

**SUSTAINABLE FORESTRY IN GHANA: TRACING ILLEGALLY  
LOGGED TIMBER SPECIES THROUGH DNA BARCODING**

**BY**

**EMILY AKUORKOR AMARH**



**THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN  
PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MPhil  
ENVIRONMENTAL SCIENCE DEGREE**

**DECEMBER, 2014**

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## DECLARATION

I hereby declare that, except for references to other peoples' work which have been duly cited, this work is the result of my own research under supervision and that this thesis has neither in whole nor in part been presented for another degree elsewhere.

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## DEDICATION

I dedicate this piece of work first to the Almighty God for his constant love, mercies and protection upon me throughout my period of study, my parents Mr and Mrs Ashitey Amarh and a special friend Lt Raymond Incoom for their support throughout my education, I say God richly bless you.



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## ABSTRACT

Forests are considered to be a strategic resource for national development and have great importance on a nation's environment. Despite increasing concern over the loss of tropical forests and the significant local and international efforts to find solutions to the problems, the rate of deforestation in the tropics continues to increase. Though Ghana's timber export is the fourth largest industry after gold, tourism and cocoa, her primary rain forest has reduced drastically over the years. It is imperative to make conscious efforts to save our forest and timber resources. However, the correct identification of all timber species is the first step towards their proper management. This study sought to use DNA barcoding as a tool in the identification of timber tree species that are used in commercial trade to enhance sustainable forestry in Ghana. DNA barcoding is an innovative technology appropriate to identify organisms by comparing a sequence of a standard gene region from an unknown specimen with a comprehensive database of sequences from species of established identity. Silica-dried leaf samples of timber trees species in commercial trade in southern Ghana were collected from three biodiversity hotspots in the country namely Bia National Park, Ankasa Resource Reserve and Kakum National Park and sequenced at rbcLa gene region. A success rate of 96.77% was obtained from the sequence. These sequences form the database of DNA barcodes for the identification of timber tree species in commercial trade in southern Ghana. Six timber species were sequenced to verify the utility of the database; they were successfully sequenced and matched with their counterparts in the main database. A hundred percent matching success was achieved which implies that DNA barcoding can correctly identify all timber species. A purposive sampling method was employed to determine the knowledge of plant identification, timber resource situation, timber species used on the industry and the level and the importance of forest conservation using structured

questionnaires and interview guides. Identification of plants using morphological features was the only method used by the respondents in the identification of timber species. Sawn timber was identified by the use of colour and scent produced by the wood which at times is misleading and virtually impossible for woods with the same colour and produces mild or no scent. DNA barcoding is therefore, the efficient identification tool which must be accepted and use by the timber industry to solve these identification challenges. 80% of the respondents were aware of the importance of forest conservation, however, 43% think it is irrelevant to the protection of timber trees species. To ensure the sustainability of our forest both the direct and indirect causes must be tackled simultaneously.

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## LIST OF ABBREVIATIONS

BP	Base pairs
CBOL	Consortium for the barcode of life
CIA	Chloroform Isoanyl Alcohol
CTAB	Cetyltrimethyl Ammonium Bromide
DNA	Deoxyribonucleic acid
FAO	Food and agricultural organization
FC	Forestry Commission
IUCN	International Union for Conservation of Nature
ICTSD	International Centre for Trade and Sustainable Development
NTFPs	Non-timber forest products
PAUP	Phylogenic Analysis Using Parsimony
PCR	Polymerized Chain Reaction
RbcLa	Ribulose-1, 5-bisphosphate carboxylase/oxygenase large subunit
RNA	Ribonucleic acid

## CHAPTER ONE

### 1.0 INTRODUCTION

#### 1.1 Background

Forests create a strategic resource for national development where they are found (Abugre & Kazaare, 2010). They are, therefore, considered as capital assets of utmost economic and social importance, and they exercise great and invaluable influence on a nation's environment, not only in West and Central Africa, but also all over the world (Nani-Nutakor & Boateng, 1996). The benefits that society derives from the forest include production of wood (timber) and other non-timber forest products (NTFPS), protection and conservation of the environment (soil, water, wildlife etc.) and provision of opportunities for recreation. According to Myers (1985), forests also offer employment to many people and contribute a lot to the national economy. It has been estimated that about 60 million people are entirely dependent on forests, while more than 1.6 billion, a quarter of the world's population also depend on forest for amenities like fuel and building materials etc (Abugre & Kazaare, 2010).

The degradation of tropical forests, with the corresponding loss of global biodiversity and environmental services, has resulted in the initiation of a number of international actions to address this problem (Nielsen & Kjær, 2008). Unsustainable management of forest resources however continues, leading to a decreased forest area in large parts of the world (FAO, 2005; FAO, 2006). Besides loss of natural resources and environmental values, unsustainable management practices like illegal logging are associated with a number of negative effects such as violation of indigenous peoples' rights and public or private ownership, violation of local financial and tax regulation, and corruption of civil servants (Tacconi, 2007). Illegal logging and

trade in illegally logged timber and wood products are the cause of many economic and ecological problems both in the producer and the consumer countries and believed to be one of the chief causes of worldwide deforestation and forest degradation in many developing countries (Degen & Fladung, 2007). Forest destruction in turn contributes up to 20 percent of global carbon dioxide emission (Lawson & MacFaul, 2010). Illegal logging also robs cash-strapped governments of vital revenues, with a devastating impact on the livelihoods of forest-dependent people and fosters corruption. Trade in illegally logged timber and wood products create market disadvantages for products from sustainable forestry (Lawson & MacFaul, 2010).

Over the last decade, governments, private sectors and civil societies have recognized these impacts and have made increasing efforts to tackle these problems. A study by Asner, (2006) shows that, illegal logging of large-high value trees is often the critical first step on the road towards eventual forest destruction in primary tropical forests. Despite efforts made by governments, private sectors and civil societies to curb this menace, illegal logging continues to expand (Lawson & MacFaul, 2010).

According to Scientific Correspondence (2007), taxonomy, the science of naming and classifying organisms is the foundation of biology. Its function is to identify biological specimens or fragments of biological origin, but this has been very challenging due to a scarcity of natural history specialists. According to Chase *et al.* (2005), there can be only few experts of taxonomy for a particular group of species worldwide, thus making it very difficult for a smooth identification of such species.

Taxonomic problems are on the increase because taxonomists use largely morphological features to identify species. It is sometimes very difficult to differentiate between identical species based on morphology alone, thereby resulting in mis-identification (Scientific Correspondence, 2007). It has, therefore, become very difficult to protect vulnerable species and also identify and punish those who deal in red listed species. According to Hebert *et al.* (2003), the emergence of DNA barcoding as a means of species identification has the potential to address all the shortcomings in morphological and other molecular forms of identification.

DNA barcoding is a technique for identifying organisms based on a short, standardized fragment of genomic DNA. The rationale of using the short DNA sequence called (universal molecular yardstick), is that “it differentiates among species of a taxon under the assumption that the sequences chosen have relatively lower ‘within-taxon’ variation than that ‘between-taxa’ which can be used in distinguishing between closely related species (Scientific Correspondence, 2007). Since the proposition of this concept and the launch of the “Barcode of Life” project, this simple technique has attracted attention from various experts such as taxonomists, ecologists, conservation biologists, agriculturists, plant quarantine officers, with many others using the DNA barcode (Jinbo *et al.*, 2011). Several studies are being carried out now around the world to produce DNA barcodes like FISHBOL (barcode of fish of the world) and TREEBOL, (barcode of trees of the world) for all known organisms. Many projects are also being undertaken currently to use DNA barcoding in forensics and socio-economic development.

DNA barcoding can be employed to trace illegal logging to reduce deforestation and biodiversity loss. The fight against the threat of illegal felling of timber species with its potential associated deforestation, general environmental degradation and general loss of biodiversity may benefit

immensely from the use of DNA barcoding in the proper identification of such timber species to reduce deforestation, loss of tree species and promote sustainable forestry in Ghana.

## **1.2 Problem statement**

The World Bank has estimated that up to 60% of logging in Ghana has been illegal and other estimates range from 43% to 60% (FAO, 2001). In the last 50 years, Ghana's primary rainforest has been reduced by 90% and in the period 1990-2005, the country lost 1.9 million ha or 26% of its tropical forest cover (FAO, 2001). Large areas of forest have been destroyed by illegal logging, illegal gold mining and agricultural conversion for cacao (<http://www.illegal-logging.info>).

Ghana's virgin forests have been declining at a very fast rate since 1990 in spite of the numerous values of the forest resources (Abugre & Kazaare, 2010). According to FAO (2005), the average estimated annual rate of deforestation between 1990 and 2000 was 120,000 hectares; the average growing stock in the remaining forest area is only 49 m<sup>3</sup> per hectare. At the beginning of this century, Ghana's forest zone, which covered 8.2 million hectare, has been reduced drastically to about 1.7 million ha. Pressure on the remaining forest has increased because of the large number of wood processing plants and illegal operations (Chachu, 1989). At the current rate of wood consumption in Ghana, whether for the timber industry, illegal timber trade, or fuel wood use, the remaining fragmented forest patches will likely disappear soon unless serious changes are made immediately to combat these threats.

Illegal logging has been increasingly recognized as a leading problem facing forest management globally (Abugre & Kazaare, 2010). Thus this study seeks to use DNA barcoding as an identification tool to trace illegal logging to reduce deforestation. In many instances of illegal logging and trade in illegal timber and wood products prosecution in the law courts is difficult because law enforcement officers are not able to prove beyond all reasonable doubt that the species in question is one that is prohibited by law to be logged without a valid permit (Hayman Brack &, 2002). Law enforcement officers lack the capacity to identify correctly their exhibits in court. This is because they use only morphological characteristics and these characteristics are not always reliable. In this way illegal loggers go unpunished. It normally becomes very difficult to enforce the law without accurate and precise identification of commercial trees, and trees that are illegally logged. DNA barcoding will ensure accurate and rapid identification of trees in commercial trade.

### **1.3 Justification**

Ghanaian timber exports bring US\$ 400 million to the domestic economy, making it the fourth largest industry after gold, tourism and cocoa (ICTSD, 2008) but logging practices in the country have been widely criticized as unsustainable as illegal harvesting is rampant (ICTSD, 2008). In view of this, the current study is important as it will provide DNA barcode sequences of commercial timber species in the country. This will ensure the accurate identification of trees and allow the successful prosecution of illegal loggers so as to reduce illegal logging and the trade in illegal timber and wood products, thus reducing deforestation, loss of tree species and enabling sustainable forestry and development.

#### **1.4 Objectives of the study**

The main objective of this research is to use DNA barcoding as a tool in the identification of tree species that are used in commercial timber trade to enhance sustainable forestry in Ghana.

The specific objectives are to:

- Identify timber species that are commonly logged and are in commercial trade in Ghana
- Identify current methods of timber identification and its challenges.
- Produce DNA barcodes for commercial timber tree species in Ghana.
- Verify the utility of DNA barcodes in the identification of timber trees.

## CHAPTER TWO

### 2.0 LITERATURE REVIEW

#### 2.1 State of Ghana's Forests

Many authors indicate that, Ghana's relatively undisturbed forests harbored abundant biodiversity (Alpert, 1993), which protect fragile soils (FAO, 2007; UNEP, 2002), and regulate the supply of scarce water resources (Glantz & Katz, 1985). However, illegal logging, deforestation and global climate change among other impacts, are significantly causing a rapid loss of biodiversity in the country (Boon *et al.*, 2009). The degradation of forests and the loss of biodiversity in Ghana have increased sharply in recent decades (Dixon *et al.*, 1996). Ghana's total forest zone is currently estimated at 81,342 km<sup>2</sup> and accounts for about 40% of the total land area, out of which about 17,845 km<sup>2</sup> are known to be under reservation (Boon *et al.*, 2009). The reserved forest is made up of 11,590 km<sup>2</sup> of production forests; 4,323 km<sup>2</sup> of protection forests; and about 1,980 km<sup>2</sup> of game production reserves (Siaw, 2001; Ghana Forestry Commission, 1995). Ghana, like many tropical countries, continues to lose its remaining closed forests at an alarming rate. According to Allotey (2007), the area of undisturbed forest has reduced to less than 25% of its original value and now exists in fragmented patches estimated to be about 20 to 524 km<sup>2</sup>. Between 1990 and 2005, Ghana has lost about 1.9 million hectares of forest or 26% of her forests cover; the annual deforestation rate is 2.0% (Boon *et al.*, 2009).

According to FAO (2001), most of the forests have lost their pristine interior habitats that are critical for the protection of vulnerable species. It was recorded in 1992 that, Ghana was left with only about 1.5 million ha of "intact closed forest" with an annual loss of about 20,000 to agriculture, through bush fires, illegal logging and other anthropogenic activities (Agyarko,

2001; IUCN, 1992). The forests are now characterized by excessive harvesting of logs, a reduction in standing volumes of species, dwindling resource base, species depletion and loss of biodiversity (Agyarko, 2001). Allotey (2007) stated in his study that about 14% of the total permanent forest reserves in Ghana are now without adequate forest cover. National parks and other protected areas of Ghana's territory, contain some of the richest biodiversity, but are assigned for timber production. If managed effectively, these forests could maintain their biodiversity values including viable populations of large forest-dwelling species, such as elephants, bongos, and primates; some of which are rare, threatened or endangered.

## **2.2 Importance of forest**

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, 2009). It is estimated that forests account for an average of 6% of Gross Domestic Product in Africa, which is the highest in the world (NEPAD, 2003). According to FAO (2001), 15% of Ghanaians depend on the forest for their livelihood with over two-thirds of Sub-Saharan Africa's (600 million) people directly or indirectly relying on forests for their livelihoods as well as for food security (CIFOR, 2005). Ghana obtains 70% of her energy needs through fuel wood from forest (FAO, 2001). Forests are essential in the recharging of water bodies as well as controlling water flow (Tutu & Akol, 2009). They are, therefore, vital in the health of communities, agricultural production and electricity power generation, which depends on this water. Forests also serve as habitats for numerous species in the world. They help in combating land degradation and desertification and mitigating climate change, by absorbing and sequestering carbon dioxide, a major greenhouse gas which pose serious threats to

agricultural production among other economic activity (Tutu & Akol, 2009). Despite the numerous benefits of forest to Ghana's economy, many activities including illegal logging, bushfires and illegal mining among others contribute to the destruction of the forest and if nothing is done to minimize the rate at which the forest is being lost, the future generation will be denied of their right to enjoy the forest.

### **2.3 Sustainable Forestry**

Sustainable forestry is the managing of our forest resources to meet the needs of today without interfering with our future generations' needs (Green works, 2005). According to Cubbage (nd), sustainable forestry has become a widely accepted paradigm for forest management since 1992. Forests provide wide-range and diverse benefits to people in the world. These benefits consist of economic outputs such as the income and employment that is generated by forest industries. Well-managed forests also deliver a range of 'social and environmental' goods and services. Some of these goods and services include the provision of opportunities for open-access outdoor recreation. Sustainable forestry also contributes to the visual quality of the landscape. Other benefits are improving air quality, regulating water supply and water quality, and providing protection for archaeological sites (Forestry Commission, 2004). These social and environmental benefits cannot be valued in monetary terms; however, understanding the value that people place on these benefits provides useful information for the management of forest resources.

## **2.4 Factors affecting sustainable forestry**

Over the years, sustainable management of the tropical forest resources has been of primary concern due to its potential impact on biological diversity and their importance in maintaining global ecological functions such as weather conditions (Ezebilo, 2004). Most of the African timber rich zones are faced with diminishing forest resources due to illegal logging activities, human and animal population pressures, shifting cultivation, global climate change among others, which have led to forest degradation (Ezebilo, 2004). Kio (1992) predicted that, within the next thirty years, unless adequate measures are taken, most humid tropical forestland area in Africa could be transformed into unproductive land and the deterioration of the savanna into desert will be accelerated. Some factors affecting sustainable forestry are discussed in the sections that follow.

### **2.4.1 Effect of logging on forests**

Logging can seriously degrade forests (Putz *et al.*, 2001). According to Abdullhadi and Surkardjo (1981), logging activities may result in the disappearance of species thus reducing species diversity and the potential of the forest. Uncontrolled logging and illegal logging activities has considerable impacts on biodiversity conservation, forest structure and species composition and may lead to loss and fragmentation of forests (Foaham & Jonkers, 1992). Many authors have indicated declines in numbers of large tree species after logging (Okali & Ola-Adams, 1987; Primack & Lee, 1991). Even when there is a minimum of mechanization and relatively little incidental damage during extraction (Ganzhorn *et al.*, 1990), there are declines in over storey tree size, increased abundance of a few small-stemmed species, and a decrease in larger commercial species even several decades after a logging event (Bawa & Seidler, 1997).

Logging reduces canopy cover and produces large amounts of litter fall. This fuel material renders the forest more susceptible to human-induced forest burning (Cochrane & Schulze, 1999, Nepstad *et al.*, 1999), which is often triggered by ignition sources in adjacent cattle pastures, slash-and-burn plots, and commercial crops (Holdsworth & Uhl, 1997; Gascon *et al.*, 2000; Barlow & Peres, 2004).

#### **2.4.2 Effect of mining on forests**

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

### **2.4.3 Shifting cultivation and forest degradation**

Shifting agriculture is the clearing of forested land for raising or growing the crops until the soil is exhausted of nutrients and/or the site is overtaken by weeds and then moving on to clear more forest (Chakravarty *et al.*, 2012). Lands are used for a few years and then are gradually abandoned to natural vegetation for fallow periods of up to 20 or more years. According to Sponsel (2005), shifting cultivation is practiced by 240 to 500 million people on nearly one-half of the land area of the tropics, since this requires as much as 15-30 hectares to feed one person due to the lengthy fallow period generally required. In the past, shifting cultivation created little or no concerns as human populations were generally low. In recent years, however, the practice has become unsustainable in the light of the vast areas of land required by the exploding human populations. Shifting cultivation accounts for half the world's rainforest destruction (Colchester & Lohmann, 1993).

