management is the tool allowing forests to contribute fully to sustainable development overall. The novelty of the concept of sustainable forest management

- as compared to the most advanced forms of forest management in use today whether by the national forest services, communities or the private sector - is primarily its systematic approach to sustaining each component of the forest ecosystem and their interactions.

In the unlikely events of unsustainable Forest Management, Governments, mostly in developing countries, lose an estimated US$15 billion a year as a result of uncollected taxes and royalties. Recent estimates suggest that up to 15% of internationally traded round wood might originate from illegal sources (Brack*et al*., 2002; Contreras-Hermosilla*et al*., 2007). Rare tree species and those with high value for timber or non-timber forest products are often in danger of becoming locally extinct (FAO, 2006b; IUCN, 2004).

Forestry can have a variety of negative impacts on biodiversity, particularly when carried out without management standards designed to protect natural assets. Biodiversity loss: unsustainable forest operations and other pressures on forest resources, such as gathering of fuelwood, can lead to forest degradation and permanent losses in biodiversity. Globally, over half of the temperate broadleaf and mixed forest biome and nearly one quarter of the tropical rain forest biome have been fragmented or removed by humans (Gale, 2008).

Illegal hunting: Increased hunting continues to be a major threat to forest biodiversity in many countries. The depletion of wildlife is intimately linked to the food security and livelihood of numerous tropical forest-region inhabitants, as many of these forest-dependent people have few alternative sources of protein and income. Unsustainable hunting pressures are often linked to logging activities (Nasi*et al*., 2008).

2.2 Forestry and its importance

A forest is an area with a high density of trees. As with cities, depending on various cultural definitions, what is considered a forest may vary significantly in size and have different classifications according to how and of what the forest is composed (Lund, 2006). A forest is usually an area filled with trees but any tall densely packed area of vegetation may be considered a forest, even underwater vegetation such as kelp forests, or non-vegetation such as fungi (Statmets, 2006) and bacteria. Tree forests cover approximately 9.4 percent of the Earth's surface (or 30 percent of total land area), though they once covered much more (about 50 percent of total land area). They function as habitats for organisms, hydrologic flow modulators, and soil conservers, constituting one of the most important aspects of the biosphere.

A typical tree forest is composed of the over story (canopy or upper tree layer) and the understory. The understory is further subdivided into the shrub layer, herb layer, and also the moss layer and soil microbes. In some complex forests, there is also a well-defined lower tree layer. Forests are central to all human life because they provide a diverse range of resources: they store carbon, aid in regulating the planetary climate, purify water and mitigate natural hazards such as floods. Forests also contain roughly 90 percent of the world's terrestrial biodiversity.

Forests can be found in all regions capable of sustaining tree growth, at altitudes up to the tree line, except where natural fire frequency or other disturbance is too high, or where the environment has been altered by human activity.

The latitudes 10° north and south of the Equator are mostly covered in tropical rainforest, and the latitudes between 53°N and 67°N have boreal forest. As a general rule, forests dominated by angiosperms (broadleaf forests) are more species-rich than those dominated by gymnosperms (conifer, montane, or needle leaf forests), although exceptions exist.

Forests sometimes contain many tree species only within a small area (as in tropical rain and temperate deciduous forests), or relatively few species over large areas (e.g., taiga and arid montane coniferous forests). Forests are often home to many animal and plant species, and biomass per unit area is high compared to other vegetation communities. Much of this biomass occurs below ground in the root systems and as partially decomposed plant detritus. The woody component of a forest contains lignin, which is relatively slow to decompose compared with other organic materials such as cellulose or carbohydrate.

Forests are differentiated from woodlands by the extent of canopy coverage: in a forest, the branches and the foliage of separate trees often meet or interlock, although there can be gaps of varying sizes within an area referred to as forest. A woodland has a more continuously open canopy, with trees spaced farther apart, which allows more sunlight to penetrate to the ground between them.

2.2.1 Classification of Forests

Forests can be classified in different ways and to different degrees of specificity. One such way is in terms of the "biome" in which they exist, combined with leaf longevity of the dominant species (whether they are evergreen or deciduous). Another distinction is whether the forests are composed predominantly of broadleaf trees, coniferous (needle-leaved) trees, or mixed.

- Boreal forests occupy the subarctic zone and are generally evergreen and coniferous.
- Temperate zones support both broadleaf deciduous forests (e.g., temperate deciduous forest) and evergreen coniferous forests (e.g., temperate coniferous forests and temperate rainforests). Warm temperate zones support broadleaf evergreen forests, including laurel forests.

- Tropical and subtropical forests include tropical and subtropical moist forests, tropical and subtropical dry forests, and tropical and subtropical coniferous forests.
- Physiognomy classifies forests based on their overall physical structure or developmental stage (e.g. old growth vs. second growth).
- Forests can also be classified more specifically based on the climate and the dominant tree species present, resulting in numerous different forest types (e.g., ponderosa pine/Douglas-fir forest).

A number of global forest classification systems have been proposed, but none has gained universal acceptance (Jenkins, 2007). UNEP-WCMC's forest category classification system is a simplification of other more complex systems (e.g. UNESCO's forest and woodland 'subformations'). This system divides the world's forests into 26 major types, which reflect climatic zones as well as the principal types of trees. These 26 major types can be reclassified into 6 broader categories: temperate needle leaf; temperate broadleaf and mixed; tropical moist; tropical dry; sparse trees and parkland; and forest plantations. Each category is described as a separate section below.

- **Temperate needle leaf**

Temperate needle leaf forests mostly occupy the higher latitude regions of the northern hemisphere, as well as high altitude zones and some warm temperate areas, especially on nutrient-poor or otherwise unfavourable soils. These forests are composed entirely, or nearly so, of coniferous species (Coniferophyta). In the Northern Hemisphere pines Pinus, spruces Picea, larches Larix, silver firs Abies, Douglas firs Pseudotsuga and hemlocks Tsuga, make up the canopy, but other taxa are also important. In the Southern Hemisphere, most coniferous trees (members of the Araucariaceae and Podocarpaceae) occur in mixtures with broadleaf species that are classed as broadleaf and mixed forests.

- **Temperate broadleaf and mixed**

Temperate broadleaf and mixed forests include a substantial component of trees in the Anthophyta. They are generally characteristic of the warmer temperate latitudes, but extend to cool temperate ones, particularly in the southern hemisphere. They include such forest types as the mixed deciduous forests of the United States and their counterparts in China and Japan, the broadleaf evergreen rainforests of Japan, Chile and Tasmania, the sclerophyllous forests of Australia, central Chile, the Mediterranean and California, and the southern beech Nothofagus forests of Chile and New Zealand.

- **Tropical moist**

There are many different types of tropical moist forests, although most extensive are the lowland evergreen broad leaf rainforests, for example várzeaandigapó forests and the terra firma forests of the Amazon Basin; the peat swamp forests, dipterocarp forests of Southeast Asia; and the high forests of the Congo Basin. Forests located on mountains are also included in this category, divided largely into upper and lower montane formations on the basis of the variation of physiognomy corresponding to changes in altitude (Chape*et al*., 2011).

- **Tropical dry**

Tropical dry forests are characteristic of areas in the tropics affected by seasonal drought. The seasonality of rainfall is usually reflected in the deciduousness of the forest canopy, with most trees being leafless for several months of the year. However, under some conditions, e.g. less fertile soils or less predictable drought regimes, the proportion of evergreen species increases and the forests are characterised as "sclerophyllous". Thorn forest, a dense forest of low stature with a high frequency of thorny or spiny species, is found where drought is prolonged, and especially where grazing animals are plentiful. On very poor soils, and especially where fire is a recurrent phenomenon, woody savannas develop (see 'sparse trees and parkland').

- **Sparse trees and parkland**

Sparse trees and parkland are forests with open canopies of 10–30% crown cover. They occur principally in areas of transition from forested to non-forested landscapes. The two major zones in which these ecosystems occur are in the boreal region and in the seasonally dry tropics. At high latitudes, north of the main zone of boreal forest or taiga, growing conditions are not adequate to maintain a continuous closed forest cover, so tree cover is both sparse and discontinuous. This vegetation is variously called open taiga, open lichen woodland, and forest tundra. It is species-poor, has high bryophyte cover, and is frequently affected by fire.

- **Forest plantations**

Forest plantations, generally intended for the production of timber and pulpwood increase the total area of forest worldwide. Commonly mono-specific and/or composed of introduced tree species, these ecosystems are not generally important as habitat for native biodiversity. However, they can be managed in ways that enhance their biodiversity protection functions and they are important providers of ecosystem services such as maintaining nutrient capital, protecting watersheds and soil structure as well as storing carbon. They may also play an important role in alleviating pressure on natural forests for timber and fuel wood production.

The scientific study of forest species and their interaction with the environment is referred to as forest ecology, while the management of forests is often referred to as forestry. Forest management has changed considerably over the last few centuries, with rapid changes from the 1980s onwards culminating in a practice now referred to as sustainable forest management. Forest ecologists concentrate on forest patterns and processes, usually with the aim of elucidating cause and effect relationships. Foresters who practice sustainable forest management focus on the integration of ecological, social and economic values, often in consultation with local communities and other stakeholders.

Anthropogenic factors that can affect forests include logging, urban sprawl, human-caused forest fires, acid rain, invasive species, and the slash and burn practices of swidden agriculture or shifting cultivation. The loss and re-growth of forest leads to a distinction between two broad types of forest, primary or old-growth forest and secondary forest. There are also many natural factors that can cause changes in forests over time including forest fires, insects, diseases, weather, competition between species, etc. In 1997, the World Resources Institute recorded that only 20% of the world's original forests remained in large intact tracts of undisturbed forest (World Resources Institute, 1998).

2.3 Forest Reserves

Forest reserves are portions of state lands where commercial harvesting of wood products is excluded in order to capture elements of biodiversity that can be missing from sustainably harvested sites. Small (patch) reserves will conserve sensitive, localized resources such as steep slopes, fragile soils, and habitat for certain rare species that benefit from intact forest canopies. Large (matrix) reserves will represent the diversity of relatively un-fragmented forest landscapes remaining in Massachusetts today. Matrix reserves will ultimately support a wider diversity of tree sizes and ages than typically occurs on sustainably harvested sites, and will also support structures and processes associated with extensive accumulations of large woody debris that are typically absent from harvested sites.

Matrix reserves will ultimately include a wide range of tree sizes and ages, from large, old trees 200500 years old, to small, young trees that occur in open gaps where old trees have died or been blown over. Matrix reserves will ultimately feature extensive “pit and mound” micro-topography that occurs when old trees are blown over and their roots are pulled from the ground. Pits are formed when roots of large trees are pulled out of the ground during a natural disturbance like a wind storm. Pits collect moisture, organic matter, and nutrients over time, and provide unique, protected micro-climates for plants and invertebrate wildlife. Over time, the exposed roots of toppled trees degrade and form mounds characterized by extreme soil conditions of low moisture, low organic matter, and low nutrients that are markedly different from, yet in close proximity to pits originally occupied by the roots (Beatty, 1984). The trunks and branches of large trees that are toppled during wind storms will accumulate as large woody debris in the forest, and will support decades or even centuries of activity by micro-organisms and invertebrate wildlife that occupy, feed upon, and ultimately break down these massive stores of organic material.

2.3.1 Importance of reserves

Reserves allow people to experience and to understand how forest ecosystems function when timber and other wood products that are normally extracted for human use remain in place. While it is important to have the great majority of forestland open to the sustainable harvest of wood products in order to support human society, it is equally important to retain portions of our forested landscapes in a condition where all components of the ecosystem remain in place. Forest reserves allow us to more fully assess human impacts on harvested sites, and may provide insights into how extractive management of harvested forestlands can be improved.

Most private forest landowners can ill-afford to forgo harvesting of large sawn timber and to allow sawn timber trees to be blown down and remain in the forest. Revenues generated from harvesting on private lands also make it economically viable to retain private forestland in forest use. State-owned forestlands are generally able to provide more accumulation of large woody debris than private lands, but in order to meet a range of existing goals, the sustainable harvest and commercial sale of renewable wood products is appropriate on most state lands. At the same time, it is also appropriate to establish reserves on state lands that will provide unique environments where all woody biomass remains on site. Reserves will likely support substantially higher densities of certain species of moss and lichens that typically occur only on older trees (Selva, 1996). Feather flat moss (Neckarapennata), lungwort lichen (Lobariapulmonaria), and shaggy fringe lichen (Anaptychiapalmulata) are examples of species that do not typically occur on harvested sites in Massachusetts. Some beetle species which occupy the forest-floor appear to be more abundant in old-growth than in managed forests (Flatebo *et al*., 1999). Certain forest songbirds (e.g., Blackburnian warbler, Magnolia warbler, and Solitary vireo) occur at substantially higher densities in forest reserves than in harvested forestlands (Haney and Schaadt, 1996).

