KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

GHANA

COLLEGE OF AGRICULTURE

FACULTY OF RENEWABLE NATURAL RESOURCES

DEPARTMENT OF AGROFORESTRY

STUDIES ON THE EFFECT OF FOREST AND AGRICULTURAL LAND USES AND FIRE ON TREE FLORA CONSERVATION IN AND AROUND TAIN 11 FOREST RESERVE.

BY

GOKAH ALFRED YAO

JUNE, 2015

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THESIS SUBMITTED TO THE DEPARTMENT OF AGROFORESTRY

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN COLLEGE OF AGRICULTURE

BY

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JUNE, 2015

DECLARATION

I declare that the information contained in this thesis is a result of my own work and has never been submitted for an award to any University or institution of higher learning. Statements from other people's work have appropriately been acknowledged.

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DR. OLIVIA AGBENYEGA. …………………….. ……………………...

(Head of Department) Signature Date

DEDICATION

This work is dedicated to my beloved families whose dreams have always been to see me attain greater heights in academics.

ACKNOWLEDGEMENTS

This study was possible because of the contributions of many people. First and foremost, I thank the almighty God for seeing me through this research work, also the Ministry of Food and Agriculture for granting me steady leave with pay, without which I would have been in serious difficulty. Secondly, to my supervisors; Dr. Victor Rex Barnes who devoted his time to help me throughout this study thank you for being patient with me even when I sometimes did not do what he expected in time , and Dr. Twum for his brilliant and fatherly guidance.

I thank Faculty of Forest Resources Technology, Sunyani for having allowed me to use their Guest house during my field work at the study sites.

In a special way, I wish to thank my families for their financial, moral and material support throughout this study. May the Almighty God bless them all.

Finally I appreciate the support and encouragements of Forestry Commission Sunyani, forest guard Oppong Kwame and my colleagues course mates, Peter Agyaka, Okai Brako and Alexander Gyasi. I also thank all other persons and institutions that I cannot mention by name in this dissertation.

ABSTRACT

Effect of forest and agricultural landuses and fire on tree floral conservation was studied in Tain II forest reserves in the Brong Ahafo Region of Ghana. The general objective was to examine the influences of forest and agricultural landuses and fire on flora and their implications on floral conservation. Six landuse categories were selected in and around the reserve, namely Taungya (Agroforestry) farm, Maize/Cassava farm, Natural forest, Cocoa farm, Teak plantation and Yam farm. These selected land use categories were placed under two major study zones (fire prone and less fire prone). Eighteen (18) plots of size 30metre x 30metre were randomly laid within each zone, making a total of thirty six (36) plots in all. Data on tree heights, diameter and numbers were collected on trees that had diameters 5cm and above dbh. Tree seedlings were also enumerated and data was analyzed for comparison. In terms of tree population density, with respect to trees of diameter 5cm to 35cm, taungya farm had the highest number of trees per ha (459.26/ha) and maize farm recorded the least population (29.63/ha) (P =0.001). Similar result was obtained from the diameter class of 36cm to 66cm where teak plantation recorded the highest tree density. However, the high population densities in Taungya and Teak plantations compared to natural forest for the diameter-size class of 5-35cm and 36-66cm did not correspond to the diameter-size class at 67cm and above dbh. The natural forest had the higher density of trees per ha (88.89) at this diameter class (67 and above dbh) (P = 0.009). It is therefore important to note that, low tree population density recorded by maize/cassava farm in the study area, could be as a result of logging and conversion of forest to farmland. In case of tree species richness and tree diversity cocoa farm and natural forest had the highest results of 30.40 and 2.28 respectively in the less fire prone zone whiles teak plantation recorded the lowest value of 6.82 and 0.39 in the less fire and fire prone zone respectively. The lowest tree species richness recorded by teak plantation could be attributed to the practice of growing teak as monoculture plantation. Natural forest exhibited highest basal area of trees (222.33), whiles maize/cassava farm recorded the lowest basal area (BA) of 2.92. The higher basal area of the natural forest per ha confirmed the fact that natural forest had a greater number of larger trees as result of less farming activities as the reserve is being regulated by the Forestry Commission. There were no significant effects of tree density between fire prone and less fire

prone zones as far as fire regime is concerned. However, tree species richness, tree diversity and tree basal area were significantly different between fire prone and less fire prone zones suggesting that fire can cause deforestation and deterioration of ecological systems. Natural forest again had the highest relative abundance of scarlet star and pink star rated species whiles teak plantation had the lowest. This least figure recorded in teak plantation partly implies that these star rated species were heavily exploited in the past by legal and illegal logging. The interaction between landuses and the fire regimes showed significant similarities. Finally the land use categories and wild fires in Tain II forest reserve has not only transformed the physical landscape but also impacted negatively on the biological community of trees in the area. The impact of landuse, particularly maize and cassava farm had been very severe on tree resources thereby reducing significantly tree population density. And in the fire prone zone there is preponderant occurrence and vigorous growth of savanna grasses as well as many noxious farm weeds. The most relative abundant trees encountered during the study include *Tectona grandis* (Teak), this obviously for the teak plantation area, *Blighia sapida* (Akye), *Sterculia tragacantha* (Osofo), *Spathodea campanulata* (Kokonisue), *Anogeissus leiocarpus* (Kane), *Holorrhena floribunda* (Sese), *Lonchoocarpus sericeus* (Sante) and Ficus *exasperate* (Nyankyerene).

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LIST OF ACRONYMS

AAC	Annual Allowable Cut
ANOVA	Analysis of Variance
DBH	Diameter at breast height
DFID	Department for International Development
DSE	Department of Sustainability and Environment
DSD	Dry semi-deciduous
DSFZ	Dry semi-fire zone
EPA	Environmental Protection Agency
FAO	Food and Agricultural Organization
FDPB	Forestry Department Planning Branch
FIP	Forest Investment Program
FORIG	Forest Research Institute of Ghana
FONG	Farmers Organization Network in Ghana
FPCU	Forest fire protection and control unit
FSD	Forestry service division
FZ	Fire zone
GDP	Gross Domestic Product
IFAP	Information for Financial Aid Professionals
IPCC	International Panel on Climate Change
ITTO	International Tropical Timber Organization
IUCN	International Union for Conservation of Nature
IZ	Inner zone
ME	Moist evergreen
MLF	Ministry of Land and Forestry
MLFM	Ministry of Land, Forestry and Mines
MOES	Ministry of Environment and Science
MSD	Moist semi- deciduous
NTFPS	Non-timber forest products
REDD	Reducing Emissions from Deforestation and Forest Degraadation
SGS	Short Grass Savanna
SO	South-east outlier
TIDD	Timber Industry Development Division
UE	Upland evergreen
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change

UNU-INRA	United Nations University-Institute for Natural Resources in Africa
USDA	United State Department of Agriculture
VPA	Voluntary Partnership Agreement
WE	West evergreen

CHAPTER ONE

1.0 INTRODUCTION

Forest resources are essential to social and economic activities in Africa. As a result, they are important elements in both poverty reduction and sustainable development strategies for many Sub-Saharan African countries (Tutu and Akol, 2009). However in recent years the rate of deforestation occurring around the world is so alarming, for instance in Ghana it is estimated that about 20,000 hectares of the trees in the forest reserves are lost to agriculture as well as bush fires and other human activities per annum (Tabi- Agyarko, 2001). And about 14% of the total permanent forest reserves in Ghana are also without adequate forest cover. The worst affected areas are the moist semi-deciduous North-west and South-east sub-type of forest zones which include Tain II Forest Reserve and its environs in Sunyani West District (Tabi- Agyarko, 2001). Current evidence indicates that the deforestation and degradation of this forest reserve could be largely attributed to landuses and wildfires over the years (Ntiamoa-Baidu and Gordon, 1991; Ryan and Ntiamoa-Baidu, 1998).

Rapid increases in the world's population demand the production of ever increasing quantities of food, fibre and fuel from the land and to meet societal needs, vast tracts of land are being farmed more intensively, and large areas of forests are being over exploited and degraded. As a result the demand for more agricultural land and increase in land use activities have exerted pressure on forests whose tree species composition and structure have changed over the past few decades (Food and Agricultural Organisation, 1993). Recent projected land use trends in the tropics indicate that land use activities are causing rapid changes in natural forest tree composition and structure. Extensive uncontrolled and unplanned land use accelerates forest fragmentation and results in substantial loss of trees. The growing concern about unsustainable tree resource management and utilization practices as well as the associated decline in tree population have led to the realisation that the impacts of human activities on the forest cannot be addressed without analysing the land use activities on the forest and its environs. The issue is; are landuse categories negatively affecting flora in and around Tain II reserve? And/or do these landuses have the potential for floral conservation?

Beside the effects of landuses on trees, fire is the next phenomenon that has also played an important part in creating many of the vegetative communities and much of the landscape in the world. From the global perspective, wildfires contribute significantly to environmental degradation including global warming (Zhengxi *et al.,* 2007).

A greater part of deforestation in the world and Ghana as well is due to shifting cultivation (slash-and-burn techniques) and the long-term effects of repeated and uncontrolled wildfires which accompany fuelwood collection, grazing and harvesting of minor forest products. The high frequency of wildfires in degraded vegetation types is a major impediment to the restoration of formal forest type or development of climax forest (Goldammer, 1986).

In Ghana fire has been shown to be responsible for reducing productivity and depleting the genetic diversity of most forests (Hawthorne, 1994).

By 1993, the total area of forest reserves in the high forest zone affected by fire was 0.917 million hectares, more than half the total area of reserved forest. The increase in wildfires during the past two decades seriously threatens the survival of some of the nation's premium timber species notably, Pericopsis elata (Afrormosia), Milicia spp. (Iroko) and Entandrophragma and Khaya spp. (African mahogany) among others (FORIG, 2003).

Despite all efforts to control fires in Ghana, wildfires, which were once a rare occurrence, have become an annual affair threatening the sustainability of local and national economies as well as the non-tangible benefits derived from the forest. The state of fire incidence in the Sunyani and the surrounding areas in general during the dry season is very alarming. For instance, a total of 120 fire incidence was recorded in 2007/2008 fire season alone. Considering this, however, the smaller size trees and younger plants which constitute the very future of our forest are the most affected by these fires (Orgle, 1994).

The indiscriminate use of fire as well as shorter fire-return interval combined with continuous logging could potentially lead to forest tree degradation. The loss of forest resources and biodiversity as well as degradation of trees could have drastic consequences on individual welfare and economic development of the country. One may ask; are these fires negatively affecting flora in and around Tain II reserve? And/or do these fires have the potential for floral conservation? All these questions I have raised are what my work tends to address.

1.1 PROBLEM STATEMENTS

Tain 11 forest reserve is among the forest reserves in the country where relics of tropical rain forest could be found. The area is under severe pressures, due to population explosion, encroachments on forest lands, loss of forest cover for other non-forest uses, shifting cultivation practices around the reserve and degradation caused by illicit felling, lopping for fuelwood, fodder and forest fires etc (Hawthorne and Abu-Juam, 1995).

In addition to the landuse practices, wildfire is perhaps the most single threat to the integrity of forest in Ghana. The loss of trees and forest cover has seriously affected Tain II forest reserve, local hydrology and the loss of a wild range of non-timber products (MLFM, 2006). However, understanding the effects of landuses and fire on flora in and around Tain 11 area is lacking.

Studies in the past and the present, have not considered this issue in detailed, for instance Orgle, 1994, who looked at fire degrading in fire and less fire prone areas in Ghana, and Owusu- Afriyie, 2009 who also assessed the effect of recurrent fires in Tain II forest reserve and their plant biological resources all focused on the effect of fire without much emphasis on the fire effects in different landuses around Tain 11 forest reserve. The effect of interactions of fire and forest as well as agricultural landuses on the potential for floral conservation in and around the reserve is often poorly explained.

Fires have become an important threat to the sustainable agriculture and forestry particularly in the study area. It has altered the composition and structure of 30% of the semi-deciduous forests (Hawthorne, 1994) which is the main forest vegetation type in the transitional belt. Fire is presently by far the greatest threat to the long-term productivity, genetic wealth and the general health of the semi-deciduous forests in Ghana. A number of forest reserves that used to have distinct forest structure, dense and rich in biodiversity have now become large tracts of *Chromolaena odorata* and grasslands of mainly *Panicum maximum* with scattered fire damaged trees. Therefore, landscapes in the transitional zone are covered with patches of intact forests, degraded forests, recovering forests and plantations (mainly teak).

1.2 JUSTIFICATION

Forest conservation and agricultural landuse practices and fire prevention appears not to be effective. This research focuses on the effects of landuse and wildfires on floral conservation. The information generated will bridge the knowledge gap on landuse and wildfire effects on plant communities in and around Tain 11 forest reserve.

The study will also provide baseline information for future research on the subject in and around the reserve and beyond. The study again will provide scientific community with enhanced knowledge on the subject in the study area.

The availability of this knowledge will be useful to convince farmers to adopt appropriate landuse practices to enhance conservation or put policies in place to be able to promote landuse that conserve flora. It will finally be useful in policy formulation for an effective fire prevention and control in similar ecosystems in Ghana

1.3 OBJECTIVES

1.3.1 General objective

To examine the influences of forest and agricultural landuses and fire on flora and their implications on floral conservation.

1.3.2 Specific objectives

- To evaluate the effect of forest and agricultural landuses on tree flora.
- To identify the forest and agricultural landuse systems which promote tree flora conservation.
- To examine the effects of fire on tree flora
- To examine the effects of interactions of forest and agricultural landuses and fire on tree floral conservation.
- To identify appropriate agroforestry MPTs to boost flora conservation for economic and environmental sustainability.

1.3.3 Hypotheses

- Forest and agricultural landuses can substantially contribute to flora diversity conservation
- Fire can reduce floral diversity and conservation.
- The interactions of forest and agricultural landuses and fire cannot contribute to floral diversity conservation.

CHAPTER TWO

2.0 Literature review

2.1 General introduction

Reservation, consisting of the selection, demarcation, and constitution of forest reserves within the high forest began shortly after World War I. Today it covers about 1 million ha of production forest (1.37 million ha) and protection (0.43 million ha) forest. The reservation activities defined the land use within the high forest as the reserve areas were permanently dedicated to forestry. The unreserved forest under no specific land use plan was destined to meet the needs of the people for food farming, commercial and plantation agriculture, and other forms of development involving land clearing. The result is that today, a satellite image of the high forest zone clearly resembles the forest reserve map of the area with the reserves standing out in clear contrast with the surroundings which have been heavily degraded (Kingsley *et al.*, 1995).

The high forest has the capacity to provide many goods and services. The list is extensive and includes wood products, food, fodder, medicine, and energy. It also plays vital roles in the stability and fertility of the soil and the quality and the perenniality of streams and rivers. Above all, it harbours enormous biodiversity necessary for the maintenance of resource productivity through nutrient recycling and environmental processes that support livelihood.

The bane of high forest management in the past was lack of adequate knowledge of the forest Silva that would enable sound decisions on the seemingly luxuriant growth of multiplicity of species and sizes, little of which was considered to be of commercial value. The increased pace of disappearance and increasing commercialization of the forest today raises serious doubts about its survival and prospects for sustainable management (Ghartey *et al.*, 1995).

The outside forest reserves destined for agricultural and other purposes have been largely planted to cocoa, oil palm, citrus and other subsistence farming activities. The land area of approximately 6.5 million ha has been heavily degraded requiring rehabilitation. Yet, this area is expected to supply about 75% (1.5 million m^3) of Ghana's annual allowable cut of 2 million m^3 (Ghartey *et al.*, 1995).

Another estimates put the costs of environmental degradation in Ghana at nearly 10 per cent of the GDP. Over the past 50 years, Ghana's primary rainforest has been reduced by 90% and currently it loses about 2% of its forest cover annually, with only 4% of the trees cut being replaced. Bushfires, fuel wood collection, logging, agriculture and mining are considered the direct causes of forest losses.

2.2 Vegetation of Ghana

The terrestrial ecosystem of Ghana may be seen to be spread in two major biomes, namely, the tropical high forest and the savannas (Sudan and Guinea savannas). The tropical rain forest may be subdivided, according to Hall and Swaine (1981), into various vegetation types in relation to annual precipitations and keystone plant associations. These are: High Forest Zone, moist semi-deciduous and dry semi-deciduous (DSD) or Transition zone (Fig.1).

However, for convenience and for the purpose of this work, it may be categorised into two. These are the closed forest (high forest or closed canopy forest) zone covering about 34% of the country (8.22 million ha) and the savanna zone of an area 15.62 million ha or about 66% of the land area of Ghana (K. Nsiah-Gyabaah, 1996*)*.

2.2.1 High Forest Zone

Dry semi-deciduous (DSD) or Transition zone

The closed forest is floristically very rich and diverse and contains a large reserve of commercial timber species. About 2/3 of the country's human population and economic activities are concentrated in this zone. The closed forest and savanna ecosystems in Ghana continue to experience major biophysical environmental changes, which are generally degradation in character, and closely associated with production pressures including slash and- burn agriculture, uncontrolled bush burning and hunting to meet the food and nutritional needs of the growing population. It is estimated that only about 2 million hectares of the closed forest, made up of about 1.7 million hectares within Forest Reserves and 0.3-0.5 million hectares outside the legally reserves forests, have not been modified through cultivation, bush burning, deforestation etc.

One of the most important timber species, Odum (Milicia excelsa**),** reaches its maximum abundance in the DSD (IZ) sub-type although at present this species is endangered. The DSD (FZ) sub-type is characterized by the occurrence of periodic fires, especially during the dry season. This is found in between the evergreen rain forest and the savanna zone. This contained the study area.

2.2.2 The Savannas

The savanna vegetation has evolved under conditions of annual bush fires, which has been increased by human activities. The vegetation consists of short grasses with scattered fire-tolerant trees and with low-density woodland of drought and fire-resistant species. This vegetation type is not homogeneous.