### **2.4.4 Effect of Population growth on forests**

“Since the genesis of human history, the fate of humans and trees has remained tightly bound. Forests have exerted tremendous influence on livelihoods and economic development in many societies. One of the most important concerns of this age is the question of population growth and whether the earth’s resources can sustain this rapid expansion of population in most parts of the world. This has reignited an extensive debate worldwide on the relationship between population growth, depletion of resources and environmental sustainability” (Asongu & Jingwa 2011). The role of population in deforestation is a contentious issue (Mather, 1991; Colchester & Lohmann, 1993; Cropper & Griffiths, 1994; Ehrhardt-Martinez, 1998; Sands, 2005).

Overpopulation is believed to be one of the causes of forest loss according to the international agencies such as FAO and intergovernmental bodies (Chakravarty *et al.*, 2012).

According to the United Nations in 2001, the world population quadrupled from 1.6 billion to 6.1 billion during the period 1900 to 2000. It is also estimated that the world's population was 4 billion in 1975, 5 billion in 1987, 6 billion in 1999 and just recently in 2011 the world counted its 7 billionth person. In the same progressive vein, the projected estimates for 2027 and 2046 are 8 and 9 billion, respectively (United Nations, 2001). However, this rapid population growth and development has occurred unevenly throughout the world with African countries experiencing higher rates with the consequences of increasing unsustainable utilization of the forest resources.

Furthermore the population of Africa increased from 233 million in 1950 to 399 million in 1980, to 633 million in 1990, and to 744 million in 1995. It is estimated that by the year 2025 the population will reach 1.5 billion (WRI and UNEP, 1996-7). Over population has put severe pressure on the land and has accelerated its rate of degradation (Boon, 2007). According to Chakravarty *et al.* (2012), more people require more food and space which requires more land for agriculture and habitation. This in turn results in more clearing of forests.

## **2.5 Some solutions to factors affecting sustainable forestry**

According to Chakravarty *et al.* (2012), the struggle to save the world's rainforests continues and there is a growing worldwide concern about the issue. In order to save forests, we need to know why they are being destroyed which serves as the first point of solution. Distinguishing between the agents of degradation and its causes is very important in order to understand the major determinants of forest degradation. The agents of degradation include shifting cultivation by

different categories of farmers such as commercial farmers, ranchers, loggers, firewood collectors, infrastructure developers and others who are cutting down the forests.

In order to address the challenge of forest destruction, there is the need to promote sustainable forest management.

In order to promote sustainable forest management, it must be sustainable ecologically, economically and socially (Chakravarty *et al.*, 2012). Achieving ecological sustainability means that the ecological values of the forest must not be degraded and if possible they should be improved. This also implies that silviculture and management should not reduce biodiversity, logging and soil erosion should be controlled, and soil fertility should not be lost, water quality on and off site should be maintained and that forest health and vitality should be safeguarded (Chakravarty *et al.*, 2012).

Some of the measures to put in place to ensure sustainable forestry in the country could include the following: participatory forest management and rights, encourage the utilization of substitutes e.g., bamboo and the use of modern technology such as DNA Barcoding in the identification of trees to provide a disincentive to illegal logging and hence ensuring sustainable forestry.

### **2.5.1 Participatory forest management and rights**

Forest is nominally owned by the state, but the reach of government and the rule of law are weak and property rights insecure (Chakravarty *et al.*, 2012). In order for forest management to succeed, all parties with an interest in the fate of the forest should be communally involved in planning, management and profit sharing (Colchester & Lohmann, 1993). The balance of rights can be tilted strongly toward society in the form of publicly owned strictly protected areas. State

ownership and management can be retained but with sustainable timber extraction allowed. As of now much of the world's tropical forest are state owned but community participation in forest ownership and management needs to be encouraged with restrictions on extraction and conversion (Chomitz *et al.*, 2007). The establishment of the collaborative forest management unit by the Ghana Forestry Commission (FC) was a step in the right direction. This is because the unit has been promoting participatory forest management across the country since its inception in the early 1990s. This approach has helped to reduce illegal logging since the involvement of local stakeholders in managing the forests has contributed to the reduction of forest degradation in the country.

### **2.5.2 Encouraging traditional commercial timber**

For all purposes where tropical or other timber is used, other woods or materials could be substituted. We can stop using timber and urge others to do the same. As long as there is a market for wood products, trees will continue to be cut down. Labelling schemes, aimed at helping consumers to choose environmental friendly timbers, are currently being discussed in many countries (Anon., 1990). The Bamboo and Rattan Department Programme has been set up in Ghana to promote the use of bamboo and rattan as alternatives to wood to help to reduce the pressure on our forest resources.

In conclusion Ameyaw (2012), states that the fight to promote sustainable forestry by addressing factors affecting it adversely needs to be continued and it is also our moral obligation to preserve our forest so as to pass it on to the next generation, because if we fail in this regard, posterity will not forgive us.

## 2.6 DNA barcoding.

DNA barcoding is a standard tool for rapid identification of animals, fungi, microbes and plants species (Hebert *et al.*, 2003) based on a single universal marker or DNA barcode sequence (Fretzal *et al.*, 2008) that mutates enough to distinguish closely related species (Mendelson, 2003). It differs from molecular phylogeny in that the main goal is not to determine classification but to identify an unknown sample in terms of a known classification (Kress *et al.*, 2005).

Scientists have come to believe that DNA barcoding will provide a ‘universal key’ that will allow identification of a species by running unknown DNA sequences through a DNA barcode database (Scientific Correspondence, 2007).

According to the Consortium for the Barcode of life (2012), until now, biological specimens were identified using morphological features. In some cases a trained technician could make routine identifications using morphological “keys”, but in most cases an experienced professional taxonomist is needed. If a specimen is damaged or is in an immature stage of development, even specialists may be unable to make identifications. DNA Barcoding solves these problems, because non-specialists can obtain barcodes from tiny amounts of tissue. This is not to say that traditional taxonomy has become less important, but rather that DNA barcoding can serve a dual purpose as a new tool in the taxonomists’ toolbox supplementing his/ her knowledge as well as being an innovative device for non-experts who need to make a quick identification.

## 2.7 Some applications of DNA barcoding

DNA barcoding has practical applications in several essential ways including; tracing of illegal logging and trade in endangered and threatened plant and animal species, including CITES and red list species, forensic science, verification and authentication of herbal medicines and among others.

DNA barcoding has the prospect of tackling illegal logging. According to Heng (2012), DNA is nature's barcode. It is inherent in nearly every cell in every organism, and could just be our answer to curbing illegal timber trade. DNA fingerprinting for trees based on technologies routinely used in criminal forensics holds much promise in the field of international enforcement. In other words, these tools are prime candidates for putting a check on illegal logging – an industry which has devastating consequences for biodiversity, ecosystems and national economies alike. According to Nielsen & Kjær (2008), DNA obtained from dried wood samples can be amplified and thus with available DNA data of timber species, dried wood can be traced from the source even to the consumer. This is a positive prospect to deal with the continually challenging problem of illegal logging facing the forestry industry. Lowe & Cross (2011), states that DNA barcoding offer tremendous promise for use in timber tracking at all levels; regional scale, concession and for tracking individual logs or wood products and can also be easily automated offering quick, cheap and high-volume processing.

According to Ratnasingham & Hebert (2007) and Ross *et al.* (2003), DNA sequence database using a standardized gene fragment has the ability to identify wildlife products, whether as processed meat, skins or whole animals hence making it a potential tool for tracing illegal trade in wildlife and wildlife products.

Existing legislation and treaties governing the trade in wildlife, such as the Convention on the International Trade of Endangered Species (CITES) and the United States Endangered Species Act (ESA), are based on the recognition of distinct population or taxonomic units (Eaton *et al.*, 2010). Accurate identification is often impaired due to the types of products involved, which are typically processed and difficult to identify using morphological techniques (Eaton *et al.*, 2010). Baker (2008) argues that to improve our ability to detect; monitor and control the trade in wildlife and wildlife products, so that lawbreakers can be impeached, more accurate and efficient methods of species identification are required such as DNA barcoding.

The application of DNA barcoding in many forensic cases involves plant evidence that may be useful to link a suspect, a victim, a weapon, a vehicle to crime scenes (Yoon, 1993; Coyle *et al.*, 2001). According to Coyle *et al.* (2001), DNA barcoding has the potential to identify a plant species from minute leaf fragments and pollen grains and these have increased its acceptance and use by forensic botanists because often botanical trace evidence does not contain the necessary morphological features that would allow one to identify a plant at the genus or species level.

Volpato *et al.* (2009), applied forensic DNA barcoding to a case where unknown plant material, declared as “almond leaves”, was being imported into Canada from Haiti Border Service. Officers seized the unknown plant material suspecting that it might be tobacco. DNA barcoding was able to reveal that the plant material was from the genus of *Terminalia*. This genus of large trees includes species like *Terminalia catappa*, which is used in traditional Haitian medicine. Chemical analysis also suggested that the plant material in question was not tobacco further

supporting barcoding results. This clearly demonstrates the practical utility of DNA barcoding for these kinds of samples.

## **2.8 Challenges of DNA Barcoding**

The success of DNA barcoding is based on the assumption that the short DNA sequence chosen has relatively lower ‘within-taxon’ variation than that ‘between-taxa’ and thus can discriminate among species ([www.barcodinglife.org](http://www.barcodinglife.org)). According to Chase *et al.* (2005), the efforts to produce DNA barcodes have been very successful for animals and fungi using the cytochrome oxidase 1 gene (COX 1).

Unlike animals, ‘land plants have had the reputation of being problematic for DNA barcoding for two general reasons: the standard DNA regions used in algae, animals and fungi have exceedingly low levels of variability and the typically used land plant plastid phylogenetic markers (e.g. *rbcL*, *trnL-F*, etc.) appear to have too little variation’ (Chase *et al.*, 2005).

The mitochondrial locus being used for many animal groups and algae is not suitable for use in land plants, and an appropriate alternative is needed. Progress has been made in the selection of two alternative regions for plant DNA barcoding (Cowan & Fay, 2012). There are however many challenges in finding a solution that fulfills all the requirements of a successful, universally applicable barcode, and in the short term a pragmatic solution that achieves as much as possible and has payoffs in most areas has been chosen. Research continues in areas ranging from the technicalities of sequencing the regions to data analysis and the potential improvements that may result from the developing technology and data analysis systems (Cowan & Fay, 2012).

In conclusion, the application of DNA barcoding is an efficient tool that can reduce the difficulties in identification and finding of new species using only morphological characters.

It will be important for our country to develop skills and infrastructure to apply the principle of the DNA barcoding technique in essential areas of the country that deals with research on biodiversity to enforcement of food laws, quarantine and phyto-sanitary laws, illegal logging and protection of wildlife.

## CHAPTER THREE

### 3.0 MATERIALS AND METHODS

According to the Forestry Commission Ghana, fifty timber tree species are in commercial trade, (Table 1). However, only 31 of the timber species could be identified and sampled in three biodiversity hotspots in the country. The biodiversity hotspots are Ankasa Resource Reserve, Kakum National Park and Bia Biosphere Reserve. DNA barcode database was developed from the 31 tree species sampled from the three study sites in Ghana for future identification of such tree species.

To verify the authenticity of the data in the molecular identification of such timber trees, DNA barcodes were produced for six trees already in the reference database for comparison which were randomly selected. Detailed descriptions of the sites are presented below.

#### 3.1 Study Area

Three forested areas in southern Ghana were selected for the study. These were the Bia Biosphere Reserve, Ankasa Production Reserve and Kakum National Park. They were selected because they form the most significant and high biodiversity hot spots in the country. Also they have timber species of commercial importance and are better protected.

##### 3.1.1 Bia Biosphere Reserve

Bia Biosphere Reserve is in the Western Region of Ghana and lies in Southwest Ghana on the border with La Côte d'Ivoire, within the administrative jurisdiction of Juabeso District Assembly and traditionally under the Paramount stool of the Sefwi Wiawso Traditional Council at Sefwi Wiawso. It lies between latitudes 6° 20' to 6° 38' N and longitude 2°58' to 3° 58'W, (Forestry

Commission, 2010). The Bia Biosphere Reserve lies in the transition zone between two of Ghana's vegetation categories; the northern part lies within the Moist Evergreen Forest Vegetation Zone while the southern part is within the Moist Semi-deciduous Vegetation Zone (Hall and Swaine, 1981).

Bia Biosphere Reserve lies in the south-west corner of the Southern Ashanti Uplands (Diame, 2010). Topography is undulating, and the geology mixed, with Lower Birrimian (middle Pre-Cambrian) to the east, granites to the west, and Upper Birrimian forming a north-south strip through the middle (Diame, 2010). According to Hall & Swaine (1981), the soils derived from the mixture are Acrisols, locally classified as forest Ochrosols. It is a moderately acidic soil with pH of 6-7 and generally red or reddish brown appearance. The Biosphere reserve protects the headwaters of River Panabo and River Sukusuku which flow into La Côte d'Ivoire and river Tawya which is a tributary of River Bia (Diame, 2010). The climate is humid tropical, with a distinct dry season from December to March (Forestry Commission, 2010). Temperatures are estimated to vary from a minimum of 20-22°C (July/August) to a maximum of 29-34°C (February/March). Rainfall peaks are in June and October and the mean annual total is between 1500-1700mm (Forestry Commission, 2010). Fig. 1 presents the map of Bia Biosphere Reserve and the settlements within and around it.



### 3.1.2 Ankasa Resource Reserve

The Ankasa Resource Reserve (APR) is located in southwestern Ghana on the border with La Côte d'Ivoire. It lies between 5° 09' and 5° 25' North, and between 2° 29' and 2° 45' West. It covers an area of 509 km<sup>2</sup> and is composed of Nini-Suhien National Park and Ankasa Resource Reserve. Ankasa Resource Reserve lies within the wet evergreen zone. It is situated south of the Nini and Tano Rivers and north of the Axim–Elubo Road.

The climate of the Ankasa Resource Reserve has a distinctive bi-modal rainfall pattern occurring from April to July and September to November with an average annual rainfall of 1,700 to 2,000 mm. Mean monthly temperatures are typical of tropical lowland forest and range from 24°C to 28°C (Forestry Commission, 2010). Relative humidity is high throughout the year, at about 90% during the night falling to 75% in early afternoon. Ankasa Resource Reserve has rugged, deeply divided terrain in the north and west with flatter swampy ground associated with the Suhien watershed in the East.

The northern part of Ankasa Resource Reserve is an area of rolling granite topography with frequent, steep sided, small round hills rising 60 to 150 m with no flat uplands and no broad valleys. South of the granites is the Pre-Cambrian Lower Birrimian series, sediment of clay. At the south side are late tertiary sands that are relatively recent deposits (FAO & UNESCO, 1988). Fig. 2 presents the map Ankasa Resource Reserve and the settlements within and around it.