Forest reserves provide potential refugia for unique species assemblages, and may provide habitat for invertebrate wildlife and soil micro-organisms that have not been well studied to date. Reserves will provide unique recreational, aesthetic, and educational opportunities for the people of Massachusetts. Forest reserves provide reference sites for objective assessment of the sustainability of forest management practices (Norton, 1999), and are essential for practicing adaptive resource management (Walters and Holling, 1990). Reserves create opportunities for connectivity within the landscape, conservation of species and processes, buffering against future uncertainty, and other hard to measure but valuable functions (Jackson and Hunter, 1996).

While no forestland in Massachusetts is free of human impact from ubiquitous influences such as air pollution and invasive, exotic organisms introduced by people, forest reserves can still help ensure that representative examples of biodiversity indigenous to an area are more likely to be conserved since wood fiber is not extracted and invasive plant species are less likely to be introduced in reserves. Natural disturbance processes will, to a large degree, determine the structure and composition of the forest ecosystem in reserves. Reserves will provide valuable late-seral forest habitat for wildlife that may ultimately support species assemblages and abundances that do not occur on the sustainably harvested sites. Long term ecological monitoring (LTEM) is planned on reserve sites to document the composition of plant and animal communities over time. EOEA has contracted with researchers at the University Of Massachusetts Department Of Natural Resource Conservation to design and implement comprehensive LTEM in reserves. The results of LTEM may eventually aid in refining management practices on harvested sites to enhance conservation of biodiversity across all forestlands. Reserves can be used to conserve small, isolated resources (e.g., rare species habitats or sites with fragile soils), and to establish extensive areas that represent the diversity of forest ecosystems that occur in Massachusetts.

A combination of small (patch) reserves and large (matrix) reserves will be created on state lands to insure that all elements of biodiversity are represented across Massachusetts' forestlands. Reserves will be imbedded within the extensive, working forest landscapes of Massachusetts, where the great majority of land is open to commercial harvesting of renewable wood products. Together, sustainably harvested sites and reserves will provide a range of ecological and recreational opportunities on stateowned forest lands.

2.3.2 Forest products and their economic importance

A forest product is any material derived from a forest for commercial use, such as lumber, paper, or forage for livestock. Wood, by far the dominant commercial forest product, is used for many industrial purposes, such as the finished structural materials used for the construction of buildings, or as a raw material, in the form of wood pulp, that is used in the production of paper. All other nonwood products derived from forest resources, comprising a broad variety of other forest products, are collectively described as non-timber forest products.

Non-timber forest products (NTFP) are considered as any commodity obtained from the forest that does not necessitate harvesting trees. It includes game animals, fur-bearers, nuts and seeds, berries, mushrooms, oils, foliage, medicinal plants, peat, fuel wood, forage, etc. A few examples of the many different kinds of NTFPs include mushrooms, huckleberries, ferns, transplants, seed cones, piñon seed, tree nuts, moss, maple syrup, cork, cinnamon, rubber, tree oils and resins, and ginseng. Some definitions also include small animals and insects.

Products are commonly grouped into categories such as floral greens, decoratives, medicinal plants, foods, flavours and fragrances, fibres, and saps and resins. Other terms synonymous with non-timber forest product include special forest product, non-wood forest product, minor forest product, alternative forest product and secondary forest product. These terms are useful because they help highlight forest products that are of value to local people and communities, but that have often been overlooked in the wake of forest management priorities such as timber production and animal forage. In recent decades interest has grown in using NTFPs as an alternative or supplement to forest management practices such as clear-cut logging. In some forest types and under the right political and social conditions forests could be managed to increase NTFP diversity, and consequently biodiversity and economic diversity.

2.4 Forestry and Timber

Forestry is the science, art, and craft of creating, managing, using, conserving, and repairing forests and associated resources in a sustainable manner to meet desired goals, needs, and values for human benefit. Forestry is practiced in plantations and natural stands. The main goal of forestry is to create and implement systems that allows forests to continue a sustainable provision of environmental supplies and services. The challenge of forestry is to create systems that are socially accepted while sustaining the resource and any other resources that might be affected.

Silviculture, a related science, involves the growing and tending of trees and forests. Modern forestry generally embraces a broad range of concerns, including assisting forests to provide timber as raw material for wood products, wildlife habitat, natural water quality management, recreation, landscape and community protection, employment, aesthetically appealing landscapes, biodiversity management, watershed management, erosion control, and preserving forests as 'sinks' for atmospheric carbon dioxide. A practitioner of forestry is known as a forester. The word "forestry" can also refer to a forest itself. Forest ecosystems have come to be seen as the most important component of the biosphere, and forestry has emerged as a vital field of science, applied art, and technology.

2.4.1 Foresters

Foresters work for the timber industry, government agencies, conservation groups, local authorities, urban parks boards, citizens' associations, and private landowners. The forestry profession includes a wide diversity of jobs, with educational requirements ranging from college bachelor's degrees to PhDs for highly specialized work. Industrial foresters plan forest regeneration starting with careful harvesting. Urban foresters manage trees in urban green spaces. Foresters work in tree nurseries growing seedlings for woodland creation or regeneration projects. Foresters improve tree genetics. Forest engineers develop new building systems. Professional foresters measure and model the growth of forests with tools like geographic information systems.

Foresters may combat insect infestation, disease, forest and grassland wildfire, but increasingly allow these natural aspects of forest ecosystems to run their course when the likelihood of epidemics or risk of life or property are low. Increasingly, foresters participate in wildlife conservation planning and watershed protection. Foresters have been mainly concerned with timber management, especially reforestation, maintaining forests at prime conditions, and fire control (Gale, 2001).

2.4.2 Forestry Plans

Foresters develop and implement forest management plans relying on mapped resource inventories showing an area's topographical features as well as its distribution of trees (by species) and other plant cover. Plans also include landowner objectives, roads, culverts, proximity to human habitation, water features and hydrological conditions, and soils information. Forest management plans typically include recommended silvicultural treatments and a timetable for their implementation.

Forest management plans include recommendations to achieve the landowner's objectives and desired future condition for the property subject to ecological, financial, logistical (e.g. access to resources), and other constraints. On some properties, plans focus on producing quality wood products for processing or sale. Hence, tree species, quantity, and form, all central to the value of harvested products quality and quantity, tend to be important components of silvicultural plans.

Good management plans include consideration of future conditions of the stand after any recommended harvests treatments, including future treatments (particularly in intermediate stand treatments, and plans for natural or artificial regeneration after final harvests.

The objectives of landowners and leaseholder influence plans for harvest and subsequent site treatment. In Britain, plans featuring "good forestry practice" must always consider the needs of other stakeholders such as nearby communities or rural residents living within or adjacent to woodland areas. Foresters consider tree felling and environmental legislation when developing plans. Plans instruct the sustainable harvesting and replacement of trees. They indicate whether road building or other forest engineering operations are required. Agriculture and forest leaders are also trying to understand how the climate change legislation will affect what they do. The information gathered will provide the data that will determine the role of agriculture and forestry in a new climate change regulatory system.

2.4.3 Our Timber

The range of species is very large and expanding. In one form or another Ghana at present exports more than fifty species and continues to promote many more. They include some of the strongest and most durable species in the world and embrace a big variety of colour and grain, from almost white (Wawa) to very dark (Kaku), and from timbers suitable for the toughest use as sea defence, bridge construction and railway sleepers to the handsome woods for furniture, panelling and flooring, and to the very light-weight species for interior work. Whatever the end uses, there is a suitable Ghanaian species.

Ghana is recognized as one of the most advanced tropical African countries in established forest policy, legislation, forest inventory, management planning, and in having a National Forest Standard and principles, criteria and indicators for judging the quality of forest management and usage.

The forest industry is a large employer, much of it in the informal sector. The Ghana FC has an established approach to forest management more especially in forest reserves. A range of measures have been put in place to reduce illegal logging, including a Wood Tracking System (WTS) which has been successfully piloted and will receive a nationwide coverage for all productive forests in 2012. The WTS is designed to monitor timber from standing trees in forest to processing facilities, or from points of imports to processing facilities and to local sale outlets and or export facilities. The process will enable the tracking of individual logs and consignments of processed wood products, and will include product labelling, physical inspections and documentary checks. The system will provide the full traceability of timber from all sources and certify the origin and legal and regulatory compliance of all timber products.

2.5 Logging

Logging is the cutting, skidding, on-site processing, and loading of trees or logs onto trucks or skeleton cars. In forestry, the term logging is sometimes used in a narrow sense concerning the logistics of moving wood from the stump to somewhere outside the forest, usually sawmill or a lumber yard. However, in common usage, the term may be used to indicate a range of forestry or silviculture activities.

Illegal logging refers to what in forestry might be called timber theft. It can also refer to the harvest, transportation, purchase or sale of timber in violation of laws. The harvesting procedure itself may be illegal, including using corrupt means to gain access to forests; extraction without permission or from a protected area; the cutting of protected species; or the extraction of timber in excess of agreed limits.

Clear-cut logging is not necessarily considered a type of logging but a harvest or silviculture method and is simply called clear-cutting or block cutting. In the forest products industry logging companies may be referred to as logging contractors, with the smaller, non-union crews referred to as "gyppo loggers."

Cutting trees with the highest value and leaving those with lower value, often diseased or malformed trees, is referred to as high grading. It is sometimes called selective logging, and confused with selection cutting, the practice of managing stands by harvesting a proportion of trees.

2.5.1 Clear-cutting

Clear-cutting, or clear-felling, is a harvest method that removes essentially all the standing trees in a selected area. Depending on management objectives, a clear-cut may or may not have reserve trees left to attain goals other than regeneration, including wildlife habitat management, mitigation of potential erosion or water quality concerns. Silviculture objectives for clear-cutting, (for example, healthy regeneration of new trees on the site) and a focus on forestry distinguish it from deforestation. Other methods include Shelter wood cutting, group selective, single selective, seed-tree cutting, patch cut and retention cutting.

2.5.2 Logging methods

The above operations can be carried out by different methods, of which the following three are considered industrial methods:

2.5.2.1 Tree-length logging

Trees are felled and then delimbed and topped at the stump. The log is then transported to the landing, where it is bucked and loaded on a truck. This leaves the slash (and the nutrients it contains) in the cut area where it must be further treated if wild land fires are of concern.

2.5.2.2 Full-tree logging

Trees and plants are felled and transported to the roadside with top and limbs intact. The trees are then delimbed, topped, and bucked at the landing. This method requires that slash be treated at the landing. In areas with access to cogeneration facilities, the slash can be chipped and used for the production of clean electricity or heat. Full-tree harvesting also refers to utilization of the entire tree including branches and tops. This technique removes both nutrients and soil cover from the site and so can be harmful to the long term health of the area if no further action is taken, however, depending on the species, many of the limbs are often broken off in handling so the end result may not be as different from tree-length logging as it might seem.

2.5.2.3 Cut-to-length logging

Cut-to-length logging is the process of felling, delimbing, bucking and sorting (pulpwood, sawlog, etc.) at the stump area, leaving limbs and tops in the forest. Harvesters fell the tree, delimb and buck it, and place the resulting logs in bunks to be brought to the landing by a skidder or forwarder. This method is routinely available for trees up to 900 mm in diameter. Harvesters are employed effectively in level to moderately steep terrain. Harvesters are highly computerized to optimize cutting length, control harvest area by GPS and utilize price list for each specific logs to archive most economical results during harvesting.

2.6 Sustainable Forest Management

Sustainable forest management (SFM) is the management of forests according to the principles of sustainable development. Sustainable forest management uses very broad social, economic and environmental goals. A range of forestry institutions now practice various forms of sustainable forest management and a broad range of methods and tools are available that have been tested over time.

A definition of SFM was developed by the Ministerial Conference on the Protection of Forests in Europe (MCPFE), and has since been adopted by the Food and Agriculture Organization (FAO). It defines sustainable forest management as: The stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems.

In simpler terms, the concept can be described as the attainment of balance – balance between societies' increasing demands for forest products and benefits, and the preservation of forest health and diversity. This balance is critical to the survival of forests, and to the prosperity of forestdependent communities.

For forest managers, sustainably managing a particular forest tract means determining, in a tangible way, how to use it today to ensure similar benefits, health and productivity in the future. Forest managers must assess and integrate a wide array of sometimes conflicting factors – commercial and non-commercial values, environmental considerations, community needs, and even global impact – to produce sound forest plans. In most cases, forest managers develop their forest plans in consultation with citizens, businesses, organizations and other interested parties in and around the forest tract being managed. The tools and visualization have been recently evolving for better management practices.