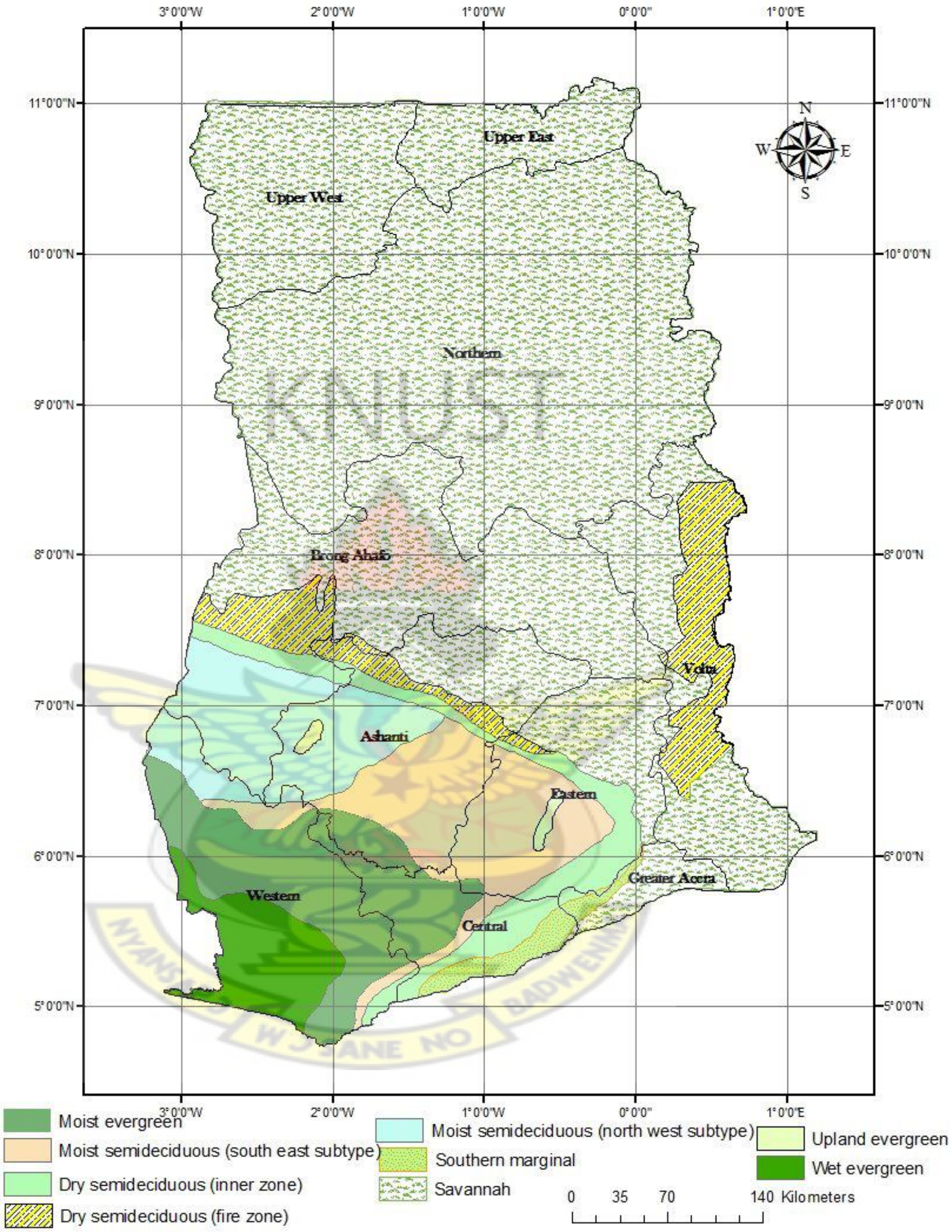


Figure 2.1: Vegetation Map of Ghana showing the major forest types

Source: Ghana - Forest Investment Program (FIP) Plan, 2012

2.3 The conditions of Ghana's forest (vegetation) over the years

Ghana was once renowned for its extensive forests and wooded savanna, but this has changed drastically. Tropical moist forests originally extended over 145,000 km^2 of Ghana. By the turn of the century it was estimated that 88,000 km^2 of forests remained, occupying 35% of total land area. Between 1938 and 1981, the area of closed forest in Ghana was reduced by 64% from 47,000 km^2 to 17,200 km^2: and open woodland declined by 37% from 111,000 km^2 to 69,800km^2. The current area of intact forest is now estimated at between 15,800 km^2 and 17,200 km^2 which represents between 10.9 and 11.8% of the original cover and 6.9% of the country's total area (Ministry of Environment and Science, 2002).

It was again stated by (MOES, 2002) that for the past 15 years (1990-2005), Ghana has lost about 1.9 million hectares of forest or 26 percent of its forest covers.

According to FAO (2001), lots of factors affect forest resource change and dynamics in Ghana. These factors include: excessive logging, unsustainable agricultural practices, bush burning, mining and quarrying, and settlement and related infrastructure construction. However, increases in population growth coupled with migration, especially in the forest areas, also account for a high rate of deforestation (FAO, 2000). As population density increases and land becomes scarce, its value rises and farmers then find it cost-effective to intensify production. Others resort to clearing virgin forest for additional cultivation. The poor tend to be pushed onto ecologically sensitive areas with low agricultural potential (for example semi-arid savanna, erosion-prone hill-sides and tropical forests). The situation is aggravated where large-scale farmers respond to growing pressure to expand primary commodity export and thus enlarge the areas on which cash crops are grown.

2.4 Factors responsible for forest (vegetation) losses in Ghana

The pressures on Ghana's forests have been recognized for many years with "alarming deforestation" noted as early as 1908. Agricultural changes were partly responsible over many years for the forest loss, but recent evidences show that there are other driving forces and factors, which have influenced the face of forests in Ghana (FSD, 1994).

There are indications that Ghana has never successfully practiced sustainable forest management. The forests have been depleted and degraded and the sector is now characterized by excessive harvesting of logs over and above the AAC, reduction in standing volumes of species, dwindling resource base, species depletion and loss of biodiversity (FSD, 1994).

The driving engines that have shaped the structure and composition of the vegetation are logging, unsustainable farming, annual bushfires, surface mining and infrastructural development. Underlying these driving engines are forest policy failures, unrealistic forest fee regimes, external prices of timber and weak institutional structures (FSD 1994).

2.4.1 Excessive Logging

The harvesting of timber is the most important single factor contributing to deforestation in Ghana. However in 1991, logging operations accounted for only 14% of the deforested areas in Ghana (FSD Annual Reports–1962-94). Outside the Forest Reserves logging has been on the increase mainly due to lack of effective control. In recent times, logging activity has been intensified more in the semi-deciduous zones than in the evergreen forest due to greater densities of desirable timber species. These drier zones are now in critical conditions partly due to logging.

When logging is appropriately managed, then it needs not to be a serious threat to the forest vegetation. The problem is that logging in recent decades has certainly not been managed appropriately, and this is the main reason for the poor quality of many forest areas. The detrimental effect of logging on the resistance of the vegetation to "natural" hazards, particularly fire, is the most serious risk of heavy exploitation (FSD 1994).

2.4.2 Unsustainable agricultural practices

The area of land under agriculture increases every year due to the extensive system of farming being practiced in the country, which also involves cutting of vegetation. The traditional bush fallow system of cultivation involves slash and burn of forest and grassland. However, long fallows necessary for the forest to regenerate fully is only possible if population growth and pressure on the land are low. With increasing national population over the last two decades, demand pressure on land has been considerable. Demand for subsistence agricultural cultivation has been compounded by demand for cash crops like cocoa, coffee, oil-palm, cereals and for urbanization and infrastructural development (MOES, 2002).

Even, farming whether under the *Taungya* system or not is seriously bad in conservation terms where it is either persistent or occurs over large areas. Only few temporary farms may well recover to good forest when abandoned. It is known that farming established in the forest areas is a *fait accompli*, much harder to remove than to prevent in the first place and also a timorous source of fire within. It was stated that, 70% of deforestation in Ghana has been attributed to shifting cultivation (bush fallow) (FSD 1994). Some areas have been badly blighted by farms due to local pressure for land. Such pressures are unlikely to be abated and new farms, which prevent regenerating phases of the vegetation, are likely to increase.

Conversion of areas of reserved forest into plantations of exotic trees like cocoa, Teak (*Tectonic grandis*) and *Gmelina* is also another source of deforestation in the country. The *Taungya* systems have failed disastrously in many areas and several areas, which ought to have been completely protected, have been reduced to *Eupatorium-solanum* fire hazards (MOES, 2002).

The trend that the forest resources have been under persistent attacks by agriculture partially due to the absence of a national land use plan, contributed also to a decrease in forest area (MOES, 2002).

2.4.3 Bush burning

Forest fire has been the immediate cause of most forest degradation in the country over the last few years. According to data gathered over the years, every year about 30% of the forest areas are destroyed by fire. Bushfires occur annually in the dry season usually from November to May.

The causes of bush fires are both intentional and unintentional. Intentional fires are called early burning used as a management tool to reduce the ferocity of late dry-season fires in vegetation near the forest-savannah boundary. Though this management practice has been in use since time immemorial, it has a negative influence on forest regeneration and contributes significantly to deforestation. Unintentional fires result from activities of hunters who may fail to extinguish campfires.

More than 1 million m^3 of exportable timber have been lost to fire over the last decade. Burnt forests are dominated by pioneer trees of little economic merit and are more prone to burn in the future. Fire is now the greatest threat to the long-term survival of half the forest in Ghana. Fire prevents forest from developing into primary forest and records indicate that only 20% of the forest zone is currently covered by forest which has not burnt regularly (Hawthorne, 1994).

2.4.4 Mining & quarrying

Open cast mining activities for gold and diamond, especially those by the small-scale operators and large-scale mining for bauxite, manganese and gold, pose serious threat to forest in the forest region of Ghana.

Layout of mines and infrastructure (including waste dumps, storage, tailings ponds, plant yards, roads and accommodation) destroy large areas of forestry reserves. Today, gold mining poses the greatest threat, particularly to reserves in and near the genetic "hotspots" of the wet evergreen zone. Areas have implications for the supply of urban land for housing and for the provisions of infrastructure and other social services (MOES, 2002).

2.5 Landuse

Several definitions of land use exist. However there is one common denomination in all the definitions. They all refer to certain types of management activities conducted by man on a tract of land. De Bie, (2000) defined land use in his PhD thesis as "series of operations on land, carried out by humans with the intention to obtain products and/or benefits through using land resources".

Minae and Avila, 1999, landuse is defined as a distinctive combination of crop, livestock, tree and/or other production systems on a given area of land. These include farm, region or watershed, which are determined by an interacting combination of ecological, physical, political, socio-economic and technological realities and potentials facing the land users. Although there are usually a fairly large number of unique landuse systems in any geographical area, it is essential to identify the recurring, common or typical patterns of land use in the area so as to be able to describe, analyse and understand their management and performance.

Ghana had a total area covered as 238,540 sq. km; whiles 230,020 sq. km (Land), and 8,520 sq. km by Water. Out of 230,020 sq. km covered by land, the following land uses figures were recorded: 12%: Arable Land, 17%: Permanent Crops, 22%: Permanent Pastures, 35%: Forests &Woodlands, and 24% for other (Table 2.1)

Table 2.1: Landuses figures of Ghana

Landuses	Area sq. km	Area %
Arable land	27,602.40	12
Permanent crops	16,101.40	7
Permanent pastures	50,604.40	22
Forests & Woodlands	80,507.00	35
Others	55,204.80	24
Total	230,020.00	100

Source: Timber Industry Development Division (TIDD) of the Ghana Forestry Commission, (1993).

2.6 Type of landuses

2.6.1 Forest landuses

The tropical forests of the America, Asia and Africa in 1980 covered about 1,359 million hectares of which 1,200 million hectares were closed forest and 735 million were open tree formations. In addition, fallow forest land accounted to 410 million hectares (FAO, 1985).

About 2,000 million people live in this zone, where the population is increasing at a net annual average rate of 2.6 percent. The increasing population is exerting pressure for the use of forest land for agricultural and settlement purposes. According to Gupta *et al.,* 2004; Kozlowski, 2000, forests in the tropics are particularly under threat from human-induced disturbances and approximately 13 million ha of tropical forests are felled, burned or converted to other land uses each year (FAO, 2006).

This was confirmed by TIDD (1993) that, the greater part of forest depletion in Ghana is due to shifting agriculture (slash-and-burn techniques) and the long- term effects of repeated and uncontrolled wildfire which accompany fuelwood collection, grazing and the harvest of minor forest products.

Again for decades, the state has allowed timber and mining corporations free reign to destroy Ghana's forests. As a result, Ghana's forest cover has dwindled from 8.2 million hectares to less than 1.5 million hectares between 1900 and 1990. Between 1990 and 2005 the rate of deforestation actually accelerated to a historical high with significant forest reserves losing their entire forest cover. At current rates commercial species could be logged out in as little as 5 years. Deforestation is already having a noticeable impact on water supplies, soil fertility and climate pointing to a looming environmental disaster (Katako and Vigoda, 2007).

2.6.2 Agricultural landuses

Agricultural production strongly influence biodiversity and ecosystem processes in a variety of habitats, often changing community composition, plant biomass, vegetation structure and nutrient cycling due to the interactions between biological, social and economic factors (Greenberg *et al.*, 2000, Reitsma *et al.*, 2001, Dietsch *et al.*, 2004, Perfecto *et al.*, 2005, Phippott *et al.*, 2006, Gordon *et al.*, 2007, Steffan Dewenter *et al.*, 2007).

According to Ikusemoran (2009), since the beginning of the 19th C, vast portion of the earth's surface in Nigeria has been modified, whole ecosystems destroyed and global biomass altered or eliminated. The most important of the land surface changes in this part of the country has that of man activities, especially farming, bush burning, wood cutting and other activities.

It has been estimated that the total area burnt or cleared (all ecosystems worldwide) amounted to 630 million to 690 million per hectares per year (Goldammer, (1988**)**, but the total forested areas cleared annually for agricultural purposes in the tropics accounts for about 30 million to 80 million hectares.

The wealth of Ghana's natural resources plays a significant role in its economy through farming, fishing, forestry and mining. The history of overexploitation and mismanagement of these resources combined with lack of environmental information undermines the sustainable development of the country (FONG and IFAP, 2010).

2.6.3 Agroforestry landuses

Agroforestry is a collective name for land-use systems and technologies where woody perennials (such as trees, shrubs, palms, bamboos etc.) are deliberately used on the same land- management units as agricultural crops and/or animals, in some form of spatial arrangement or sequence (Lundgren and Raintree, 1982).

In agroforestry systems there are both ecological and economical interactions between the different components (Lundgren and Raintree, 1982).

It has the potential to provide rural households with food, fodder, fuelwood and other tree products. At the same time, it can help ensure the sustained productivity of the natural-resource base by enhancing soil fertility, controlling erosion and improving the microclimate of cropping and grazing lands.

In Ghana majority of the populace depend on agriculture for their livelihood. According to UNU-INRA, 2003 about 70% of Ghanaian population directly or indirectly depend on agriculture for food and nutritional needs. The current high rate of irreversible environmental degradation in Ghana continues to be a bane on socio-economic well-being and maintenance of environmental stability of the country. The Ghanaian physical environment in general is made up of forests, savannah, and water bodies, soil, atmosphere, farmlands, human settlements which provide goods and services to support the social, cultural, economic and healthy well being of the people.

It is therefore important to study the landuse system which has the opportunities to provide these important needs of mankind.

The taungya is one of the agroforestry systems which were practiced in the past also promoted the clearing of healthy forests by farmers. The system which was supported with the idea to expand plantations allowed farmers to use reserve areas for farming and plant trees to take over after a certain period (Hawthorne and Abu-Juam, 1993).

After the failure of the taungya system a lot of areas like the Tain 11 forest reserve and other forest reserves have been dominated by the fire prone species like Eupatorium, giant star grass and others (Hawthorne and Abu-Juam, 1993).

2.6.4 Mining landuses

Mining, in its broadest sense, is the process of obtaining useful minerals from the earth's crust. The process includes excavations in underground mines and surface excavations in open-pit or open cut (strip) mines. Mining normally means an operation that involves the physical removal of rock and earth. A number of substances, notably natural gas, petroleum, and some sulfur, are produced by methods (primarily drilling) that are not classified as mining.

Mining operations, particularly surface mining are a serious threat to forests in certain areas of the country Ghana. Iron ore extraction around Awaso caused a considerable damage to the forest. Gold mining however, is a major threat, particularly to the forest in Wet Evergreen forest zone which harbour most of Ghana's genetic hotspots. Another, painful example is large scale gold surface mining established in the early 1990s, which chopped off the northern half of Neung North Forest Reserve, one of the Ghana's outstanding botanical hotspots(Abbiw *et, al*, 2002).

Minerals such as gold and diamond are the leading contributors to Ghana's foreign exchange earnings). Despite the important role these minerals play in the Ghanaian economy, mining has had devastating effects on forests leading to several hectares of forest loss (Codjoe and Dzanku, 2009; Kotey *et al*., 1998 Hawthorne, (1994).; Hawthorne and Abu- Juam, 1993). Grainger (1993) stated that deforestation occurs when minerals buried under forests are exploited. Open cast mining which is most practiced in Ghana by mining companies have become important cause of deforestation in the country (Grainger, 1993). Surface mining has been detrimental to the forests in Ghana due to the fact that, it is not only the forests biomass which are removed but also the soil (Hawthorne and Abu-Juam, 1993).

The present situation is very alarming as massive deforestation is taking place in forest reserves under the pretext of gold exploration, where surface mining is hardly discernible from exploration. Ghana's mining regulation, which permits mineral exploration in forest reserves, is the main culprit (Abbiw *et. al.,* 2002).

2.7 Biodiversity

Biological diversity or biodiversity - is a term use to describe the variety of life on Earth. It refers to the wide variety of ecosystems and living organisms: animals, plants, their habitats and their genes.

Biodiversity is the foundation of life on Earth. It is crucial for the functioning of ecosystems which provide us with products and services without which we could not live. Oxygen, food, fresh water, fertile soil, medicines, shelter, protection from storms and floods, stable climate and recreation, all have their source in nature and healthy ecosystems. But biodiversity gives us much more than this. We depend on it for our security and health; it strongly affects our social relations and gives us freedom and choice (IUCN, 2010).

This is broadly defined as the variety of life and associated ecological processes that occur in an area. This variety is sometimes broken down into genetic, species, and ecosystem components (Salwasser, 1990). In dealing with vegetation, it is convenient to think of the spectrum of components as being plant, community, and landscape. The landscape can be viewed as a mosaic of patches, which are plant communities typically described as vegetation types, succession stages, stands, and age classes.

According to the Ghana National Biodiversity Strategy, natural or biological resources in the country have been negatively impacted by increasing pressure from agriculture expansion, mining, and timber extraction (Ministry of Science and Environment, 2002).

2.7.1 The status of Ghana's biodiversity

Ghana signed and ratified the Convention on Biological Diversity since 1992. She is therefore under obligation to develop a national strategy for the sustainable use of the country's biological resources.

Based on that, the entire country falls within three main biogeographically zones, namely: the south western portion within the Guineo-Congolian, the middle belt within the Guineo-Congolian/Sudanian Transition zone, while the northern-tip of the country falls within the Sudanian zone. So far, about 2,974 indigenous plant species, 504 fishes, 728 birds, 225 mammals, 221 species of amphibians and reptiles have been recorded (Ministry of Environment and Science, 2002).

Sixteen percent (16%) of Ghana's land surface area has been set aside to conserve representative samples of her natural ecosystems in the form of forest reserves, national parks and other wildlife reserves including various traditional forms of conservation.

Despite this effort, increasing pressure from agricultural expansion, mining, timber extraction and other socio-economic factors have negatively impacted the biological resources of the country. It is estimated that the country is experiencing a rapid deforestation rate of about 22,000ha annually. The economic loss to the nation of loss of biodiversity through deforestation and land degradation has been estimated at about US$54bn (about 4% of the Gross Domestic Product) (Tutu, *et al.*, 1993).

Also, the general knowledge and information on genetic diversity of various life-forms and organisms existing in the country are diffuse, incomplete and inaccurate. Lack of up-to-date knowledge and information gaps and inaccuracies exist because of a number of constraints. Notable among these are the limited technical capabilities and inadequate logistics support, low financial resource allocations as well as the general lack of appreciation for the worth of biodiversity conservation (Ministry of Environment and Science, 2002).