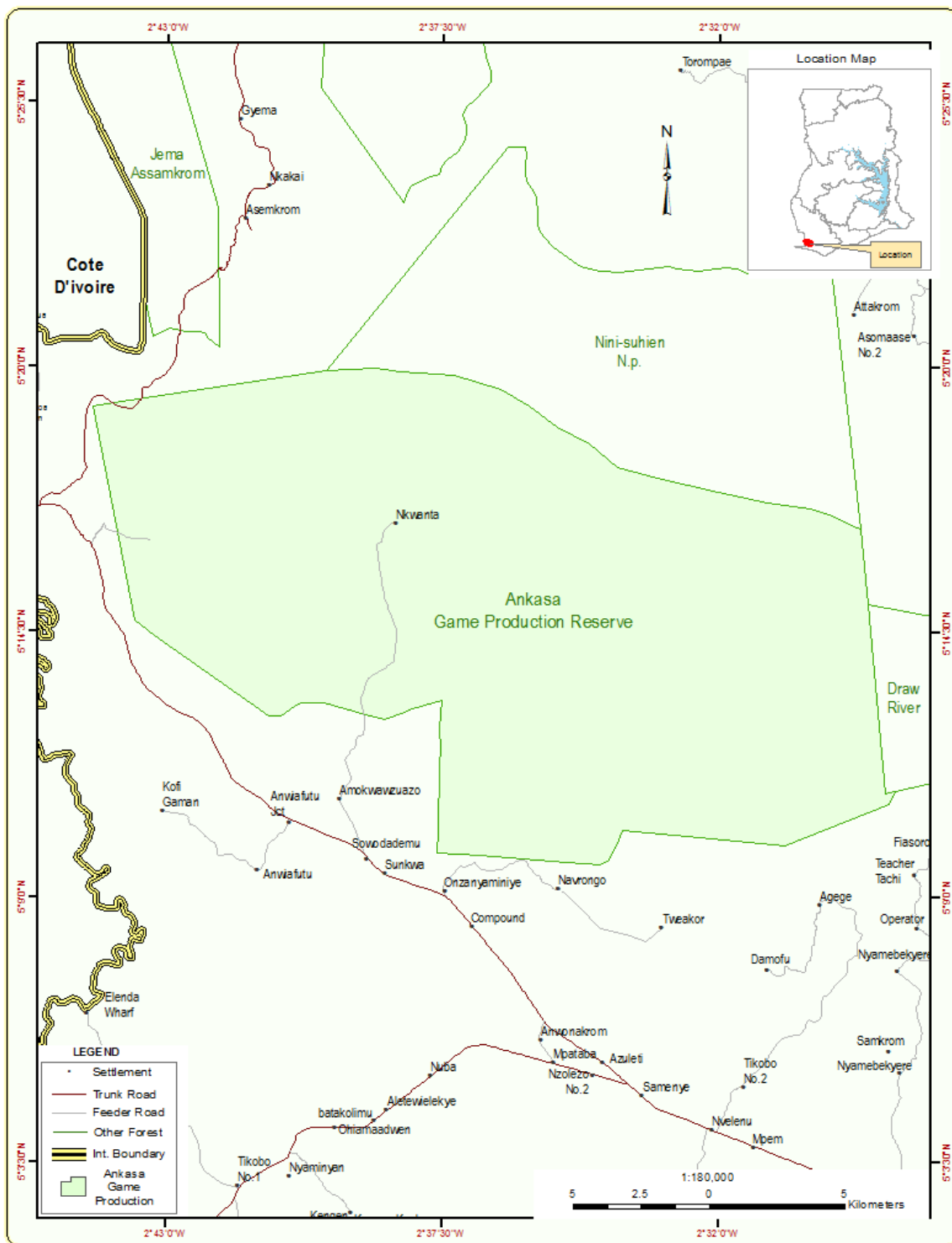


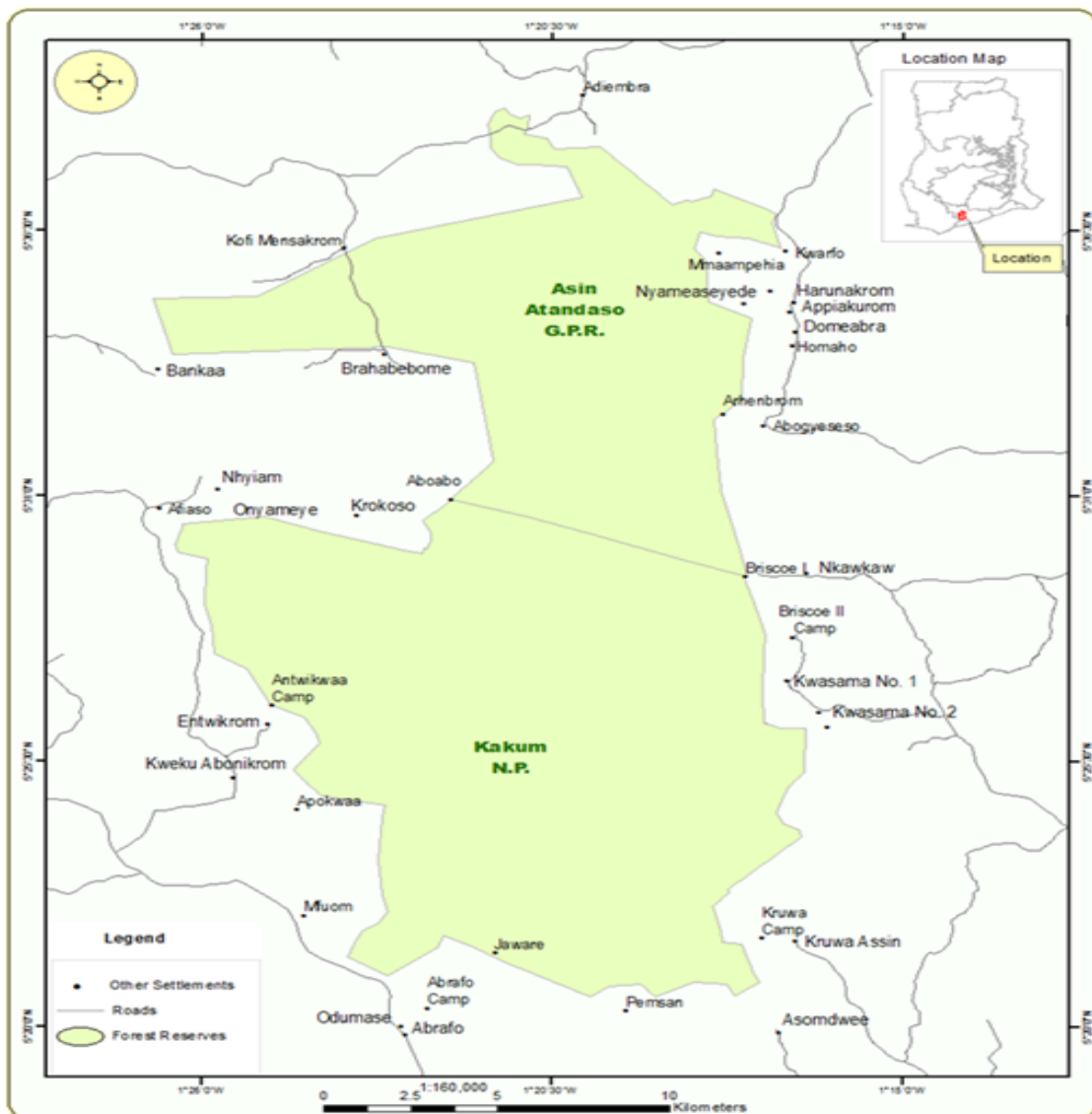
Figure 2: Map showing the location of Ankasa Resource Reserve

### 3.1.3 Kakum National Park

The Kakum National Park is located in the Twifo Heman Lower Denkyera (referred to as Twifo Heman) and Assin Districts of the Central Region of Ghana. Kakum National Park lies within the moist evergreen zone. The reserve lies between longitudes 1°51' and 1°30' W and latitudes 5°20' and 5°40'N (Forestry Commission, 1996). It overlies the Proterozoic Middle Precambrian Cape Coast granitoid complex, which outcrops in some areas like Aboabo, Ahomaho etc (Forestry Commission, 1996).

The Kakum National Park is generally flat with only a few undulating highlands ranging between 150-250 m above sea level (Forestry Commission, 1996). Most of the hills occur in the south-western portion rising up to 250 m. The soils of Kakum National Park are mainly Forest Ochrosols and Forest Gleisols along rivers and streams (Brammer 1962). The corresponding classification by FAO is Rhodic Ferralsols or Haplic Ferralsols and Dystric Gleysols along rivers and streams (FAO UNESCO, 1988).

The mean annual rainfall is between 1,500 mm and 1,750 mm. The prevailing winds are south-westerly and are generally light. The average relative humidity is about 85% with temperatures fluctuating between 10.2°C and 31.6°C (Forestry Commission, 1996). Fig. 3 presents the map of Kakum National Park and the settlements within and around it.



**Figure 3: Map showing the location of Kakum National Park.**

### **3.2 Taxon Sampling**

Green healthy leaf samples of 31 tree species (Appendix A) were collected with a pole pruner from the three biodiversity hot spots (Bia Biosphere Reserve, Ankasa Resource Reserve and Kakum National Park). Leaf samples of each species were collected in duplicate from the same or different forest reserve. In cases where the samples were collected from the same forest the distance between two plants, was at least 1km interval. Leaf samples of all the six trees for verification of the reference were collected from semi deciduous degraded forests around the city of Aburi in the eastern region of Ghana. The spotting of all the tree species in the field was done with the aid of a taxonomist from the Ghana Herbarium, University of Ghana. Specimens that were not immediately confirmed in the field were sent to the Ghana Herbarium for confirmation. Relevant literature such as Hawthorne, (1990), Hawthorne & Jongkind, (2006) and Hawthorne and Gyakari (2006) were used to confirm some of the identifications in the field.

Global Positioning System (GPS) coordinates of each tree species from which samples were taken was recorded with a Garmin Trex handheld GPS. Leaf samples taken were then prepared for DNA extraction and herbarium voucher specimens.

### **3.3 Preparing samples for DNA Extraction**

Green healthy leaf samples of each tree species were cut into smaller pieces with a pair of scissors and put into a Ziploc bag containing silica gel (Chase & Hills, 1991). A small voucher with the following information; name of collector(s), place of collection, GPS location, species name of plant, date of collection and voucher number were prepared and inserted into the Ziploc bag with the voucher number written outside of the bag with a permanent marker. The bag was then sealed with caution to eliminate air. The silica gel in each Ziploc bag is changed after

turning near white colour, an indication of absorbing moisture. Total dryness of each sample was achieved within 24 hours and stored in a refrigerator awaiting DNA extraction.

### **3.4 Preparing Sample for herbarium voucher**

A herbarium voucher is a collection of dried plants or specimen of plants that are systematically arranged for reference. According to Bridson and Forman (1992), the importance of collecting good herbarium specimens is that a small number of really well preserved and annotated specimens are far more valuable than a large number of poor specimens. In collecting herbarium specimen, the collected sample must show as wide a range of variations as possible, hence some important features of the plant such as flowers, fruits, seeds, leaf/leaflet arrangements etc. are collected.

The supporting branch of the part that can best be a representation of the population was cut with a pair of secateurs or sickle to retain all important features such as petioles, axillary buds, stipules, flowers; and fruits if any. It was then trimmed with both a pair of scissors or secateurs and a tag with collection number written in pencil tied to the specimen. Photographs of the whole plant, the prepared specimen, the fruits, seeds and flowers were taken with a digital camera.

Important features such as the colour of the flowers, fruits; ripped and unripe, shape and venations of leaves, colour of stem, approximate height of tree, colour of exudates if any, etc, and a brief description of the plant were recorded. The prepared herbarium specimen was then placed in an old newspaper with the voucher number written with a permanent pen on it. The

newspaper is then placed in between two paper folders and then pressed in between aluminum foils to straighten and flatten the leaves before they dry. The specimens were then dried over a wire mesh on a gas burner.

Large fruits and seeds were dried separately with the same collection number as that of the sample written in permanent ink on it. After thorough drying, the samples were glued onto a herbarium sheet with special herbarium glue. Fruits and seeds were kept at a different place with a reference to the voucher specimen

### **3.5 DNA Extraction**

Laboratory analyses were done at the Vincent Savolainen Laboratory, Imperial College, London United Kingdom (UK). Total genomic DNA was extracted from each of the thirty one silica-dried leaves samples using a modified cetyl trimethylammonium bromide (CTAB) technique (Doyle & Doyle, 1990).

### **3.6 Extraction Process**

About 0.3 g of each silica-dried leaf samples were ground with a laboratory mortar and pestle to break up the thick cell wall covering the cells of the plant in order to release the DNA of the leaf sample. To each ground leaf sample, one ml extraction buffer was added and incubated for 1 hr. at 60°C with occasional swirling after which samples were cooled at room temperature. 600 µL Chloroform isoanyl alcohol (CIA) was added to each sample and mixed gently for 5 minutes followed by a 15 minute centrifuge. The supernatants were then transferred to new tubes and equal volume of isopropanol added and mixed gently. The samples were then incubated at -20°C

overnight and centrifuged for 15 minutes. The pellets were then washed with 70% ethanol followed by another 10 minutes centrifuge. The wash was then repeated for two more times. The DNA was then dried and the pellets dissolved in 50  $\mu$ L TERNase solution and incubated for 1 hr at 37°C after which the DNA is ready for amplification. All chemicals were used according to manufacturers recommended concentrations and quantities.

### **3.7 DNA Amplification**

The extracted DNA sample was made to undergo a 30- 40 cycles of 3 steps; Denaturation at 94°C which is the separation of a double strand into two single strands, which occurs when the hydrogen bonds between the strands are broken. Annealing at 50°C which in genetics means for complementary sequences of single-stranded DNA or RNA to pair by hydrogen bonds to form a double-stranded polynucleotide. The term is often used to describe the binding of a DNA probe or the binding of a primer to a DNA strand during a polymerised chain reaction (PCR). The term is also often used to describe the reformation (renaturation) of complementary strands that were separated by heat (thermally denatured) and finally Extension at 72°C in which the DNA polymerase synthesizes a complementary strand. The enzyme reads the opposing strand sequence and extends the primers by adding nucleotides in the order in which they can pair. The whole process was repeated over and over after which the DNA sample was ready to be sequenced.

### 3.8 DNA Sequencing And Editing

The amplified DNA sample was then placed into a Polymerized Chain Reaction (PCR) machine and the cycle sequencing program started. The Consortium for the Barcode of Life (CBOL) plant working group recommended the 2-locus combination of ribulose-1, 5-bisphosphate carboxylase oxygenase large subunit (*rbcL*) and maturase K (*matK*) as the standard plant barcode based on assessments of recoverability, sequence quality and levels of species discrimination (CBOL Plant Working Group, 2009). In this work the *rbcLa* gene region was sequenced and is composed of 119 sequences, with sequences having a minimum of 431 base pairs (bp) and a maximum of 579 bp. Previous studies (Bafeel *et al.*, 2011; Fazekas *et al.*, 2008) have proven that the *rbcLa* gene region shows a high amplification success rate when used in the identification of plant species than the *matK*. The *rbcLa* primer (ATGTCACCACAAACAGAGACTAAAGC) was used due to its reported high success sequence yielding rate (Kress & Erickson, 2007; Norris *et al.*, 2009).

In the PCR machine, a 26 cycle of three steps; 10 seconds of denaturation at 96°C, 5 seconds annealing at 50°C and finally 4 minutes extension at 60°C take place. After these processes the sequenced DNA samples were ready to be edited. DNA strands were edited and assembled using Sequencher 3.1. (Gene Code, ANN arbor, Michigan, USA) and the *rbcLa* sequences were aligned manually in Phylogenetic Analysis Using Parsimony software program (PAUP\*) v.4.0b.10 (Swofford, 2002). Finally, a DNA sequence of each timber tree species generated was combined to form single-locus DNA matrices. These matrices represent a DNA cladogram database for the timber trees that are in commercial trade in Ghana.

### **3.9 Social Survey**

The social survey carried out during this study deals with two kinds of data: primary data obtained from questionnaires and a face to face interview of a targeted population which consisted of some managers in the Forestry Commission and traders in timber industry. Secondary data obtained from relevant documents on illegal logging activities and the timber industry from journals and the Forestry Commission of Ghana.

#### **3.9.1 Secondary Data**

A thorough and extensive literature review of relevant documents on illegal logging activities and the timber industry was done using secondary data from journals to increase reliability and validity of the data collected (Babbie, 2002; Kumar, 2002 cited by Phiri, 2009). The review provided valuable issues surrounding the research core objectives. Documents related to timber species lost through illegal activities were sought for clarifications with the staff of the Forest Services Division of the Forestry Commission of Ghana.

#### **3.9.2 Primary Data**

A purposive sampling method which targeted a group made up of wood traders, furniture producers and selected key managers of the Forest Services Division whose roles involve forest management, planning and the verification of legal timber was used in the survey. Questionnaires and interview guides (Appendix B) were used to elicit information on the timber species they use in their industry, method of identification of timber species they use, timber resource situation and the level of awareness, the source of awareness and the importance of

forest conservation were also found from the respondents. Also the existing methods used in tracking illegal timber species and their challenges were also found.

### **3.9.3 Data analysis**

A statistical tool, SPSS 17 and Microsoft windows excel were used to analyze the samples.

Percentages, means, frequencies, tables and chats were used in the analyses of the data.

## CHAPTER FOUR

### 4.0 RESULTS

#### 4.1 Timber species commonly logged and are in commercial trade in Ghana

In Table 1 is presented the list of 50 species that are commonly logged and are in commercial trade in Ghana according to the Forestry Commission of Ghana and their conservation status. Of these 31 trees were identified and sampled during the study. 32% of the species are vulnerable while 52% of the species have not been assessed by the International Union for Conservation of Nature.

**Table 1: Commonly logged timber species in commercial trade and their conservation status**

Scientific Name	Local names	Conservation status
<i>Afzelia africana</i>	Papao	Vulnerable
<i>Albizia ferruginea</i>	Awiemfuosemena	Vulnerable
<i>Albizia zygia</i>	Okoro	Not assessed
<i>Alstonia boonei</i>	Sinuro/ Nyamedua	Not assessed
<i>Amphimas pterocarpoides</i>	Yaya	Not assessed
<i>Anopyxis klaineana</i>	kokote	Vulnerable
<i>Antiaris toxicaria</i>	Kyenkyen	Vulnerable
<i>Antrocaryon micraster</i>	Aprokuma	Vulnerable
<i>Bombax bunopozense</i>	Akata/Akondie	Not assessed
<i>Cedrela odorata</i>	Cedrela	Vulnerable
<i>Ceiba pentandra</i>	Onyina	Not assessed
<i>Celtis mildbraedii</i>	Esa	Not assessed

Scientific Name	Local names	Conservation status
<i>Celtis philippensis</i>	Esafufuo	Not assessed
<i>Celtis zenkeri</i>	Esa Kokoo	Not assessed
<i>Chrysophyllum albidum</i>	Akasaa	Not assessed
<i>Chrysophyllum perpulchrum</i>	Atabene	Not assessed
<i>Cola gigantean</i>	Watapuo	Not assessed
<i>Cylicodiscus gabunensis</i>	Denya	Not assessed
<i>Cynometra ananta</i>	Ananta	Not assessed
<i>Daniellia ogea</i>	Hyedua	Not assessed
<i>Distemonanthus benthamianus</i>	Bonsamdua	Not assessed
<i>Entandrophragma angolense</i>	Edinam	Vulnerable
<i>Entandrophragma cylindricum</i>	Sapele/Penkwa	Vulnerable
<i>Entandrophragma utile</i>	Utile	Vulnerable
<i>Gmelina arborea</i>	Gmelina	Not assessed
<i>Guarea cedrata</i>	Kwabohoro	Vulnerable
<i>Heritiera utilis</i>	Nyankom	Vulnerable
<i>Holoptelea grandis</i>	Nakwa	Not assessed
<i>Khaya Ivorensis</i>	Mahogany	Vulnerable
<i>Lannea welwitschii</i>	Kumanini	Not assessed
<i>Lophira alata</i>	Kaku	Vulnerable
<i>Lovoa trichilioides</i>	Dubinibiri/Walnut	Vulnerable
<i>Mansonia altissima</i>	Oprono	Not assessed
<i>Melicia excelsa</i>	Odum	Not assessed
<i>Nauclea diderrichi</i>	Kusia	Not assessed
<i>Nesogordonia papverifera</i>	Danta	Not assessed
<i>Panda oleosa</i>	Kokroboba	Not assessed
<i>Petersianthus macrophylla</i>	Esia	Not assessed
<i>Pouteria aningeri</i>	Asamfena-Nini	Not assessed
<i>Piptadenistrum africanum</i>	Dahoma	Not assessed
<i>Pterygota macrocarpa</i>	Kyere	Vulnerable

Scientific Name	Local names	Conservation status
<i>Pycnanthus angolensis</i>	Otie	Not assessed
<i>Sterculia oblonga</i>	Ohaa	Not assessed
<i>Sterculia rhinoptela</i>	Wawabima	Not assessed
<i>Tectonia grandis</i>	Teak	Not assessed
<i>Terminalia ivorensis</i>	Emire	Vulnerable
<i>Terminalia superba</i>	Ofram	Not assessed
<i>Tieghemella heckelli</i>	Baku/Makore	Not assessed
<i>Triplochiton scleroxylon</i>	Wawa	Least concern
<i>Turraeanthus africanus</i>	Apapaye/ Avodire	Vulnerable
<i>Zanthoxylum leprieurii</i>	Oyaa	Not assessed

#### 4.2 Characteristics of DNA Barcodes of tree species in commercial trade in Ghana

Characteristics of the 31 timber species covering 14 different families and 28 genera used in generating the cladogram and their sequences at the rbcLa gene region are presented below.