Because forests and societies are in constant flux, the desired outcome of sustainable forest management is not a fixed one. What constitutes a sustainably managed forest will change over time as values held by the public change.

2.6.1 Decentralization of Forest Management

Although a majority of forests continue to be owned formally by government, the effectiveness of forest governance is increasingly independent of formal ownership. Since neo-liberal ideology in the 1980s and the emanation of the climate change challenges, evidence that the state is failing to effectively manage environmental resources has emerged. Under neo-liberal regimes in the developing countries, the role of the state has diminished and the market forces have increasingly taken over the dominant socio-economic role. Though the critiques of neo-liberal policies have maintained that market forces are not only inappropriate for sustaining the environment, but are in fact a major cause of environmental destruction. Hardin (1968) tragedy of the common has shown that the people cannot be left to do as they wish with land or environmental resources. Thus, decentralization of management offers an alternative solution to forest governance.

The shifting of natural resource management responsibilities from central to state and local governments, where this is occurring, is usually a part of broader decentralization process. According to Rondinelli and Cheema (1981), there are four distinct decentralization options: these are: (i) Privatization – the transfer of authority from the central government to non-governmental sectors otherwise known as market-based service provision, (ii) Delegation – centrally nominated local authority, (iii) Devolution – transfer of power to locally acceptable authority and (iv) Deconcentration – the redistribution of authority from the central government to field delegations of the central government. The major key to effective decentralization is increased broad-based participation in local-public decision making. In 2000, the World Bank report reveals that local government knows the needs and desires of their constituents better than the national government, while at the same time, it is easier to hold local leaders accountable. From the study of West African tropical forest, it is argued that the downwardly accountable and/or representative authorities with meaningful discretional powers are the basic institutional element of decentralization that should lead to efficiency, development and equity. This collaborates with the World Bank report in 2000 which says that decentralization should improve resource allocation, efficiency, accountability and equity by linking the cost and benefit of local services more closely.

Many reasons point to the advocacy of decentralization of forest. (i) Integrated rural development projects often fail because they are top-down project that did not take local people's needs and desire into account. (ii) National government sometimes have legal authority over vast forest area that they cannot control, thus, many protected area project result in increased biodiversity loss and greater social conflict. Within the sphere of forest management, as state earlier, the most effective option of decentralization is “devolution”-the transfer of power to locally accountable authority. However, apprehension about local governments is not unfounded. They are often short of resources, may be staffed by people with low education and are sometimes captured by local elites who promote clientele relation rather than democratic participation. Enters and Anderson (1999) point that the result of community-based projects intended to reverse the problems of past central approaches to conservation and development have also been discouraging.

Broadly speaking, the goal of forest conservation has historically not been met when, in contrast with land use changes; driven by demand for food, fuel and profit. It is necessary to recognized and advocate for better forest governance more strongly given the importance of forest in meeting basic human needs in the future and maintaining ecosystem and biodiversity as well as addressing climate change mitigation and adaptation goal. Such advocacy must be coupled with financial incentives for government of developing countries and greater governance role for local government, civil society, private sector and NGOs on behalf of the “communities”.

2.7 Sustainable Forest Management Partnership – Ghana

Sustainable Forest Management Partnership – Ghana (SFMP-Ghana) is a collaborative effort of seven organizations that work within the sector of forest management. These organizations are:

1. The National Working Group on Forest Certification (WG)
2. Rural Development and Youth Association (RUDEYA)
3. The Kumasi Wood Cluster (KWC)
4. Agribusiness in Sustainable Natural African Plant Products (ASNAPP)
5. Friends of the Earth (FOE).
6. Green Earth Organisation (GEO)
7. WassaAmenfi Traditional Council (WATC)

They are joined by a shared vision of sustainable management of Ghana’s forests and a strengthened position of forest dependent people to generate income and employment.

2.7.1 Objectives of Collaborating Partners

The collaborating partners have the following objectives:

1. To facilitate, and advocate for equitable forest benefit sharing and good governance for Forest Fringe Communities;
2. To promote public education and public discourse on Ghana’s forest policy, laws and programs for enhancement of forest governance;
3. To promote sustainable production, utilization and marketing of non-timber forest products

(NTFP's).

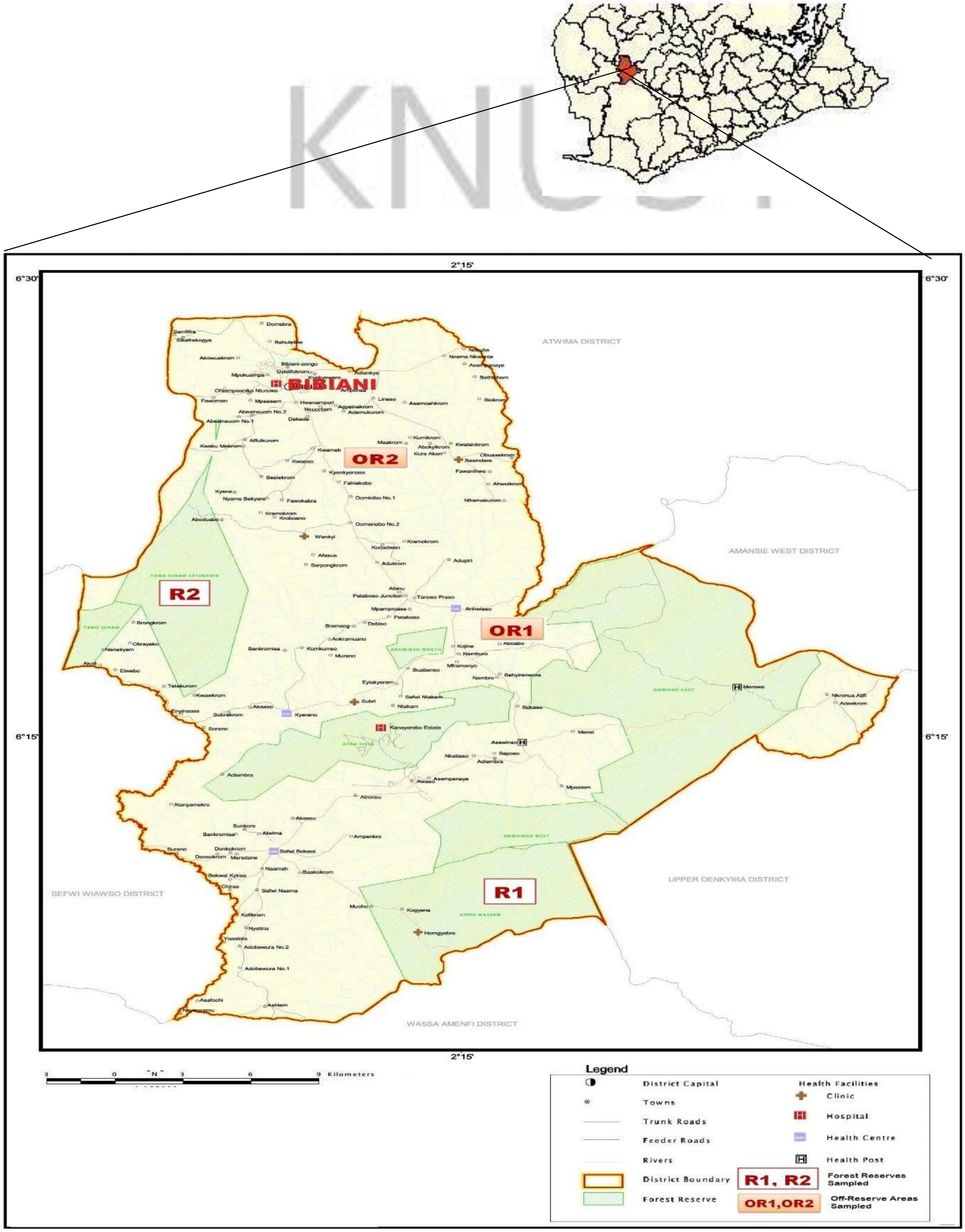
CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study area

This study was carried out in the Bibiani Anhwiaso Bekwai District in the Western Region of Ghana (Figure 1). The district lies within Latitudes 6°- 3° and Longitudes 2°- 3°. The district is bounded on the north and north-east by the Atwima Mponua District in the Ashanti region. It shares boundaries in the south by Wassa Amenfi District in the Western region, and on the west and south-west by Sefwi Wiawso District in the Western Region (Figure 1).

The District capital, Bibiani, is 88 km from Kumasi the capital of the Ashanti Region and 356 km from the Western Regional capital, Sekondi. The district has a total land area of 873 km, approximately 5.4% of the total area of the region. About 32.8% (286.17 square km) of this total land area is made up of forest reserves, 60% (523.8 square km) under tree and food crop cultivation with the rest lying fallow or built up (Ministry of Communications, 2011).



2°15'
6°30'
6°15'
BIBIANI
OR2
OR1
R2
R1
ATWIMA DISTRICT
AMANSIE WEST DISTRICT
UPPER DENKYIRA DISTRICT
SEFWI WIAWSO DISTRICT
WASSA AMENFI DISTRICT
3 0 3 6 9 Kilometers
Legend
District Capital
Towns
Trunk Roads
Feeder Roads
Rivers
District Boundary
Forest Reserve
Health Facilities
Clinic
Hospital
Health Centre
Health Post
R1, R2
Forest Reserves Sampled
OR1,OR2
Off-Reserve Areas Sampled

Figure 1: Study area in Bibiani Anhwiaso Bekwai District in the Western Region. Courtesy of Centre of Remote Sensing and Geographical Information Services (CERSGIS).

3.1.1 Climatic conditions of study area

The District is located in the equatorial climate zone with the annual rainfall average between 1200 mm and 1500 mm. The pattern is bimodal, falling between March – August and September – October. The dry season is noticeable between November – January and the peak periods are June and October. The average temperature throughout the year is about 26°C. There is a high relative humidity averaging between 75% in the afternoon and 95% in the night and early morning.

The implication here is that the climate of the area is suitable and can facilitate the growing of most traditional and non-traditional crops for export. Some of the traditional crops are cassava, yam and plantain. The non-traditional crops also include pineapple cashew (Ministry of Communications, 2011).

3.1.2 Vegetation and Forest Type

The vegetation is of the equatorial rain forest type, having a moist semi-deciduous forest producing various tree species such as odum, mahogany, wawa, etc. (Ministry of Communications, 2011).

3.1.3 Soils and soil type

The District is endowed with rich forest ochrosols and forest oxysols and this explains the extensive cultivation of food and cash crops. Whilst gold and bauxite are extracted from the Precambian rocks of the Birimian and Tarkwaian formations (Ministry of Communications, 2011).

3.1.4 Drainage

The District is drained by the River Ankobra and its tributaries. The terrain is uniformly low, averaging 350 m above sea level, with the highest point of 660 m at Atta Nyamekrom which is also the highest point in the entire Western Region of Ghana (Ministry of Communications, 2011).

3.2 Data Collection

3.2.1 Identification and classification of timber species sampled in On and Off- Reserves

All timber trees harvested by timber companies within the On and Off- Reserves were sampled for a period of 8 months (January to August, 2013). This direct sampling was done in order to get current information on the timber species harvested and compare it with that over the period 2002 to 2012. The timber trees were felled from 2 sites within the On-Reserve and 2 sites within the Off-Reserve. The trees were identified and classified according to their scientific taxa. The total number of species in each family exploited from both On-Reserve and Off-Reserve areas was determined. The conservation status and ecological guild of the trees were also determined according to Hawthorne and Abu-Juam (1995).

3.2.2 Measurement of diameter and determination of ages of timber species harvested

The diameter measurements were taken at breast-height (1.3 m) with a diameter tape. Measurements of diameter at breast-height were taken from the uphill side where there was a slope. Diameters of all trees that were felled in the yield (species due for harvest) were measured and recorded to the nearest centimetre. The length of the felled trees were also determined to enable the calculation of the volume. The total, annual and monthly average of volume and number of trees exploited was determined for the entire study area. Assistance in obtaining the measurements was provided by three Forest Services Division personnel.

The ages of tree species were determined using the diameter measurements of the trees and mean annual increments (MAI) obtained from Resources Management Support Centre (RMSC) of the Forestry Commission. The MAI have been generated from permanent sample plots (PSP's) that were established in the 1980's and which have been re-measured at least twice. Thus the age of a tree was calculated as follows: Diameter x MAI = Age of tree (yrs) (Philip, 1994).