2.7.2 Effect of landuse on biodiversity loss (floral diversity)

Anonymous (2001) stated that, most obvious causes of biodiversity loss in India have been habitat loss, over-exploitation, and introduction of invasive species and lack of national land use policy. The secondary factors which concerns the managers is unsustainably high rates of human population growth and natural resource consumption; inadequate knowledge and insufficient use of information and economic systems and policies that fail to value the environment and its resources.

A variety of socio-economic factors have led to forest fragmentation which threatens the variability of biodiversity in Ghana. According to EPA, (2010) various factors pose threats to biodiversity. These include indiscriminate mining activities, use of agro-chemicals, overgrazing and overexploitation of certain species. Hawthorne (1993) also stated that, in Ghana tree populations are being reduced by farming and notoriously by commercial timber extraction.

2.7.3 Land use effect on climate change

Climate change is arguably the greatest contemporary threat to forest ecosystems, biodiversity and livelihood of poor forest fringe communities. It is one of the greatest environmental, social and economic threats the world has ever faced (Ahenkan and Boon, 2010). It is real and happening faster than we previously thought with serious devastating impacts in developing countries, particularly on the Africa continent. However, the poor countries in particular are the most vulnerable because of their high dependence on natural resources and their limited capacity to adapt to a changing climate. These impacts are expected to deepen poverty, food insecurity, poor livelihoods, desfunction of infrastructural facilities, environmental resources and unsustainable development (Ahenkan and Boon, 2010).

Vulnerability and adaptation to the adverse impacts of climate change are among the most crucial concerns of many developing countries, especially Ghana (Denton *et al*., 2001). The main cause of climate change is the rising concentration of greenhouse gases (GHGs) in the atmosphere, which stem primarily from both natural and human activities (IPCC, 2007).

The main GHGs are carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), principally from the burning of fossil fuels, forest destruction and agriculture.

Scientists also have documented changes in the global carbon cycle due to increases in atmospheric carbon dioxide (CO2), changes in biogeochemical cycling due to increased nutrient deposition (for example, nitrogen), and changes in land use and cover. These changes are expected to continue for the foreseeable future (IPCC 2001).

According to studies, by Litterman, *et al.*, (2003) carbon dioxide from agriculture has been found to be one of the causes that lead to increasing level of CO_2 in the atmosphere. Agriculture has been increasing carbon dioxide emission since the mid-1800s and has been the main source of emission since before the 1920's. Today, the main source of carbon dioxide emissions is fossil fuel usage; nonetheless, the second largest cause of increased carbon dioxide emission is due to land conversion for agriculture.

This is so because the conversion of land for agriculture involves the destruction of plants life which leads to the release of carbon dioxide into the air. With respect to the world's total anthropogenic carbon dioxide emission, agricultural activity is responsible for 20% of the total (Litterman *et al*, 2003).

2.7.4 Land use effects on water bodies

Agricultural land uses can affect the quality of water and watersheds. The types of crops planted, tillage practices, and various irrigation practices can limit the amount of water available for other uses. Runoff from pesticides, fertilizers, and nutrients from animal manure can also degrade water quality. Additionally, agricultural land uses may result in loss of native habitats or increased wind erosion and dust, exposing humans to particulate matter and various chemicals. Environmental Protection Agency is concerned about the use of land because of the potential effects of land use and its byproducts on the environment (EPA, 2010).

Population growth, changes in landuse patterns and climatic variability have resulted in dwindling of freshwater resources in Ghana. The high rates of logging, fuel wood extraction, poor agricultural practices and surface mining have exacerbated the vulnerability of freshwater resources.

2.7.5 Effect of landuse on animal diversity

As in many other countries in West Africa, wildlife resources in Ghana have dwindled drastically over the past few decades. This has largely been attributed to the growth in human population, high demand for land for farming and poor enforcement of the country's wildlife laws, which combined has resulted in a virtually uncontrolled bush meat trade, posing a major threat to biodiversity in general and to wildlife resources in particular. Consequently, many of the country's wildlife species such as duikers (forest antelopes), porcupine, tree pangolin, bare-headed rock fowl, forest elephant and primates have become threatened. Current estimates suggest that at least 20 of the larger mammal species in the forest zone of Ghana are globally threatened by improper landuse practices (Ntiamoa-Baidu, 1987).

2.8 Wildfire

A wildfire is any uncontrolled fire in combustible vegetation that occurs in the countryside or a wilderness area. Other names such as brush fire, bushfire, forest fire, desert fire, grass fire, hill fire, peat fire, vegetation fire, veldfire, and wildland fire may be used to describe the same phenomenon depending on the type of vegetation being burned. A wildfire differs from other fires by its extensive size, the speed at which it can spread out from its original source, its potential to change direction unexpectedly, and its ability to jump gaps such as roads, rivers and fire breaks. Wildfires are characterized in terms of the cause of ignition, their physical properties such as speed of propagation, the combustible material present, and the effect of weather on the fire.

Fire is a manifestation of burning process that produces light and heat and smoke, flame and ashes. It is the result of chemical reaction "combustion" in which a substance called fuel (dead leaves, twigs, branches etc.) combines rapidly with oxygen in the presence of heat to produce light, heat, ashes and smokes. Wildfire is a term applied to any uncontrolled fire in the natural vegetation and cultivated lands (Barnes *et. al*, 2004).

Wildfires, which were once a rare occurrence, have become annual affairs threatening the sustainability of local and national economics as well as the non-tangible benefits derived from the forest. Smaller size trees and younger plants which constitute the very future of our forest are the most affected by surface fires (Orgle, 1994).

FAO's in 1982/83 assessment indicated 50% of Ghana's vegetation cover destroyed by fire. Fire has altered the composition and structure of 30% of semi-deciduous forest in Ghana Over 4 million cubic meters of exportable timber lost in 1982/83 fires. Fire is presently the greatest threat to the integrity of forests in Ghana. The germination of many weedy forest species in Ghana (*Momordica charantia* and secondary forest species e.g. *Ceiba pentandra* found in the fire zone sub type of the Dry Semi-deciduous Forest are favoured by burning (Hall and Swaine, 1981)

In Ghana, wildfires have become a major cause of forest cover loss and decline in agricultural crop production since the 1983 wildfires ravaged the semi-deciduous forest zone (Hawthorne, 1994; Nsia-Gyabaah, 1996). The use of fire in slashes and burn agriculture has been seriously criticized and blamed for the high incidence of wildfires.

According to Amissah, (2008) wildfire incidences in Ghana have been strongly linked with agriculture. To effectively management wildfire incidence it is important to understand the role fire plays in livelihood activities especially farming from the perspective (indigenous knowledge) of the local people.

2.8.1 Types of wildfire (forest fire)

Forest fires can be divided into three main classes (Trollope *et al.,* 1991). The three main fires are Ground fires, Surface fires and Crown fires.

2.8.1.1 Ground fire/Subsurface fires:

These fires normally burn on or beneath the forest floor. There is seldom a flame but instead a steady, smoldering, marked by a block spread of heat. The burning involved duff (topsoil particularly layer with fallen and decayed leaves, twigs, small animals and soil microbes), fallen or decayed woody materials at a depth that may vary from 8-10cm in dry areas to 1m in wet areas (Barnes *et. al.*, 2004). Ground fires are often difficult to deal with quickly, since it is difficult to locate the exact position of the fire. They are likely to reoccur unexpectedly after the area is apparently safe.

2.8.1.2 Surface fires:

The surface fires burn on and above the forest floor (excluding crown of trees). Fires normally involve debris, vegetations, windfalls, brush, slash, saplings, lower branches of standing timber and terrestrial animals. Forest growth up to 7.5cm may be affected (Barnes *et. al.*, 2004).

2.8.1.3 Crown fires:

Crown fires burn in the upper foliage and crowns of standing trees in conjunction with surface fires. In some cases, running crown fires may develop. These are fires which travel through the canopy ahead of the surface fires and is generally carried by wind (Barnes *et. al.*, 2004). Crown fires can also be classified into low crown fires and high crown fires. Low crown fires burn the lower branches and destroy smaller trees while high crown fires burns both lower and upper canopies and are very destructive.

2.9 Causes of wildfires

The use of fire in slashes and burn agriculture has been seriously criticized and blamed for the high incidence of wildfires. Slash and burn agriculture involves about 500 million people and affects about 240×106 ha of closed forest and 170 ×106 ha of open forest in the tropics (Goldammer, 1993). This is approximately 21% of the total tropical forest area (FAO/UNDP, 1982). Hence, many people with diverse professional backgrounds and interests blame fire use in agriculture for the rapid vegetation and soil degradation in the tropics (Greenland, 1975; Korem, 1985).

Although the criticisms on the use of fire in agriculture has been persistent, fire usage in agriculture appears to exacerbate. Regrettably, alternative methods to the use of fire have not benefited much from research and scientific innovations. Jansen (1995) argues that scientists' views on burning are inconsistent. For example, while burning is often condemned in peasant farming systems, experiments are being conducted into the use of fire as a new technique for clearing weeds and pests from fields, and stimulating plant growth in the United States of America. Hence, the problems involved in burning relate to the conditions under which it is used, the cultural practices and rationality of its use and not the actual technology of burning or not burning.

In Ghana the effects of wildfire on rural livelihoods and on the ecosystem are increasingly becoming extensive and damaging. However, it has been difficult to reduce or completely eliminate wildfire.

The difficulties of eliminating wildfire completely means that there is need for a clear understanding of the causes and effects of wildfire so that wildfire policies can address the undesirable effects with respect to forestry, arable agriculture, rangeland, soil conservation and wildlife(Nsiah-Gyabaah, 1996).

The causes of bushfires (wildfire) worldwide can be placed into two groups: natural causes and those caused by human activities (Nsiah-Gyabaah, 1996,).

2.9.1 Natural causes

The evidence of natural fires has been found in carboniferous coal deposits of 400 million years ago and in the tertiary deposits of brown coal. Lightening was the main cause of these fires before the advent of humans. Meteorites were ignition sources and falling igneous rocks from volcanic eruptions undoubtedly caused local fires then as they do today. Lightening is estimated to cause about 50,000 wildland fires worldwide each year (Burton *et al.*, 1998).

Also, in the United States, in 1987, the Klamath and Stanislaus national forest in northern California had two of the biggest fires due to a three-year long drought and winter of no snowpack. Lightning strikes accompanying dry thunderstorms ignited over 900 fires, destroying the forest (Fuller, 1995).

However, these natural causes are most common in Europe and America but as far as Ghana is concerned, there are no records on wildfires, which originated from the natural causes.

2.9.2 Human causes

Wright and Bailey (1982) stated that humans have been a major source of ignition, having used fire for various purposes during the past 20,000 years.

Barnes *et. al.*, (2004) confirmed this fact that, wildfire in Ghana is usually caused by two main human causes; these are the inherent causes and human activities. Inherent cause includes: negligence, ignorance, arson, accident, traditional, culture and belief. The activities associated with wildfire are farming, hunting, palm wine tapping, charcoal burning and honey harvesting.

According to Nsiah-Gyabaah, (1996) there are many factors and causes of uncontrolled wild fires. Among the natural and anthropogenic causes of bushfires, it appears that human activities, especially in agriculture (including farming, hunting, livestock production and others), are the primary causes of indiscriminate and uncontrolled wild fires in Ghana.

2.9.2.1 Farming activity

In the forest ecosystem, fire is practically the cheapest means available for clearing slash and felled trees from fields to create a larger planting area for crops. Burning is essential for a good crop with minimum of labour. Farmers share the opinion that when the vegetation is burned, large quantities of nutrient-rich-ashes are deposited on the soil surface which provides the newly planted crops with the benefits of the biomass that has grown on the site. This observation is supported by studies which confirm the availability of nutrients (e.g., ash) for growing plants (Nsiah-Gyabaah, 1996).

In farming, fire is also used to remove biomass from cleared land, get rid of unwanted residue, manage shade and also for cooking food on the farm (FORIG, 2003).

2.9.2.2 Hunting

Hunting is also an important economic activity in the forest ecosystems, and most hunters set fires to drive out game in hunting. In Ghana, using fire in hunting is mainly used to smoke out the game, to remove animal hair, roast the meat and light cigarette to keep hunters awake. Therefore, problems arise from the lack of alternative sources of protein/meat and wildlife by-products. They also result from ignorance of better techniques of hunting. Since meeting protein needs of households' leads to misuse and abuse of fire, incentives should be given to individuals who engage in activities which promote livestock productive to produce more meat so as to reduce the pressure on wildlife (Nsiah-Gyabaah, 1996).

2.9.2.3 Palm wine tapping and honey harvesting

Fire is used to control pest, prevent rottenness of the palm tree, and ensure better taste and to increase yield of the wine during palm wine processing (FORIG, 2003). It is also used to move bees away for easy honey harvesting.

2.9.2.4 Charcoal burning

Other man made causes of wildfires in Ghana include; charcoal burning, gathering of dry firewood and cooking on the farm, burning of pastures and logging (Korem, 1985). Firewood collection and charcoal production are in most cases the major products of the forests in Ghana (Palo and Yirdaw, 1996). The use and demand for these products keep increasing (Foli *et al.*, 2009). It is estimated that about 91 % of total round wood produced is used for firewood and charcoal production (Teye, 2005). Fuel wood and charcoal account for more than 75 % of all energy needs of Ghana and a high percentage of both rural and urban households use them for cooking and water heating purposes (FAO, 2006). In 2005, fuel wood accounted for 28,253,000 m^3 of the total of 29,458,000 m^3 of wood products removed from the forests (FAO, 2006). This value was more than the total volume of wood products extracted from the forests in 2000 (FAO, 2006).

2.10 Fire regimes

Fire regime refers to the nature of fire occurring over long periods and the prominent immediate effects of fire that generally characterize an ecosystem.

Classifications of fire regimes can be based on the characteristics of the fire itself or on the effects produced by the fire (Agee 1993). Fire regimes have been described by factors such as fire frequency, fire periodicity, fire intensity, size of fire, pattern on the landscape, season of burn, and depth of burn (Kilgore, 1987). The detail of a classification determines its best use.

In other words the burn severity describes the degree to which a site is altered or disrupted by fire, and is the product of fire intensity (heat) and residency (duration).

However, three factors, frequency, intensity and fire types are the most important characteristics of fire regimes (Chandler *et al.,* 1983).

2.10.1 Frequency

Fire frequency refers to the recurrence of a fire in a given area over time. The return interval is the average number of years between successive fires. Frequency is also expressed as fire cycle; the length of time required to burn over an area equal to that under consideration. Fire frequency affects the floristic composition of ecosystems by selecting the species that will comprise of the vegetation of an area. A species cannot survive if fire occurs too often, too early, or too late in its life cycle. In other words fire can be irregular in frequency, intensity, severity and burning pattern. These characteristics are primarily controlled by climate, fuel accumulation and flammability, soil water and especially topography. In addition, fire frequency varies depending on the dryness of the vegetation, how much lightening there is locally, and on factors such as slope, exposure, and altitude (Chandler *et al.,* 1983).

In some areas interval between two fires could vary from less than 100 years to a maximum of 500 years whereas in some areas there may be only a few years between fires (Burton *et al.,* 1998).

2.11 Wildfire effects on vegetation

This encourages the growth of perennial grasses with underground stems but kills or damages many trees, resulting in poor form of trees. Seeds of certain species are stimulated to germinate when treated by fires. Others are killed by heat.

However, uncontrolled fire has become one of the main environmental issues facing the global community, and in fact, the most important global disturbances, considering the observed effects it has on land area and biodiversity. At global level an estimated 150 to 250 million hectare of the recorded 1.8 billion hectare of tropical forests are affected by wildfire annually. Many mature and immature forest trees are killed by high intensity fires annually. In the Amazonian forests for instance, wildfire has been reported to cause high mortality in many useful species with the rate ranging between 36-96%. Consequently fires affect timber supplies from which income and other livelihood needs are generated for the majority of people, particularly, in developing countries.

It was estimated by Goldammer, (1988**)** that the total area burnt or cleared (all ecosystems worldwide) amounted to 630 to 690 million hectares per year and more than 98% of burnt and cleared area is in the tropics and subtropics.

Wildfires destroy vegetation and open up forest canopy which also lead to the invasion of shrubs and grasses like *Chromalaena odorata, and Panicum maximum*, as well as climbers and severely reduce the productive capacity of the forest in all the agro ecological zones of Ghana.

Statistics at the forestry sector reveals that the annual loss of revenue from merchantable timber to wildfire is about US$24 million. The cumulative effect of wildfires is an annual loss of 3% of Gross Domestic Product (GDP) estimated at about US$210 million. Although the devastating effects of wildfires are felt by all, it is the poor who are particularly at risk because they depend directly on land for their livelihood and often live in fragile ecosystems (ITTO, 2002).

In Ghana, (one of the leading exporters of timber in Africa), for instance, wildfires caused more than 4 million m^3 of exportable timber in losses between1982-1983. An estimated annual loss of 3% of GDP was recorded for the past two decades, due to wild fires.

2.12 Effects of wildfire on forest fauna

In forests where fire is not a natural disturbance, it can have devastating impacts on forest vertebrates and invertebrates – not only killing them directly, but also leading to longer-term indirect effects such as stress and loss of habitat, territories, shelter and food. The loss of key organisms in forest ecosystems, such as invertebrates, pollinators and decomposers, can significantly slow the recovery rate of the forest (Boer, 1989).

Wildfires may also kill or injure young and nursing mothers, eggs, and nursing site and finally exposes animals to hunters and predators. A very hot wildfire that destroys extensive areas of natural forest or burns up natural prairies can have a negative effect on wildlife. The destruction of standing cavity trees as well as dead logs on the ground has negative effects on most small mammal species (e.g. tarsiers, bats and lemurs) and cavity-nesting birds (Kinnaird and O'Brien, 1998). Fires can cause the displacement of territorial birds and mammals, which may upset the local balance and ultimately result in the loss of wildlife, since displaced individuals have nowhere to go.

Estimates from the 1998 fires in the Russian Federation suggest that mammals and fish were badly affected. Mortality of squirrels and weasels, estimated immediately after the fires, reached 70 to 80 percent; boar 15 to 25 percent; and rodents 90 percent (Shvidenko and Goldammer, 2001).

However, studies showed by FORIG (2003) in Ghana that, hunters and farmers think that species like the grasscutters and giant rats do benefit from forest fire, whereas, others such as monkeys, reptiles, duikers, red river hogs and other slow moving terrestrial animals (e.g tortoise) are killed by fire. In short, real forest species seldom survive forest fire in most times. They die out of burns or smoke inhalation.

2.13 Wildfire effects on soil

The soil is the basic natural resource of agriculture and silviculture. The way soil is managed determines in large part its productivity for human purposes. Unfortunately, immediate needs take priority over long term soil conservation and what is convenient today could be damaging in the long term, especially with reference to burning. Annual burning accelerates runoff and erosion due to the soil exposure after burning .Early burning may also encourage wind erosion. Although there are contradictory results, burning appears to reduce the humus content of the soil. Early burning is less destructive. Nonetheless, fire is not always damaging and its effects on the soil depend on certain specific factors. These are: Chemical properties, nutrient losses and availability and organic matter (Wells, 1979).