##### 4.1.1.0 Species: *Amphimas pterocarpoides* Harms.

Family: Leguminosae

Specimen: GH 0227

Location: Bia Biosphere Reserve 195m 6°34.522'N 3°07.437'W

Description: *Amphimas pterocarpoides* is deciduous, crown dense and dark with leaves clustered at twig tips. Leaves are pinnate and almost alternate. Flowers are yellowish petals, 2.5cm long and deeply notched. Fruits are flat papery wind-dispersed pods up to 20 x 5 cm with raised veins, with single kidney shaped seed 2 cm long (Hawthorne & Gyakari, 2006).



Plate 1: *Amphimas pterocarpoides* Harms.

DNA barcode; rbcLa

```
CAAAC TAAAGCAAGTGTGGATTCAAAGCTGGTGTTAAAGATTATAAATTGACTTATTATACTCCTGA
CTATGAAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACTCCTCAACCTGGAGTTCCGCCTG
AAGAAGCAGGTGCCGCGGTAGCTGCCGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGATGGG
CTTACCAGTCTTGATCGTTACAAAGGACGATGCTACTACATCGAGCCCCTTGCTGGAGAAGAAAATCA
ATATATTGCTTATGTAGCTTATCCCTTAGACCTTTTTGAAGAAGGTTCTGTACTAACATGTTTACTTCC
ATTGTAGGTAATGTATTTGGGTTCAAGGCCCTGCGCGCTCTACGTCTGGAGGATTTGCGAATCCCTACT
TCTTATATTA AAACTTTCCAAGGTCCGCCTCACGGCATCCAAGTTGAGAGAGATAAATTGAACAAGTA
TGGCCGTCCCCTATTGGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGAATTACGGTAGAG
CAGTTTATGAATGTCTCCGCGGTGGACTTGATTTTACCAAAGATGATGAAAATGTGAATTTCCAACCAT
TTATGCGTTGGAGAGACCGTTTCTTATTTTGTGCCGAAGCACTTTATAAAGCACAGGCCGAAACAGGT
GAAATCAAAGGGCATTACTTGAATGCACTG
```

4.1.1.1 Species: *Amphimas pterocarpoides* Harms.

Family: Leguminosae

Specimen: GH 0225

Location: Kakum National Park 176m 5°51.160'N 2°44.184'W

DNA barcode; rbcLa

```
CAAAC TAAAGCAAGTGTGGATTCAAAGCTGGTGTTAAAGATTATAAATTGACTTATTATACTCCTGA
CTATGAAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACTCCTCAACCTGGAGTTCCGCCTG
AAGAAGCAGGTGCCGCGGTAGCTGCCGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGATGGG
CTTACCAGTCTTGATCGTTACAAAGGACGATGCTACTACATCGAGCCCCTTGCTGGAGAAGAAAATCA
ATATATTGCTTATGTAGCTTATCCCTTAGACCTTTTTGAAGAAGGTTCTGTACTAACATGTTTACTTCC
ATTGTAGGTAATGTATTTGGGTTCAAGGCCCTGCGCGCTCTACGTCTGGAGGATTTGCGAATCCCTACT
TCTTATATTA AAACTTTCCAAGGTCCGCCTCACGGCATCCAAGTTGAGAGAGATAAATTGAACAAGTA
TGGCCGTCCCCTATTGGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGAATTACGGTAGAG
CAGTTTATGAATGTCTCCGCGGTGGACTTGATTTTACCAAAGATGATGAAAATGTGAATTTCCAACCAT
TTATGCGTTGGAGAGACCGTTTCTTATTTTGTGCCGAAGCACTTTATAAAGCACAGGCCGAAACAGGT
GAAATCAAAGGGCATTACTTGAATGCACTG
```

4.1.2.0 Species: *Antiaris toxicaria* (Rumph.ex Pers.)Leschen

Family: Moraceae

Specimen: GH0230

Location: Bia Biosphere Reserve 179m 6°22.121'N 2°59.168'W

Description: It is a common canopy or emergent tree across Ghana, especially in secondary forests, old farms etc. Leaves are simple, alternate, and sometimes rough like sandpaper. Its seedlings are usually abundant in the vicinity of the parent plant. Flowers are inconspicuous, in leaf axils while fruits are usually reddish velvety on the outside (Orwa *et al.*, 2009).

Plate 2 *Antiaris toxicaria* (Rumph.ex Pers.) Leschen

DNA barcode; rbcLa

```

CAGAAACTAAAGCTTTTGGTGGATTCAAAGCTGGTGTAAAGATTATAAATTGACTTATTACACTCCTG
AATATGAAGTCAAAGATACTGATATCTTGGCAGCATTTTCGAGTAACTCCTCAACCTGGAGTTCCTCCTG
AAGAAGCAGGGGCTGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCTGTATGGACTGACGGG
CTTACCAGTCTTGATCGCTACAAAGGTCGATGCTACAACATCGAGCCCGTTGCTGGAGAAGAAAATCA
ATATATTGCTTATGTAGCTTACCCTTTAGACCTTTTTGAAGAGGGTTCTGTTACTAACATGTTTACTTCC
ATTGTGGGTAATGTATTTGGGTTCAAAGCTCTGCGGGCGTTACGTCTGGAAGATTTGCGAATCCCTCCT
TCTTATTCTAAAACCTTTCCAAGGACCACCCCATGGTATCCAAGTTGAGAGAGATAAATTGAACAAGTA
TGGCCGTCCTTATTGGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGAATTACGGTAGAG
CAGTTTATGAATGTCTTCGCGGTGGACTTGATTTTACCAAAGATGATGAGAACGTGAATTTCCAACCCCT
TTATGCGTTGGAGAGACCGTTTCTTATTTTGTGCCGAAGCACTTTATAAAGCACAAAGCTGAAACAGGT
GAAATCAAAGGACATTACTTGAATGCAACTG

```

4.1.2.1 Species: *Antiaris toxicaria* (Rumph.ex Pers.)Leschen

Family: Moraceae

Specimen: GH0228

Location: Kakum National Park 176m 5°51.160'N 2°44.184'W

DNA barcode; rbcLa

```
CAGAAACTAAAGCTTTTGTGGATTCAAAGCTGGTGTTAAAGATTATAAATTGACTTATTACACTCCTG
AATATGAAGTCAAAGATACTGATATCTTGGCAGCATTTTCGAGTAACTCCTCAACCTGGAGTTCCTCCTG
AAGAAGCAGGGGCTGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCTGTATGGACTGACGGG
CTTACCAGTCTTGATCGCTACAAAGGTCGATGCTACAACATCGAGCCCGTTGCTGGAGAAGAAAATCA
ATATATTGCTTATGTAGCTTACCCTTTAGACCTTTTTGAAGAGGGTCTGTTACTAACATGTTTACTTCC
ATTGTGGGTAATGTATTTGGGTTCAAAGCTCTGCGGGCGTTACGTCTGGAAGATTTGCGAATCCCTCCT
TCTTATTCTAAAACCTTTCCAAGGACCACCCCATGGTATCCAAGTTGAGAGAGATAAATTGAACAAGTA
TGGCCGTCCCCTATTGGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGAATTACGGTAGAG
CAGTTTATGAATGCTTTCGCGGTGGACTTGATTTTACCAAAGATGATGAGAACGTGAATTCCAACCCT
TTATGCGTTGGAGAGACCGTTTCTTATTTGTGCCGAAGCACTTTATAAAGCACAAAGCTGAAACAGGT
GAAATCAAAGGACATTACTTGAATGCAACTG
```

4.1.3.0 Species: *Ceiba pentandra* (Linn) Gaertn.

Family: Malvaceae

Specimen: GH0235

Location: Bia Biosphere Reserve 195m 6°34.522'N 3°07.437'W

Description: It a very common pioneer tree which is widespread in the tropics. Leaves are usually alternate with 5-9 leaflets, petiole up to 15 cm. Flowers are 2.5 cm long, in clusters; 5 white petals with densely silky hairs and the fruits are usually dark, ellipsoid pendulous capsule with 5 values, 10-30 cm long; inside with dense flossy dirty white 'kapo' with many seeds (Orwa *et al.*, 2009).



Plate 3: *Ceiba pentandra* (Linn) Gaert

## DNA barcode; rbcLa

CAGAAACTAAAGCAAGTGTTGGATTCAAAGCTGGTGTAAAGAGTATAAATTGACTTATTATACTCCT  
 GAATATGAAGTCAAAGATACTGATATCTTGGCAGCCTTCCGAGTAACTCCTCAACCCGGAGTCCGCC  
 TGAGGAAGCAGGGGCGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCGTGTGGACCGATG  
 GGCTTACCAGCCTTGATCGTTACAAAGGGCGATGCTACCACATTGAGCCCGTTGCTGGAGAAGAAAAT  
 CAATATATATGTTATGTAGCTTACCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTT  
 CCATTGTGGGTAATGTATTTGGGTTCAAAGCCCTGCGCGCTCTACGTCTAGAGGATCTGCGAATCCCTA  
 CTTCTTATACTAAAACCTTTCCAAGGCCCGCCTCATGGCATCCAGGTTGAAAGAGATAAATTGAACAAG  
 TACGGTCGCCCCCTATTAGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGAACTACGGTAG  
 AGCAGTTTATGAATGTCTACGTGGCGGACTTGATTTTACTAAAGATGATGAGAATGTGAACTCCCAAC  
 CATTTATGCGCTGGAGAGACCGTTTCGTATTTTGTGCCGAAGCAATTTATAAAGCACAGGCTGAAACA  
 GGTGAAATCAAAGGGCATTACTTGAATG

4.1.3.1 Species: *Ceiba pentandra* (Linn) Gaertn.

Family: Malvaceae

Specimen: GH0233

Location: Kakum National Park 176m 5° 51.160N' 0°10.488'W

## DNA barcode; rbcLa

CAGAAACTAAAGCAAGTGTTGGATTCAAAGCTGGTGTAAAGAGTATAAATTGACTTATTATACTCCT  
 GAATATGAAGTCAAAGATACTGATATCTTGGCAGCCTTCCGAGTAACTCCTCAACCCGGAGTCCGCC  
 TGAGGAAGCAGGGGCGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCGTGTGGACCGATG  
 GGCTTACCAGCCTTGATCGTTACAAAGGGCGATGCTACCACATTGAGCCCGTTGCTGGAGAAGAAAAT  
 CAATATATATGTTATGTAGCTTACCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTT  
 CCATTGTGGGTAATGTATTTGGGTTCAAAGCCCTGCGCGCTCTACGTCTAGAGGATCTGCGAATCCCTA  
 CTTCTTATACTAAAACCTTTCCAAGGCCCGCCTCATGGCATCCAGGTTGAAAGAGATAAATTGAACAAG  
 TACGGTCGCCCCCTATTAGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGAACTACGGTAG  
 AGCAGTTTATGAATGTCTACGTGGCGGACTTGATTTTACTAAAGATGATGAGAATGTGAACTCCCAAC  
 CATTTATGCGCTGGAGAGACCGTTTCGTATTTTGTGCCGAAGCAATTTATAAAGCACAGGCTGAAACA  
 GGTGAAATCAAAGGGCATTACTTGAATG

4.1.4.0 Species: *Celtis mildbraedii* Engl.

Family: Ulmaceae

Specimen: GH0238

Location: Bia Biosphere Reserve 195m 6°34.522'N 3°07.437'W

Description: It is extremely abundant in semi-deciduous forests across tropical Africa. Leaves are simple, alternate, and serrated. Flowers clusters in leaf axils, greenish, without petals, 2 styles each splitting into 2 stigmas (Hawthorne & Gyakari, 2006).



Plate 4 *Celtis mildbraedii* Engl.

DNA barcode; rbcLa

```
CAGAAACTAAAGCTTTTTGTTGGGATTCAAAGCCGGTGTTAAAGATTATAAATTGACTTATTACACTCC
TGAATATGAAACCAAAGATACTGATATCTTGGCAGCATTTTCGAGTAACTCCTCAACCTGGAGTTCCCC
CTGAAGAAGCAGGGGCTGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCTGTATGGACTGAC
GGGCTTACCAGCCTTGATCGCTACAAAGGTCGATGCTACCACATCGAGCCCCTTGCTGGAGAAGAAAA
TCAATATATTGCTTATGTAGCTTACCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACT
TCCATTGTGGGTAATGTATTTGGGTTCAAGGCCCTGCGCGCTCTACGTCTGGAGGATTTGAGAATCCCT
CCTGCTTATACTAAAACCTTCCAAGGCCCGCCTCATGGCATCCAAGTTGAGAGAGATAAATTGAACAA
GTATGGCCGCCCTATTGGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGAATTACGGTA
GAGCTGTTTATGAATGTCTTCGCGGTGGACTTGATTTTACCAAAGATGATGAGAACGTGAATTCCCAA
CCATTTATGCGTTGGAGAGACCGTTTCTTATTTGTGCCGAAGCACTTTATAAAGCACAGGCTGAAACA
GGTGAAATCAAAGGACATTACTTGAATGCAACTC
```

4.1.4.1 Species: *Celtis mildbraedii* Engl.

Family: Ulmaceae

Specimen: GH0236

Location: Kakum National Park 130m 5° 10.416'N 0°22.984'W

DNA barcode; rbcLa

```
CAGAAACTAAAGCTTTTTGTTGGGATTCAAAGCCGGTGTTAAAGATTATAAATTGACTTATTACACTCC
TGAATATGAAACCAAAGATACTGATATCTTGGCAGCATTTTCGAGTAACTCCTCAACCTGGAGTTCCCC
CTGAAGAAGCAGGGGCTGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCTGTATGGACTGAC
GGGCTTACCAGCCTTGATCGCTACAAAGGTCGATGCTACCACATCGAGCCCCTTGCTGGAGAAGAAAA
TCAATATATTGCTTATGTAGCTTACCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACT
```

TCCATTGTGGGTAATGTATTTGGGTTCAAGGCCCTGCGCGCTCTACGTCTGGAGGATTTGAGAATCCCT  
 CCTGCTTATACTAAAACCTTTCCAAGGCCCGCCTCATGGCATCCAAGTTGAGAGAGATAAATTGAACAA  
 GTATGGCCGCCCCCTATTGGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGAATTACGGTA  
 GAGCTGTTTATGAATGTCTTCGCGGTGGACTTGATTTTACCAAAGATGATGAGAACGTGAATTCCCAA  
 CCATTTATGCGTTGGAGAGACCGTTTCTTATTTTGTGCCGAAGCACTTTATAAAGCACAGGCTGAAACA  
 GGTGAAATCAAAGGACATTACTTGAATGCAACTC

#### 4.1.5.0 Species: *Celtis philippensis* Blanco

Family: Ulmaceae

Specimen: GH0369

Location: Kakum National Park 176m 5°51.160'N 0°10.488'W

Description: It is a completely hairless leaves with basal nerves reaching higher and generally larger teeth; its slash is pure white (Hawthorne & Gyakari, 2006).