3.2.3 Conservation star ratings of timber species harvested

Species conservation star ratings are marked with a coloured star according to Hawthorne and Abu Juam (1995) as follows:

- Black Star; species are globally rare and high priorities for careful management
- Gold Star; species are globally restricted
- Blue Star; species are of some rarity value in Ghana
- Scarlet Star; species are threatened, in Ghana at least, by over-exploitation
- Red Star; heavily exploited in Ghana
- Pink Star; of some commercial interest.

3.2.4 Collection of secondary data

Secondary data on the volume and the number of economic timber species extracted on the monthly basis between 2002 and 2012 for the On and Off-Reserve Forests were collected from the Forest Services Division District Official records, files, monthly and annual reports.

3.3 Data Analysis

The data was analysed with one- way analysis of variance (ANOVA) and this was used to test for significant differences in the number of stems and volume extracted between 2002 and 2012 in the study area. The analysis was carried out using Statistical Package for Social Sciences (SPSS) version 20. The results were presented in tables and graphs.

CHAPTER FOUR

4.0 RESULTS

4.1 Taxonomy of harvested timber species sampled in On and Off- Reserves

A total of 57 timber species which were harvested by timber companies from the on and off-reserve area (Bibiani Anhwiaso Bekwai District) were sampled for a period of eight months (January-August, 2013) (Table 1). The 57 timber species belonged to 22 families. Meliaceae was the most dominant family having 9 (15.8%) of the timber species, followed by Sterculiaceae 8 (14.0%) species, Caesalipiniaceae 7 (12.3%) species, Mimosaceae 5 (8.8%), Bombacaceae 3 (5.2%), Sapotaceae 3 (5.2%), Ulmaceae 3 (5.2%), whilst 4 of the families recorded 2 species each (14.0%) and 11 families recorded only 1 species each (19.3%) (Table 1).

Ecological guild of all the species recorded are Pioneer (Table 1). Most of the timber species 17 (29.8%) identified have conservation status of Pink. Red star were 16 (28.1%), Scarlet star 12 (21.1%), whilst only 2 species (3.5%) recorded a conservation status of Blue. Species of little conservation concern are marked as Green star 10 (17.5%).

Table 1: Taxonomy of harvested timber species sampled in On and Off-Reserves

No.	Scientific Name	Local Name	Trade/Common Name	Family	Conservation Status	Guild
1	*Afzeliaa fricana* **Pers.**	Papao	Afzelia	Caesalipiniaceae	Red Star	Pioneer
2	*Albizia ferruginea* (**Guill. & Perr.**) **Benth**	Awiemfosamina	Albizia	Mimosaceae	Scarlet Star	Pioneer
3	*Albizia zygia* **(DC.) J. F. Macbr**	Okoro	Okoro	Fabaceae	Pink Star	Pioneer
4	*Alstonia boonei* **De Wild**	Sinuro/ Nyamedua	Alstonia	Apocynaceae	Green Star	Pioneer
5	*Amphimas pterocarpoides* **Harms**	Yaya	Bokanga	Caesalipiniaceae	Red Star	Pioneer
6	*Aningeria robusta* (**A.Chev.) Aubrev. & Pellegr**	Asanfena	Anigre	Sapotaceae	Green Star	Pioneer
7	*Antairis Africana* **Engl.**	Kyenkyen	Antiaris	Moraceae	Red Star	Pioneer
8	*Antrocaryon micraster* **A. Chev. & Guillaumin**	Aprokuma	Onzabili	Anacardiaceae	Pink Star	Pioneer
9	*Blighia sapida* **K. D. Koenig**	Akyenfufuo	Ackee	Sapindaceae	Green Star	Pioneer
10	*Bombax brevicuspe* **Sprague**	Onyinakobin	Krondroti	Malvaceae	Green Star	Pioneer
11	*Bombax buonopozense* **P. Beauv.**	Akonkodie / Akata	Gold bombax Coast	Bombacaceae	Pink Star	Pioneer
12	*Canarium schweinfurthii* **Engl.**	Bediwonua	African elemi	Burseraceae	Red Star	Pioneer
13	*Cedrela odorata* **L.**	Cedrella	Spanish cedar	Meliaceae	Green Star	Pioneer

Table 1.Contd.

14	*Ceiba pentandra* **(L.) Gaertn**	Onyina	Java cotton	Bombacaceae	Red Star	Pioneer
15	*Celtis adolphi-friderici* **Engl.**	Esakosua	African celtis	Ulmaceae	Pink Star	Pioneer
16	*Celtis mildbreadii* **Engl.**	Esafufuo	White stinkwood	Ulmaceae	Pink Star	Pioneer
17	*Celtis zenkeri* **Engl.**	Esakoko	Ohia	Ulmaceae	Pink star	Pioneer
18	*Chrysophyllum albidum* **G. Don**	Akasaa	White star apple	Sapotaceae	Green Star	Pioneer
19	*Chrysophyllum perpulchrum* **Midbr. Ex Hutch. &Dalziel**	Atabene	English monkey	Sapotaceae	Pink Star	Pioneer
20	*Cola gigantean* **A. Chev**	Watapuo	Cola tree	Sterculiaceae	Green Star	Pioneer
21	*Cylicodiscus gabunensis* **Harms**	Denya	African greenheart	Mimosaceae	Pink Star	Pioneer
22	*Daniella ogea* **Rolfe**	Hyedua	Canarium	Caesalipiniaceae	Red Star	Pioneer
23	*Dialium aubrevillei* **Pellegr**	Dubankye	Giakaba	Caesalpiniaceae	Pink Star	Pioneer
24	*Distemonanthus benthamianus* **Baill**	Bonsamdua	Nigerian satinwood	Caesalpiniaceae	Red Star	Pioneer
25	*Entandrophragma angolense* (**Welw.) C.DC**	Edinam	GeduHohor	Meliaceae	Scarlet Star	Pioneer
26	*Entandrophragma candollei* **Harms**	Penkwa-akoa	Candollei	Meliaceae	Scarlet Star	Pioneer
27	*Entandrophragma cylindricum* (**Sprague) Sprague**	Penkwa	Sapele	Meliaceae	Scarlet Star	Pioneer
28	*Entandrophragma utile* **(Drawe&Sprague) Sprague**	Efobrodidwo	Utile	Meliceae	Scarlet Star	Pioneer

Table 1.Contd.

29	*Gilbertiodendron spp.*(**Limbali)**	Tetekon	African tekon	Caesalipiniaceae	Blue Star	Pioneer
30	*Guarea cedrata* **(A. Chev.) Pellegr**	Bohoro	Guarea	Meliaceae	Red Star	Pioneer
31	*Guarea thompsonii* **Sprague & Hutch**	Kwadwuma	Black guarea	Meliaceae	Red Star	Pioneer
32	*Guibortia ehie* (**A .Chev.) J. Leonard**	Hyeduanini/ Anokye-hyedua	Ovangkol	Caesalipiniaceae	Scarlet Star	Pioneer
33	*Hannoa klaineana* **Pierre &Engl**	Hotrohotro	Otwenoa	Simaroubaceae	Green Star	Pioneer
34	*Khaya ivorensis* **A. Chev.**	Dubini	African Mahogany	Meliaceae	Scarlet Star	Pioneer
35	*Klainedoxa gabonensis* **Pierre**	Kroma	Odudu	Irvinglaceae	Pink Star	Pioneer
36	*Lannea welwitschii* **(Hiern) Engl**.	Kumanini	Muumbu	Anacardiaceae	Green Star	Pioneer
37	*Lophira alata* **Banks ex C.F Gaertn**	Kaku	Red iron wood	Ochnaceae	Red Star	Pioneer
38	*Lovoa trichiloides* **Harms**	Dubinibiri	Lovoa	Meliaceae	Red Star	Pioneer
39	*Mammea africana* **Sabine**	Bompagya	African apricot	Guttiferae	Blue Star	Pioneer
40	*Mansonia latissimi* **(A. Chev.) A. Chev.**	Oprono	Mansonia	Sterculiaceae	Red Star	Pioneer
41	*Milicia excels* **(Welw.) C. C. Berg**	Odum	African teak	Moraceae	Scarlet Star	Pioneer
42	*Nauclea diderrichi* **(De Wild. & T. Durand)**	Kusia	Opera	Rubiaceae	Scarlet Star	Pioneer

Table 1.Contd.

43	*Nesogordonia papaverifera* **(A. Chev.) Capuron ex N. Halle**	Danta	Kotibe	Malvaceae	Pink Star	Pioneer
44	*Parinari excelsa* **Sabine**	Afam	African excelsa	Rosaceae	Green Star	Pioneer
45	*Parkia bicolor* **A. Chev.**	Asoma	Essang	Mimosaceae	Pink Star	Pioneer
46	*Petersianthus macrocarpus* (**P. Beauv.) Liben**	Esia	Krahn	Lecythidaceae	Pink Star	Pioneer
47	*Piptadeniastrum africanum* (**Hook.f) Brenan**	Dahoma	African greenheart	Mimosaceae	Red Star	Pioneer
48	*Pterygota macrocarpa* **K. Schum**	Kyere / koto	African pterygota	Sterculiaceae	Scarlet Star	Pioneer
49	*Pycanthus angolensis* (**Welw.).Warb**	Otie	African nutmeg	Myristicaceae	Red Star	Pioneer
50	*Sterculia oblonga* **Mast.**	Ohaa	Yellow sterculia	Sterculiaceae	Pink Star	Pioneer
51	*Sterculiar hinopetela* **K. Schum.**	Wawabima	White sterculia	Sterculiaceae	Pink Star	Pioneer
52	*Strombosia glaucescens* **Engl.**	Afena	Itako	Olacaceae	Pink Star	Pioneer
53	*Terminalia ivorensis* **A. Chev.**	Emire	Black afara	Combretaceae	Red Star	Pioneer
54	*Terminalia superba* **Engl. & Diels**	Ofram	Afara	Combretaceae	Red Star	Pioneer
55	*Tieghemella heckelii* **(A. Chev.) Pierre ex Dubard**	Baku	Cherry mahogany	Olacaceae	Scarlet Star	Pioneer
56	*Triplochiton scleroxylon* **K. Schum.**	Wawa	Obeche/ Wawa	Sterculiaceae	Scarlet Star	Pioneer
57	*Turraeanthus africanus* **(Welw. Ex C. DC.)**	Apapaye	Avodire	Maliaceae	Pink Star	Pioneer

Table 1.Contd.

4.2 Number of timber species harvested in On and Off-Reserve for a period of eight months

Timber species harvested in On and Off-reserve areas for a period of eight months are represented in Table 2. The total number of trees harvested from the On and Off- reserves during the eight months period were 660 and 220, respectively. Except for *Alstonia boonei*, all of the timber species were harvested in the On-reserve within the 8 months period. In the On-reserves *Celtis zenkeri* was the most exploited species harvested during the period with 84 trees followed by *Triplochiton scleroxylon* with 76 trees, *Piptadeniastrum africanum* with 42 trees, *Celtis mildbreadii* with 40 trees and *Ceiba pentandra* also with 40 trees. While 18 species were the least exploited with only 1 tree each felled during the eight months period. In the Off-reserves, 22 species out of 57 were harvested. Mostly, *Celtis zenkeri* was the exploited species harvested during the period with 52 trees followed by *Ceiba pentandra* with 47 species.

Table 2: Number of timber species harvested in On and Off- Reserve for a period of eight months

No.	Species	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Total	
	Reserve	O	OR	O	OR	O	O R	O	OR	O	OR	O	OR	O	O R	O	OR	O	OR
1	*Afzelia Africana*			1														1	0
2	*Albizia ferruginea*					1						2				1		4	0
3	*Albizia zygia*							1										1	0
4	*Alstonia boonei*		3															0	3
5	*Amphimas pterocarpoides*													1				1	0
6	*Aningeria robusta*	2		1		4		3			2			9		14		33	2
7	*Antiaris Africana*	5	2	11		3		8	4	3	4		5	7				37	15
8	*Antrocaryon micraster*					3												3	0
9	*Blighia sapida*			1														1	0
10	*Bombax brevicuspe*							2							3			2	3
11	*Bombax buonopozense*		1							3			1					3	2
12	*Canarium schweinfurthii*					1												1	0
13	*Ceiba pentandra*		11	2	9		9	3	10	10		4		11	6	10	2	40	47
14	*Celtis adolphi-friderici*			2						1								3	0
15	*Celtis mildbreadii*			2	8		3	16						15	1	7		40	12
16	*Celtis zenkeri*	14		12	19	14	18	10	4	20	3			14			8	84	52

17	*Chrysophyllum albidum*	**1**		**2**		**1**												**4**	**0**

Table 2.Contd.