2.14 Chemical properties of soil

Wild fires affect the chemical properties of soils by ashing the organic materials contained in the above ground vegetation. The immediate impact of burning on soil nutrients is conversion of much of the organically bound nutrients in the forest floor, woody debris, and herbaceous vegetation into their inorganic forms. Whether these inorganic nutrients remain on site as solids or are lost through volatilization depends upon the temperatures reached during the burning and the differential volatilization temperatures of the nutrients (Wells, 1979).

2.14.1 Nutrient losses and availability in the soil

Fire has variable effects on nutrient availability in soils, sometimes mobilizing nutrients, inducing deficiency or causing no effect. Most changes in nutrient availability result from two different processes; (1) in-situ changes, and (2) translocation of organic substances downward into the soil. In general, burning increases the available nutrients in the surface soil with the possible exception of nitrogen. Some studies report significant nitrogen loss, but others report small losses or no effect. In general, fire increases nutrient availability at the soil surface. These nutrients are derived from ashes resulting from burnt vegetation and from the combustion of surface organic matter (Traubaud, 1983).

2.14.2 Organic matter

Loss of organic matter is one of the most important effects of fire on soils. Physically the surface organic matter is a protective layer and the organic matter on the mineral soil improves water relations. The loss of surface organic accumulations depends, upon fire duration, intensity, and fuel moisture. Severe fires can remove up to 50cm of organic matter over rock on dry site (Wells, 1979).

2.15 Wildfire effects on agriculture

Wildfires do not destroy forest in Ghana but also agricultural fields. The Food and Agriculture Organisation (FAO) assessment during the 1982-1983 fires in Ghana showed that about 35% (154,000 metric tonnes) of standing crops and stored cereal were destroyed by bush fire (Ampadu-Agyei, 1988). In 1984-85, about 145 bushfires were reported in the northern savanna zone alone. The crops most affected were rice and maize. The average size of farms affected was 50 ha, with the largest covering about 10 ha (Nsiah-Gyabaah, 1996).

2.16 Wildfire effects on economy

Each year fire burns between 6 and 14 million hectares of forest, about half of this in the tropics. The resulting amount of forest loss and degradation is of the same order of magnitude as that caused by destructive logging and conversion to agriculture. Fires thus have the potential to significantly affect the capacity of forests in the tropics to provide goods and services including tropical timber on a sustainable basis. This is having a major impact not only on timber industries but also on rural communities whose livelihoods depend on the forests (ITTO, 2002).

In Africa and Asia, even though in some case wild fires had been ignited for apparently no valid ecological reasons, the use of fire had been and is still an integral part of land use and livelihood systems. Fire is used for field preparation in slash-and-burn agriculture on which majority of the rural people depends to meet energy and food needs. However, wildfire is perhaps the most important single threat to the integrity of forests in Ghana. In recent years, Ghana has lost an ever-increasing percentage of its Gross Domestic Product (GDP) to the indiscriminate ravages of wildfires. It is also the direct cause of irreversible environmental damage in Ghana. In certain areas of the country the process of desertification has been hastened due to wildfires, which have permanently destroyed delicate but vital organic soil material. At present, most fire affected areas show progressive degradation. A number of Forest Reserves, which were formerly tall, dense tropical forest, rich in biodiversity have become grasslands with scattered fire-damaged relict canopy trees (Ministry of Land and Forestry, 2006).

2.17 The effect of fire on general environment

Wildfires have different impacts on different parts of the environment. And before formulating restrictions as to the practice of burning, it is important to study in detail the impact of fire in the environment and the consequences of its elimination.

Restrictions on burning in the Twentieth Century resulted in changes in many ecosystems, with an increase in brush land, along with the accumulation of ground fuels, both green and dry, which increased the risk of large and damaging wildfires out of control (Long, 2006).

For purposes of discussion, the effects of fire on the environment are separated into the following areas of impact:

• Fire effect on air quality

• Fire effect on rainfall

• Fire effect on Climatic change

• Loss of biodiversity

2.17.1 The effect of fire on air quality

In a public opinion survey in St. Louis, USA, it was found that 40% of the people associated air pollution with smoke, but just 14% thought that vehicle emissions were the cause of air pollution. In other words, "the more visible, the more dangerous" (Shusky, 1966). According to Mikell (1971) the most important cause of air pollution is vehicles followed by agricultural and forest fire.

Another of the crucial contaminants of the air is nitrogen oxide. For its formation, nitrogen oxide requires temperatures at least 1.450°C, which are seldom reached during a forest fire (Komarek, 1970). In 2001, Dr. Stanhill, an Israeli researcher, discovered a phenomenon that shows that the amount of sunlight penetrating to the surface of the earth is decreasing. He calculated that the intensity of sunlight is diminishing between one and two percent per year, as a global average (Sington, 2005). This phenomenon was given the name of *global dimming*. The effect appears to be the result of environmental pollution caused by humans during burning of the vegetation.

Other researchers in other parts of the world have found evidence that supports the theory of Dr. Stanhill. Particles of soot, ash, sulphur compounds and other compounds appear to be the cause of global dimming. The most important pollutant of wildfires and burning is visible smoke, which is principally a mixture of particulates and water (USDA Forest Service, 1989).

2.17.2 Fire effect on rainfall

The impacts of forest fires and the resulting loss of forest have been linked to a reduction in rainfall and increased effects of the drying North-easterly winds from the Sahara (harmattan). A reduction in the area of coastal rainforests might have the additional effect of reducing the amount of rainfall heading inland to the drought prone countries of West Africa. With a rural economy mainly based on fire and agriculture it may be difficult to remove wildfire from the West African landscape in the foreseeable future (Orgle, 2003).

2.17.3 The effect of fire on climate change

The United Nations Framework Convention on Climate change (UNFCCC) defines climate change as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. The atmosphere contains gases such as water vapour, carbon dioxide, methane and other gases, which trap some of the outgoing heat energy from the sun thereby retaining heat within the earth's atmosphere. This maintains an average global temperature balance of 60^{F}, without which would have resulted in very cold atmospheric temperature, perhaps not suitable for human habitation. However, what has aroused concern is the increasing amount of these atmospheric gases, which have enhanced the heat-trapping potential of the earth's surface. The consequential effects are increases in the earth's surface temperature, sea level rise, more precipitation, droughts and floods. These in turn have impacts on human and natural systems brought about by human activities which have a dual effect on increasing greenhouse gas emission at the same time have a direct effect on human and natural systems.

Clearing land for urban development and agriculture now adds more carbon dioxide to the atmosphere each year than is being absorbed by living plants and these estimated to be between 1 to 2 billion tonnes of carbon a year or more, according to the Intergovernmental Panel on Climate Change (IPCC). Most of these emissions are thought to come from tropical forests.

More forest fires outbreaks could shift large amounts of the carbon stored in living things to the atmosphere where it could make climate change worse. In fact, some models project up to two billion extra tonnes of carbon ending up in the atmosphere as a result of forest decline (Intergovernmental Panel on Climate Change, 1995).

Forest fires in Indonesia have dragged the attention of the international community because of their environmental, social and economic consequences. They have large negative impacts on local and national development as they directly affect biodiversity, the livelihood and health of local people, and can also negatively affect infrastructure, transport and the forest industry. They also emit a large amount of green house gases: fires in 1997-1998 made Indonesia one of the largest emitters of greenhouse gases in that year, as they released more than 700 million metric tonnes of CO_2 into the atmosphere (Applegate *et al*., 2002).

Climate change matters to the poor in Ghana because it would increase the vulnerability of this group by adversely affecting their health, livelihood and undermining growth opportunities crucial for poverty reduction. In many poor countries like Ghana, Climate change will significantly aggravate water stress, reduce food security, increase impacts from extreme weather events, displace millions of people (due to floods and sea level rise) and potentially increase the transmission of vector – borne diseases. Unfortunately, IPCC assessments reports illustrate that in general developing countries are most likely to suffer the negative impacts of climate change. This therefore calls for adaptive strategies to reduce the vulnerability of Ghana in other to achieve the GPRS goals (IPCC, 1995).

Although, statistical data on incidence and impact of wildfire are inadequate, it has been estimated that the total land area prone to wildfire annually ranges from 30% in the High Forest and Transitional Zones to over 90% in the Dry Northern Savannah Zones. An assessment of Ghana's vulnerability to climate change carried out recently by Environmental Protection Agency (EPA) indicated that carbon dioxide (C02) accounted for the largest share of Ghana's greenhouse gas emissions. The increasing levels of C02 were principally attributed to the removal of woody biomass stock and emissions from fuel combustion, which are basically the result of annual wildfires.

When the current trends continue then within the next decade, the annual temperature is going to rise by 2.50C whilst annual rainfall will decrease by 170 mm. This will lead to a decrease in crop yield thereby undermine food security in the country and worsen poverty (Intergovernmental Panel on Climate Change, 1995).

2.17.4 Effect of fire on Losses of biodiversity

The world is currently experiencing an unprecedented loss of biological diversity. The local and global extinction of species of plants, animals, fungi and microbial organisms, that we are witnessing on this planet constitute a major environmental problem that requires urgent attention.

Forest fires destroy large forest areas that serve as habitat for biodiversity. They directly eliminate plants and animals and also result in forest degradation that leads to a decrease in the survival rate of the species.

These forest reserves are important areas which have suffered from neglect and rampant bushfires over the years, a situation which poses serious threats to its biodiversity. The use of bushfires as a major tool for clearing agricultural land (e.g. shifting cultivation) in most African societies, including Ghana (Hall & Swaine, 1981; Korem, 1985), has resulted in intense burning and grazing of grasslands leading to habitat fragmentation and changes in vegetation height and density. Over the long term, bushfires pose very serious threat to biodiversity conservation in Ghana (Gboloo, 1998).

2.18 Wildfire management

Fire is the greatest risk to the success of any forest reserve. Fire management incorporates efforts to maintain fire within a desire fire regime (Schweithelim, 1999). Fire management is employed to reduce fire risks and will focus on four main axes: fuel load reduction, fire breaks, establishment and training of a fire squad, and awareness rising on the risks of fire for local people.

There are many model and approaches which have evolved worldwide about fire management systems. FAO, 2009 defines fire management as the discipline of using fire to achieve land management and traditional use objectives, together with the safeguarding of life, property and resources through the prevention, detection, control, restriction and suppression of fire in forest and other vegetation in rural areas. Managing forest fires is a complex task due to a wide range of issues bordering on prevention, pre-suppression and suppression/control (FORIG, 2003).

2.18.1 Fire prevention

This is the first step towards protecting forest reserves and off-reserves from devastating effects of fire (Ninnoni *et al.*, 2003). FAO, (2006) defined fire prevention as all measures in fire management, fuel management, forest management and forest utilization concerning the land users and the general public, including law enforcement, that may result in the prevention of outbreak of fires or the reduction of fire severity and spread.

Chandler *et al.*, (1983) stated that successful fire prevention activities should include three components; education, law enforcement and engineering. However, in Ghana, fire prevention programmes are carried out in fire management includes; law enforcement, talk shows, mobile van education, leaflets, pamphlets and community durbars (Ninnoni *et al.*, 2003).

The importance of this operation is the fact that it serves as the most cost- effective and efficient mitigation programme an agency or community can implement (FAO, 2006). This is also said to be much safer than fire suppression and need to be strongly emphasized for successful fire management programmes (Ninnoni *et al.*, 2003).

2.18.2 Fire pre-suppression

Fire pre-suppression activities are undertaken prior to fire season. These pre-fire season activities involve cooperation action with collaborators, contractors and organization in support of fire management (FAO, 2006).

The objective of fire-suppression management is to plan and prepare for fire suppression activities prior to their occurrence (Ninnoni, *et al.*, 2003). The following pre-suppression preparations are carried out (Ninnoni, *et al.*, 2003).

2.16.2.1 Awareness raising

Traditionally, people have used fire as a means of clearing land and hunting. Though a fire may boast soil fertility for a short period, the reduction of organic matter to ashes has profound negative effects on soil organic matter, soil fauna and soil flora and through this on soil water holding capacity and fertility.

It would also be proper to explain the principles of fire fighting to the people in the surrounding villages in cooperation with agricultural extension agencies. The aim is that people will see how they can profit from developing agricultural systems which focus on soil organic matter, fire prevention and improved fallow. If successful, the overall risk of fire will be greatly reduced.

2.18.2.2 Early burning/ Fuel load reduction

Early burning as a pre-suppression measure is used as fuel management tool where an area is burnt under controlled conditions in order to reduce the fuel available for late burning when conditions are favourable for wildfires Ninnoni *et al.,* (2003).

The management of the reserve, plantations and the cooperation with farmers (intercropping system) assures regular weeding and the removal of combustible biomass during the dry season. After canopy closure the shade of the trees will repress undergrowth. This way the fuel load will not be allowed to build up and the risk of fire spreading through the area is greatly diminished.

The importance of early burning according to *Ninnoni et al.,* (2003) is that the fire intensity is low so the impact on young trees and soil fauna are minimal.

2.18.2.3 Green fire breaks

Green fire breaks have been identified as one of the most effective pre-suppression measures to ensure the containment of wildfires.

Fire breaks will be installed around the peripheral as well as within compartments of the reserve so eventual fires can be contained. Fire breaks will be sufficiently wide to prevent the fire from leaping over them. Fire breaks will be at least 10 metres wide (depending on circumstances) and will be planted with evergreen trees and crops (e.g. *Cassia siamea* and food crops).

According to Ninnoni *et al.,* (2003), the advantage of green firebreaks is that they are cheap to establish and maintain since the approach normally is to use local communities to plant the firebreaks.

2.18.2.4. Fire squad

It is obvious that though physically the risk of fire occurrence can be reduced we will have to keep watch during the risk season. For this purpose the staff will be trained in fire prevention and combat. These people will patrol the reserve throughout the dry seasons. In case of fire they will warn all people in the vicinity and organise the workers to extinguish the fire. If necessary, pickup carrying water must be standby during this season.

2.18.2.5 Fire Suppression

Barnes et al., (2004) defined fire suppression as all the work and activities connected with fire extinguishing operation, beginning with discovery and continuing until fire is completely extinguished. This is based on the ability of well trained and equipped fire crew to safety and rapidly respond to a wild fire within a certain time limit and be ready to respond again (Sanders, 2003).

The objective of fire suppression is to contain and control fire at minimum cost consistent with land and resources management objectives (Barnes *et al.,* 2004). Based on this objective, three basic fire suppression methods, which are used to confine or control fires in wildland areas. This includes direct attack method, indirect attack method and parallel attack method.

2.19 Biodiversity conservation

Human activities are changing the Planet, inducing high rates of extinction and a worldwide depletion of biological diversity at genetic, species, and ecosystem level. Biodiversity not only has an ethical and cultural value, but also plays a role in ecosystem function and, thus, ecosystem services, which are essential to civilization, economic production, and human wellbeing. The functional role of biodiversity is still poorly known; a minimum level of biodiversity is required for sustainable preservation of ecosystem functions, and as insurance for future environmental changes.

2.20 Conservation measures

Biodiversity loss is one of the world's most pressing crises with many species declining to critically low levels and with significant numbers going extinct. At the same time there is growing awareness of how biodiversity supports human livelihoods. Governments and civil society have responded to this challenge by setting clear conservation targets, such as the Convention on Biological Diversity's 2010 target to reduce the current rate of biodiversity loss. In this context, *The IUCN Red List of Threatened Species* (hereafter The IUCN Red List) is a clarion call to action in the drive to tackle the extinction crisis, providing essential information on the state of, and trends in, wild species.

2.20.1 IUCN red list

The IUCN Red List Categories and Criteria are widely accepted as the most objective and authoritative system available for assessing the global risk of extinction for species (De Grammont and Cuarón 2006, Lamoreux *et al.* 2003, Mace *et al*. 2008, Rodrigues *et al.* 2006). The IUCN Red List itself is the world's most comprehensive information source on the global conservation status of plant and animal species. It is based on an objective system allowing assignment of any species (except micro-organisms) to one of eight Red List Categories based on whether they meet criteria linked to population trend, size and structure and geographic range (Mace *et al*. 2008).

The rich biodiversity of Ghana is presently under threat from both natural and human influences. According to the Red List of Threatened Species, 103 plant species are listed as under threat (IUCN, 2001). There are a total of over 3600 plant species in Ghana (MOES, 2002). These represent three major taxonomic groups, which comprise over 2,900 indigenous and 250 introduced species. Forty-three (43) species are endemic. All this information allows scientists to undertake detailed analyses of biodiversity across the globe.

2.20.2 Working in partnership

The IUCN Red List is compiled and produced by the IUCN Species Programme based on contributions from a network of thousands of scientific experts around the world. These include members of the IUCN Species Survival Commission Specialist Groups, Red List partners (currently Conservation International, Birdlife International, Nature Serve and the Zoological Society of London), and many others including experts from Universities, Museums, research institutes and nongovernmental organizations. Assessments can be done by anyone and submitted to IUCN for consideration. Assessments are impartial and are developed and approved based on their scientific merits without consideration of their policy implications. (Salafsky *et al.* 2008)

2.21 Conservation in Ghana

Ghana is part of the Upper Guinea forest ecosystem region of West Africa, which contains exceptionally diverse ecological communities of forest habitat providing refuge to numerous endemic species. Ghana is also considered one of the world's top priority regions for conservation because of its high endemism of flora and fauna. This area is one of the world's 25 biological richest and most endangered terrestrial eco regions. However, a variety of socio-economic factors have led to forest fragmentation which threatens the variability of biodiversity in the country. The overall forest ecosystem of the region covered approximated 420,000 square kilometres but estimates of existing forest suggest a loss of nearly 80 percent. The study area of Ghana has many unique biological features which make it important for conservation. Although the existing forests are heavily fragmented, and this presents a tremendous opportunity for species conservation due to the existence, of a relatively high capacity for conservation and the absence of civil conflict (Allotey, 2007).

2.21.1 Importance of bio-conservation in Ghana

In Ghana, as in many other countries, people associate biodiversity with the direct economic values that can be derived from it. To some extent, there is appreciation for its indirect use value with regards to ecological and environmental functions of watershed and catchment protection, erosion control, carbon sequestration, air pollution reduction and soil fertility restoration by forests and trees (Tutu *et al.,* (1993).

In the conservation and use of biodiversity in Ghana, little premium is put on its option existence values. This is the result of the growing demand of people to satisfy present socioeconomic needs by exploiting resources at rates and levels that jeopardize the system's ability to sustain these rates and levels. In addition, the entire spectrum of biodiversity values is unknown to many Ghanaians given also that the mode of value assessment is generally cumbersome, unreliable and unsophisticated. Tutu *et al.,* (1993) conservatively estimated the annual cost of deforestation and land degradation to the Ghanaian economy at about 4% of Gross Domestic Product, approximately US $54 billion.

2.21.2 Threats to Biodiversity in Ghana

Threats to biodiversity in Ghana include bush meat trade, agricultural expansion, commercial logging and mining, extraction of non-timber forest products. Ghana was once renowned for its extensive forests and wooded savanna, but the situation has changed drastically. Tropical moist forest originally extended over 145,000 km^2 of Ghana. By the turn of the country it was estimated that 88,000km^2 forests remained, occupying 35% of the total land area. Between 1938 and 1981 the area of closed forest in Ghana was reduced by 64% from 47,000km^2 to 17,200km^2 and open woodland declined by 37% from 111,000km^2 to 69,000km^2. The current area of intact forest is now estimated at between 10.9 and 11.8% of the original cover and 6.9% of the country's total area. The current rates of deforestation average 22,000 ha/annum or about 1.3 %(Allotey, 2007).