Plate 5: *Celtis philippensis* Blanco

DNA barcode; rbcLa

CAGAAACTAAAGCAAGTGTTGGATTCAAAGCCGGTGTTAAAGATTATAAATTGACTTATTACACTCCT  
 GAATATGAAACCAAAGATACTGATATCTTGGCAGCATTTTCGAGTAACTCCTCAACCTGGAGTCCCCC  
 TGAAGAAGCAGGGGCTGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCTGTATGGACTGACG  
 GGCTTACCAGCCTTGATCGCTACAAAGGTCGATGCTACCACATCGAGCCCGTTGCTGGAGAAGAAAAT  
 CAATATATTGCTTATGTAGCTTACCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTT  
 CCATTGTGGGTAATGTATTTGGGTTCAAGGCCCTGCGCGCTCTACGTCTGGAGGATTTGAGAATCCCTC  
 CTGCTTATACTAAAACCTTTCCAAGGCCCGCCTCATGGCATCCAAGTTGAGAGAGATAAATTGAACAAG  
 TATGGCCGCCCCCTATTGGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGAATTACGGTAG  
 AGCTGTTTATGAATGTCTTCGCGGTGGACTTGATTTTACCAAAGATGATGAGAACGTGAATTCCCAACC  
 ATTTATGCGTTGGAGAGACCGTTTCTTATTTTGTGCCGAAGCACTTTATAAAGCACAGCTGAAACAGGT  
 GAAATCAAAGGACATTACTTGAATGCAACTG

4.1.5.1 Species: *Celtis philippensis* Blanco

Family: Ulmaceae

Specimen: GH0239

Location: Kakum National Park 170m 4°41.150'N 0°9.388'W

DNA barcode; rbcLa

CAGAAACTAAAGCAAGTGTGGATTCAAAGCCGGTGTTAAAGATTATAAATTGACTTATTACACTCCT  
 GAATATGAAACCAAAGATACTGATATCTTGGCAGCATTTTCGAGTAACTCCTCAACCTGGAGTCCCCC  
 TGAAGAAGCAGGGGCTGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCTGTATGGACTGACG  
 GGCTTACCAGCCTTGATCGCTACAAAGGTCGATGCTACCACATCGAGCCCGTTGCTGGAGAAGAAAAT  
 CAATATATTGCTTATGTAGCTTACCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTT  
 CCATTGTGGGTAATGTATTTGGGTTCAAGGCCCTGCGCGCTCTACGTCTGGAGGATTTGAGAATCCCTC  
 CTGCTTATACTAAAACCTTTCCAAGGCCCGCCTCATGGCATCCAAGTTGAGAGAGATAAATTGAACAAG  
 TATGGCCGCCCCCTATTGGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGAATTACGGTAG  
 AGCTGTTTATGAATGTCTTCGCGGTGGACTTGATTTTACCAAAGATGATGAGAACGTGAATTCCCAACC  
 ATTTATGCGTTGGAGAGACCGTTTCTTATTTTGTGCCGAAGCACTTTATAAAGCACAGCTGAAACAGGT  
 GAAATCAAAGGACATTACTTGAATGCAACTG

4.1.6.0 Species: *Celtis zenkeri* Engl.

Family: Ulmaceae

Specimen: GH0242

Location: Ankasa Resource Reserve 110m 5°13.040'N 2°39.089'W

Description: It is commonly found in semi-deciduous forests, especially the drier ones, across tropical Africa. Leaves are usually simple, alternate and asymmetric at base with 3-5 other pair's of laterals. The fruit is red, rounded and 6mm long (Hawthorne & Gyakari 2006).

Plate 6: *Celtis zenkeri* Engl.

## DNA barcode; rbcLa

CAGAAACTAAAGCAAGTGTTGGATTCAAAGCCGGTGTTAAAGATTATAAAATTGACTTATTACACTCCT  
GAATATGAAACCAAAGATACTGATATCTTGGCAGCATTTTCGAGTAACTCCTCAACCTGGAGTTCCTCC  
TGAAGAAGCAGGGGCTGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCTGTATGGACTGACG  
GGCTTACCAGCCTTGATCGCTACAAAGGTCGATGCTACCACATCGAGCCCGTTGCTGGAGAAGAAAAT  
CAATATATTGCTTATGTAGCTTACCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTT  
CCATTGTGGGTAATGTATTTGGGTTCAAGGCCCTGCGCGCTCTACGTCTGGAGGATTTGAGAATCCCTA  
CTTCTTATACTAAAACCTTTCCAAGGCCCGCCTCATGGCATCCAAGTTGAGAGAGATAAAATTGAACAAG  
TATGGCCGCCCCCTATTGGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGAATTACGGTAG  
AGCTGTTTATGAAGTTCCTTCGCGGTGGACTTGATTTTACCAAAGATGATGAGAACGTGAATTCCCAACC  
ATTTATGCGTTGGAGAGACCGTTTCTGCTTTTGTGCCGAAGCACTTTATAAAGCACAGGCTGAAACAG  
GTGAAATCAAAGGACATTACTTGAATGCAACTG

4.1.6.1 Species: *Celtis zenkeri* Engl.

Family: Ulmaceae

Specimen: GH0240

Location: Ankasa Resource Reserve 100m 2° 16.789'N 2°44.184'W

## DNA barcode; rbcLa

CAGAAACTAAAGCAAGTGTTGGATTCAAAGCCGGTGTTAAAGATTATAAAATTGACTTATTACACTCCT  
GAATATGAAACCAAAGATACTGATATCTTGGCAGCATTTTCGAGTAACTCCTCAACCTGGAGTTCCTCC  
TGAAGAAGCAGGGGCTGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCTGTATGGACTGACG  
GGCTTACCAGCCTTGATCGCTACAAAGGTCGATGCTACCACATCGAGCCCGTTGCTGGAGAAGAAAAT  
CAATATATTGCTTATGTAGCTTACCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTT  
CCATTGTGGGTAATGTATTTGGGTTCAAGGCCCTGCGCGCTCTACGTCTGGAGGATTTGAGAATCCCTA  
CTTCTTATACTAAAACCTTTCCAAGGCCCGCCTCATGGCATCCAAGTTGAGAGAGATAAAATTGAACAAG  
TATGGCCGCCCCCTATTGGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGAATTACGGTAG  
AGCTGTTTATGAAGTTCCTTCGCGGTGGACTTGATTTTACCAAAGATGATGAGAACGTGAATTCCCAACC  
ATTTATGCGTTGGAGAGACCGTTTCTGCTTTTGTGCCGAAGCACTTTATAAAGCACAGGCTGAAACAG  
GTGAAATCAAAGGACATTACTTGAATGCAACTG

4.1.7.0 Species: *Cedrela odorata* Linn.

Family: Meliaceae

Specimen: GH0245

Location: Bia Biosphere Reserve 179m 6°22.121'N 2°59.168' W

Description: It is commonly found in forest zone areas. It has pinnate leaves clustered at twig tips and panicles of small flowers. Fruits are splitting capsule with 5 valves and 25 mm flat seeds (Orwa *et al.*, 2009).



Plate 7 *Cedrela odorata* Linn.

DNA barcode; rbcLa

```
GAAACTAAAGCAAGTGTTGGATTCAAAGCCGGTGTTAAAGATTATAAATTGACTTATTATACTCCTGA
CTATGTAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACTCCTCAACCCGGAGTTCCGCCCG
AGGAAGCAGGGGCTGCGGTAGCTGCGGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGATGG
GCTTACTAGCCTTGATCGTTACAAAGGACGATGCTACAACATTGAGCCAGTTGCTGGAGAAGAAAATC
AATATATATGTTATGTAGCTTACCCTTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACGTC
CATTGTGGGTAATGTATTTGGGTTCAAAGCCCTGCGCGCTCTACGTCTAGAGGATCTACGAATCCCTCC
CGCGTATTCTAAAACCTTCCAAGGGCCGCCTCATGGCATCCAAGTTGAGAGAGATAAATTGAACAAGT
ATGGTCGTCCCCTATTGGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGAATTACGGTAGA
GCAGTTTATGAATGTCTACGCGGTGGACTTGACTTTACCAAAGATGATGAGAACGTGAACTCCCAACC
ATTTATGCGTTGGAGAGACCGTTTCGTATTTGTGCGGAAGCAATCTATAAAGCGCAAGCTGAAACAA
GGTGAAATCAAAGGTCATTACTTGAAATGCAACTG
```

4.1.7.1 Species: *Cedrela odorata* Linn.

Family: Meliaceae

Specimen: GH0243

Location: Ankasa Resource Reserve 140m 5°13.040N' 2°39.089'W

DNA barcode; rbcLa

```
GAAACTAAAGCAAGTGTTGGATTCAAAGCCGGTGTTAAAGATTATAAATTGACTTATTATACTCCTGA
CTATGTAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACTCCTCAACCCGGAGTTCCGCCCG
AGGAAGCAGGGGCTGCGGTAGCTGCGGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGATGG
GCTTACTAGCCTTGATCGTTACAAAGGACGATGCTACAACATTGAGCCAGTTGCTGGAGAAGAAAATC
AATATATATGTTATGTAGCTTACCCTTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACGTC
CATTGTGGGTAATGTATTTGGGTTCAAAGCCCTGCGCGCTCTACGTCTAGAGGATCTACGAATCCCTCC
```

CGCGTATTCTAAAACCTTTCCAAGGGCCGCCTCATGGCATCCAAGTTGAGAGAGATAAATTGAACAAGT  
 ATGGTCGTCCCCTATTGGGATGTACTATTAAACCTAAATTGGGGTTATCCGCTAAGAATTACGGTAGA  
 GCAGTTTATGAATGTCTACGCGGTGGACTTGACTTTACCAAAGATGATGAGAACGTGAACTCCCAACC  
 ATTTATGCGTTGGAGAGACCGTTTCGTATTTTGTGCGGAAGCAATCTATAAAGCGCAAGCTGAAACAA  
 GGTGAAATCAAAGGTCATTACTTGAAATGCAACTG

#### 4.1.8.0 Species: *Chrysophyllum albidum* G. Don.

Family: Sapotaceae

Specimen: GH0250

Location: Ankasa Resource Reserve 130m 2°16.789'N 0°22.984'W

Description: *C.albidum* is cultivated in villages for its fruit, which have pointed tips. It is sometimes found in dry forest patches, but not in moist forests. Leaves are generally white-ish (Houessou *et al.*, 2012).



Plate 8 *C.albidum* G. Don.

DNA barcode; rbcLa

CGAACTAAAGCAAGTGTTGGATTCAAAGCGGGTGTTAAAGATTACAAATTGACTTATTATACTCCTGA  
 CTATGAAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACTCCTCAACCTGGAGTTCCACCTG  
 AAGAAGCAGGGGCCGCGGTAGCTGCCGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGATGG  
 ACTTACTAGCCTTGATCGTTACAAAGGGCGATGCTACCACATCGAGCCCGTTGCTGGAGAAGAAAATC  
 AATATATTGCTTATGTAGCTTATCCTTTAGACCTTTTTGAAGAAGGTTCTGTTACTAATATGTTTACTTC  
 CATTGTGGGGAATGTATTTGGGTTCAAAGCCCTGCGCGCTTTACGTCTGGAAGATCTGCGAATCCCTCC  
 TGCGTATTCTAAAACCTTTCCAAGGACCGCCTCATGGCATCCAAGTTGAAAGAGATAAATTGAACAAGT  
 ACGTTCGTCCCCTGTTGGGATGTACTATTAAACCTAAATTGGGGTTATCTGCTAAAACTACGGTAGA  
 GCGGTTTATGAATGTCTCCGCGGTGGACTTGATTTTACCAAAGATGATGAGAACGTGAACTCCCAACC  
 ATTTATGCGTTGGAGAGATCGTTTCGTATTTTGTGCGGAAGCAATTTATAAAGCACAGGCTGAAACAG  
 GTGAAATCAAAGGGCATTACTTGAAATGCAACTG

#### 4.1.8.1 Species: *Chrysophyllum albidum* G. Don.

Family: Sapotaceae

Specimen: GH0248

Location: Kakum National Park 130m 5°10.416'N 0°22.984'W

DNA barcode; rbcLa

```
CGAACTAAAGCAAGTGTGGATTCAAAGCGGGTGTAAAGATTACAAATTGACTTATTATACTCCTGA
CTATGAAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACTCCTCAACCTGGAGTTCCACCTG
AAGAAGCAGGGGCCGCGGTAGCTGCCGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGATGG
ACTTACTAGCCTTGATCGTTACAAAGGGCGATGCTACCACATCGAGCCCGTTGCTGGAGAAGAAAATC
AATATATTGCTTATGTAGCTTATCCTTTAGACCTTTTTGAAGAAGGTTCTGTTACTAATATGTTTACTTC
CATTGTGGGGAATGTATTTGGGTTCAAAGCCCTGCGCGCTTTACGTCTGGAAGATCTGCGAATCCCTCC
TGCGTATTCTAAAACCTTCCAAGGACCGCCTCATGGCATCCAAGTTGAAAGAGATAAATTGAACAAGT
ACGGTCGTCCCCTGTTGGGATGTAATAAACCTAAATTGGGGTTATCTGCTAAAACTACGGTAGA
GCGGTTTATGAATGTCTCCGCGGTGGACTTGATTTTACCAAAGATGATGAGAACGTGAACTCCCAACC
ATTTATGCGTTGGAGAGATCGTTTCGTATTTGTGCCGAAGCAATTTATAAAGCACAGGCTGAAACAG
GTGAAATCAAAGGCATTACTTGAATGCACTG
```

#### 4.1.9.0 Species: *Distemonanthus benthamianus* Baill.

Family: Leguminosae

Specimen: GH0253

Location: Bia Biosphere Reserve 179m 6°22.121'N 2°59.168'W

Description: It is a plant that is commonly found in disturbed forests. Leaves are pinnate with 7-11 alternate leaflets with closely parallel lateral nerves. Flowers are in lax pink panicles with 5 reddish sepals, 3 white petals and 2 stamens. Fruits are usually flat, 9 x 3.5 cm pale brown pod, hairless when ripe, with fine transverse lines and 1-4 seeds (Orwa *et al.*, 2009).



Plate 9 *Distemonanthus benthamianus* Baill.

DNA barcode; rbcLa

CGAACTAAAGCAAGTGTGGATTCAAAGCTGGTGTTAAAGATTATAAATTGACTTATTATACTCCTGA  
 CTATGAAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACTCCTCAACCTGGAGTTCCCCCTG  
 AAGAAGCAGGTGCCGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGATGGG  
 CTTACCAGTCTTGATCGTTACAAAGGACGATGCTACCACATCGAGCCCCTTGGTGGAGAAGAAAATCA  
 ATATATTGCTTATGTAGCTTATCCCTTAGACCTTTTTGAAGAAGGTTCTGTACTAACATGTTTACTTCC  
 ATTGTGGGTAATGTATTTGGGTTCAAGGCCCTGCGCGTCTACGCCTGGAGGATTTGCGAATCCCTCCC  
 GCTTATACGAAAACCTTTCCAAGGTCCGCCTCACGGCATCCAAGTTGAGAGAGATAAATTAACAAGTA  
 TGGCCGTCCCCTATTGGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGAATTACGGTAGAG  
 CAGTTTATGAATGTCTCCGCGGTGGACTTGATTTTACCAAAGATGATGAGAACGTGAATTCCCAACCA  
 TTTATGCGTTGGAGAGACCGTTTCTGTTTTTGTGCCGAAGCAATTTATAAAGCACAGGCCGAAACGGG  
 CGAAATCAAAGGGCATTACTTGAATGCACT

4.1.9.1 Species: *Distemonanthus benthamianus* Baill.

Family: Leguminosae

Specimen: GH0251

Location: Ankasa Resource Reserve 150m 5°13.040'N 2°39.089'W

DNA barcode; rbcLa

CGAACTAAAGCAAGTGTGGATTCAAAGCTGGTGTTAAAGATTATAAATTGACTTATTATACTCCTGA  
 CTATGAAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACTCCTCAACCTGGAGTTCCCCCTG  
 AAGAAGCAGGTGCCGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGATGGG  
 CTTACCAGTCTTGATCGTTACAAAGGACGATGCTACCACATCGAGCCCCTTGGTGGAGAAGAAAATCA  
 ATATATTGCTTATGTAGCTTATCCCTTAGACCTTTTTGAAGAAGGTTCTGTACTAACATGTTTACTTCC  
 ATTGTGGGTAATGTATTTGGGTTCAAGGCCCTGCGCGTCTACGCCTGGAGGATTTGCGAATCCCTCCC  
 GCTTATACGAAAACCTTTCCAAGGTCCGCCTCACGGCATCCAAGTTGAGAGAGATAAATTAACAAGTA  
 TGGCCGTCCCCTATTGGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGAATTACGGTAGAG  
 CAGTTTATGAATGTCTCCGCGGTGGACTTGATTTTACCAAAGATGATGAGAACGTGAATTCCCAACCA  
 TTTATGCGTTGGAGAGACCGTTTCTGTTTTTGTGCCGAAGCAATTTATAAAGCACAGGCCGAAACGGG  
 CGAAATCAAAGGGCATTACTTGAATGCACT

4.1.10.0 Species: *Daniellia Ogea* Harms

Family: Leguminosae

Specimen: GH0370

Location: Kakum National Park 176m 5°51.160'N 0°10.488'W

Description: It is normally found in semi-deciduous forests. Leaves are pinnate, with 4-9 pairs of hairless leaflets. It is characterized by the combination of flowers with four imbricate sepals, five petals, ten stamens and fruits that are 'hemi-legumes (Hawthorne & Gyakari, 2006).