18	*Chrysophyllum perpulchrum*													**1**				**1**	**0**
19	*Cidrella odorata*	**12**						**5**								**15**		**32**	**0**
20	*Cola gigantean*				**1**							**1**						**1**	**1**
21	*Cylicodiscus gabunensis*						**3**							**18**				**18**	**3**
22	*Daniella ogea*	**1**		**1**														**2**	**0**
23	*Dialium aubrevillei*	**1**																**1**	**0**
24	*Distemonanthus benthamianus*	**2**		**1**					**1**									**3**	**1**
25	*Entandrophragma angolense*	**6**		**5**		**1**		**2**		**2**		**6**		**3**		**1**		**26**	**0**
26	*Entandrophragma candollei*	**1**		**1**				**1**						**1**				**4**	**0**
27	*Entandrophragma cylindricum*	**3**		**1**		**4**		**1**				**1**						**10**	**0**
28	*Entandrophragma utile*	**4**		**4**		**1**												**9**	**0**
29	*Gilbertiodendron spp.*									**1**								**1**	**0**
30	*Guarea cedrata*	**2**		**1**		**2**		**3**				**2**		**4**				**14**	**0**
31	*Guarea thompsonii*			**1**						**1**								**2**	**0**
32	*Guibortia ehei*			**1**				**1**										**2**	**0**
33	*Hannoa klaineana*			**1**						**1**								**2**	**0**
34	*Khaya ivorensis*	**2**				**3**							**1**			**1**		**6**	**1**
35	*Klainedoxa gabonensis*									**1**								**1**	**0**
36	*Lannea welwitschii*			**1**														**1**	**0**

37	*Lophira alata*											**1**						**1**	**0**
38	*Lovoa trichiloides*							**1**										**1**	**0**

Table 2.Contd.

39	*Mammea africana*							**1**										**1**	**0**
40	*Mansonia altissima*		**3**											**2**				**2**	**3**
41	*Milicia excels/regia*	**1**				**2**										**4**		**7**	**0**
42	*Nauclea diderrichi*	**1**						**1**										**2**	**0**
43	*Nesogordonia papaverifera*	**1**		**5**		**1**		**1**			**3**	**11**	**3**	**5**		**3**		**27**	**6**
44	*Pariniari excelsa*	**1**																**1**	**0**
45	*Parkia bicolor*	**1**																**1**	**0**
46	*Petersianthus macrocarpus*		**3**	**4**		**5**		**2**	**6**	**4**				**3**				**18**	**9**
47	*Piptadeniastrum africanum*	**13**	**2**	**8**				**6**	**3**	**5**	**5**	**6**	**7**	**6**		**2**	**2**	**42**	**19**
48	*Pterygota macrocarpa*				**9**		**3**	**1**			**4**			**6**		**17**		**24**	**16**
49	*Pycnanthus angolensis*			**1**		**1**				**10**	**4**		**2**	**4**		**2**		**18**	**6**
50	*Sterculia oblonga*								**2**	**2**	**3**	**2**						**4**	**5**
51	*Sterculia rhinopetela*					**1**				**1**								**2**	**0**
52	*Strombosia glaucescens*	**3**								**2**						**1**		**6**	**0**
53	*Terminalia ivorensis*		**2**							**1**								**1**	**2**
54	*Terminalia superba*		**3**	**1**		**1**		**1**		**5**			**1**	**2**	**3**			**10**	**7**
55	*Tieghemella heckelii*					**1**						**1**						**2**	**0**

56	*Triplochiton scleroxylon*	**17**		**5**		**6**		**5**		**5**	**3**	**15**		**13**	**2**	**10**		**76**	**5**
57	*Turraeanthus africanus*	**4**		**3**				**2**				**14**		**2**				**25**	**0**
	Total	**98**	**30**	**80**	**46**	**56**	**36**	**77**	**30**	**68**	**31**	**66**	**20**	**127**	**15**	**88**	**12**	**660**	**220**

4.3 Monthly average volume of trees harvested for a period eight months

The monthly average volume of trees harvested for the period of eight months are represented in Table 3. The number of trees felled and the volume of trees recorded from the On-reserves were higher than those from the Off-reserves during the eight months period. The highest number for trees (126) felled in the On-reserves was recorded in July whilst the highest number (34) felled in the Off-reserves was in June. The highest recorded volume of trees in the On-reserves was in July (2046.020 m^3) whilst the highest recorded in the Off-reserves was in April (515.439 m^3).

Table 3: Monthly average volume of trees harvested for a period eight months

Month	Total no. of trees		Volume (m^3)		Total	
	On	Off	On	Off	No. of trees	Volume (m^3)
Jan	79	20	1239.208	316.570	99	1555.778
Feb	71	9	941.499	100.141	80	1041.640
Mar	52	20	730.485	332.146	72	1062.631
Apr	65	30	756.627	**515.439**	95	1272.066
May	60	18	826.147	198.507	78	1024.654
Jun	81	**34**	1190.975	295.435	115	1486.410
Jul	**126**	12	**2046.020**	233.904	138	2279.924
Aug	79	20	1569.405	269.451	99	1838.856
Total	**613**	**163**	**9,300.366**	**2,261.593**	**776**	**11,561.959**

4.4 Diameter and age determination of timber species harvested in On and Off-Reserves

The ages of timber species harvested in the On and Off- Reserve during a period of eight months are represented in Table 4. The ages of tree species were calculated with information derived from the diameter and mean annual increments (MAI) of the trees. Diameter range of each of the timber species was determined in order to determine the age range of the species harvested. The diameter of all the timber species harvested ranged from 24 to 141 cm. The highest MAI of 1.483 was recorded by *Cylicodiscus gabunensis*. The ages of all the timber species harvested ranged from 4.368 to 190.068 years. *Strombosia glaucescens* was the youngest harvested timber with age range of 4.368 - 6.734 whereas *Bombax buonopozense* was the oldest harvested timber with age range of 128.060 - 190.068. This indicates that the greater the MAI, the older the tree or the ages of the trees increase with increased MAI.

Table 4: Diameter and age determination of timber species harvested in On and Off- Reserves

No.	Scientific Name	Local Name	Diameter Range (cm)	Mean Diameter (cm)	MAI	Age Range (yrs)
1	*Albizia ferruginea*	Awiemfosamina	92 - 102	97	0.088	8.096 - 8.976
2	*Albizia zygia*	Okoro	70 - 82	76	0.975	68.250 - 79.950
3	*Alstonia boonei*	Sinuro/ Nyamedua	74 - 90	82	0.177	13.098 - 15.930
4	*Amphimas pterocarpoides*	Yaya	70 - 72	71	0.111	7.770 - 7.992
5	*Aningeria robusta*	Asanfena	69 - 71	70	0.486	33.534 - 34.506
6	*Antairis africana*	Kyenkyen	90 - 110	100	1.289	116.010 - 141.790
7	*Antrocaryon micraster*	Aprokuma	70 - 76	73	0.273	19.110 - 20.748
8	*Blighia sapida*	Akyenfufuo	70 - 94	82	0.177	12.390 - 16.638
9	*Bombax brevicuspe*	Onyinakobin	70 - 98	84	0.185	12.950 - 18.130
10	*Bombax buonopozense*	Akonkodie/ Akata	95 - 141	118	1.348	128.060 - 190.068
11	*Canarium schweinfurthii*	Bediwonua	81 - 99	90	0.894	72.414 - 88.506
12	*Ceiba pentandra*	Onyina	98 - 132	115	1.341	131.418 - 177.012
13	*Celtis mildbreadii*	Esafufuo	67 - 104	85	0.189	12.663 - 19.656
14	*Celtis zenkeri*	Esakoko	80 - 106	93	0.226	18.080 - 23.956

Table 4.Contd.

15	*Cola gigantean*	Watapuo	59 - 72	70	0.179	10.561 - 12.888
16	*Colitis adolphi-friderici*	Esakosua	61 - 99	80	0.275	16.775 - 27.225
17	*Cylicodiscus gabunensis*	Denya	93 - 128	110	1.483	137.919 - 189.824
18	*Daniella ogea*	Hyedua	55 - 105	80	0.657	36.135 - 68.985
19	*Dialium aubrevillei*	Dubankye	58 - 73	65	0.482	27.956 - 35.186
20	*Distemonanthus benthamianus*	Bonsamdua	61 - 95	78	0.114	6.954 - 10.830
21	*Entandrophragma angolense*	Edinam	90 - 102	96	0.350	31.500 - 35.700
22	*Entandrophragma cylindricum*	Penkwa	105 - 135	120	0.183	19.215 - 24.705
23	*Gilbertiodendron spp.*	Tetekon	60 - 76	68	0.247	14.820 - 18.772
24	*Guarea cedrata*	Kwabohoro	70 - 76	73	0.273	19.110 - 20.748
25	*Guibortia ehei*	Hyeduanini/ Anokye- hyedua	62 - 80	71	0.111	6.882 - 8.880
26	*Hannoa klaineana*	Hotrohotro	72 - 99	85	0.189	13.608 - 18.711
27	*Khaya ivorensis*	Dubini	61 - 79	70	0.486	29.646 - 38.394
28	*Klainedoxa gabonensis*	Kroma	70 - 92	81	0.345	24.150 - 31.740
29	*Lannea welwitschii*	Kumanini	70 - 84	77	0.981	68.670 - 82.404
30	*Lophira alata*	Kaku	71 - 89	80	0.126	8.946 - 11.214
31	*Milicia excelsa*	Odum	80 - 92	86	0.706	56.480 - 64.952

Table 4.Contd.

32	*Nauclea diderrichi*	Kusia	70 - 86	78	0.694	48.580 - 59.684
33	*Nesogordonia papaverifera*	Danta	68 - 83	75	0.300	20.400 - 24.900
34	*Parkia bicolor*	Asoma	50 - 68	59	0.623	31.150 - 42.364
35	*Petersianthus macrocarpus*	Esia	84 - 117	100	0.444	37.296 - 51.948
36	*Piptadeniastrum africanum*	Dahoma	98 - 143	120	0.701	68.698 - 100.243
37	*Pterygota macrocarpa*	Kyere / koto	85 - 106	95	0.615	52.275 - 65.190
38	*Pycanthus angolensis*	Otie	70 - 88	79	0.293	20.510 - 25.784
39	*Sterculia oblonga*	Ohaa	64 - 77	70	0.171	10.944 - 13.167
40	*Strombosia glaucescens*	Afena	24 - 37	30	0.182	4.368 - 6.734
41	*Terminalia ivorensis*	Emire	71 - 106	88	0.326	23.146 - 34.556
42	*Terminalia superba*	Ofram	73 - 101	87	0.909	66.357 - 91.809
43	*Tieghemella heckelii*	Baku	90 - 104	97	0.719	64.710 - 74.776
44	*Triplochiton scleroxylon*	Wawa	90 - 106	98	1.124	101.160 - 119.144
45	*Turraeanthus africanus*	Apapaye	60 - 81	70	0.374	22.440 - 30.294

4.5 Number of timber species and trees felled over a period of eleven years (20022012)

The number of timber species and trees felled over a period of eleven years (2002-2012) in the On and Off -Reserves of Bibiani Anhwiaso Bekwai District are represented in Table 5. A total of 2,501 species constituting a total of 18,885 trees were harvested within the eleven years period. The annual total number of trees and species recorded from On-reserves are higher than those of the Off-reserves. This is a clear indication that, there are more trees in the forest reserves than that of the off-reserves. This is also due to the annual bad farming activities that goes on in the off- reserve areas leading to rampant felling of trees.

Table 5: Number of timber species and trees felled over a period of eleven years (2002-2012)

Year	No.of Species		No. of Trees		Total		No. of Family
	On-Reserve	Off-Reserve	On-Reserve	Off-Reserve	No. of species	No. of trees	
2002	171	96	1,359	405	267	1,764	13
2003	98	75	**297**	**309**	173	606	13
2004	118	71	1,042	308	189	1,350	14
2005	131	72	1,124	487	203	1,611	12
2006	138	62	903	358	200	1,261	14
2007	137	88	1,033	431	225	1,464	15
2008	187	78	2,533	331	265	2,864	13
2009	186	75	2,472	263	261	2,735	12
2010	198	72	2,080	309	270	2,389	16
2011	182	83	1,208	346	265	1,554	15
2012	114	69	984	303	183	1,287	15
Total						**18,885**	**152**

4.6 Monthly number of trees felled over a period of eleven years (2002-2012)

The monthly number of trees felled during the period 2002 – 2012 in both the forest reserves and off-reserve areas are represented in Table 6. Total number of trees felled appear to fluctuate within each year both in forest reserves and off- reserve areas within the 2002-2012 decade. This fluctuation of figures is mainly due to periods of operation; for example, timber operations are easier in the dry season than during the raining season. More especially where the area in question falls within the Equatorial climate with a bimodal annual rainfall averaging between 1200 mm and 1300 mm.