Desertification is largely brought about through deforestation resulting from farming practices and fuel wood collection and is now a major concern threatening the study area (Allotey, 2007).

2.21.3 Conservation policies adopted in Ghana

The Forest and Wildlife Policy of Ghana aims at conservation and sustainable development of the nation's forest and wildlife resources for maintenance of environmental quality and perpetual flow of optimum benefits to all segments of society.

Again, like many other tropical countries, the loss of Ghana's natural forests has been counteracted by comprehensive reform programmes in the forestry sector (MLF, 2006) and on the micro level; forestry in Ghana is permeated with biodiversity conservation measures. The following are some examples (Hawthorne and Abu-Juam, 1995):

(a) When preparing forest management plans (working plans) in the production forests, every 20th compartment is left unlogged.

(b) The royalty rate structure has, since at least 1988, been used to steer logging away from the overused species by adding a 'penalty' to the rate per cubic metre payable for those species by concessionaires.

(c) When log export bans were introduced for one species after the other, beginning in the 1980s, it was first for the threatened species.

(d) When additional export levies were recently introduced on air-dried processed timber, it was only on nine species considered threatened.

(e) Where the stocking of a coupe to be harvested is less than the average stocking per km2 derived from the national inventory for the vegetation type in question, no logging is allowed. The rule is intended to prevent over-exploitation.

(f) Any species with an abnormal frequency distribution may not be harvested without a special permit.

(g) When surveying land for possible establishment of plantations, 21 indigenous tree species are singled out for protection: 'The presence of any of the following species should be recorded in the field books, and their approximate location marked on compartment sketch maps. These species have been identified by the Botany Unit of the Planning Branch as having particular conservation value. Even individual trees may be an important genetic resource.' (Forestry Department Planning Branch, 1995)

(h) Certain very rare species, called 'black star species' in Ghana, may not be harvested at all, and a 100-meter wide buffer zone should be established around them in which no felling, skidding or roading will be permitted (FD Planning Branch, 1995, Instruction Sheet D5, Para 5.8).

(i) Four species may only be logged with special permit, and during the pre-logging stock survey enumeration these species – if their diameters are bigger than the minimum felling limit – should be marked in the field book and on the bole with a 'P' (FD Planning Branch, 1995, Instruction Sheet D2, Para 7.4).

Another very relevant measure taken in this context in Ghana has been the building up of an exceptionally large data base. Three very comprehensive surveys have been carried out in the high forest zone of Ghana by the Government with the support of the DFID, namely a conventional forest inventory, a non-timber forest products inventory, and a botanical/ecological survey. Their purpose was:

(a) To assess the amount of timber and its future potential;

(b) To provide a picture for management purposes of the distribution of biodiversity in Ghana's forest reserves; and

(c) To estimate the abundance and degree of use of non-timber forest products.

Many of the previously mentioned measures linking sustainable production to biodiversity conservation were based on information obtained from those surveys.

In spite of all the previously mentioned efforts by the Forestry Department, Ghana's forests are under threat. The comprehensive botanical/ecological survey showed that although the borders of the old reserves have indeed been remarkably well preserved, the quality of what is inside those borders has deteriorated (Hawthorne and Abu-Juam, 1995.)

2.22 Fire policies

In the past, a number of legislations were passed to address and manage wildfires in the country. However, the absence of a clear-cut national policy led to ad hoc and uncoordinated planning, inconsistencies in the implementation and poor enforcement of wildfire laws. The resultant effect has been increasing incidence of wildfires over the years leading to severe environmental degradation and widespread poverty.

Therefore, to conserve, enhance and protect the natural environment from uncontrolled fires, it is important to have a comprehensive national policy, which will give a more proactive, pragmatic and comprehensive framework to guide and determine government actions towards wildfire management. The policy will also ensure consistency in formulation of legislation and bye-laws at all levels of governance to deal with the issues of wildfires in the country. In addition, by developing a national policy on wildfire, Ghana will be addressing global concerns for environmental quality management, and minimise risks from climate change. Example of some legislations and laws enacted in Ghana which do not eliminate wildfires completely include the followings:

2.22.1 PNDCL46 (1983) -Control of Bushfire Law

This law was enacted to control bushfires in the country. However, the law failed to make provision for implementation arrangements in terms of responsibilities for governmental agencies and roles for communities and Traditional Authorities. In addition, fines and penalties prescribed under the law were not deterrent enough and hence the law did not achieve the desired results.

2.22.2 P.N.D.C.L 229 (1990) - Control and Prevention of Bushfire Law

This law, which replaced P.N.D.C.L 46, was an improvement over the 1983 law in assigning functions to the District Assemblies and making provision for the establishment of Village Fire Volunteer Squads. Nevertheless, it did not provide a comprehensive framework for addressing the wildfire menace in the country.

2.22.3 The Forest and Wild life Policy of 1994 and The Revised Forest and Wild life Policy of 2012

This policy aimed at conservation and sustainable development of the nation's forest and wildlife resources for maintenance of environmental quality and perpetual flow of optimum benefits to all segments of society. However, the policy did not consider wildfire as a major issue in forest management and therefore did not place wildfire management high on the national agenda.

The situation became uncontrollable in 1983 when the country lost most of its natural forests thus marking a turning point towards the adoption of a comprehensive fire management effort in the country. These efforts culminated in the implementation of several donor-funded projects on wildfires, the formation of inter-agency working groups to plan and manage wildfires in the country and the enactment of various policies and legislative instruments to deal with the problem of wildfires.

The Revised Forest and Wild life Policy of 2012

The implementation of the 1994 Forest and Wildlife Policy witnessed significant changes in the structure and form of the forestry sector in Ghana. The sector institutions were transformed into a corporate Forestry Commission in accordance with the 1992 constitution. A number of strategic initiatives were introduced to improve and develop the forest and wildlife resource base; integrate good governance, transparency, and equity and poverty reduction into the forest and wildlife sector. The 1994 policy introduced equitable sharing of management responsibilities; increased benefit flows to local stakeholders, especially the rural poor; and increased participation, transparency and accountability in the sector activities.

However, there is a paradox. The implementation of the 1994 policy with all the associated reforms could not halt the degradation in the forest resource base. Illegal chainsaw and mining (*galamsey*) operations in forest areas have thrived over the years despite conscious national efforts to curb the situation in collaboration with the security agencies. Wood fuel productions especially in the fragile areas of the savanna regions have remained unsustainable whilst wildfires continue to be an annual occurrence in all the ecosystems. The timber industry still operates with obsolete equipment and has installed capacities exceeding the Annual Allowable Cut (AAC).

Besides the challenges inhibiting the attainment of the 1994 Forest and Wildlife Policy objectives, the forestry sector today is also confronted with emerging global issues like the Voluntary Partnership Agreement (VPA), Forest Certification, Climate Change and Reducing Emissions from Deforestation and forest Degradation (REDD) which have far reaching implications for the forest and wildlife industry as well as local livelihoods.

In keeping with the objectives of the national development agenda, the forest and wildlife sector will have to explore new measures to halt, and reverse the pace of deforestation and forest degradation in Ghana. There are emerging opportunities for sustainable forest financing especially through Carbon Credit schemes which the country needs to take advantage of to develop the forestry sector. In addition, the Civil Society Organizations and the local people are today much better organized and well informed to be mainstreamed into the forestry sector decision-making and resource management.

A revised policy is therefore necessary to take advantage of these emerging opportunities to maximize the rate of social and economic development of thecountry and secure optimum welfare and adequate means of livelihood from the forestry sector to all Ghanaians.

2.22.4 The Ghana National Fire Service Act, 1997 (Act 537)

This is an Act that re-established the National Fire Service to provide for the management of undesired fires and made provisions for related matters. However, the Act was flawed with respect to wildfire management as it was highly skewed towards industrial and domestic fire management. In addition, the Act did not go far enough with respect to empowering local communities and groups to deal with wildfire management issues. Even though the Act advocated for the establishment of community based fire volunteers, it was silent on how logistics could be provided to assist their operations.

Despite the existence of these various legislations, the conservation and management of the country's biological resources still leaves a lot to be desired. The past experience has demonstrated that wildfires cannot be controlled through legislations, bye-laws and annual launching of wildfire control educational campaigns at the central level. The country needs to move away from piece-meal approach to wildfire management to a more comprehensive and sustainable community-based approach. The challenge is how to formulate a national policy that would give direction and change people's attitudes to adopt more sustainable approaches to minimize the incidence and impacts of wildfire.

Poorly planned or inappropriate government policies can have influence on deforestation and forest degradation (Appiah *et al.,* 2009; Blom and Cummins, 2009; Siry *et al.*, 2005; Teye, 2005; Capistrano and Kiker, 1995; Grainger, 1993).

Policies and legislations which create conducive environment to clear forests for other land uses are major drivers of deforestation (Blom and Cummins, 2009; Siry *et al.,* 2005). Deforestation continues to increase in Ghana because successive government social and economic policies including those from the colonial era have directly or indirectly promoted it (Codjoe and Dzanku, 2009; Dadebo and Shinohara, 1999; Kotey *et al.,* 1998). Policies on agriculture particularly cocoa expansion and pricing, land ownership, mining, and forest resources management have had immense impacts on the way forest resources have been managed, exploited and utilized (Dadebo and Shinohara, 1999; Kotey *et al.,* 1998).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 The study area

3.1.1 Legislative Establishment of the District

Tain11 forest reserve is in Sunyani West District of the Brong Ahafo Region of Ghana.

The Sunyani West District is one of the twenty-two Districts of the Brong Ahafo Region of the Republic of Ghana. It was established in November 2007 through LI 1881, 2007, and inaugurated on 29th February, 2008. The Administrative capital of the District is Odomase.

Tain 11 Forest Reserve: Little is known of the history of the Tain 11 Forest Reserve prior to it reservation. However, it was noted that this reserve was established in 1931 and finally constituted in 1934. It covered about 509.20sqkm.

3.1.2 Location and Size

The study area lies between latitude 7º 19´N and 7º 35´N and longitudes 2º 08´ W and 2º 31´ W. It shares boundaries with Wenchi Municipality to the North East, Tain District to the North, Berekum and Dormaa East to the West, Sunyani Municipal to the South East and to the Eastern boundaries of the District are Tano North and Ofinso North District. Sunyani West District has a total land area of 1658.7 square kilometers.

3.1.3 Geology and Soil Type

The area is underlain by the precambian formation of rock believed to be rich in mineral deposits. Soils in the study area fall into the Ochrosols group which is generally fertile and therefore support the cultivation of cocoyam, maize, cassava, cocoa, plantain and yam.

There is also widespread production of legumes, rice and vegetables in areas rich in alluvial soil. The area also has an extensive clay deposit which is being extracted for the production of bricks, tiles, cooking utensils and other ceramics. There are prospects of Gold and other minerals around Chiraa.

3.1.4 Relief and Drainage:

The topography of the study area can be described generally as undulating. The area lies within heights ranging from 700 feet (213.36 metres) to 1100 feet (335.28 metres) above sea level.

The drainage is best described as dendritic with several streams and rivers being seasonal ones. The River Tano provides the most reliable source of water for both domestic and agricultural uses in the lean season. Other rivers found in the district include: River Abisu, River Sise, River Nyinahini, River Ahunyan, River Bisi, River Bore, among others.

3.1.5 Climate and Rainfall:

The climatic zone of Sunyani West District of which the study area is located falls within the Wet Semi-Equatorial region and therefore has two rainy seasons in a year.

The major rains begin in April and end in July and the minor rainy season is from September to October. Average annual rainfall is about 1142.5mm to 1750mm. The abundance of rainfall offers the District a comparative advantage in agricultural production and forestry.

The mean annual temperature range between 21.4 ^{o}C to 31.2 ^{o}C and there is relatively prolonged dry season sometimes lasting from November to March, resulting in annual wildfire incidence.

3.1.6 Vegetation

The area again falls within the Dry-semi deciduous forest vegetation zone with Tain11 forest reserves. This is seen in Fig 2 below. The forest reserve contains timber, wild life, herbs and other valuable resources. Timber species found in the reserve are *Melicia excelsa* (Odum), *Khaya grandifoliola* (Mahogany), *Triplochiton scleroxylon* (Wawa), *Terminalia superba* (Oframo), Tectona grandis (Teak), *Antiaris toxicaria* (Kyenkyen), *Entandrophragma angolensis* (Sapele), Terminalia *ivorensis* (Amire), *Pouteria spp* (Asamfena) and *Ceiba pentandra* (Onyina). These trees are currently rare or absent in the area. The dominant trees now found during the study were *Blighia sapida* (Akye), *Sterculia tragacantha* (Osofo), *Spathodea campanulata* (Kokonisue), *Holorrhena floribunda* (Sese), *Lonchoocarpus sericeus* (Sante) and *Albizia adianthifolia* (Pampana).

Some crops that are cultivated in and outside the reserve include Cassava, Plantain, Cashew nut, Palm oil, Cocoyam Maize, etc. Minerals like gold and diamond are available for extraction in the District. Clay is another natural resource that abounds in the District.

3.2 Socio-economic conditions

3.2.1 Population Size and growth

The villages in the study area has population growing steadily since1970, with the population of the District as a percentage of the region population increasing from 3.8% in 1970 to 4.4% in 2000. Assuming the area had local population increase rate of 3.3% per year, and according to the population and housing census conducted in 2006 saw the study area had the total population of 3,808 people, then the present (2010) population density would be estimated to be some 4,356 people.

3.2.2 Main occupation

According to the data collected during group field survey UDS, (2007), it was realized that the main occupation of the people of the study area is farming. However, there are other occupations like petty trading, hair dressing and others. The predominant farming method is the extensive farming using the traditional slash and burn method. Most farmland is small, that is 2 hectares or less, and the fragmentation of farmland is taking place in accordance with the population increase.

3.3 Threats issues in the study area

In the recent times, the forest reserve in the study area is being depleted through human activities such as agricultural activities, wild fires, indiscriminate felling of trees and settlement expansion and the approaching Sahara desert.

3.3.1 Agricultural activities/illegal farming

The availability of vast land and its high rate of fertility encourages farming activities. This in turn led to a very significant increase in forest clearing with its entailed profound negative environmental, economic and political consequences. Both cocoa and food crops cultivation have contributed significantly to degradation of the rich floristic composition (Attua, 2003). To improve the ecological integrity of the study area for sustainable agriculture, tree-based agro systems that are locally adaptable to the soils of the area may have to replace the current system of farming.

3.3.2 Wildfire problems

The Tain II forest reserve has suffered from wildfires over the years, a situation which poses serious threats to its biodiversity. The use of bushfires as a major tool for clearing agricultural lands reported by (Hall & Swaine, 1981; Korem, 1985) is one of the major causes of wildfire.

3.3.3 Indiscriminate felling of trees

The one activity that has bedeviled Tain II forest reserve which is a major threat to flora conservation is illegal chainsaw operation. This involves the cutting of timber species by people who are either not licensed and or do not have the permit to fell trees for sale either in log or partially processed form. Not only does it threatens to reduce tree biodiversity, but also endangers the livelihoods of the communities, as well as the country. Though the Forest Service Division tries to combat this, the problem still persists in all landuse systems especially fallow lands and annual crop farms. It was estimated that as much as US$50 million of wood is illegally exported from Ghana annually (Aiken, 1995). Tain II forest reserve is not exception.

3.3.3.1 Summary results from 1991 to 2000 tree inventory of Tain 11 forest reserve

The Reserve was inventoried from 1991 to 2000. This was systematic sampling using a sampling intensity of 0.25% without stratification. Here, all tree species were included in the assessment. The total timber production area has reduced since 1989 and the most economic timber species (scarlet) are rare especially in the diameter classes. However, the total loss of forest cover from 1991 to 2000 is amounted to 342.50 sq. km.

Table 3.1: The results of Tain II forest reserve inventories are summarized.

FOREST COVER	AREA/Sq km
Area of forest reserve	509.2
Area of forest cover in year 1991	451.37
Area of forest cover in year 2000	108.87
FOREST COVER	% CHANGE
Percentage change of forest cover from 1991-2000	78.62
Percentage change of forest cover per annual	7.86

It was commented particularly in the 1989 inventory report that in relation to similar forest within this eco-zone, this Reserve was poor especially in the stocking of FIP species ≥70 cm dbh (FSD, 2001). The report recommended that harvesting should be curtailed because of low stocking essentially putting the area under convalescence and conversion (FSD, 2001).

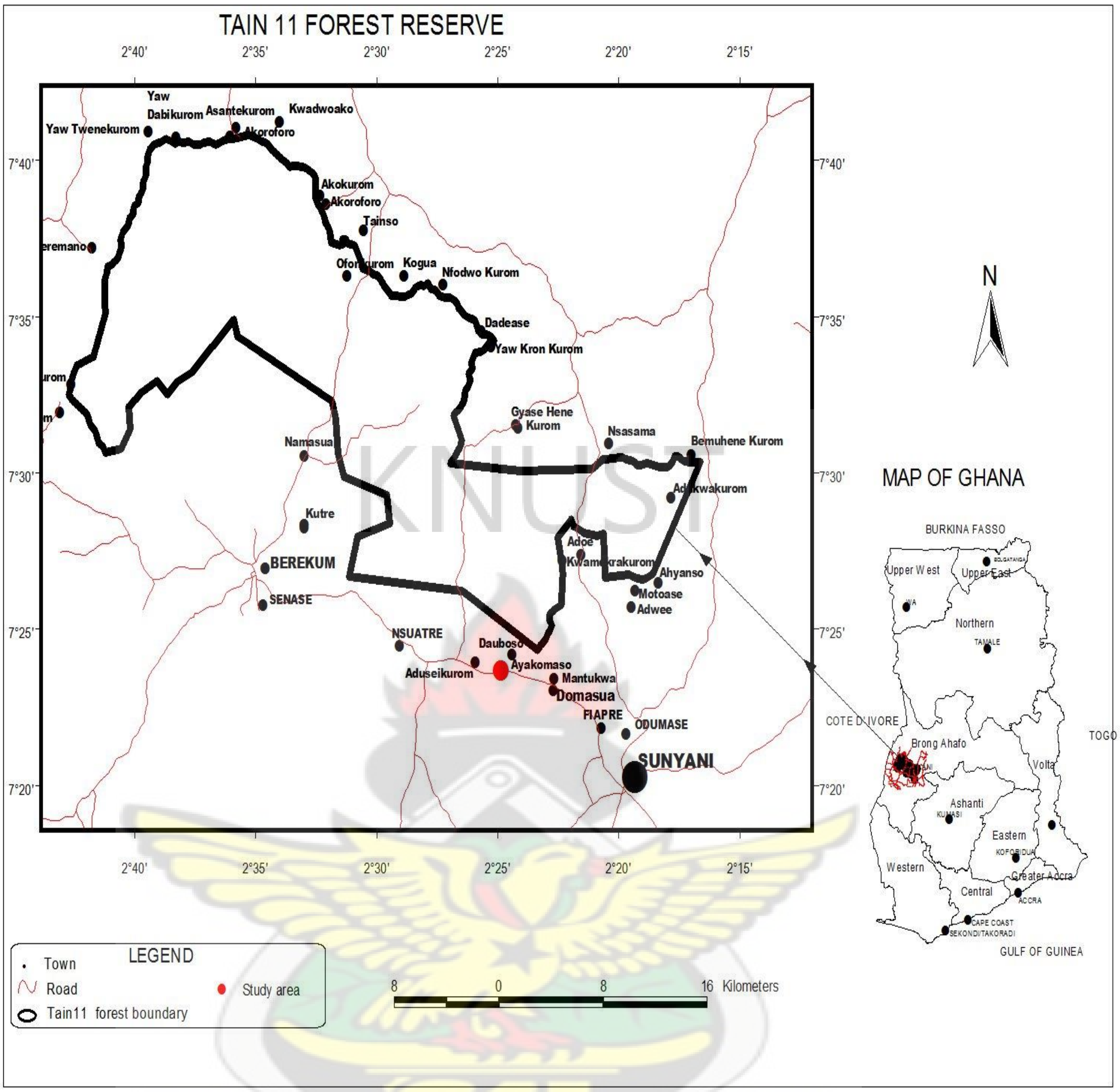


Figure 3.1: Tain 11 Forest Reserve Map.