Plate 10 *Daniellia ogea* Harms

DNA barcode; rbcLa

```

AAAAC TAAAGCACGTGTTGGATTCAAAGCAGGTGTTAAAGATTATAAATTGACTTATTATACTCCTGA
CTATGAAACCAAGGATACTGATATCTTGGCAGCATTCCGAGTATCTCCTCAACCTGGAGTTCCGCCCCG
AAGAAGCAGGTGCCGCAGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGACGGG
CTTACCAGCCTTGATCGTTACAAAGGACGATGCTACCACATTGAGCCCCGTTGCTGGAGAAGAAAATCA
ATATATTGCTTATGTAGCTTATCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTTCC
ATTGTGGGTAATGTCCTTTGGGTTCAAGGCCCTGCGCGCTCTACGTCTGGAGGATTTGCGAATCCCTACT
GCTTATATTA AAACTTTCCAGGGTCCGCCTCACGGTATCCAAGTTGAGAGAGATAAATTGAACAAGTA
TGGCCGCCCCCTATTGGGATGTA CTATTA AACCTAAATTGGGGTTATCCGCTAAGAATTACGGTAGAG
CGGTTTATGAATGTCCTCCGCGGTGGACTTGATTTTACCAAAGATGATGAGAACGTGAATTTCCCAACCA
TTTATGCGTTGGAGAGACCGTTTCTTATTTTGTGCCGAAGCAATTTATAAAGCACAGGCTGAAACGGGT
GAAATTAAGGGCATTACTTGAATGCAACTG

```

4.1.10.1 Species: *Daniellia Ogea* Harms

Family: Leguminosae

Specimen: GH0254

Location: Kakum National Park 176m 5°51.160'N 0°10.488'W

DNA barcode; rbcLa

AAAAC TAAAGCACGTGTTGGATTCAAAGCAGGTGTTAAAGATTATAAATTGACTTATTATACTCCTGACTATGAAACCAAGGATACTGATATCTTGGCAGCATTCCGAGTATCTCCTCAACCTGGAGTTCCGCCCCAAGAAGCAGGTGCCGCAGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGACGGGCTTACCAGCCTTGATCGTTACAAAGGACGATGCTACCACATTGAGCCCGTTGCTGGAGAAGAAAATCAATATATTGCTTATGTAGCTTATCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTTCCATTGTGGGTAATGTCTTTGGGTTCAAGGCCCTGCGCGCTCTACGTCTGGAGGATTTGCGAATCCCTACTGCTTATATTA AAACTTTCCAGGGTCCGCTCACGGTATCCAAGTTGAGAGAGATAAATTGAACAAGTATGGCCGCCCTATTGGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGAATTACGGTAGAGCGGTTTATGAATGTCTCCGCGGTGGACTTGATTTACCAAAGATGATGAGAACGTGAATTCCAACCA TTTATGCGTTGGAGAGACCGTTTCTATTTTTGTGCCGAAGCAATTTATAAAGCACAGGCTGAAACGGGTGAAATTAAGGGCATTACTTGAATGCAACTG

4.1.11.0 Species: *Entandrophragma cylindricum* (Sprague)

Specimen: GH0371

Family: Meliaceae

Location Kakum National Park 130m 5°10.416'N 0°22.984'W

Description: It is commonly found in semi-deciduous forests. Leaves are usually pinnate with 5-9 pairs leaflets. Flowers have 2mm long slightly hairy yellowish petals (Hawthorne & Gyakari, 2006).



Plate11 *Entandrophragma cylindricum* (Sprague)

DNA barcode; rbcLa

GACTAAAGCAAGTGTGGATTCAAAGCCGGTGTAAAGATTATAAATTGACTTATTATACTCCTGACTATGTAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACTCCTCAACCCGGAGTTCCGCCCCGAGGAAGCAGGAGCTGCGGTAGCTGCGGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGATGGGCT

TACTAGCCTTGATCGTTACAAAGGACGATGCTACAACATTGAGCCCCTTGCTGGAGAAGAAAATCAAT  
 ATATATGTTATGTAGCTTACCCTTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACGTCCAT  
 TGTGGGTAATGTATTTGGGTTCAAAGCCCTGCGCGCTCTACGTCTAGAGGATCTACGAATCCCTACCGC  
 ATATATTA AAACTTTCCAAGGTCCACCTCATGGCATCCAAGTTGAGAGAGATAAAATTGAACAAGTATG  
 GCCGTCCCCTATTGGGATGTACTATTAACCAA AAATTGGGGTTATCCGCTAAGAATTACGGTAGAGCA  
 GTTTATGAATGTCTACGCGGTGGACTTGACTTTACCAAAGATGATGAGAACGTGAACTCCCAACCATT  
 TATGCGTTGGCGAGACCGTTTCGTATTTTGTGCGGAAGCAATCTTTAAAGCACAAGCTGAAACAGGTG  
 AAATCAAAGGTCATTACTTGAATGCAT

#### 4.1.11.1 Species: *Entandrophragma cylindricum* (Sprague)

Specimen: GH0255

Family: Meliaceae

Location Kakum National Park 130m 5°10.416'N 0°22.984'W

DNA barcode; rbcLa

GACTAAAGCAAGTGTGGATTCAAAGCCGGTGTTAAAGATTATAAATTGACTTATTATACTCCTGACT  
 ATGTAACCAAAGATACTGATATCTTGGCAGCATTCAGTAACCTCAACCCGGAGTTCCGCCCGAG  
 GAAGCAGGAGCTGCGGTAGCTGCGGAATCTTCTACTGGTACATGGACAACGTGTGTGGACCGATGGGCT  
 TACTAGCCTTGATCGTTACAAAGGACGATGCTACAACATTGAGCCCCTTGCTGGAGAAGAAAATCAAT  
 ATATATGTTATGTAGCTTACCCTTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACGTCCAT  
 TGTGGGTAATGTATTTGGGTTCAAAGCCCTGCGCGCTCTACGTCTAGAGGATCTACGAATCCCTACCGC  
 ATATATTA AAACTTTCCAAGGTCCACCTCATGGCATCCAAGTTGAGAGAGATAAAATTGAACAAGTATG  
 GCCGTCCCCTATTGGGATGTACTATTAACCAA AAATTGGGGTTATCCGCTAAGAATTACGGTAGAGCA  
 GTTTATGAATGTCTACGCGGTGGACTTGACTTTACCAAAGATGATGAGAACGTGAACTCCCAACCATT  
 TATGCGTTGGCGAGACCGTTTCGTATTTTGTGCGGAAGCAATCTTTAAAGCACAAGCTGAAACAGGTG  
 AAATCAAAGGTCATTACTTGAATGCAT

#### 4.1.12.0 Species: *Gmelina arborea* Roxb.

Family: Verbenaceae

Specimen: GH0260

Location: Kakum National Park 164m 5°21.172'N 1°21.171'W

Description: *Gmelina arborea* is a moderately sized to large deciduous tree with a straight trunk.

It is wide spreading with numerous branches forming a large shady crown, attains a height of 30 m or more and a diameter of up to 4.5 m. Leaves are opposite-decussate, mostly rather soft and limp; petioles cylindrical, 5-15 cm long, puberulent or glabrous. Flowers are abundant, scented,

reddish, brown or yellow, in terminal and axillary 1- to-3-flowered cymes on the panicle branches, which are about 8-40 cm long (Orwa *et al.*, 2009).



Plate 12 *Gmelina arborea* Roxb.

DNA barcode; rbcLa

```
CAGAAACTAAAGCAAGTGTTGGATTCAAAGCGGGTGTTAAAGAGTACAAATTGACTTATTATACTCCT
GAATACGAAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACTCCTCAACCTGGAGTTCGGCC
TGAAGAAGCAGGGGCCGAGTAGCTGCCGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGATG
GACTTACCAGTCTTGATCGTTACAAAGGGCGATGCTACCACATCGAGCCCGTTCTTGGAGAAAAAGAT
CAATATATCTGTTATGTAGCTTACCCTTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTT
CCATTGTAGGAAATGTATTTGGATTCAAAGCCTTACGTGCTCTACGTCTGGAAGATCTGCGAATCCCTC
AGGCTTATATTA AAAACTTTCCAAGGCCCGCCTCATGGGATCCAAGTTGAGAGAGATAAATTGAACAAG
TATGGTCGTCTCTGTTGGGATGTACTATTA AACCAA AATTGGGGTTATCTGCTAAAAACTATGGTAGA
GCAGTTTATGAATGTCTTCGCGGTGGGCTTGATTTTACCAAAGATGATGAAAACGTGAACTCCCAGCC
GTTTATGCGTTGGAGAGATCGCTTCTTATTTTGTGCCGAAGCAATTTATAAATCACAGGCTGAAACAGT
GAAATCAAAGGGCATTACTTGAATGCAACTG
```

4.1.12.1 Species: *Gmelina arborea* Roxb.

Family: Verbenaceae

Specimen: GH0258

Location: Kakum National Park 130m 5°10.416'N 0°22.984'W

DNA barcode; rbcLa

```
CAGAAACTAAAGCAAGTGTTGGATTCAAAGCGGGTGTTAAAGAGTACAAATTGACTTATTATACTCCT
GAATACGAAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACTCCTCAACCTGGAGTTCGGCC
TGAAGAAGCAGGGGCCGAGTAGCTGCCGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGATG
GACTTACCAGTCTTGATCGTTACAAAGGGCGATGCTACCACATCGAGCCCGTTCTTGGAGAAAAAGAT
CAATATATCTGTTATGTAGCTTACCCTTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTT
CCATTGTAGGAAATGTATTTGGATTCAAAGCCTTACGTGCTCTACGTCTGGAAGATCTGCGAATCCCTC
AGGCTTATATTA AAAACTTTCCAAGGCCCGCCTCATGGGATCCAAGTTGAGAGAGATAAATTGAACAAG
TATGGTCGTCTCTGTTGGGATGTACTATTA AACCAA AATTGGGGTTATCTGCTAAAAACTATGGTAGA
GCAGTTTATGAATGTCTTCGCGGTGGGCTTGATTTTACCAAAGATGATGAAAACGTGAACTCCCAGCC
```

GTTTATGCGTTGGAGAGATCGCTTCTTATTTTGTGCCGAAGCAATTTATAAATCACAGGCTGAAACAGT  
GAAATCAAAGGGCATTACTTGAATGCAACTG

4.1.13.0 Species: *Holoptelea grandis* (Hutch.)Mildbr

Family: Ulmaceae

Specimen: GH0266

Location: Kakum National Park 164m 5°21.172'N 1°21.171'W

Description: It can be found in dry and to a lesser extent moist semi-deciduous forest. Leaves are simple, alternate with 5-8 pairs of laterals. Flowers are usually small, green from nodes behind current years' leaves and fruits are usually flat and round (Obeng, 2011).



Plate 13 *Holoptelea grandis* (Hutch.)Mildbr

DNA barcode; rbcLa

CGACTAAAGCAAGTGTTGGGATTCAAGGCTGGTGTTAAAGATTATAAATTGACTTATTATACTCCTGA  
CTATGAAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACTCCTCAACCTGGAGTTCCGCCCCG  
AGGAAGCAGGGGCCGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGATGGG  
CTTACCAGTCTTGATCGTTATAAAGGACGATGCTACGACATCGAGCCCGTTGCTGGAGAAGAAAATCA  
ATATATTGCTTATGTAGCTTACCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTTCC  
ATTGTGGGTAATGTATTTGGGTTCAAAGCCCTACGCGCTCTACGTCTGGAGGATTTGCGAATCCCCCT  
TCTTATTCTAAAACCTTTTCAAGGCCACCTCACGGCATCCAAGTTGAGAGAGATAAATTGAACAAGTA  
TGGTCGCCCTCTATTGGGCTGTACTATTAACCTAAATTGGGGTTATCCGCTAAGAATTACGGTAGAGC  
AGTTTATGAATGTCTACGCGGTGGACTTGATTTTACCAAAGATGATGAGAATGTGAACTCCCAACCAT  
TTATGCGTTGGAGAGATCGTTTCTTATTTTGTGCCGAAGCACTTTATAAAGCACAGGCTGAGACCGGTG  
AAATCAAAGGGCATTATTTAAACGCACCG

#### 4.1.13.1 Species: *Holoptelea grandis* (Hutch.)Mildbr

Family: Ulmaceae

Specimen: GH0264

Location: Ankasa Resource Reserve 160m 5°13.040'N 2°39.089'3W

DNA barcode; rbcLa

```
CGACTAAAGCAAGTGTGGGATTCAAGGCTGGTGTTAAAGATTATAAATTGACTTATTATACTCCTGA
CTATGAAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACTCCTCAACCTGGAGTTCCGCCCCG
AGGAAGCAGGGGCCGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGATGGG
CTTACCAGTCTTGATCGTTATAAAGGACGATGCTACGACATCGAGCCCGTTGCTGGAGAAGAAAATCA
ATATATTGCTTATGTAGCTTACCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTTCC
ATTGTGGGTAATGTATTTGGGTTCAAAGCCCTACGCGCTCTACGTCTGGAGGATTTGCGAATCCCCCT
TCTTATTCTAAAACCTTTCAAGGCCACCTCACGGCATCCAAGTTGAGAGAGATAAATTGAACAAGTA
TGGTCGCCCTCTATGGGCTGTACTATTAACCTAAATTGGGGTTATCCGCTAAGAATTACGGTAGAGC
AGTTTATGAATGTCTACGCGGTGGACTTGATTTTACCAAAGATGATGAGAATGTGAACTCCCAACCAT
TTATGCGTTGGAGAGATCGTTTCTTATTTGTGCCGAAGCACTTTATAAAGCACAGGCTGAGACCGGTG
AAATCAAAGGGCATTATTTAAACGCACCG
```

#### 4.1.14.0 Species: *Heritiera utilis* Sprague

Family: Malvaceae

Specimen: GH0372

Location: Ankasa Resource Reserve 95m 5°13.040'N 2°39.089'W

Description: A very common, medium sized or tall tree to 30 m, and 90 cm diameter, often with stilted plank roots. The leaves are usually digitate with 5 - 7 leaflets and a long petiole, but young plants and flowering branches may have simple leaves (Hawthorne & Gyakari, 2006).



Plate 14 *Heritiera utilis* Sprague

DNA barcode; rbcLa

CAGAAACTAAAGCAAGTGTGGATTCAAAGCTGGTGTAAAGAGTATAAATTGACTTATTATACTCCT  
 GAATATGAAGTCAAGGATACTGATATCTTGGCAGCCTTCCGAGTAACTCCTCAACCCGGAGTCCGCC  
 TGAGGAAGCAGGGGCCGAGTAGCTGCTGAATCTTCTACTGGTACATGGACAGCCGTGTGGACCGATG  
 GGCTTACCAGCCTTGATCGTTACAAAGGGCGATGCTACCACATTGAGCCCGTTGCTGGAGAAGAAAAT  
 CAATATATATGTTATGTAGCTTACCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTT  
 CCATTGTGGGTAATGTATTTGGGTTCAAAGCCCTGCGCGCTCTACGTCTAGAGGATCTGCGAATCCCTA  
 CTTCTTATACTAAAACCTTTCCAAGGCCCGCCTCATGGCATCCAGGTTGAAAGAGATAAATTGAACAAG  
 TACGGTCGCCCCCTATTAGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGAAGTACGGTAG  
 AGCAGTTTATGAATGTCTACGTGGTGGACTTGATTTTACCAAAGATGATGAGAATGTGAACTCCCAAC  
 CATTTATGCGCTGGAGAGACCGTTTCTTATTTTGTGCCGAAGCACTTTATAAAGCACAGGCTGAAACA  
 GGTGAAATCAAAGGGCATTACTTGATGACG

4.1.14.1 Species: *Heritiera utilis* Sprague

Family: Malvaceae

Specimen: GH0263

Location: Ankasa Resource Reserve 90m 5°13.040'N 2°39.089'W

DNA barcode; rbcLa

CAGAAACTAAAGCAAGTGTGGATTCAAAGCTGGTGTAAAGAGTATAAATTGACTTATTATACTCCT  
 GAATATGAAGTCAAGGATACTGATATCTTGGCAGCCTTCCGAGTAACTCCTCAACCCGGAGTCCGCC  
 TGAGGAAGCAGGGGCCGAGTAGCTGCTGAATCTTCTACTGGTACATGGACAGCCGTGTGGACCGATG  
 GGCTTACCAGCCTTGATCGTTACAAAGGGCGATGCTACCACATTGAGCCCGTTGCTGGAGAAGAAAAT  
 CAATATATATGTTATGTAGCTTACCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTT  
 CCATTGTGGGTAATGTATTTGGGTTCAAAGCCCTGCGCGCTCTACGTCTAGAGGATCTGCGAATCCCTA  
 CTTCTTATACTAAAACCTTTCCAAGGCCCGCCTCATGGCATCCAGGTTGAAAGAGATAAATTGAACAAG  
 TACGGTCGCCCCCTATTAGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGAAGTACGGTAG  
 AGCAGTTTATGAATGTCTACGTGGTGGACTTGATTTTACCAAAGATGATGAGAATGTGAACTCCCAAC  
 CATTTATGCGCTGGAGAGACCGTTTCTTATTTTGTGCCGAAGCACTTTATAAAGCACAGGCTGAAACA  
 GGTGAAATCAAAGGGCATTACTTGATGACG

4.1.15.0 Species: *Khaya ivorensis* A.Chev

Family: Meliaceae

Specimen: GH0315

Location: Kakum National Park 130m 5°10.416'N 0°22.984'W

Description: It is common in evergreen forests, increasingly restricted to low-lying places near streams in semi-deciduous forests. Leaves are usually pinnate, with 5-6 (4-7) pairs, hairless,

slightly leathery leaflets, each with < 10 pairs of laterals. Flowers are yellow scented 5 petalled in lax terminal panicles (Orwa *et al.*, 2009).