However, the fluctuation can also be due to either periods of expiry of Permits or renewal of Property Marks. Property Marks are renewed twice in a year and Permits are also extended when expired. And so, the number of timber Contractors operating during such periods are limited. The zero number recorded in the forest reserve in November, 2003, indicates that there was no operation at all during the period; and this could be due to either expiry of permit or machinery problems.

Generally, there are more felling of trees in the On reserve than what is recorded in the Offreserve areas. The highest number of trees felled (536) was recorded in 2008, in the On reserve, whilst the lowest number (7) was observed in the years 2002 and 2005, all in the Offreserve areas.

Table 6: Monthly number of trees felled over a period of eleven years (2002 – 2012)

Year	**2002**		**2003**		**2004**		**2005**		**2006**		**2007**		**2008**		**2009**		**2010**		**2011**		**2012**	
Month	**R**	**OR**	**R**	**OR**	**R**	**OR**	**R**	**OR**	**R**	**OR**	**R**	**OR**	**R**	**OR**	**R**	**OR**	**R**	**OR**	**R**	**OR**	**R**	**OR**
Jan	132^{e}	10^{ab}	46^{f}	$31f^{g}$	21^{b}	13^{a}	9_{a}	42_{d}	104_{g}	26_{c}	49_{c}	20_{b}	134_{e}	24^{de}	56_{a}	15_{b}	168_{d}	21_{c}	57_{c}	14_{a}	18_{a}	21_{de}
Feb	107^{d}	82^{g}	30^{de}	$31f^{g}$	12^{a}	26^{cd}	71_{e}	31_{c}	184_{i}	36_{f}	37_{b}	46_{f}	194_{f}	60_{h}	164_{c}	11_{a}	201_{h}	40_{f}	174_{i}	15_{a}	55_{d}	16_{b}
Mar	214^{h}	40^{d}	31^{e}	10^{a}	38^{d}	31^{de}	24_{c}	16_{b}	79_{f}	18_{a}	72_{e}	32_{d}	121_{c}	51_{g}	312_{j}	14_{b}	279_{k}	29_{e}	142_{h}	51_{e}	120_{g}	9_{a}
Apr	275^{i}	7^{a}	11^{b}	24^{d}	27^{c}	31^{de}	175_{i}	8_{a}	33_{b}	43_{g}	19_{a}	80_{h}	286_{h}	36_{f}	148_{b}	19_{c}	32_{a}	25_{d}	59_{c}	28_{c}	84_{e}	8_{a}
May	13^{a}	28^{c}	29^{de}	15^{b}	30^{c}	21^{bc}	13_{b}	72_{f}	70_{e}	22_{b}	23_{a}	21_{b}	232_{g}	25	145_{b}	20_{cd}	179_{e}	10_{a}	133_{g}	22_{b}	211_{i}	24_{e}
Jun	199^{g}	7^{a}	12^{b}	57^{h}	69^{e}	32^{e}	139_{g}	16_{b}	68_{e}	30_{d}	80_{f}	15_{a}	536_{j}	18_{bc}	175_{d}	39_{g}	69_{b}	19_{bc}	85_{e}	24_{b}	42_{c}	21_{de}
Jul	15^{a}	30^{c}	51^{g}	23^{cd}	12^{a}	24^{bc}	25_{c}	7_{a}	71_{e}	47_{h}	208_{i}	27_{c}	81_{a}	33_{f}	223_{f}	21_{cd}	201_{h}	39_{f}	210_{j}	47_{d}	35_{b}	37_{f}
Aug	63^{b}	30^{c}	27^{d}	21^{c}	41^{d}	13^{a}	43_{d}	63_{e}	70_{e}	33_{e}	105_{g}	71_{g}	344_{i}	21^{cd}	162_{c}	23_{de}	268_{j}	31_{e}	84_{e}	61_{f}	161_{h}	39_{f}
Sep	12^{a}	57^{e}	11^{b}	29^{ef}	14^{a}	20^{b}	104_{f}	15_{b}	129_{h}	22_{b}	66_{d}	15_{a}	234_{g}	15_{b}	285_{g}	23_{de}	184_{f}	18_{bc}	104_{f}	16_{a}	18_{a}	37_{f}
Oct	72^{c}	13^{b}	19c	8^{a}	490^{g}	45^{f}	264_{j}	38_{d}	9_{a}	37_{f}	221_{j}	37_{e}	132_{e}	8_{a}	308_{i}	22_{cd}	197_{g}	29_{e}	39_{a}	23_{b}	99_{f}	54_{g}
Nov	154^{f}	64^{f}	0^{a}	34^{g}	268^{f}	21^{bc}	154_{h}	110_{g}	38_{c}	19_{a}	33_{b}	44_{f}	128_{d}	20_{cd}	295_{h}	26_{e}	210_{i}	31_{e}	47_{b}	14_{a}	44_{c}	17_{bc}
Dec	103^{d}	37^{d}	30^{de}	26^{de}	20_{b}	31^{de}	103_{f}	69_{f}	48_{d}	25_{c}	120_{h}	23_{b}	111_{b}	20_{cd}	199_{e}	30_{f}	92_{c}	17_{b}	74_{d}	31_{c}	97_{f}	20_{cd}

Means (in same column) with different letters in superscripts differ significantly ($p < 0.05$)

4.7 Monthly and annual number of Species from 2002 to 2012)

The annual distribution of tree species in both the forest reserves and off-reserve areas is represented in Table 7. The total number of tree species also appear to fluctuate within each year both in forest reserves and off- reserve areas within the 2002-2012 decade. The highest annual total number of species (198) was recorded in 2010 in the On reserve. Whilst the lowest annual total number of species (62) was observed in 2006 in the Off-reserve area.

Table 7: Monthly and annual number of timber species from 2002 to 2012

Year	2002		2003		2004		2005		2006		2007		2008		2009		2010		2011		2012	
Month	**R**	**OR**	**R**	**OR**	**R**	**OR**	**R**	**OR**	**R**	**OR**	**R**	**OR**	**R**	**OR**	**R**	**OR**	**R**	**OR**	**R**	**OR**	**R**	**OR**
Jan	24d	3a	9cd	4ab	10cd	3a	6ab	4bcd	13ef	3a	9cd	6a	20g	9cd	14bc	6abc	20d	7de	14d	6a	7b	4ab
Feb	21d	14e	11d	4ab	7bc	9d	12e	3abc	9cd	4ab	6ab	7ab	17def	7abc	14bc	6abc	13b	7de	25g	6a	15d	2a
Mar	21d	10bcd	11d	4ab	13e	10d	6ab	2ab	11de	3a	11de	7ab	18efg	5ab	19ef	5ab	20d	8ef	11bc	11b	17d	2a
Apr	23d	7b	8c	8c	9c	4ab	20g	1a	4a	6bc	5a	9bc	19fg	8bc	15bcd	4a	8a	5bcd	9ab	5a	17d	4ab
May	4a	3a	7bc	6bc	9c	6bc	4a	10h	7bc	4ab	6ab	7ab	24h	5ab	10a	4a	13b	2a	21f	5a	24e	8de
June	21d	7b	5b	2a	12de	3a	10de	7efg	11de	7c	8bc	6a	16cde	7abc	14bc	8cd	7a	3ab	7a	5a	11c	6bcd
July	7ab	11cde	20e	9cd	4a	8cd	7bc	5cde	7bc	6bc	22h	7ab	7a	5ab	14bc	6abc	13b	5bcd	28h	13b	3a	7cde
Aug	9b	10bcd	9cd	9cd	8c	3a	10de	9gh	16g	6bc	19g	11c	11b	11d	13b	7bcd	22de	10f	12cd	11b	11c	9e
Sep	5a	12de	8c	7bc	5ab	8cd	15f	7efg	29h	6bc	13e	6a	9ab	6abc	16cd	5ab	16c	4abc	12cd	6a	6b	5bc
Oct	17c	3a	2a	4ab	12de	6bc	22g	10h	5ab	6bc	16f	6a	14c	4a	19ef	7bcd	26f	8ef	13cd	5a	12c	9e
Nov	10b	8bc	0a	11d	22f	5ab	10de	8fgh	14fg	3a	6ab	9bc	17def	7abc	17de	9d	23e	6cde	13cd	5a	10c	6bcd
Dec	9b	8bc	8c	7bc	7bc	6bc	9cd	6def	12ef	8c	16f	5a	15cd	4a	21f	8cd	17c	7de	17e	5a	10c	7cde
Total	**171**	**96**	**98**	**75**	**118**	**71**	**131**	**72**	**138**	**62**	**137**	**88**	**187**	**78**	**186**	**75**	**198**	**72**	**182**	**83**	**144**	**69**

Means (in same column) with different letters in superscripts differ significantly ($p < 0.05$)

4.8 Monthly and annual average volume of trees felled over the period 2002-2012

The annual distribution of tree volumes in both the On reserves and Off-reserve areas are represented in Table 8. Both the monthly and annual volumes of trees appear to fluctuate within each year in the On reserves and off- reserve areas within the 2002 to 2012 period.

Generally, the volumes from the On reserves are much higher than those from the Off-reserve areas. But there are some situations where the reverse is the case. This runs through almost all the years. The highest volume (3839m^3) was recorded in 2009 in the On reserve. Whilst the lowest volume (66.6m^3) was observed in 2003 in the Off-reserve areas.

Table 8: Monthly and annual average volume of trees felled over the period 2002 – 2012

Year	2002		2003		2004		2005		2006		2007		2008		2009		2010		2011		2012	
Month	**R**	**OR**	**R**	**OR**	**R**	**OR**	**R**	**OR**	**R**	**OR**	**R**	**OR**	**R**	**OR**	**R**	**OR**	**R**	**OR**	**R**	**OR**	**R**	**OR**
Jan	2308.0	166.0	447	527	345.9	535	102.0	544	1476	451.6	446.5	256	1453.0	421.00	774.3	164	1970.0	210	696	120	226	213
Feb	2068.0	1419.0	570	527	145.3	260	628.0	370	686	666.8	487.4	512	2279.0	1074.00	1713.0	148	1918.0	596	2120	180	503	338
Mar	3459.0	691.0	377	228	264.1	306	217.0	189	550	308.3	645.2	454	1499.0	741.60	3839.0	159	2959.0	398	1551	724	1278	190
Apr	3604.0	98.6	162	418	423.7	526	820.0	182	331	813.0	242.9	872	3397.0	500.90	1713.0	293	316.2	401	595	407	989	68.4
May	122.0	290.0	427	191	184.8	338	122.0	266	736	520.5	194.3	182	2815.0	300.30	1692.0	282	2066.0	196	1595	279	2584	372
Jun	3584.0	97.3	175	965	1090.0	311	900.0	217	819	396.1	1033.0	130	2548.0	255.40	1837.0	543	610.7	197	617	349	575	440
Jul	83.4	531.0	797	259	140.3	417	83.4	92.7	662	957.9	1221.0	393	1017.0	438.90	2344.0	358	2156.0	638	2227	814	339	518
Aug	456.0	596.0	424	530	494.4	147	377.0	456	649	469.2	1202.0	1521	1177.0	337.80	2005.0	253	3196.0	305	1003	920	1323	723
Sep	176.0	861.0	163	430	205.5	215	1065.0	169	1643	463.2	578.1	179	609.1	162.30	3435.0	298	1940.0	193	1120	260	214	480
Oct	607.0	2844.0	255	66.6	1394.0	568	1692.0	367	117	713.2	710.1	650	1510.0	68.44	3649.0	267	2010.0	296	429	296	1109	1108
Nov	1156.0	1084.0	0	378	1756.0	299	1156.0	2027	376	193.5	406.4	609	1597.0	190.70	3555.0	354	2266.0	369	611	127	513	249
Dec	593.0	612.0	594	256	361.7	689	593.0	1216	444	351.2	1391.0	285	1482.0	408.80	2136.0	267	896.9	148	1029	437	1593	317
Total	**18216.4**	**9290.9**	**4392**	**4776**	**6806.7**	**4611**	**7755.4**	**6096**	**8489**	**6304.5**	**8557.9**	**6043**	**21383.1**	**4900.1**	**28692.3**	**3386**	**22305.8**	**3947**	**13593**	**4913**	**11246**	**5016**

4.9 New National Forest Plantation Development Program (NNFPDP)

The New National Forest Plantation Development Program which took place within the communities in the District as well as the achievements attained vis-a-vis the required target from 2010 – 2013 are represented in Table 9. The plantation development program targeted the planting of cedrela, mahogany, ofram, onyina, and teak with plantation in 25 different communities (Table 9). Total achievements therefore, do not exactly reach the expected target within each year. The targets were not achieved because the program was a new one that was introduced by the Government which the workers deserted half-way due to unfulfilled promises. The program was a very laudable one put in place by the Government of the day in order to see if the rate of extraction could be breached with the plantation program. The total target for the period 2010 – 2013 was 2164.80 hectares whilst the total achievement was 1163.77 hectares.