Plate 3.1: Aerial view of Tain 11 Forest Reserve. The reserve is now a mosaic of Teak and Agriculture landuses

Plate 3.2: Aerial view of Tain 11 Forest Reserve. The fire effects on tree flora conservation.

3.4 Field Design

Cocoa farm which is fruiting

Old Taungya plantation

Natural Forest

Maize/cassava mixed, Maize harvested

Old Teak Plantation(10-15years)

Yam farm (Some harvested)

Plate 3.3: Pictures of all the six land use systems selected (Cocoa farm, Taungya plantation, Natural forest, Maize/cassva mixed farm, Teak plantation and Yam farm)

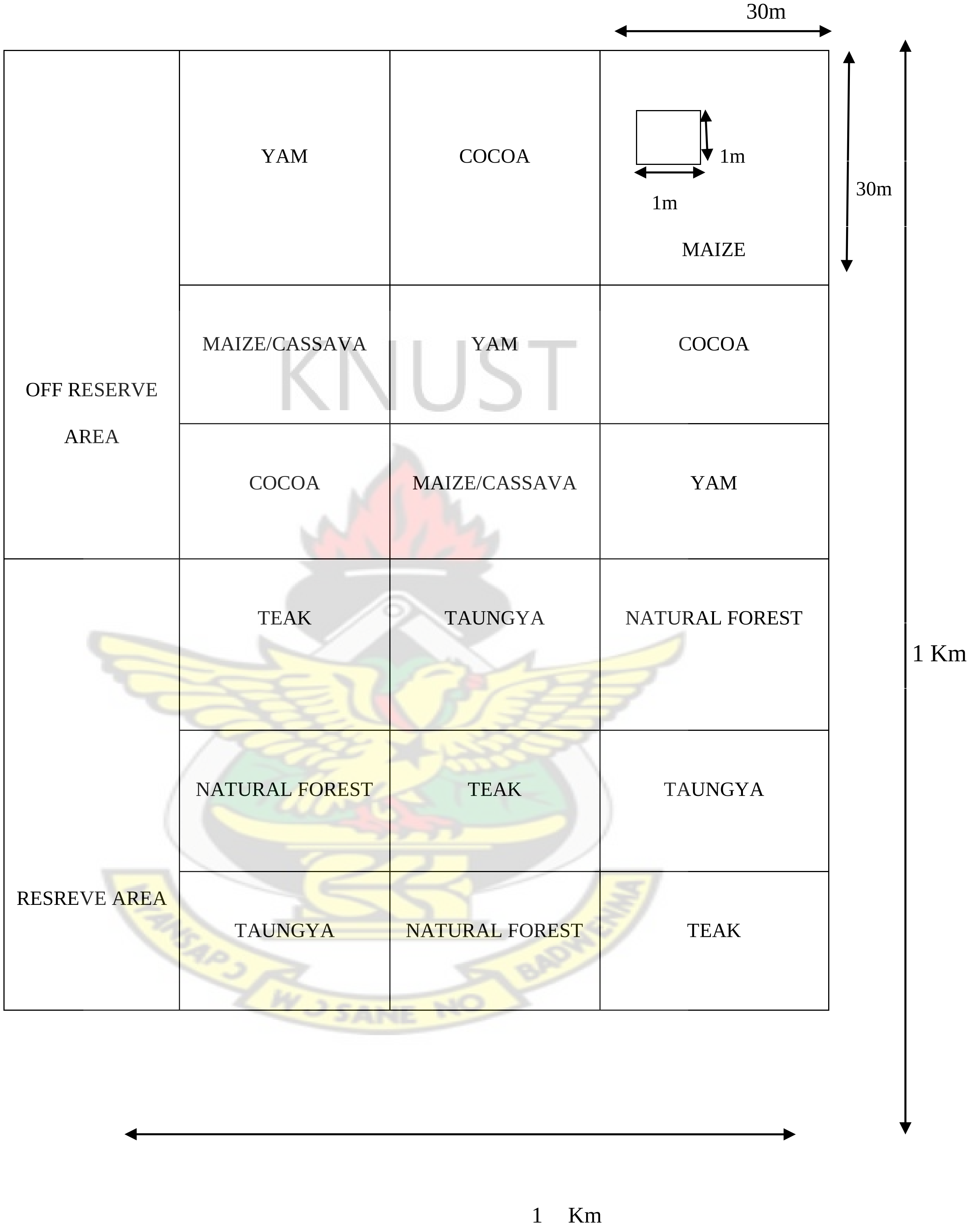
Upon arrival in the study area in January, a two-day reconnaissance survey was carried out to gather the following information: map of Tain 11 Forest reserve, landuse systems, and fire management practices. It also afforded me the opportunity to have prior discussions with local village chiefs who are the custodians of the land and also get an idea about their traditional beliefs and taboos and finally select the type of dominant landuse systems in the area.

Six landuse systems were selected in fire prone and less-fire prone areas of the reserve, namely Taungya farm, Maize/Cassava farm, Natural forest, Cocoa farm, Teak plantation and Yam farm.

The areas selected were designated as two major study zones and an area of one (1) kilometer by one (1) kilometer transects were laid across each zone. Eighteen (18) plots of size 30metre x 30metre were randomly laid within the reserve and off reserve of each zone, making total of thirty six (36) plots in all. Trees species below 5cm diameter at breast height were sampled and counted in 3 quadrates of 1m x 1 m in each plot per landuse.

Most of the trees were identified in the field by slashing the bark and then looking for diagnostic features like colour, smell, and exudates among others. Specimens of the bark, leaves, flowers and fruits, where available, of those species that could not be identified were collected and identified using standard reference textbooks specific for the forests of Ghana (Hutchinson and Dalziel, 1958; Irvine, 1961; Hawthorne, 1993; Hawthorne and Jongkind, 2006) and also with the help of experts from the Faculty of Forest Resource Technology, Sunyani

Figure 3.2. Plot layout of fire prone and less fire prone area



3.5 Data collection

3.5.1 Diameter

Diameter at breast height is defined as the average stem diameter outside bark at a point of 1.30metres above the ground. This is measured from the uphill side of the stem with 100metre tape measure, except for trees with buttresses, where measurements were made just above the buttress that is about 0.3m above the buttresses. For plants with irregular-shaped stems, three readings were taken around the stem of each individual of a species and averaged.

3.5.2 Height

The measurement of height is the determination of linear distance of some object from the surface of the earth to the apex of the object. The height is required in volume estimates and is also a useful measure of growth.

Height can be determined by various methods such as ocular estimation, direct measurement using poles, heighting, rod and indirect methods using hypsometer.

However ,on the field, total height of trees were taken using clinometric instrument, generally, basic trigonomical principles most frequently embodied in this hypsometer were applied. All these data were collected in the dry season, which is from January to March.

3.6 Data analysis

3.6.1 Population density

Population densities were determined on per hectare basis (Mishra *et al.*, 2005; Addo Fordjour *et al.*, 2009). The densities of trees calculated on per hectare basis for each landuse and this further used to the calculation of mean number of individuals/ha for the entire stands.

3.6.2 Basal area (BA)

Basal area of a tree is the cross-sectional area at breast height per unit area. It is always expressed in metre square per unit area (m^2/area)

$(\Pi d^2)/4x\ m^2\ ha^{-1}$

d = diameter at breast height in metre

x = area per plot

Basal area was determined on per hectare basis (Mishra *et al.*, 2005; Addo Fordjour *et al.*, 2009). The basal areas of the trees in each landuse were summed up and converted to basal area per hectare. The mean basal area per hectare was calculated, using the individual values obtained from the six landuses.

3.6.3 Species richness

Plant species richness is defined as the total number of species in an area and is one indicator of biodiversity. Since the larger the sample, the more species we would expect to find, the number of species is divided by the square root of the number of individuals in the sample. There are several different methods for determining or estimating plant species richness. However, the purpose of this study Menhinick's index method was used.

This particular measure of species richness is known as D, the Menhinick's index.

$D = s/\sqrt{N}$

Where s equals the number of different species represented in your sample, and N equals the total number of individual plants or organisms in your sample.

3.6.4 Diversity indices

Diversity Indices: Measuring the number and modeling the abundances of tree species per unit area makes use of diversity indices. A number of different diversity indices exist. Shannon-Weiner (H_0), Simpson and Berger-Parker indices as described by various authors are examples of diversity indices. The differences in these indices stemmed from their ways of combining species richness and evenness, and some indices are more influenced by richness whereas others are more influenced by evenness (Kindt, 2002). Shannon–Wiener's index (Shannon, 1948) which is widely used and recommended for various ecological studies was adopted for this research.

3.6.4.1 The shannon-weiner index

Diversity indices take into account both species richness and the relative abundance of each species to quantify how well species are represented within a community. One of the most commonly used diversity index is the Shannon-Wiener Index (H'). The Shannon-Wiener Index takes both species richness and the relative abundance of each of these species in a community into account to determine the uncertainty that an individual picked at random will be of a given species. Biologically realistic H' values range from 0 (only one species present with no uncertainty as to what species each individual will be) to about 4.5 (high uncertainty as species are relatively evenly distributed).

In theory, the H’ value can be much higher than 4.5, although most real world estimates of H’ range from 1.5 to 3.5. In general, it is thought that more disturbed and less stable environments should have lower H’ values.

The Shannon-Wiener Index can, however, be difficult to compare between sites because this value can only not differ due to changes in the relative abundance of different species, but also due to increases in species richness.

Equation

Equation below is used in calculating Shannon index (Kent & Coker, 1992).

$H = H = -\sum^{s}_{i=1} Pi \ln Pi$

Where:

H = Shannon-Wiener index

Pi = is proportion of individual from the ith species

S= is the number of species in the community

In = is the log base n

3.7 Indices used as basis for conservation prioritisation

Species which are nationally and internationally rare, or genetically unusual or scarce for other reasons, are markedly concentrated into a few ‘hotspot’ areas in Ghana. The anatomy of these hotspots, the degree to which various forests are represented inside them, and the species content, has been more thoroughly researched for plants in Ghana than in most other tropical countries (Hawthorne and Abu Juam, 1993). The results are expressed as various indices; species are assigned to Stars, from which are derived two main indices of biodiversity content.

3.7.1 Stars

A Star is a category of conservation priority assigned to each forest species of vascular plant in Ghana, based primarily on global distribution, but also influenced by other 'adjustment factors' such as tendency to local abundance, taxonomy, ecology, dependence of other species on it etc. Black Star species have highest conservation priority; Green Star species the lowest, with Gold and Blue star between. Species which are common and otherwise of low conservation priority can be assigned Scarlet, Red or Pink stars if they are threatened by overexploitation. Scarlet Stars are seriously over exploited, pink stars potentially so.

Although Stars indicate conservation concern at the species level, we are primarily concerned with the conservation of communities here. In this context, community indices derived from the relative representation of the different Star categories are of most interest.

Stars, and (plant) species composition, are the foundation of the two indices which follow. Stars are strongly related to 'intrinsic biodiversity merit' of the species, with a bias towards merit as any global biologist is likely to assess it.

3.7.2 Genetic Heat Index (GHI)

The GHI is a weighted average of species present, where the weights attached are based on the star system. A Star earns a weight inversely proportional to the average area of earth its member species occupy. An area of forest with a high GHI has a high proportion of species of more 'valuable', generally less widespread, species. A biodiversity 'hotspot' is an area of forest, typically several adjacent forest reserves, with generally high GHI scores. The GHI scores can be applied at a higher resolution to reveal, for instance, that hill tops and slopes tend to have a higher score, and more 'valuable' biodiversity content, than swamps and flat land. Very disturbed forest usually (but not always) has a lower score 10 than adjacent undisturbed forest, depending on the time since disturbance and its severity.

Table 3.2: Summary of the star categories of conservation priority for Species

Star Category	Number of Species	Weight for GHI(and EI)	Comment
Black	52	27(0)	Urgent attention to conservation of populations needed. Rare internationally, and at least uncommon in Ghana.
Gold	208	9(0)	Fairly rare internationally and locally
Blue	414	3(0)	Widespread internationally but rare in Ghana, or vice versa
Scarlet	14	2(3)	Common, but under serious pressure from heavy exploitation
Red	40	2(2)	Common, but under pressure from exploitation
Pink	19	2(1)	Common and moderately exploited. Also non-abundant species of high potential value.
Green	1044	9(0)	No particular conservation concern

A two-factor (landuses, fires) experimental design was used for an ANOVA on each of the dependent variables (Population density, Basal area, Species richness and Diversity index).

Diversity was compared within landuses and fires within the study area. When the analysis found the means statistically significant, Tukey's post hoc tests were used to determine which means were significantly different.

3.8 Limitations

The notable limitations encountered include the following: limited technical personnel and inadequate logistics support, low financial resources as well as the general lack of appreciation for the worth of biodiversity conservation by the farmers in the study area.

CHAPTER FOUR

4.0 RESULTS

4.1 Effects of forest and agricultural landuses on tree flora

The composition of all trees above and below 5cm DBH, were sampled and various parameters about tree species in different landuses were considered. These are (1) Density (the number of trees per unit area), (2) Species richness (3) Shannon's index. Tree density, richness, basal area and diversity have been compared for the various landuses in Table 4.1 and 4.2.

4.1.1 Tree population density

Two thousand two hundred and ninety five (2,295) trees per hectare were recorded during the study. Trees were separated into three diameter classes due to conservation and economic reasons.

Diameter class of 5cm to 35cm.

In terms of tree population density, significant differences were observed among the landuse systems (F =15.35, df =5, p= 0.001). Taungya plantations had the highest number of trees, averagely (459.26) per ha, in less fire prone area whiles maize and cassava farm recorded the least population of (29.63) per ha in the fire prone area (Table 4.1). The most relative abundant trees found under this class were (*Lonchoocarpus sericeus*) Sante, (*Blighia sapida*) Akye and (*Ficus exasperate*) Nyankyerene respectively.

Diameter class of 36cm to 66cm.

Similar result was obtained from the diameter class of 36cm to 66cm dbh ($F = 6.58$, $df = 5$, $p = 0.001$) where there is significant differences among the landuse systems. Teak plantations had the highest number of trees, averagely (218.52) per ha, in less fire prone area whiles maize and cassava farm recorded the least population of (1.85)per ha in the fire prone area (Table 4.1). However, the high population densities in Taungya and Teak plantations compared to natural forest for the diameter-size class of 5-35cm and 36-66cm did not correspond to the diameter-size class at 67cm and above dbh. The most relative abundant trees found under this class were, (*Blighia sapida*) Akye, (*Terminalia glaucescens*) Ngo and (*Trema orientalis*) Sese.

Diameter class of 67cm and above.

Table 4.1 showed that land use categories were statistically significantly different. The natural forest had the highest density of trees (88.89 trees ha^{-1}) in less fire prone whiles maize and cassava farm had the least value (1.90) at diameter-size class of 67 and above dbh in fire prone area($F = 3.95$, $df = 5$, $p = 0.009$). The most relative abundant trees encountered during the study include *Tectona grandis* (Teak), *Blighia sapida* (Akye), *Lonchoocarpus sericeus* (Sante), Ficus *exasperate* (Nyankyerene), *Anogeissus leiocarpus* (Kane), *Holorrhena floribunda* (Sese), *Sterculia tragacantha* (Osofo), and *Spathodea campanulata* (Kokonisue), respectively.

Table 4.1. Distribution of flora (above 5cm dbh) with respect to species population density, species richness, basal area and species diversity in different landuses (± SE)

Parameter	Fire Prone					
	Taungya	Maize	Natural	Cocoa	Teak	Yam
Density						
5-35cm	340.74±67.9^{a}	29.63±6.41^{b}	62.96±52.51^{b}	81.48±27.96^{b}	411.11±125.2^{a}	88.89±23.13^{b}
36-66 cm	125.93±44.91^{a}	1.85±4.54^{b}	29.63±6.41^{b}	7.41±6.41^{b}	70.37±35.72^{a}	18.52±6.41^{b}
67cm& above	64.81±54.82^{ab}	1.90±4.53^{b}	74.08±23.13^{a}	14.81±6.41^{ab}	42.59±16.10^{ab}	3.71±2.34^{b}
Richness(m^2/ha)	12.93±8.42^{ab}	19.89±2.28^{cd}	20.74±3.98^{de}	27.38±3.14^{e}	6.82±2.73^{a}	14.92±1.62^{bc}
Basal Area/ha	94.88±37.18^{b}	2.92±0.056^{a}	153.03±56.67^{c}	27.21±3.88^{a}	40.09±19.48^{ab}	8.59±0.61^{a}
Diversity/ha	0.71±0.096^{b}	1.37±0.033^{c}	1.83±0.27^{d}	2.04±0.21^{d}	0.39±0.23^{a}	1.50±0.12^{c}

Different small letters indicate significant differences among the landuses. Tukey's post hoc test ($p \leq 0.001$)

Continuation of Table 4.1

Parameter	LessFireProne					
	Taungya	Maize	Natural	Cocoa	Teak	Yam
Density						
5-35cm	459.26±119.8[a]	51.85±12.83[b]	62.96±81.90[b]	96.32±12.83[b]	411.11±309.32[a]	70.37±25.66[b]
36-66 cm	162.96±35.72[a]	3.70±6.41[b]	18.53±16.97[b]	3.70±5.74[b]	218.52±214.98[a]	25.92±12.83[b]
67cm& above	48.15±6.42[ab]	3.70±6.41[b]	88.89±29.39[a]	25.92±23.13[ab]	70.37±112.40[ab]	7.41±6.41[b]
Richness(m^2/ha)	12.93±0.73[ab]	25.12±0.48[cd]	28.41±1.18[de]	30.40±4.53[e]	9.11±1.45[a]	19.07±1.95[bc]
Basal Area /ha	135.78±50.18[b]	5.18±4.11[a]	222.33±77.36[c]	47.87±40.16[a]	78.74±54.07[ab]	9.95±1.82[a]
Diversity/ha	0.92±0.15[b]	1.78±0.048[c]	2.28±0.12[d]	2.23±0.19[d]	0.52±0.13[a]	1.69±0.049[c]

Different small letters indicate significant differences among the landuses. Tukey's post hoc test ($p \leq 0.001$)

Tree population density below 5cm diameter

In Table 4.2, there were no significant differences in tree population density among the landuses (F= 1.628, df=5, p-value= 0.191). However, the density ranged from 107.41 in Taungya farm to 55.56/ha in maize/cassava farm of less fire prone area to125.93/ha in natural forest to 37.04/ha in teak plantation of fire prone area.