Plate15 *Khaya ivorensis* A.Chev

DNA barcode; rbcLa

```
CGACTAAAGCAAGTGTGGGATTCAAAGCCGGTGTTAAAGATTATAAATTGACTTATTATACGCCTGA
CTATGTAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACTCCTCAACCCGGAGTTCCGCCCG
AGGAAGCAGGGGCTGCGGTAGCTGCGGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGATGG
GCTTACTAGCCTTGATCGTTACAAAGGACGATGCTACAACATTGAGCCAGTTGCTGGAGAAGAAAATC
AATATATATGTTATGTAGCTTACCCTTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACATC
CATTGTGGGTAATGTATTTGGGTTCAAAGCCCTGCGCGCTCTACGTCTAGAGGATCTACGAATCCCTCC
CGCGTATTCTAAAACCTTTCCAAGGCCCGCCTCATGGCATCCAAGTTGAGAGAGATAAATTGAACAAGT
ATGGTCGTCCCCTATTGGGATGTACAATTAACCTAAATTGGGGTTATCCGCTAAGAATTACGGTAGA
GCAGTTTATGAATGTCTACGCGGTGGACTTGACTTTACCAAAGATGATGAGAACGTGAACCTCCAACC
ATTTATGCGTTGGAGAGACCGTTTCGTATTTGTGCGGAAGCAATCTATAAGCGCAAGCTGAAACAGG
TGAAATCAAAGGGCATTACTTGAATGCAACTG
```

4.1.15.1 Species: *Khaya ivorensis* A.Chev

Family: Meliaceae

Specimen: GH0313

Location: Kakum National Park 130m 6°10.416'N 5°22.984'W

DNA barcode; rbcLa

```
CGACTAAAGCAAGTGTGGGATTCAAAGCCGGTGTTAAAGATTATAAATTGACTTATTATACGCCTGA
CTATGTAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACTCCTCAACCCGGAGTTCCGCCCG
AGGAAGCAGGGGCTGCGGTAGCTGCGGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGATGG
GCTTACTAGCCTTGATCGTTACAAAGGACGATGCTACAACATTGAGCCAGTTGCTGGAGAAGAAAATC
AATATATATGTTATGTAGCTTACCCTTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACATC
CATTGTGGGTAATGTATTTGGGTTCAAAGCCCTGCGCGCTCTACGTCTAGAGGATCTACGAATCCCTCC
CGCGTATTCTAAAACCTTTCCAAGGCCCGCCTCATGGCATCCAAGTTGAGAGAGATAAATTGAACAAGT
ATGGTCGTCCCCTATTGGGATGTACAATTAACCTAAATTGGGGTTATCCGCTAAGAATTACGGTAGA
```

GCAGTTTATGAATGTCTACGCGGTGGACTTGACTTTACCAAAGATGATGAGAACGTGAACTCCCAACC  
 ATTTATGCGTTGGAGAGACCGTTTCGTATTTTGTGCGGAAGCAATCTATAAGCGCAAGCTGAAACAGG  
 TGAAATCAAAGGGCATTACTTGAATGCAACTG

4.1.16.0 Species: *Lannea welwitschii* (Hiern) Engl

Family: *Anacardiaceae*

Specimen: GH0269

Location: Kakum National Park 164m 5°21.172'N1°21.171'W

Description: Deciduous or evergreen, dioecious, medium-sized tree up to 30(–35) m tall; bole straight and cylindrical, branchless for up to 15(–26) m, up to 100(–120) cm in diameter. Leaves are arranged spirally, clustered at the ends of branchlets, imparipinnately compound with (3–)5–7(–13) leaflets. Flowers are unisexual, regular, 4-merous; pedicel 2–4 mm long; calyx lobes 0.5–1 mm long; petals free. Fruit an ellipsoid to nearly globose, slightly compressed drupe 6–8 mm long, smooth, blackish purple when ripe; stone usually 1-seeded (Orwa *et al.*, 2009).



Plate 16 *Lannea welwitschii* (Hiern) Engl(Hiern) Engl

DNA barcode; rbcLa

CAGAAACTAAAGCAAGTGTGGGATTCAAAGCCGGTGTAAAGACTATAAATTGACTTATTATACTCC  
 TGACTATGCAACCAAGATACTGATATCTTGGCAGCATTCCGAGTAACTCCTCAACCCGGAGTCCAC  
 CCGAGGAAGCAGGGGCCGCGTAGCTGCGGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGAT  
 GGGCTTACCAGCCTTGATCGTTACAAAGGACGATGCTACAACATTGAGCCCCTTGCTGGAGAAGAAAA  
 TCAATATATATGTTATGTAGCTTACCCTTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACT  
 TCCATTGTGGGTAATGTATTTGGGTTCAAAGCCCTGCGCGCTCTACGTCTAGAGGATCTACGAATCCCT

CCCGCGTATACTAAAACCTTTCCAAGGCCCGCCGCATGGGATCCAAGTTGAGAGAGATAAACTGAACAA  
 GTATGGCCGTCCCCTATTGGGATGTACTATTAACCTAAATTAGGGTTATCCGCTAAGAACTACGGTA  
 GAGCAGTTTATGAATGTCTACGTGGTGGACTTGACTTTACCAAAGATGATGAGAACGTGAACTCCCAA  
 CCATTTATGCGTTGGAGAGACCGTTTCCTATTTTTGTGCGGAAGCTCTTTTTAAATCGCAAGCTGAAAC  
 AGGTGAAATTAAGGTCATTTACTTGAATG

4.1.16.1 Species: *Lannea welwitschii* (Hiern) Engl

Family: *Anacardiaceae*

Specimen: GH0268

Location: Bia Biosphere Reserve 227m 6°32.672'N 3°01.959'W

DNA barcode; rbcLa

CAGAAACTAAAGCAAGTGTTGGGATTCAAAGCCGGTGTTAAAGACTATAAATTGACTTATTATACTCC  
 TGACTATGCAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACTCCTCAACCCGGAGTCCAC  
 CCGAGGAAGCAGGGGCCGCGGTAGCTGCGGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGAT  
 GGGCTTACCAGCCTTGATCGTTACAAAGGACGATGCTACAACATTGAGCCCCTGCTGGAGAAGAAAA  
 TCAATATATATGTTATGTAGCTTACCCTTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACT  
 TCCATTGTGGGTAATGTATTTGGGTTCAAAGCCCTGCGCGCTCTACGTCTAGAGGATCTACGAATCCCT  
 CCCGCGTATACTAAAACCTTTCCAAGGCCCGCCGCATGGGATCCAAGTTGAGAGAGATAAACTGAACAA  
 GTATGGCCGTCCCCTATTGGGATGTACTATTAACCTAAATTAGGGTTATCCGCTAAGAACTACGGTA  
 GAGCAGTTTATGAATGTCTACGTGGTGGACTTGACTTTACCAAAGATGATGAGAACGTGAACTCCCAA  
 CCATTTATGCGTTGGAGAGACCGTTTCCTATTTTTGTGCGGAAGCTCTTTTTAAATCGCAAGCTGAAAC  
 AGGTGAAATTAAGGTCATTTACTTGAATG

4.1.17.0 Species: *Mansonia altissima* A.Chev

Family: Malvaceae

Specimen: GH0274

Location: Bia Biosphere Reserve 195m 6°34.522'N 3°07.437'W

Description: Evergreen, medium-sized to fairly large tree up to 45 m tall; bole branchless for up to 30 m, up to 100(–150) cm in diameter, generally straight, cylindrical, sometimes with narrow buttresses. Leaves are alternate, simple; stipules present, early falling; petiole 2–5 cm long. Flowers are bisexual, with fruit consisting of 1–2 (–3) ovoid nuts, 0.5 cm in diameter, surface reticulate, with a large papery wing 5–6 cm × 2 cm (Orwa *et al.*, 2009).



Plate 17 *Mansonia altissima* A.Chev

DNA barcode; rbcLa

CAGAAACTAAAGCTTTTGGTGGATTCAAAGCTGGTGTTAAAGAGTATAAATTGACTTATTATACTCCTG  
 AATATCAAGTCAAAGATACTGATATCTTGGCAGCCTTCCGAGTAACTCCTCAACCCGGAGTTCCGCCT  
 GAGGAAGCAGGGGCCGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCGTGTGGACCGATG  
 GGCTTACCAGCCTTGATCGTTACAAAGGGCGATGCTACCACATTGAGCCCGTTCTGGAGAAGAAAAT  
 CAATATATATGTTATGTAGCTTACCCTTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTT  
 CCATTGTAGGTAATGTATTTGGGTTCAAAGCCCTGCGCGCTCTACGTCTAGAGGATCTGCGAATCCCTG  
 TTTCTTATATTA AAACTTTCCAAGGCCCGCTCACGGCATCCAGGTTGAAAGAGATAAATTGAACAAG  
 TACGGTCGCCCCCTATTAGGATGTACTATTA AACCTAAATTGGGGTTATCCGCTAAGA ACTACGGTAG  
 AGCAGTTTATGAATGTCTACGTGGTGGACTTGATTTTACCAAAGATGATGAGAATGTGAACTCCCAAC  
 CATTTATGCGTTGGAGAGACCGTTTCTTATTTTGTGCCGAAGCAATTTATAAAGCACAGGCTGAAACA  
 GGTGAAATCAA AAGGGCATTACTTGAATGCAACTG

4.1.17.1 Species: *Mansonia altissima* A.Chev

Family: Malvaceae

Specimen: GH0272

Location: Kakum National Park 175m 5°51.160'N 0°10.488'W

DNA barcode; rbcLa

CAGAAACTAAAGCTTTTGGTGGATTCAAAGCTGGTGTTAAAGAGTATAAATTGACTTATTATACTCCTG  
 AATATCAAGTCAAAGATACTGATATCTTGGCAGCCTTCCGAGTAACTCCTCAACCCGGAGTTCCGCCT  
 GAGGAAGCAGGGGCCGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCGTGTGGACCGATG  
 GGCTTACCAGCCTTGATCGTTACAAAGGGCGATGCTACCACATTGAGCCCGTTCTGGAGAAGAAAAT  
 CAATATATATGTTATGTAGCTTACCCTTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTT  
 CCATTGTAGGTAATGTATTTGGGTTCAAAGCCCTGCGCGCTCTACGTCTAGAGGATCTGCGAATCCCTG  
 TTTCTTATATTA AAACTTTCCAAGGCCCGCTCACGGCATCCAGGTTGAAAGAGATAAATTGAACAAG  
 TACGGTCGCCCCCTATTAGGATGTACTATTA AACCTAAATTGGGGTTATCCGCTAAGA ACTACGGTAG  
 AGCAGTTTATGAATGTCTACGTGGTGGACTTGATTTTACCAAAGATGATGAGAATGTGAACTCCCAAC  
 CATTTATGCGTTGGAGAGACCGTTTCTTATTTTGTGCCGAAGCAATTTATAAAGCACAGGCTGAAACA  
 GGTGAAATCAA AAGGGCATTACTTGAATGCAACTG

4.1.18.0 Species: *Nesogordonia papaverifera* (A.Chev.) R.Capuron

Family: Malvaceae

Specimen: GH0277

Location: Bia Biosphere Reserve 195m 6°34.522'N 3°07.437'W

Description: It is commonly found in moist and dry semi-deciduous forests. Leaves are usually simple and alternate. Flowers are white with 13 mm long hairless petals (Hawthorne & Gyakari, 2006).



Plate 18 *Nesogordonia papaverifera*

DNA barcode; rbcLa

```
CGAACTAAAGCAAGTGTTGGATTCAAAGCTGGTGTTAAAGAGTATAAATTGACTTATTATACTCCTGA
CTATGAAGTCAAAGATACTGATATCTTGGCAGCCTTCCGAGTAACTCCTCAACCCGGAGTTCCGCCTG
AGGAAGCAGGGGCCGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCGTGTGGACCGATGG
GCTTACCAGCCTTGATCGTTACAAAGGGCGATGCTACCACATTGAGCCCGTTGCTGGAGAAGAAAATC
AATATATATGTTATGTAGCTTACCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTTC
CATTGTGGGTAATGTATTTGGGTTCAAAGCCCTGCGCGCTCTACGTCTAGAGGATCTGCGAATCCCTAT
TTCTTATATTA AAACTTTCCAAGGCCCGCCTCATGGCATCCAGGTTGAAAGAGATAAATTGAACAAGT
ACGGTCGTCCCCTATTAGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGAACTACGGTAGA
GCAGTTTATGAATGTCTACGTGGTGGACTTGATTTTACCAAAGATGATGAGAATGTGAACTCCCAACC
ATTTATGCGCTGGAGAGACCGTTTCTTATTTGTGCCGAAGCAATTTATAAAGCACAGGCTGAAACAG
GTGAAATCAAAAAGGGCATTACTTGAATGCACTG
```

4.1.18.1 Species: *Nesogordonia papaverifera* (A.Chev.) R.Capuron

Family: Malvaceae

Specimen: GH0275

Location: Kakum National Park 130m 5°10.416N' 0°22.984'W

DNA barcode; rbcLa

```
CGAACTAAAGCAAGTGTGGATTCAAAGCTGGTGTAAAGAGTATAAATTGACTTATTATACTCCTGA
CTATGAAGTCAAAGATACTGATATCTTGGCAGCCTTCCGAGTAACTCCTCAACCCGGAGTTCCGCCTG
AGGAAGCAGGGGCCGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCGTGTGGACCGATGG
GCTTACCAGCCTTGATCGTTACAAAGGGCGATGCTACCACATTGAGCCCGTTGCTGGAGAAGAAAATC
AATATATATGTTATGTAGCTTACCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTTC
CATTGTGGGTAATGTATTTGGGTTCAAAGCCCTGCGCGCTCTACGTCTAGAGGATCTGCGAATCCCTAT
TTCTTATATTA AAACTTTCCAAGGCCCGCCTCATGGCATCCAGGTTGAAAGAGATAAATTGAACAAGT
ACGGTCGTCCCCTATTAGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGA ACTACGGTAGA
GCAGTTTATGAATGTCTACGTGGTGGACTTGATTTTACCAAAGATGATGAGAATGTGAACTCCCAACC
ATTTATGCGCTGGAGAGACCGTTTCTTATTTTGTGCCGAAGCAATTTATAAAGCACAGGCTGAAACAG
GTGAAATCAA AAGGCATTACTTGAATGCACTG
```

4.1.19.0 Species: *Pycnanthus angolensis* (Welw.) Warb.

Family: Myristicaceae

Specimen: GH0280

Location: Bia Biosphere Reserve 195m 6° 34.522'N 3°07.437'W

Description: This tree normally grows in moist rainforest up to about 1200 meters in elevation among other evergreens and semi- deciduous trees. It grows up to 40 meters tall and usually up to a meter wide, sometimes up to 1.5 meters or more. The leaves usually bear signs of insect damage, a feature so common; it is considered characteristic of the species. The flowers are arranged in dense, rusty panicles up to 15 cm long (Orwa *et al.*, 2009).



Plate 19 *Pycnanthus angolensis* (Welw.) Warb

## DNA barcode; rbcLa

CAGAAACTAAAGCAAGTGTTGGATTCAAAGCTGGTGTAAAGAGTACAAATTGACTTATTATACTCCT  
 GAATATGCAACCAAAGATACTGATATCTTAGCAGCATTCCGAGTAACTCCTCAACCCGGAGTTCGGCC  
 TGAGGAAGCAGGGGCTGCGGTAGCAGCCGAATCTTCTACTGGTACATGGACAACTGTGTGGACCGATG  
 GACTTACCAGCCTTGATCGTTACAAAGGACGATGCTACCACATCGAGCCCGTTGCTGGGGAGGAAAAT  
 CAATATATTGCTTATGTAGCTTACCCTTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTT  
 CCATTGTGGGTAATGTATTTGGGTTCAAAGCCCTACGAGCTCTACGTCTGGAGGATCTGCGAATTCCCA  
 CTTCTTATATCAAACTTTCCAAGGCCCGCCCCATGGCATCCAAGTTGAGAGAGATAAATTGAACAAG  
 TACGGTTCGTCCCCTATTGGGATGTACTATTAACCAAATTGGGGTTATCTGCTAAGAAGTACGGTAG  
 GGCGGTTTATGAATGTCTCCGCGGTGGACTTGATTTACCAAGGATGATGAGAACGTGAACTCCCAAC  
 CATTTATGCGTTGGAGAGACCGTTTCGTATTTGTGCCGAAGCTATTTTTAAAGCACAGGCCGAAACAG  
 GGAAATCAAAGGACATTACTTGAATGCACTG

4.1.19.1 Species: *Pycanthus angolensis* (Welw.) Warb.

Family: Myristicaceae

Specimen: GH0278

Location: Kakum National Park 130m 5°10.416N' 0°22.984'W

## DNA barcode; rbcLa

CAGAAACTAAAGCAAGTGTTGGATTCAAAGCTGGTGTAAAGAGTACAAATTGACTTATTATACTCCT  
 GAATATGCAACCAAAGATACTGATATCTTAGCAGCATTCCGAGTAACTCCTCAACCCGGAGTTCGGCC  
 TGAGGAAGCAGGGGCTGCGGTAGCAGCCGAATCTTCTACTGGTACATGGACAACTGTGTGGACCGATG  
 GACTTACCAGCCTTGATCGTTACAAAGGACGATGCTACCACATCGAGCCCGTTGCTGGGGAGGAAAAT  
 CAATATATTGCTTATGTAGCTTACCCTTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTT  
 CCATTGTGGGTAATGTATTTGGGTTCAAAGCCCTACGAGCTCTACGTCTGGAGGATCTGCGAATTCCCA  
 CTTCTTATATCAAACTTTCCAAGGCCCGCCCCATGGCATCCAAGTTGAGAGAGATAAATTGAACAAG  
 TACGGTTCGTCCCCTATTGGGATGTACTATTAACCAAATTGGGGTTATCTGCTAAGAAGTACGGTAG  
 GGCGGTTTATGAATGTCTCCGCGGTGGACTTGATTTACCAAGGATGATGAGAACGTGAACTCCCAAC  
 CATTTATGCGTTGGAGAGACCGTTTCGTATTTGTGCCGAAGCTATTTTTAAAGCACAGGCCGAAACAG  
 GGAAATCAAAGGACATTACTTGAATGCACTG

4.1.20.0 Species: *Piptadeniastrum africanum* (Hook.f.) Brenan

Family: Leguminosae

Specimen: GH0283

Location: Ankasa Resource Reserve 156m 2°16.789N' 0°22.984'W

Description: Large, briefly deciduous tree, to 45 m tall, 2.0 m diameter above the large buttresses, often in drier or disturbed forests. Leaves are usually bipinnate, with 10-19 pairs

pinnae, each with 30-60 pairs leaflets. Flowers are bisexual, pods flat, thin, 20-30 cm long, splitting to release the flat, winged, wind-dispersed seeds (Hawthorne & Gyakari, 2006).