Table 9: New National Forest Plantation Development Program (NNFPDP) from 2010 to 2013

Community	2010 (Target = 705 Ha)	2011 (Target=685 Ha)	2012 (Target =679.80 Ha)	2013 (Target = 105 Ha)
Manse	28	25	18.5	-
Merewa	53	23	21.8	-
Nkronuah	19	11	14	-
Benkromisa	-	16	7.7	-
Mpesiem	48	32	14	-
Fawokabra	-	12	27.2	-
Amobaka	21	22	19.4	-
Dominibo	-	31	21.6	-
Bayerebon No. 2	17	-	18	-
Kunkumso	-	32	10.1	-
Bethlehem	42	-	-	-
Wenchi	-	18	32	-
Subri-Nkwata	33	-	21.7	22
Kroboano	-	18	21.54	-

Table 9.Contd.

Awaso	20	-	9.25	-
Chine	-	22	6.1	-
Djaponkrom	18	-	12.32	-
Humijibre	-	-	-	-
Kojina	17	26	-	-
Muano	-	16	23.71	-
Modaso	14	-	19.5	-
Ankwaso	27	11	32.1	38
Asempanaye	-	7	-	-
Ananso	31	-	13.5	30
Total Achievement	**388**	**322**	**363.77**	**90**

4.10 Yearly mean number of trees, species and volumes of trees felled over the period 2002- 2012

The yearly mean number of trees, species and volumes of trees felled over a period of eleven years (2002- 2012) are presented in Table 10. The results from the analysis showed that there is a significant difference between the number of stems and volume exploited from the reserve and off- reserve. The results further revealed that there is no significant difference between the number of stems and volumes exploited within the eleven- years under investigation.

It is revealed from the analysis that the number of trees harvested in 2002 and 2003 from the forest reserve and off reserve areas were found to be insignificant with p-value > 0.05 while 2004 to 2012 number of trees harvested from the reserve and off reserve areas were found to be significantly different from the other with p-value < 0.005. The analyses further indicate that the number of trees harvested from the reserve from 2004 to2012 was on average higher than those of the off reserve areas. On the other hand the volumes were mostly found to be insignificant (p>0.05) but the volumes from 2009 to 2012 were found to be significant.

Table 10: Yearly mean number of trees, species and volumes of trees felled over the period 2002-2012

Years	No. of trees		No. of species		Volume	
	Reserve	Off Reserve	Reserve	Off Reserve	Reserve	Off Reserve
2002	14.25 ± 7.26cde	8.0 ± 3.48 c	113.25 ± 80.17 f	33.75 ± 24.45 bcd	1518.1 ± 1416.3 bcd	774.2 ± 762.7 c
2003	8.17 ± 4.78 a	6.25 ± 2.59 abc	24.75 ± 17.00 a	25.75 ± 12.32 ab	365.96 ± 225.3 a	774.2 ± 225.05 c
2004	9.83 ± 4.52 ab	5.92 ± 2.33 ab	139.13 ± 86.33 g	25.67 ± 8.65 ab	646.33 ± 501.9 ab	384.1 ± 162.8 ab
2005	10.65±5.33ab	6.0 ± 2.92 ab	93.67 ± 75.28 de	40.58 ± 30.64 d	567.2 ± 540.8 ab	508 ± 221.9 b
2006	10.88±6.33ab	5.12 ± 1.62 a	75.25 ± 44.71 b	29.83 ± 9.06 bc	707.4 ± 445.1 ab	525.4 ± 236.2 b
2007	11.42 ± 5.42 abc	7.33 ± 1.59 bc	86.08 ± 67.74 cd	35.92 ± 20.32 cd	713.13 ± 403.1 ab	503 ± 274.2 b
2008	15.58 ± 4.59 e	6.5 ± 2.02 abc	211.08 ± 125.36 i	27.58 ± 14.46 abc	1781.8 ± 810.23 cd	408.3 ± 274.2 ab
2009	15.5 ± 2.92 e	6.25 ± 1.53 abc	206 ± 76.56 i	21.92 ± 7.18 a	2391 ± 985.0 d	282.1 ± 107.7 a
2010	16.5 ± 5.68 e	6.0 ± 2.2 ab	173.33 ± 71.42 h	25.75 ± 8.69 ab	1858.8 ± 863.6 d	328.9 ± 159.7 a
2011	15.12 ± 6.13 de	6.92 ± 2.8 abc	100.67 ± 51.36 e	28.83 ± 15.17 abc	11327 ± 610.8 e	409.6 ± 269.1 ab
2012	12 ± 5.4 bcd	5.75 ± 2.31 ab	82.0 ± 57.02 bc	25.25± 13.14 ab	937.4 ± 695.8 abc	417.9 ± 277.5 ab

Means ± SD (in same column) with different letters in superscripts differ significantly ($p < 0.05$)

CHAPTER FIVE

5.0 DISCUSSION

Timber production in the tropical rainforest ecosystem, if not well planned is very deleterious to the environment and biological diversity conservation (Fuwape, 2001). The increasing rate of timber harvesting from the off reserve areas and reserves as revealed in this study is inimical to the realization of the objectives of sustainable forest management in Ghana. Generally, the main problems of forest management in Ghana include high rate of indiscriminate logging, over allocation of reserves to contractors, reckless felling of trees in the off-reserve areas and the allocated plots, and weak control of felling in the off-reserve areas. High demand for timber products has resulted in the over-harvesting and complete devastation of the standing stock of indigenous hardwood species in Tropical Forest (Okpo, 1996).

It should be noted that the results of this study were based on legally felled trees from available official records, annual reports and files in the Forest Services Division (FSD) of the Forestry Commission. Data on the quantity and quality of timber illegally extracted from the forests are not available. Illegal logging is very prevalent in many developing countries to the extent that what is taken out of the forest estate illegally could even be more than what is legally removed. Illegal logging in Ghana is due to corruption, youth unemployment, inefficient control of logging activities by the government agents and weak enforcement of laws. In the study area, for instance, there is a Joint Task Force on forestry (with some armed police officers cum military men), which provide security back up to the Forest Services Division (FSD) to put in check the activities of some armed gangsters who are illegal loggers in the state (Adetula, 2008). Illegal activities are serious setback to Sustainable Forest Management (SFM) in Ghana.

The limited control of the government on logging activities in the forest reserves is the reason behind the huge number of stems harvested during the eleven-year period that is significantly more than what was removed from the off reserve areas. The findings of this study corroborate the results of Akindele and Fuwape (1998), who reported that the lower proportion of timber harvested from the forest reserves could be attributed to the control on logging timber resources within the forest reserves. The enforcement of the logging policy that prohibits the cutting of undersized trees (dbh> 50cm) also contributed to the fewer number of stems extracted from the reserves.

There is pertinent control on activities in the country's forest reserves. Forest reserves are divided into compartments and loggings are carried out in each compartment according to the laid rules by the allottees. Falaye *et al*. (2006) asserted that only few forest Timber Utilization Contract (TUC) holders had allocations in forest reserves due to the exorbitant cost and inevitable bureaucracies. Timber contractors who could not afford the cost of securing allocation in the reserve usually search for wood in the off reserve areas.

Variation in the number of stems exploited for each of the species and families gave an indication that timber contractors prefer the economic, durable and high quality timber to the less durable ones. This is in conformity with the report of Akindele and Fuwape (1998) that timber merchants are very selective in terms of tree species they search for and fell. This was manifested in their preference for species like *Triplochiton scleroxylon* (obeche), *T. superba* (Afara/Ofram), *Afzelia africana* (Afzelia), *Mansonia altissima* (Mansonia), *Meliciaexcelsa* (Iroko) and the mahoganies (Khaya species). These species are critically sought for by loggers to the extent that 'under-girths are felled anywhere they are found contrary to the

Ghana logging policy. Today, these important hardwood timber species are not only rare, but they are seriously threatened with extinction. This was responsible for why their felling has been restricted to those with special permits. Their relative abundance was reported to be less than 5/ha in tropical rainforest ecosystem of South-Western Nigeria (Oyagade 1997; Onyekwelu *et al*., 2005; Adekunle, 2006).

The wide discrepancy in the number of trees and volumes exploited from month to month accentuate the impacts of climatic conditions on logging activities in the tropic. It was observed that timber harvesting was more intense during the dry season and in the months when rainfall was less frequent. Timber harvesting drastically reduced as rainfall became more intense. Ghana has bad and poor road network. They are not usually motorable, especially to timber trucks, throughout the year. The tropical ecological zone of NorthEastern part of the Western Region of Ghana where this study was carried out is characterized by a bimodal annual heavy rainfall averaging between 1200mm and 1300mm. During this season, erosion, flood and seasonal streams destroy roads, making access to the forest to be very difficult. These are great impediments to timber harvesting, skidding, and transportation. Therefore, loggers take the advantage of the dry season to exploit more trees.

The current level of demand for wood is more than the sustainable level of supply. What is removed has been reported to be far beyond the natural capacity of the forest to recuperate in order to continue its normal functions (Olajide *et al*., 2008). The negative economic, ecological and environmental impacts of logging are very grave. Continuous harvesting without adequate regeneration strategies will lead to structurally and genetically degraded forest, which are extremely difficult and expensive to rehabilitate. This calls for revisiting and implementing the basic principles of sustainable forest management (SFM) which is the only way forward to save Ghanaian forest from total collapse.

For forest managers, sustainably managing a particular forest tract means determining, in a tangible way, how to use it today to ensure similar benefits, health and productivity in the future. SFM is a system of management that guarantees continuous harvesting of forest resources (FAO, 2001). It is governed by operational rules and regulations, allows the inexhaustible or everlasting existence of forest resources for future benefits and advantages and seeks the promotion of long life survival of the forest (Pampka, 2005). SFM has potential to eradicate poverty, reduce land degradation, increase food security, and access to safe drinking water and provide affordable energy and other benefits. Managers, policy makers and all stakeholders in the forestry sub-sector need to collaborate and manage Ghanaian forest resources judiciously to be able to avert the imminent problems of deforestation.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This study examined the rate of timber harvesting in a tropical rainforest ecosystem of western Ghana using Bibiani-Anhwiaso-Bekwai District, as a case study. The results indicated that virtually all indigenous tree species are now exploited as timbers from the reserves and off reserve areas. There is sharp reduction in the availability of the most economic tropical hardwood species, so the lesser utilized ones are now in the timber market competing with the economic ones. Number of stems and species exploited from the forest reserves for the eleven-year period was discovered to be more than what was exploited from the off-reserves in the study area.

The volume of trees exploited in the reserves was also more than what came out of the offreserve areas for the eleven-year period. This points to the fact that the stringent conditions attached to logging in the reserves where all activities within are controlled by the Forest Service Division (FSD) were probably abused. Loggers only pay necessary fees as stipulated in forest stumpage on trees to be felled in the reserve and off-reserve areas but this is lower than the cost of planting and nurturing another tree for replacement. This is very inimical to sustainable forest management. The area of Tropical Rainforest in the Bibiani-AnhwiasoBekwai District is therefore on the verge of total disappearance. The implications of this on rural livelihood, wood based industries; biodiversity conservation and environmental sustainability are very serious. Thus, a sustainable forest management practice should be put in place to reduce rate of timber production if it cannot totally curb, this menace.

6.2 Recommendations

The following recommendations could affect the actualization of the principles of Sustainable Forest Management in Ghana:

- Proper forest governance
- Eradication of chronic corruption and bribery
- Campaign against all illegal activities in the forest estates
- Provision of adequate fund to FSD for effective monitoring and patrol
- Encouraging community based forest management system
- Review of the present obsolete forest laws,
- Aggressive plantation development by the public and government.