Table 4.2. Distribution of flora (below 5cm dbh) with respect to population density, species richness and species diversity (± SE)

Parameter	Fire Prone					
	Taungya	Maize	Natural	Cocoa	Teak	Yam
Density(cm)	85.187±16.97	77.78±19.24	125.93±67.89	103.70±33.94	37.04±33.95	70.37±23.13
Richness/ha	1.83±0.54	1.81±0.42	1.14±0.45	1.63±0.52	1.48±1.30	1.58±0.50
Diversity/ha	1.47±0.47	1.45±0.18	1.06±0.50	1.33±0.38	1.06±0.94	1.24±0.43
Parameter	**Less FireProne**					
	Taungya	Maize	Natural	Cocoa	Teak	Yam
Density(cm)	107.407±57.02	55.56±11.12	111.11±77.78	96.30±16.97	77.78±40.06	107.40±54.81
Richness/ha	1.29±0.45	1.79±0.39	1.58±0.28	1.72±0.70	1.80±0.08	2.67±1.02
Diversity/ha	1.09±0.59	1.30±0.31	1.39±0.41	1.32±0.61	1.40±0.27	1.56±0.48

4.1.2 Tree species richness above 5cm diameter

Cocoa farm in the less fire prone zone exhibited the highest species richness above 5cm dbh (30.40)/ha, whiles Teak plantations had the lowest richness value of (6.82)/ha in fire prone zone (F=31.18, df = 5, p=0.001) (Table 4.1) (Appendix 4). The highest species richness observed were the following trees (*Blighia sapida*) Akye, (*Lonchoocarpus sericeus*) Sante, and (*Ficus exasperate*) Nyankyerene respectively.

4.1.3 Tree species richness below 5cm diameter

The table 4.2 of trees below 5cm diameter at breast height (DBH) revealed that there were no statistical differences in species richness among the landuses (F=0.98, df=5, p= 0.45) (Appendix16). However, the species richness ranged from 2.67/ha in yam farm to 1.29/ha in Taungya farm of less fire prone area. It also ranged from 1.83/ha in taungya farm to 1.14/ha in natural forest of fire prone area.

4.1.4 Tree diversity above 5cm diameter

The P-value of 0.001 confirmed that, there is significant difference among the land uses. Teak plantation had the least mean Shannon index of 0.39/ha in fire prone area while natural forest in less fire prone area had the highest mean value of 2.28/ha of tree above 5cm dbh (F=114.31, df = 5, p = 0.001) (Appendix 17) (Table 4.1).

4.1.5 Tree diversity below 5cm diameter

No significant differences were observed between the landuses in tree diversity below 5cm diameter; nevertheless diversity index range from 1.56/ha in yam of less fire prone area to 1.06/ha in the natural forest and teak plantation respectively in fire prone area (F= 0.145, df=5, p= 0.980) (Table 4.2).

4.1.6 Tree basal area above 5cm diameter

In terms of tree basal area, significant differences were observed among the landuse systems (F=20.79, df = 5, p= 0.001). Maize/cassava farm in the fire prone zone recorded the lowest basal area (BA) of (2.92m^2/ha) while natural forest in less fire prone area had the highest value (222.33m^2/ha) (Table 4.1) (Appendix16).

4.2 Effects of fire on tree flora conservation

Observation in the study area showed that about 78% of the sampled trees showed evidence of fire damage. The effects of fire will be considered on the basis of tree population density, tree species richness, tree basal area and tree diversity.

4.2.1 Tree population density

Diameter class of 5cm to 35cm.

Two- way Anova of tree population density for fire prone and less fire prone zones are presented in Appendix 1. Tree population density showed no significant difference between fire prone and less fire prone zones (F =0.296, df =1, p= 0.591). Even though there is no difference between the fire regimes, the density ranged from 459.26/ha to 51.86/ha in less fire prone area to 411.11/ha to 29.68/ha in fire prone area (table 4.1).

Diameter class of 36cm to 66cm

Similar result was obtained from the diameter class of 36cm to 66cm dbh (F = 1.845, df =1, p= 0.187) where no significant difference was observed between the fire regimes (Appendix 2). However, the mean density ranged from 218.52/ha to 3.70/ha in less fire prone area to 125.93/ha to 1.85/ha in fire prone area (table 4.1).

Diameter class of 67cm and above.

No significant difference was also observed between fire prone and less fire prone zones at diameter-size class of 67cm and above (F = 1.208, df =1, p= 0.283) (Appendix 3). However, the mean density ranged from 88.89/ha to 3.70/ha in less fire prone area to 74.08/ha to 1.90/ha in fire prone area (table 4.1).

Tree population density below 5cm

There was no difference between fire prone zones and less fire prone zones in tree population density below 5cm dbh (F = 0.413, df =1, p= 0.527) (Appendix 7). However, the mean density ranged from 125.93/ha to 37.04/ha in fire prone area to 111.11/ha to 55.56/ha in less fire prone area (table 4.2).

4.2.2 Tree species richness above 5cm.

Species richness is significantly higher in the less fire prone zone than fire prone zone (F = 10.688, df =1, p= 0.003) (Appendix 4). Less fire prone zone had the highest value of 30.40/ha whilst fire prone zone recorded the least value of 6.82/ha (Table 4.1).

4.2.3 Tree species richness below 5cm

Meanwhile, there was no variation in species richness between fire prone and less fire zones below 5cm dbh (F = 1.189, df =1, p= 0.286) (Appendix 8). However, species richness ranged from 2.67/ha to 1.29/ha in less fire prone area to 1.83/ha to 1.14/ha in fire prone area (table 4.2).

4.2.4 Tree diversity above 5cm.

There are significant difference between the fire prone and less fire prone zones as far as tree diversity is concerned (F=26.721, df =1, p= 0.001). The Shannon index values was higher 2.28/ha in less fire prone zones whiles fire prone zone recorded the least value of 0.39/ha(Table 4.1) (Appendix 6).

4.2.5 Tree diversity below 5cm

The Shannon index between fire prone and less fire prone for trees below 5cm DBH showed no significant difference (F=0.264, df =1, p= 0.612) (Appendix 9). However, tree diversity ranged from 1.56/ha to 1.09/ha in less fire prone area to 1.47/ha to 1.06/ha in fire prone area (table 4.2).

4.2.6 Tree basal area above 5cm

The two-way ANOVA of the mean basal area (BA)values for fire regimes in the diameter class above 5cm revealed statistically significant differences among the fire prone and less fire prone zones (F=6.48, df =1, p= 0.018) (Appendix 5). The number of tree basal area recorded per hectare ranged from 222.33m^2/ha in natural forest of less fire prone zone to 2.92 m^2/ha in maize/cassava farm of fire prone area (Table 4.1).

4.3 Star rating

Most of the trees in the study area occurred in green star categories. However based on the relative abundance of the star categories, trees such as black, gold and blue stars were not found in any of the landuses.

Scarlet star

The highest relative abundance of scarlet species was recorded in the natural forest (1.07%, and 2.054%) of fire prone and less fire prone area respectively, this is followed by cocoa farm(0.21% and 0.68%) for fire and less fire prone areas, while taungya and teak in the less fire prone area had the least(0.34% and 0.17%) respectively. All other landuses such as maize/cassava and, yam farms had no scarlet rated species (Table 4.3).

Red star

Taungya farm in less fire prone area recorded the highest red star species (0.51%), this is followed by cocoa and yam (0.34%) each in less fire prone, whiles natural forest in the fire prone area had the least value of (0.21%). All other landuses had no red star rated species (Table 4.3).

Pink star

Natural forest in less fire prone area recorded the highest pink star species (2.05%), whiles taungya and yam in the less fire prone area had the least value of (0.17%) each. But landuses such as taungya farm, maize/cassava farm, teak plantation and yam farms in fire prone zone had no pink star species (Table 4.3).

Green star

Cocoa farm and teak plantation in fire prone area recorded the highest and the lowest of green star species of (6.64% and 2.78%) respectively. However, in the less fire prone area natural forest recorded the highest green star trees(6.34) and the lowest value was given by yam farm(2.91) (Table 4.3).

No rating

Generally the highest number of trees found in the study area was of no star categories. Teak trees dominated the majority of trees in this category (Table4.3). This is obvious since the area is dominated by teak plantation in taungya and teak plantation areas.

Table 4.3: Relative abundance of star categories of trees with respect to landuses and fire regimes

	Relative abundance (%)								
Landuse	Black	Gold	Blue	Scarlet	Red	Pink	Green	No Rating	Total
Fire Prone									
Taungya	0	0	0	0	0.43	0	6.21	28.91	35.55
Maize	0	0	0	0	0	0	3.85	0	3.85
Natural	0	0	0	1.07	0.21	0.43	6.42	3.64	11.78
Cocoa	0	0	0	0.21	0	1.07	6.64	0	7.92
Teak	0	0	0	0	0	0.00	2.78	27.84	30.62
Yam	0	0	0	0	0	0.00	4.28	6.00	10.28
Sub total	**0**	**0**	**0**	1.28	0.64	1.50	30.19	66.38	100
Less fire									
Taungya	0	0	0	0.34	0.51	0.17	5.99	28.60	35.62
Maize	0	0	0	0	0	0.51	3.25	0.51	4.28
Natural	0	0	0	2.05	0	2.05	6.34	0.51	10.96
Cocoa	0	0	0	0.68	0.34	1.20	6.16	0	8.39
Teak	0	0	0	0.17	0	0.34	3.25	30.99	34.76
Yam	0	0	0	0	0.34	0.17	2.91	2.57	5.99
Sub total	**0**	**0**	**0**	3.25	1.20	4.45	27.91	63.18	100

4.4 Effects of interactions of forest and agricultural landuses and fire on floral conservation (dbh above and below 5cm)

The two-way Anova of landuses and fire regimes of Tain II forest reserve and off reserve are given in Appendix 1, 2 and 3. The results showed that tree density at various diameter classes did not differ significantly between landuses and the fire regimes. These diameter classes were, diameter class of 5cm to 35cm ($F = 0.349$, df =5, $p= 0.878$), diameter class of 36cm to 66cm ($F = 1.282$, df =5, $p= 0.304$) and diameter class of 67cm and above ($F = 0.884$, df =5, $p= 0.507$).

Again the interaction of agricultural landuses and fire on trees below 5cm diameter at breast height (DBH) also showed no effects on tree density ($F= 0.607$, df=5 $p= 0.696$) (Appendix 7).

Similar results were obtained where interactions between landuses and fire on floral conservation showed no effects on species richness ($F = 0.885$, df =5, $p= 0.506$), tree diversity ($F = 1.041$, df =5, $p= 0.416$) and tree basal area ($F = 0.640$, df =5, $p= 0.671$) (Appendix 4, 5 and 6).

The interaction of agricultural landuses and fire on tree below 5cm diameter at breast height (DBH) also showed no effects on species richness ($F= 1.080$, df=5 $p= 0.397$) and tree diversity ($F= 0.484$, df=5 $p= 0.784$) (Appendix 8and 9) as well.

CHAPTER FIVE

5.0 Discussions

5.1 Effect of Landuse types of tree parameters studied

5.1.1 Tree population density

Diameter class of 5cm to 35cm

In the diameter class of 5cm to 35cm of tree population density, taungya farm had the highest number of trees per ha, in less fire prone zone, whereas maize farm recorded the least population density in fire prone zone. The decline in the number of trees in the maize/cassava farm could be as a result of continuous clearing of the vegetation for cropping this maize/cassava since these crops are sun- loving plants and therefore required more sunshine to develop. This is confirmed by (Myers, 1988), that the rate of forest destruction is alarming in West Africa and continuous clearing of the vegetation for arable crops reduces tree population density. Hence, the hypotheses that all the landuses will contribute to flora diversity conservation is not valid.

Diameter class of 36cm to 66cm.

The result obtained from the diameter class of 36cm to 66cm showed that teak plantations had the highest tree population density and maize/cassava farm recorded the least. The FAO (2010) estimates the annual deforestation rate in Ghana at 2.1% per year, which corresponds with an average annual forest loss of 115,000 ha. This resulted mainly from indiscriminate logging and conversion of forest to farmland. In response of these challenges, the Ghana Government embarked on reforestation programme with the aim to promote private and commercial plantation and teak is the most dominant species in today's plantation estate. This programme might contribute to the higher tree population density of teak in the study area.

The results obtained from this research indicate that *Tectona grandis is* the predominant tree at the Diameter class of 36cm to 66cm followed by *Blighia sapida, Terminalia glaucescens* and *Trema orientalis*.

Diameter class of 67cm and above.

The natural forest in the diameter class of 67cm and above had the highest density of larger trees in less fire prone zone whiles maize and cassava farm had the least value. According to Marfo (2010) the present rate of destruction to the high forests may cause a serious threat to merchantable trees in the future. And the higher number of larger tree density observed in natural forest (of diameter 67 and above) confirmed the fact that, older and larger trees were found in the natural forest as compared with other landuses (Krishna, 2004). The study indicated also that land use such as maize/cassava farm, had negative impact on tree populations by reducing tree density to minimum level compared to other landuses in the study area. However, the absence of these trees indicate other types of pressure such as unsustainable farming, loggings and over-exploitation of forest resources which significantly reduce the forest area and degrade nearly 30 percent of reserved forest and over 70 percent of forest outside reserves Ministry of Lands and Forestry,(2006).

The results was also supported by findings of Sala *et al.*, (2000) that land-use change especially agriculture is an important form of global pressure affecting tree population in Europe.

There were no differences in tree population density below 5cm diameter among the landuses. The similarity in tree densities among the land use categories may be due to the effect of annual slash and burning and recurrent of wildfires in the study area.

5.1.2 Tree species richness

Similarly, cocoa farm in the less fire prone zone exhibited the highest species richness above the diameter class of 5cm whiles Teak plantations had the lowest species richness value in fire prone zone, this epitomises how different types of landuse categories can impact on species richness. It implies that cocoa farm has the benefit of increasing and probably maintaining tree species richness in the Country. This observation corresponds to similar finding by Quisumbing (2002) in some part of Ghana, and stated that one of the environmental benefits of cocoa farming in Ghana is the promotion of species richness. This study has confirmed that conclusion.

Perhaps, other explanations for these observations stems from the management practices employed in cocoa farming. Young cocoa need to be protected from excessive sunlight if they are to survive the seedlings stage hence farmers intentionally leave trees during land preparation for cocoa farming. This might also contributed to higher tree species richness in cocoa farms. And hence the hypothesis that all land uses can substantially contribute to flora diversity conservation cannot be valid for species richness (Appendix 4, Table 1).

Some desirable trees species which farmers intentionally maintained in their cocoa farms are A*lbizia coriaria* (Awiemfo samna), A*lstonia boonei* (Nyamedua), E*ntandrophragma angolense* (Edinam) and G*liricidia sepium* (Gliricidia).

The results from trees below 5cm DBH showed similarity among the land uses. Thus suggesting that the differences in the figures observed may be attributed to the recurrent of wildfires activities there.

5.1.3 Tree diversity

The study showed that the values of Shannon's diversity index were higher in the natural forest (2.28) and lower in teak plantation (0.39). These varying values may be attributed to the intensive farming activities going on in the study area, which means the continuous clearing of vegetation for arable and tree crops has caused loss of natural tree diversity. Chima *et al.* (2011) in a study carried out in Niger Delta of Nigeria attributed low tree species diversity to high human influence and several years of continuous arable cropping.

The decline in the tree diversity in teak plantation could also be attributed to the tree canopy cover that shades light from entering the forest floor to encourage the growth of light demanding tree species as reported by Brockerhoff *et al.,* (2003). This could explain why few shade-bearer species such as *Celtis mildbraedii* and *Chrysophyllum gigiantia* were observed in the teak plantation. Other explanation means that, the height of Teak trees suppressed the growth of small trees by intercepting much of the solar radiation that might otherwise reach the forest floor. Hence, the hypotheses that all the landuse will contribute to flora diversity conservation is invalid (Appendix 6, Table 1).

No effect was observed among the landuses on tree diversity below 5cm dbh. This may be attributed to the fire disturbances in the area. The finding on diversity is consistent with a similar study reporting no significant difference in tree diversity between teak plantation and natural forest in Afram headwaters forest reserve of Ghana (Farwig *et al.,* 2009). Also the height of trees in the natural forest and teak plantation have an implication for subordinate trees as these big trees suppress the growth of small trees by intercepting much of solar radiation that might otherwise reach the forest floor and this must be the reasons why there were no effects.

5.1.4 Tree basal area (BA)

Natural forest in less fire prone zone had the highest basal areas while maize/cassava farm in the fire prone zone recorded the lowest basal area (Table 1). This result is quite comparable to Tripathi and Singh, (2005), who said that basal area is an important indicator of tree stocking which reflect stand volume of biomass and added that basal area was slightly higher in natural forest than plantation forest in Northern India. This result disagreed with the hypothesis that all landuse can substantially contribute to flora diversity conservation. This again confirmed the fact that natural forest had a greater number of larger trees as result of human activities such as farming (agriculture) in the reserve being regulated by the Forestry Commission.

5.2 Effect of Fire on tree parameters studied

The regional and international attention to wild fires in Ghana has been increasing as a result of its implications for environment and development. Most fires are human-induced, either by direct or indirect causes. In addition, their intensity and extent is, and will increasingly continue to be, partly influenced by climatic conditions in Ghana.

5.2.1 Tree population density

Mean tree density at 5cm to 35cm diameter classes showed no effect between fire prone and less fire prone zones. The in-significant difference recorded could most probably be due to improper land use methods and forest clearing Amissah *et al*, (2010). However, most of the time the tree population densities are higher in less fire prone zone than fire prone zone as hypothesized.

Similar results were obtained in the diameter classes of 36cm to 66cm and also 67cm and above. Similarity, in the tree densities between fire prone and less fire prone could be attributed to the type of land uses, legal and illegal logging activities in the study area. Amissah *et al*, (2010) also found out in the fire prone forest belt of Ghana that, the practices involved in the production of annual crops (maize and yam) were to be in close association with incidence of wildfires. This is also in consistent with the findings of Michael *et al* (2007) who observed that, at high fire prone areas a significantly lower number of woody trees were found.

And also, since the data for the study was taken in January to March, it may also mean that trees there might have experienced fires so frequently or at short interval that they did not have enough time for fire intolerant trees to recover or regenerate. The finding is consistent with a similar study by Kucera and Koelling, (1964) that burning every other year in Missouri pairie controlled woody tree species. Okello *et al.,* (2007) also stated that, repeated burning could have profound impacts on savanna tree density; they also argued that even a single fire had the potential to reverse tree population density in savanna ecosystems.