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APPENDICES

APPENDIX A

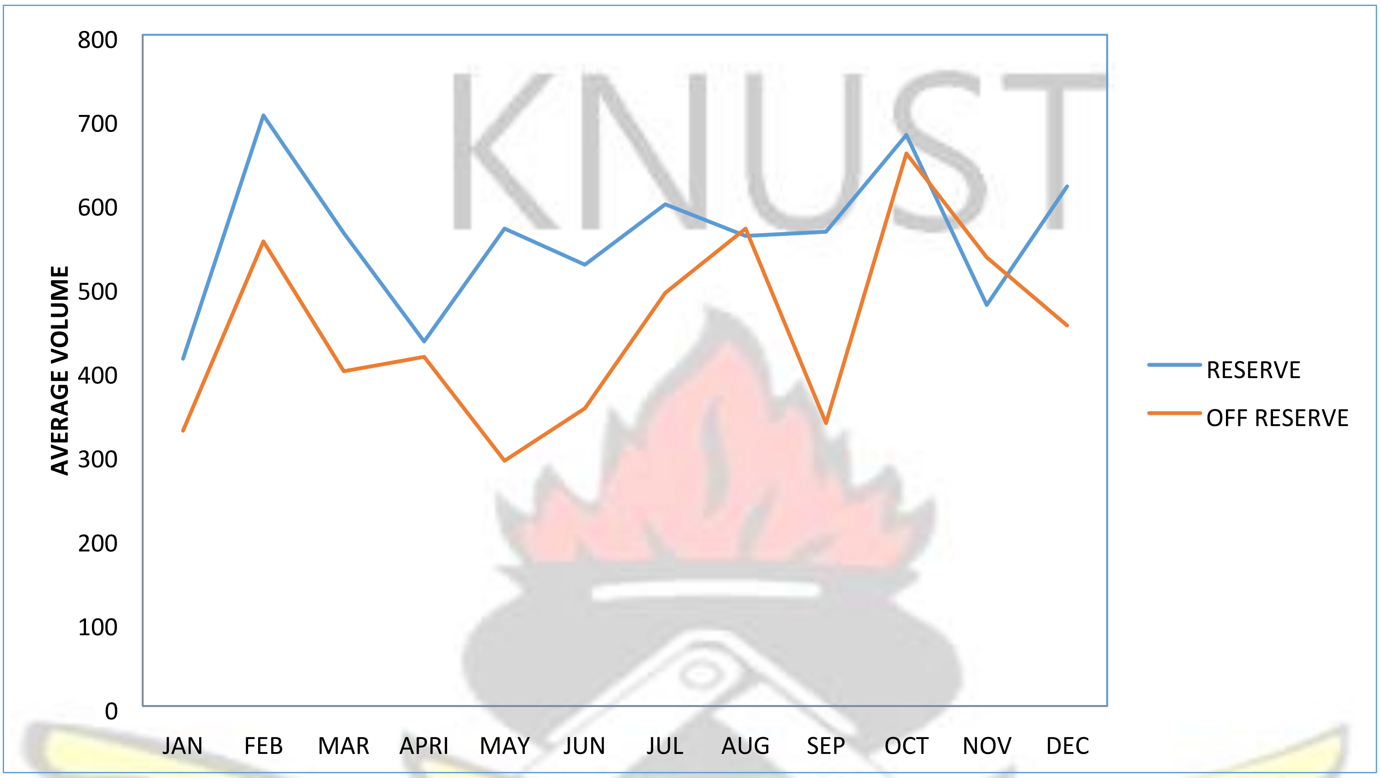

Figure 2: Monthly Average Volume for Reserves and Off Reserves

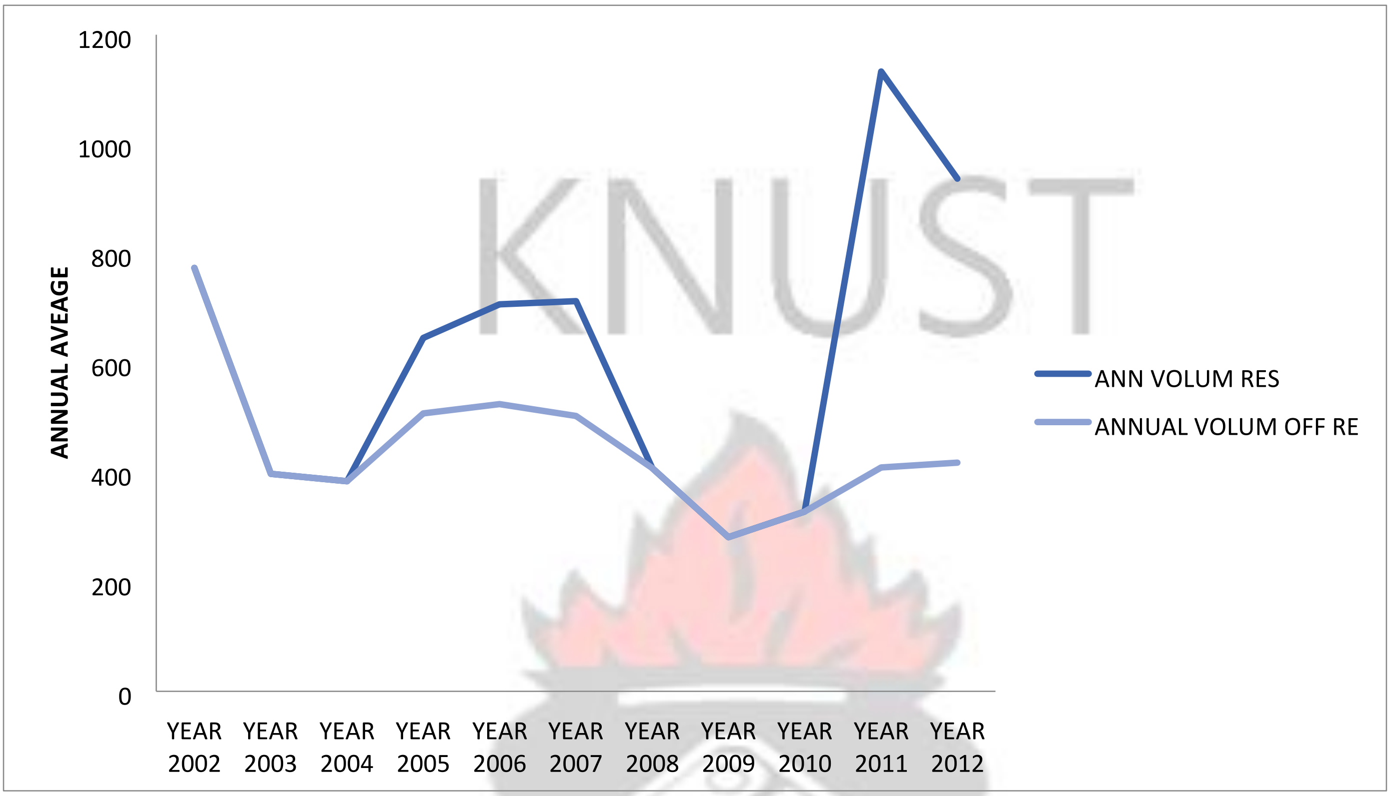

Figure 3: Annual Average Volume

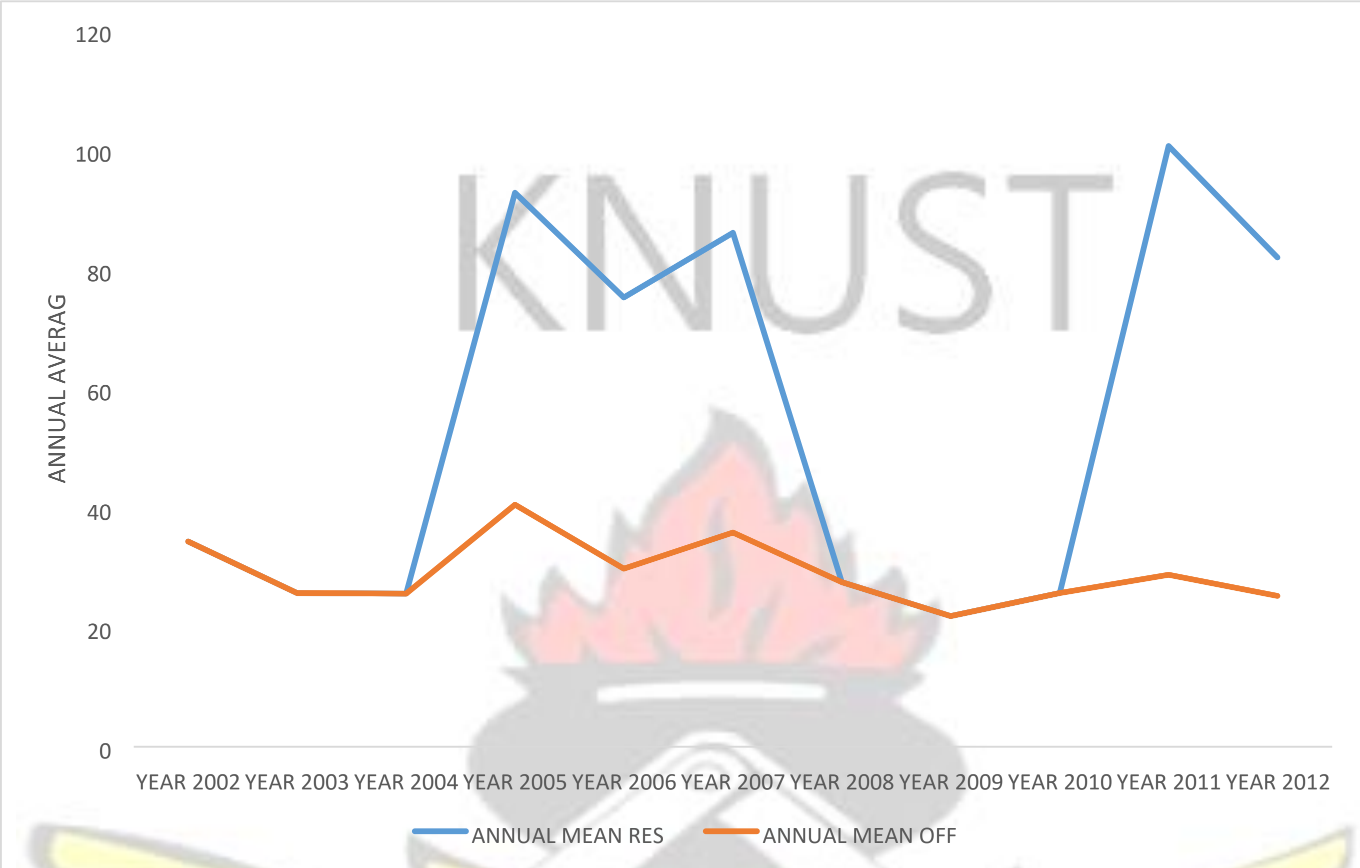

Figure 4: Annual Average Total Stem

Table 11: Result of Student T-test

Years		Number Of Trees	Number Of Species	Number Of Vulumes
2002	Reserve	14.25□7.26	113.25□80.17	1518.1□1416.3
	Off Reserve	8.0□3.48	33.75□24.45	774.2□762.7
	T-Test	0.0077	0.004	0.123
2003	Reserve	8.17□ 4.78	24.75□17.00	365.96□ 225.3
	Off Reserve	6.25□ 2.59	25.75□12.32	774.2□ 225.05
	T-Test	0.978	0.875	0.09
2004	Reserve	9.83□ 4.52	139.13□86.33	646.33□501.9
	Off Reserve	5.92□ 2.33	25.67 □8.65	384.1 162.8□
	T-Test	0.159	0.159	0.273
2005	Reserve	10.92□5.33	93.67□75.28	567.2□540.8
	Off Reserve	6.0□ 2.92	40.58□30.64	508□ 221.9
	T-Test	0.046	0.041	0.53
2006	Reserve	11.5□ 6.33	75.25□44.71 29.83□9.06	707.4□ 445.1
	Off Reserve	5.12□1.62	0.003	525.4□236.2
	T-Test	0.0032		0.22

2007	Reserve Off Reserve T-Test	11.425.42 7.33 1.59 0.022	86.0864.74 35.9220.32 0.022	713.13403.1 503 274.2 0.21

Table 11.Contd

2008	Reserve Off Reserve T-Test	15.584.59 6.5 2.02 0.000	211.08125.36 27.5814.46 0.000	1781.8810.23 408.3274.2 0.000
2009	Reserve Off Reserve T-Test	15.5 2.92 6.251.53 0.000	20676.56 21.927.18 0.000	2391985.0 282.1 107.7 0.000
2010	Reserve Off Reserve T-Test	16.55.68 6.02.2 0.000	173.3371.42 25.758.69 0.000	1858.8863.6 328.9159.7 0.000
2011	Reserve Off Reserve T-Test	15.126.13 6.92 2.8 0.0002	100.6751.36 28.8315.17 0.000	11327610.8 409.6 269.1 0.001
2012	Reserve Off Reserve T-Test	125.4 5.752.31 0.0039	82.057.02 25.2513.14 0.004	937.4695.8 417.9277.5 0.025