5.2.2 Tree species richness

The result of this study showed that species richness was higher in the less fire prone zone than fire prone zone. Cocoa farm in less fire prone zone had higher species richness value of (30.40) than cocoa farm (27.38) in fire prone zone. This result fits the hypothesis that fire can reduce floral diversity and conservation. David and Peter,(2008) conducted a study on how fire frequency influenced tree species richness in a forest and reported a general increase in species richness in less fire prone area than fire prone area.

Kucera & Koelling (1964), agree that more frequent burning in a forest results in reduction of overall species richness of shrubs and trees and also, Species richness of shrubs and trees (woody species) were higher in sites with less fire occurrence and declined with increasing fire occurrence. This is also consistent with the findings of Veen *et al*., (2008) who observed that, species richness of woody species decreases in area where fire occurrences are frequent.

The results therefore imply that fire has negative impact on the tree species richness. Therefore the major effects of this negative impact of fire on the tree species richness in Tain II reserve are the deforestation and deterioration of ecological systems with resulting negative impacts on soil fertility, water flows and biological diversity. Soil erosion such as Sheet and gully erosion has become a serious problem in many part of the area. This deforestation has also affected water catchment areas and the quantity and quality of water supplies. There is extensive evidence of reduced dry season river flows and drying up of springs and seepages. There is also increased sedimentation of rivers and dams. However, for the forest communities and the country as whole to benefit from these forest goods and services the timber and non timber forest products must be conserved.

5.2.3 Tree diversity

Similarly, tree diversity was higher in the less fire prone zone than fire prone zone. The Shannon index value was higher (2.28) in the natural forest in the less fire prone zones than the natural forest (1.83) in fire prone zones.

The results of this study showed that tree diversity was highest for less fire prone zone and it decreased in fire prone zone. Huston, (1994) confirmed this that, disturbances can reduce plant species diversity and by eliminating disturbances increase tree species diversity. Borrowing from Huston's observation, the general decrease in tree diversity in all the land use in fire prone zone could have been due to frequently or short interval of fire occurrences which eliminates intolerant tree species and hence reducing tree diversity in the study area. This is also confirmed by Brockway & Lewis, 1997 that in savannas and woodlands, tree species diversity often increases with less fire occurrence at a particular place.

Trees in the forest and off reserves play a very important role supporting the livelihood of millions of inhabitants, particularly the rural communities. However the effect of wildfires significantly degraded the forest reserve and off reserve (MLF, 2006) and this is responsible for the genetic diversity of forest in Ghana. Therefore effort should be made to conserve natural forest which constitute important habitat for wild flora and fauna as a conservation measure to prevent a decrease of tree species populations.

5.2.4 Tree basal area

The mean basal area (BA) values for the fire regimes revealed statistically significant differences between fire prone and less fire prone zones. In other words, natural forest in less fire prone zone had higher basal area (222.33) of trees than the natural forest (153.03) in fire prone zone (Table 4.1) as hypothesized in the study. This suggests that less fire prone area decreased the killing or damaging of trees, which ultimately leads to increased productivity and organic matter in soil, thus more favourable conditions for trees to grow. This result also supports the findings made by Naidu and Sribasuki (1994) that young trees are more badly affected by fires than mature ones. The higher the frequency of fire occurrence, the more difficult it is then for woody tree species to grow and to escape from the fire (Michael *et al.,* 2007). Therefore, large trees are scarce under high frequency of fire occurrence and young trees are very rare or non-existent.

In addition to these findings of a negative impact of fire occurrence on larger trees, significantly fewer larger tree species numbers were recorded at fire prone zones of ecosystems (Michael *et al.,* 2007). Reduced fire frequency or less fire occurrence may also permit tree species to increase in size. However, since rapid conversion of forest to agriculture remains the most imminent threat to the forest ecosystem, Klink *et al*. (1995) stated that frequent burning will continue to have a serious impact on trees sizes. Fire is a serious threats hence its consequences on the citizenry in the study area. This destroyed large areas of natural commercial forests as well as agricultural crops; and it may finally result in communal and household conflicts and loss of revenue from natural resources.

5.3 Star rating

The investigations into the star rating of the trees in the study area revealed a high proportion of green star species as compared to other tree stars. This is owing to the fact that these species are common in Ghana and are of no particular conservation concern (Hawthorne and Gyakari, 2006). *Blighia sapida* had been found to be the most dominant tree species in the green star category found in the less fire prone zone of the reserve followed by *ficus exasperata* mostly found in fire prone zone.

Natural forest in fire and less fire prone zones had the highest relative abundance of scarlet species and teak plantation had the lowest in less fire prone. The age of the teak trees in the study area were about ten to fifteen years. This age could be a contributing factor by creating competition between the teak and the young scarlet star species for sunlight and nutrients as teak attempt to outgrow them. Boakye, (2011) had similar results in a case study of woody species diversity in Afram Headwater forest reserve. This star category was dominated mostly by *Albizia ferruginea* tree species in the study area.

Taungya farm in less fire prone zones had the highest relative abundance of red star species and natural forest in fire prone zone had the lowest. The natural forest had the least because these species are common, and also under pressure from past exploitation by chain saw operators and timber loggers in the area (Hawthorne and Gyakari, 2006). Furthermore, the effect of unsustainable farming practices and wildfire could have also reduced the population of red star species. Benhin (2006) stated that agriculture has been noted as a major cause of forest loss having been estimated to account for about 90 percent of all deforestation in the tropics. The dominant *Antiaris toxicaria* tree species were found in this category of study area.

The pink star species constituted the second highest rated stars in the study area. Natural forest had the highest pink star species, while taungya and yam farms recorded the lowest pink star species, all are in less fire prone zone. The Taungya farm had the least because pink species are non-abundant species of high commercial value (Hawthorne, 1993). The lower pink star by taungya and yam farms may also be due to pressure from landuse practices, excessive lumbering and frequent fire encountered in the area. This is in consonance with the findings of (Hawthorne and Gyakari, 2006), who stated that, serious pressure from heavy exploitation in the past may be responsible for the low proportion of the pink star species. *Albizia zygia* had been found to be the most dominant tree species in the pink star category found in the site.

However, no figures were recorded for black, gold and blue star species; this could be due to the fact that they are of rarity value in Ghana (Hawthorne and Gyakari, 2006).

Finally, the reserve will soon see the few Scarlet, red and pink star trees detected in the study area getting lost, therefore maintenance of the off- reserve trees is importance for sustainable forest reserve management (Kotey *et al.*, 1998).

5.4 The effects of interactions of forest, agricultural landuses and fire on tree parameters studied.

The results from the study indicate that mean interaction between landuses and the fire regimes showed no effects on tree density, species richness, diversity and basal areas. However, most of the time, the results were higher in less fire prone zone than the fire prone zone. This result fits the hypothesis that interactions of forest and agricultural landuses and fire cannot contribute to floral diversity conservation. With the exception of natural forest and teak plantation, the in-significant difference in other land uses could be due to the similar landuse practices occurring in the areas. This is confirmed by Parrotta, (1995); Lugo *et al*. (1993) that type of farming and management practices are very important factors influencing the plant density and species diversity in an area. On the other hand, the difference in the figure observed could also be due to the illegal logging activities occurring in the site.

According to Amissah *et al.*, (2010) certain types of farming practices in concert with inherent flammability of particular vegetation types predispose the environment to wildfires. The cultivation of vegetables like tomato, okra and pepper was considered highly associated with wildfire incidence followed by annuals such as maize/cassava and yam, and to a lesser extent, perennials. All these crops are the main sources of income and foods for the people living around the Tain II forest reserve, hence the similar effects on the trees in the study area.

CHAPTER SIX

6.0 Conclusions

In conclusion, the study has shown that tree density, species richness, diversity and basal area strongly influenced by the land use systems. Annual cropping such as maize/cassava mixed farm happened to record the lowest tree density. The study further confirmed that most of economic tree species in maize/cassava mixed farms were being threatened of possible extinction as a result of traditional slash and burn method being practiced in cultivating of these crops.

Further, tree cropping such as cocoa farming was significantly highest in tree species richness and tree diversity, this could be attributed to the practice of farmers intentionally retaining different tree species in the cocoa farms to provide the needed shade for the young cocoa trees, hence make it a better option for increasing tree species richness and tree diversity than any other landuses.

From the results of this study, a conclusion can be drawn that wildfires can significantly reduce tree species richness, diversity and basal area. There was a decline in biodiversity at the fire prone area as compared to the less fire prone area. This could be due to frequent occurrence of fire as well as most of the tree species there are fire sensitive (Lai,1987).

The result also indicated that, there are no effect between landuse systems and the fire regimes in the study area.

However, the study sites are rich in scarlet star, red star and pink star rated trees in spite of many threats of unsustainable landuses, fire and illegal logging that the area has been subjected to for many years. Therefore, effective conservation and good management initiatives are most important for the reserve and its associated tree species in order to conserve the forest reserve.

CHAPTER SEVEN

7.0 Recommendation

Against the background of the conclusion given above, I therefore recommend that:

- Any agroforestry system which involves either incorporating of trees in agricultural cropping systems or incorporation of crops in forest systems, for example forest garden has the potential to conserve tree species.

- When maize/cassava and yam farming are to be practiced, farmers must be encouraged to use multipurpose trees (MPTs) in the form of trees on-farms.

- Fire management strategies in the past and the recent focused on fire prevention and control at the central level without much emphasis at the community level, fire management activities must be decentralized. Communities should be responsible for the prevention of burning on farmland areas; they should be actively involved in annual launching of National Anti-bushfire Campaigns and mobilization of village fire volunteers. Adequate public fire awareness creation, institutional arrangement, grass-root capacity building and legislation to manage fires are necessary.

- Finally star rated trees are becoming rare, because of pressure from past exploitation, therefore, they require immediate attention for protection and conservation, and farmers must be encouraged to cultivate some of them and other equally multipurpose trees on their farms to support the forest reserve in tree conservation.

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APPENDICES

Appendix 1: Density 5cm to 35cm effects of forest, agricultural landuses and fire on floral conservation (dbh above 5cm)

Source	Sqs	Df	Msq	F	Sig
Land Use	908880.15	5	181776.03	15.346	0.001
Fire Regime	3511.945	1	3511.945	0.296	0.591
LandandFire	20683.339	5	4136.668	0.349	0.878
Error	284281.572	24	11845.066		
Total	1217357.006	35			

Appendix 2: Density 36cm to 66cm effects of forest, agricultural landuses and fire on floral conservation (dbh above 5cm)

Source	Sqs	Df	Msq	F	Sig
Land Use	140812.722	5	28162.544	6.575	0.001
Fire Regime	7901.432	1	7901.432	1.845	0.187
LandandFire	27449.07	5	5489.814	1.282	0.304
Error	102799.794	24	423.325		
Total	278963.018	35			

Appendix 3: Density 67cm and above effects of forest, agricultural landuses and fire on floral conservation (dbh above 5cm)

Source	Sqs	Df	Msq	F	Sig
Land Use	29685.769	5	5937.154	3.952	0.009
Fire Regime	1814.618	1	1814.618	1.208	0.283
Land and Fire	6640.888	5	1328.178	0.884	0.507
Error	36051.73	24			
Total	74193.005	35			

Appendix 4: Species Richness effects of forest, agricultural landuses and fire on floral conservation (dbh above 5cm)

Source	Sqs	Df	Msq	F	Sig
Land Use	1823.04	5	364.608	31.179	0.001
Fire Regime	124.992	1	124.992	10.688	0.003
Land and Fire	51.75	5	10.346	0.885	0.506
Error	280.655	24	11.694		
Total	2280.421	35			

Appendix 5: Basal area effects of forest, agricultural landuses and fire on floral conservation (dbh above 5cm)

Source	Sqs	Df	Msq	F	Sig
Land Use	156345.421	5	31269.084	20.79	0.001
Fire Regime	9746.231	1	9746.231	6.48	0.018
Land and Fire	4816.451	5	963.29	0.64	0.671
Error	36096.294	24	1504.012		
Total	207,004.40	35			

Appendix 6: Tree Diversity effects of forest, agricultural landuses and fire on floral conservation (dbh above 5cm)

Source	Sqs	Df	Msq	F	Sig
Land Use	13.568	5	2.714	114.311	0.001
Fire Regime	0.634	1	0.634	26.721	0.001
Land and Fire	0.124	5	0.025	1.041	0.416
Error	0.57	24	0.024		
Total	14.896	35			

Appendix 7: Tree Density effects of forest, agricultural landuses and fire on floral conservation (dbh below 5cm)

Source	Sqs	Df	Msq	F	Sig
Land Use	15216.451	5	3043.29	1.628	0.191
Fire Regime	771.451	1	771.451	0.413	0.527
Land and Fire	5668.22	5	1133.644	0.607	0.696
Error	44855.959	24	1868.998		
Total	66512.081	35			

Appendix 8: Species Richness effects of forest, agricultural landuses and fire on floral conservation (dbh below 5cm)

Source	Sqs	Df	Msq	F	Sig
Land Use	1.981	5	0.396	0.98	0.45
Fire Regime	0.481	1	0.481	1.189	0.286
Land and Fire	2.183	5	0.437	1.08	0.397
Error	9.707	24	0.404		
Total	14.352	35			

Appendix 9: Tree Diversity effects of forest, agricultural landuses and fire on floral conservation (dbh below 5cm)

Source	Sqs	Df	Msq	F	Sig
Land Use	0.181	5	0.036	0.145	0.98
Fire Regime	0.066	1	0.066	0.264	0.612
Land and Fire	0.603	5	0.121	1.08	0.397
Error	5.976	24	0.249		
Total	6.826	35			

Appendix 10: Effects of interactions of forest, agricultural landuses and fire on floral conservation (dbh above 5cm)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	1524562.407	1	1524562.407	4502.712192	4.92473E-05
Landuse	1237560.669	5	247512.1339	192.1538155	0.009888195
Fireregime	23099.85271	1	23099.85271	47.23919347	1.081801454
Landuse * Fireregime	59641.60238	5	11928.32048	5.081705063	3.282738813
Error	459510.6185	24	19146.27577		
Total	3304375.15	36			

Appendix 11: Effects of interactions of forest, agricultural landuses and fire on floral conservation (dbh below 5cm)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	278714.2432	1	278714.2432	649.2246227	8.81922E-12
Landuse	15218.61264	5	3043.722527	2.753238688	1.620607667
Fireregime	771.9970265	1	771.9970265	1.865118604	1.425316876
Landuse * Fireregime	5671.006219	5	1134.201244	2.170371817	1.876654126
Error	44871.64197	24	1869.651749		
Total	345247.501	36			

Appendix 12: Tukey's comparison test of tree density 5cm to 35cm

Comparison		Mean difference	p-value
Taungya	Maize	359.26	0.000**
Taungya	Natural	337.04	0.000**
Taungya	Cocoa	311.11	0.001**
Taungya	Teak	-11.11	1.000 ns
Taungya	Yam	311.11	0.001**
Maize	Natural	-22.22	0.999 ns
Maize	Cocoa	-48.15	0.971 ns
Maize	Teak	-370.37	0.000**
Maize	Yam	-48.15	0.971 ns
Natural	Cocoa	-25.93	0.998 ns
Natural	Teak	-348.15	0.000**
Natural	Yam	-25.93	0.998 ns
Cocoa	Teak	-332.22	0.000**
Cocoa	Yam	0	1.000 ns
Teak	Yam	322.22	0.000**

Appendix 13: Tukey's comparison test of tree density 36cm to 66cm

Comparison		Mean difference	p-value
Taungya	Maize	142.59	0.011*
Taungya	Natural	120.37	0.041*
Taungya	Cocoa	140.74	0.021*
Taungya	Teak	0	1.000 ns
Taungya	Yam	122.23	0.037*
Maize	Natural	-22.22	0.991 ns
Maize	Cocoa	-1.85	1.000 ns
Maize	Teak	-142.59	0.011*
Maize	Yam	-20.37	0.994 ns
Natural	Cocoa	20.37	0.994 ns
Natural	Teak	-120.37	0.041*
Natural	Yam	1.85	1.000 ns
Cocoa	Teak	-140.74	0.012*
Cocoa	Yam	-18.52	0.996 ns
Teak	Yam	122.23	0.037*

Appendix 14: Tukey's comparison test of tree density 67cm and above

Comparison		Mean difference	p-value
Taungya	Maize	62.96	0.089 ns
Taungya	Natural	-9.27	0.998 ns
Taungya	Cocoa	49.99	0.259 ns
Taungya	Teak	22.22	0.916 ns
Taungya	Yam	61.1	0.103 ns
Maize	Natural	-72.22	0.037*
Maize	Cocoa	-12.96	0.992 ns
Maize	Teak	-40.74	0.472 ns
Maize	Yam	-1.85	1.000 ns
Natural	Cocoa	59.26	0.124 ns
Natural	Teak	31.48	0.723 ns
Natural	Yam	70.37	0.045*
Cocoa	Teak	-27.78	0.812 ns
Cocoa	Yam	11.11	0.996 ns
Teak	Yam	38.89	0.522 ns

Appendix 15: Tukey's comparison test of tree species richness

Comparison		Mean difference	p-value
Taungya	Maize	-9.58	0.001**
Taungya	Natural	-11.65	0.000**
Taungya	Cocoa	-15.96	0.000**
Taungya	Teak	4.97	0.159 ns
Taungya	Yam	-4.07	0.340 ns
Maize	Natural	-2.07	0.896 ns
Maize	Cocoa	-6.38	0.037*
Maize	Teak	14.54	0.000**
Maize	Yam	5.51	0.094 ns
Natural	Cocoa	-4.31	0.281 ns
Natural	Teak	16.61	0.000**
Natural	Yam	7.58	0.009*
Cocoa	Teak	20.93	0.000**
Cocoa	Yam	11.89	0.000**
Teak	Yam	9.04	0.002**

Appendix 16: Tukey's comparison test of tree basal area

Comparison		Mean difference	p-value
Taungya	Maize	112.41	0.001**
Taungya	Natural	-72.35	0.037*
Taungya	Cocoa	88.12	0.007**
Taungya	Teak	55.91	0.157 ns
Taungya	Yam	106.73	0.001**
Maize	Natural	-184.76	0.000**
Maize	Cocoa	-24.29	0.883 ns
Maize	Teak	-56.49	0.157 ns
Maize	Yam	-5.67	1.000 ns
Natural	Cocoa	160.47	0.000**
Natural	Teak	128.27	0.000**
Natural	Yam	179.09	0.000**
Cocoa	Teak	-32.21	0.704 ns
Cocoa	Yam	18.62	0.959 ns
Teak	Yam	50.82	0.245

Appendix 17: Tukey's comparison test of tree diversity

Comparison		Mean difference	p-value
Taungya	Maize	-0.756	0.000**
Taungya	Natural	-1.24	0.000**
Taungya	Cocoa	-1.34	0.000**
Taungya	Teak	0.36	0.006**
Taungya	Yam	-0.776	0.000**
Maize	Natural	-0.48	0.000**
Maize	Cocoa	-0.56	0.000**
Maize	Teak	1.116	0.000**
Maize	Yam	-0.021	1.000 ns
Natural	Cocoa	-0.08	0.943 ns
Natural	Teak	1.599	0.000**
Natural	Yam	0.463	0.000**
Cocoa	Teak	1.679	0.000**
Cocoa	Yam	0.543	0.000**
Teak	Yam	-1.137	0.000**