Plate 20 *Piptadeniastrum africanum* (Hook.f.) Brenan

DNA barcode; rbcLa

```
CGACTAAGCAAGTGTGGGTTCAAAGCTGGTGTTAAAGATTATAAAATTGACTTATTATACTCCTGACTA
TGAAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACCTCAACCTGGAGTTCGGCCTGAAG
AAGCAGGTGCCGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGATGGGCTT
ACCAGTCTTGATCGTTACAAAGGACGATGCTACCACATCGAGCCTGTTGCTGGAGAAGAAAATCAATA
TATTGCTTATGTAGCTTATCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTTCCATT
GTGGGTAATGTATTTGGGTTCAAGGCCCTGCGCGCTCTACGTCTGGAGGATTTGCGAATCCCTCCTGCT
TATTCTAAAACCTTTCCAAGGTCCGCCTCACGGCATCCAAGTTGAGAGAGATAAAATTGAACAAGTACGG
CCGTCCCCTATTGGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGAATTACGGTAGAGCTGT
TTATGAATGTCTCCGCGGTGGACTTGATTTTACCAAAGATGATGAGAATGTGAATTTCCAACCATTTAT
GCGTTGGAGAGACCGTTTCTTATTTGTGCCGAAGCTCTTTATAAAGCACAGGCCGAAACAGGTGAAA
TCAAAGGGCATTACTTGAATGCACTG
```

4.1.20.1 Species: *Piptadeniastrum africanum* (Hook.f.) Brenan

Family: Leguminosae

Specimen: GH0281

Location: Kakum National Park 176m 5°51.160'N 0°10.488'

DNA barcode; rbcLa

```
CGACTAAGCAAGTGTGGGTTCAAAGCTGGTGTTAAAGATTATAAAATTGACTTATTATACTCCTGACTA
TGAAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACCTCAACCTGGAGTTCGGCCTGAAG
AAGCAGGTGCCGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGATGGGCTT
ACCAGTCTTGATCGTTACAAAGGACGATGCTACCACATCGAGCCTGTTGCTGGAGAAGAAAATCAATA
TATTGCTTATGTAGCTTATCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTTCCATT
```

GTGGGTAATGTATTTGGGTTCAAGGCCCTGCGCGCTCTACGTCTGGAGGATTTGCGAATCCCTCCTGCT  
 TATTCTAAAACCTTCCAAGGTCCGCCTCACGGCATCCAAGTTGAGAGAGATAAATTGAACAAGTACGG  
 CCGTCCCCTATTGGGATGTACTATTA AACCTAAATTGGGGTTATCCGCTAAGAATTACGGTAGAGCTGT  
 TTATGAATGTCTCCGCGGTGGACTTGATTTTACCAAAGATGATGAGAATGTGAATTCCCAACCATTAT  
 GCGTTGGAGAGACCGTTTCTTATTTTGTGCCGAAGCTCTTATAAAGCACAGGCCGAAACAGGTGAAA  
 TCAAAGGGCATTACTTGAATGCACTG

#### 4.1.21.0 Species: *Panda oleosa* Pierre

Family: Pandaceae

Specimen: GH0373

Location: Ankasa Resource Reserve 166m 2°16.789N' 0°22.984'W

Description: It is a slow-growing, evergreen tree with a dense crown; usually growing from 10 - 20 metres tall but with some specimens to 35 metres. Leaves are simple, alternate and serrated. Fruits are large with a pitted surface (Hawthorne & Gyakari, 2006).



Plate 21 *Panda oleosa* Pierre

DNA barcode; rbcLa

CAGAACTAAAACAAGTGTTGGATTCAAGGCTGGTGTAAAGAATATAAATTGACTTATTATACTCCT  
 GACTATCAAACCAAAGATACTGATATCTTAGCAGCATTCCGAGTAACTCCTCAACCCGGAGTCCGCC  
 TGAGGAAGCGGGGCTGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACGTGTGGACTGATG  
 GGCTTACCAGTCTTGATCGTTATAAAGGACGATGCTACCACATCGAGCGCGTTATTGGAGAAAACGAT  
 CAATATATTGCTTATGTAGCTTATCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACCT  
 CCATTGTGGGTAATGTATTTGGATTCAAAGCCCTACGCGCTCTACGTCTGGAGGATTTACGAGTCCCTC  
 CTGCTTATTCTAAAACCTTCCAAGGCCCTCACGGCATCCAAGTGGAGAGAGATAAATTGAACAAG  
 TATGGTCGCCCTTATTGGGCTGTACTATTAACCGAAATTGGGGTTATCCGCTAAGAATTACGGTAGA  
 GCAGTTTATGAATGTCTCCGCGGGGGACTTGATTTTACCAAAGATGATGAGAACGTGAACCTCCCAACC  
 ATTTATGCGGTGGAGAGACCGTTTCTTATTTTGTGCCGAAGCACTTATAAAGCACAAAGCCGAAACAG  
 GGGAAATCAAAGGGCATTATTTGGATGCATG

4.1.21.1 Species: *Panda oleosa* Pierre

Family: Pandaceae

Specimen: GH0284

Location: Ankasa Resource Reserve 160m 1°16.689N' 0°22.884'W

DNA barcode; rbcLa

CAGAAACTAAAACAAGTGTGGATTCAAGGCTGGTGTAAAGAATATAAATTGACTTATTATACTCCT  
 GACTATCAAACCAAAGATACTGATATCTTAGCAGCATTCCGAGTAACTCCTCAACCCGGAGTCCGCC  
 TGAGGAAGCGGGGGCTGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACGTGTGGACTGATG  
 GGCTTACCAGTCTTGATCGTTATAAAGGACGATGCTACCACATCGAGCGCGTTATTGGAGAAAACGAT  
 CAATATATTGCTTATGTAGCTTATCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACCT  
 CCATTGTGGGTAATGTATTTGGATTCAAAGCCCTACGCGCTCTACGTCTGGAGGATTTACGAGTCCCTC  
 CTGCTTATTCTAAAACCTTTCCAAGGCCCGCCTCACGGCATCCAAGTGGAGAGAGATAAATTGAACAAG  
 TATGGTCGCCCTTATTGGGCTGTACTATTAACCGAAATTGGGGTTATCCGCTAAGAATTACGGTAGA  
 GCAGTTTATGAATGTCTCCGCGGGGGACTTGATTTTACCAAAGATGATGAGAACGTGAACCTCCAACC  
 ATTTATGCGGTGGAGAGACCGTTTCTTATTTGTGCCGAAGCACTTTATAAAGCACAAAGCCGAAACAG  
 GGGAAATCAAAGGGCATTATTTGGATGCATG

4.1.22.0 Species: *Pterygota macrocarpa* K.Schum

Family: Malvaceae

Specimen: GH0287

Location: Bia Biosphere Reserve 228m 6°32.672N' 3°01.959'W

Description: It is a deciduous tree with a small, dense crown; it can grow up to 35 metres tall. It is commonly found in semi-deciduous forests. Leaves are mostly 7- nerved at base. Flowers are unisexual, brown outside pinker within, in branched inflorescences from leaf axils. Fruits are large capsules 12-20cm long (Hawthorne & Gyakari, 2006).

Plate 22 *Pterygota macrocarpa* K.Schum

## DNA barcode; rbcLa

CAAAC TAAAGCAAGTGTGGATTCAAAGCTGGTGTTAAAGAGTATAAATTGACTTATTATACTCCTGA  
 ATATGAAGTCAAAGATACTGATATCTTGGCAGCCTTCCGAGTAACTCCTCAACCCGGAGTTCCGCCTG  
 AGGAAGCAGGGGCCGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCGTGTGGACCGATGG  
 GCTTACCAGCCTTGATCGTTACAAAGGGCGATGCTACCACATTGAGCCCGTTGCTGGAGAAGAAAATC  
 AATATATATGTTATGTAGCTTACCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTTC  
 CATTGTGGGTAATGTATTTGGGTTCAAAGCCCTGCGCGCTCTACGTCTAGAGGATCTGCGAATCCCTAC  
 TTCTTATATTA AAACTTTCCAAGGCCCGCCTCATGGCATCCAGGTTGAAAGAGATAAATTGAACAAGT  
 ACGGTCGCCCCCTATTAGGATGTACTATTA AACCTAAATTGGGGTTATCCGCTAAGA ACTACGGTAGA  
 GCAGTTTATGAATGTCTACGTGGTGGACTTGATTTTACCAAAGATGATGAGAATGTGAACTCCCAACC  
 ATTTATGCGCTGGAGAGACCGTTTCTTATTTGTGCCGAAGCACTTTATAAAGCACAGGCTGAAACAG  
 GTGAAATCAAAGGCCATTACTTGGATGCATG

4.1.22.1 Species: *Pterygota macrocarpa* K.Schum

Family: Malvaceae

Specimen: GH0285

Location: Bia Biosphere Reserve 208m 6°32.572'N 3°01.959'W

## DNA barcode; rbcLa

CAAAC TAAAGCAAGTGTGGATTCAAAGCTGGTGTTAAAGAGTATAAATTGACTTATTATACTCCTGA  
 ATATGAAGTCAAAGATACTGATATCTTGGCAGCCTTCCGAGTAACTCCTCAACCCGGAGTTCCGCCTG  
 AGGAAGCAGGGGCCGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCGTGTGGACCGATGG  
 GCTTACCAGCCTTGATCGTTACAAAGGGCGATGCTACCACATTGAGCCCGTTGCTGGAGAAGAAAATC  
 AATATATATGTTATGTAGCTTACCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTTC  
 CATTGTGGGTAATGTATTTGGGTTCAAAGCCCTGCGCGCTCTACGTCTAGAGGATCTGCGAATCCCTAC  
 TTCTTATATTA AAACTTTCCAAGGCCCGCCTCATGGCATCCAGGTTGAAAGAGATAAATTGAACAAGT  
 ACGGTCGCCCCCTATTAGGATGTACTATTA AACCTAAATTGGGGTTATCCGCTAAGA ACTACGGTAGA  
 GCAGTTTATGAATGTCTACGTGGTGGACTTGATTTTACCAAAGATGATGAGAATGTGAACTCCCAACC  
 ATTTATGCGCTGGAGAGACCGTTTCTTATTTGTGCCGAAGCACTTTATAAAGCACAGGCTGAAACAG  
 GTGAAATCAAAGGCCATTACTTGGATGCATG

4.1.23.0 Species: *Sterculia rhinopetala* K.Schum.

Family: Malvaceae

Specimen: GH0290

Locataion: Bia Biosphere Reserve 228m 6°32.672'N 3°01.959'W

Description: *Sterculia rhinopetala* is a deciduous tree growing up to 40 metres tall. The straight, cylindrical bole can be up to 120cm in diameter, it can be branchless for up to 21 m, with narrow buttresses up to 3 m high. Leaves alternate, simple and entire; stipules early caducous; petiole 3–

11 cm long; blade oblong to lanceolate or oblanceolate, 10–30 cm × 4–16 cm, rounded at base.

Flowers are unisexual, regular, 5-merous, pale or yellowish green; pedicel (Orwa *et al.*, 2009).



Plate 23 *Sterculia rhinopetala* K.Schum.

DNA barcode; rbcLa

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CAGAAACTAAAGCAAGTGTTGGATTCAAAGCTGGTGTTAAAGAGTATAAATTGACTTATTATACTCCT
GAATATGAAGTCAAAGATACTGATATCTTGGCAGCCTTCCGAGTAACTCCTCAACCCGGAGTTCCGCC
TGAGGAAGCAGGGGCCGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCGTGTGGACCGATG
GGCTTACCAGCCTTGATCGTTACAAAGGGCGATGCTACCACATTGAGCCCGTTGCTGGAGAAGAAAAT
CAATATATATGTTATGTAGCTTACCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTT
CCATTGTGGGTAATGTATTTGGGTTCAAAGCCCTGCGCGCTCTACGTCTAGAGGATCTGCGAATCCCTA
CTTCTTATACTAAAACCTTTCCAAGGCCCGCCTCATGGCATCCAGGTTGAAAGAGATAAATTGAACAAG
TACGGTCGCCCCCTATTAGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGAACTACGGTAG
AGCAGTTTATGAATGTCTACGTGGTGGACTTGATTTTACCAAAGATGATGAGAATGTGAACTCCCAAC
CATTTATGCGCTGGAGAGACCGTTTCGTATTTTGTGCCGAAGCACTTTATAAAGCACAGGCTGAAACA
GGTGAAATCAAAGGGCATTACTTGAATGCAACTG
```

4.1.23.1 Species: *Sterculia rhinopetala* K.Schum.

Family: Malvaceae

Specimen: GH0288

Locataion: Kakum National Park 130m 5°10.416'N 0°22.984'W

DNA barcode; rbcLa

```
CAGAAACTAAAGCAAGTGTTGGATTCAAAGCTGGTGTTAAAGAGTATAAATTGACTTATTATACTCCT
GAATATGAAGTCAAAGATACTGATATCTTGGCAGCCTTCCGAGTAACTCCTCAACCCGGAGTTCCGCC
TGAGGAAGCAGGGGCCGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCGTGTGGACCGATG
GGCTTACCAGCCTTGATCGTTACAAAGGGCGATGCTACCACATTGAGCCCGTTGCTGGAGAAGAAAAT
CAATATATATGTTATGTAGCTTACCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTT
```

CCATTGTGGGTAATGTATTTGGGTTCAAAGCCCTGCGCGCTCTACGTCTAGAGGATCTGCGAATCCCTA  
 CTTCTTATACTAAAACCTTTCCAAGGCCCGCCTCATGGCATCCAGGTTGAAAGAGATAAATTGAACAAG  
 TACGGTCGCCCCCTATTAGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGA ACTACGGTAG  
 AGCAGTTTATGAATGTCTACGTGGTGGACTTGATTTTACCAAAGATGATGAGAATGTGAACTCCCAAC  
 CATTATGCGCTGGAGAGACCGTTTCGTATTTGTGCCGAAGCACTTTATAAAGCACAGGCTGAAACA  
 GGTGAAATCAAAGGGCATTACTTGAATGCAACTG

#### 4.1.24.0 Species: *Sterculia oblonga* Mast.

Family: Malvaceae

Specimen: GH0293

Location: Bia Biosphere Reserve 179m 6°22.121N' 2°59.168'W

Description: Deciduous, medium-sized to large tree up to 45 m tall; bole branchless for up to 21m. Leaves are alternate, simple and entire; stipules early caducous; petiole 2–7 cm long; blade elliptical, 6–15 cm × 3–8 cm, rounded to obtuse at base. Flowers are unisexual, regular, 5-merous, cream to greenish yellow (Bosche & Louppe, 2008).



Plate 24 *Sterculia oblonga* Mast.

DNA barcode; rbcLa

CGACTAAGCAAGTGTGGATTCAAAGCTGGTGTTAAAGAGTATAAATTGACTTATTATACTCCTGAAT  
 ATGAAGTCAAAGATACTGATATCTTGGCAGCCTTCCGAGTAACTCCTCAACCCGGAGTTCCGCTGAG  
 GAAGCAGGGGCCGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCGTGTGGACCGATGGGCT  
 TACCAGCCTTGATCGTTACAAAGGGCGATGCTACCACATTGAGCCCGTTGCTGGAGAAGAAAATCAAT  
 ATATATGTTATGTAGCGTACCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTTCCAT  
 TGTGGGTAATGTATTTGGGTTCAAAGCCCTGCGCGCTCTACGTCTAGAGGATCTGCGAATCCCTACTTC  
 TTATACTAAAACCTTTCCAAGGCCCGCCTCATGGCATCCAGGTTGAAAGAGATAAATTGAACAAGTACG  
 GTCGTCCTTATTAGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGA ACTACGGTAGAGCA

GTTTATGAATGTCTACGTGGTGGACTTGATTTTACCAAAGATGATGAGAATGTGAACTCCCAACCATTT  
 ATGCGCTGGAGAGACCGTTTCTTATTTTGTGCCGAAGCAATTTATAAAGCACAGGCTGAAACAGGTGA  
 AATCAAAGGGCATTACTTCATGCATG

4.1.24.1 Species: *Sterculia oblonga* Mast.

Family: Malvaceae

Specimen: GH0291

Location: Kakum National Park 130m 5°10.416'N 0°22.984'W

DNA barcode; rbcLa

CGACTAAGCAAGTGTGGATTCAAAGCTGGTGTTAAAGAGTATAAATTGACTTATTATACTCCTGAAT  
 ATGAAGTCAAAGATACTGATATCTTGGCAGCCTTCCGAGTAACTCCTCAACCCGGAGTTCCGCTGAG  
 GAAGCAGGGGCCGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCGTGTGGACCGATGGGCT  
 TACCAGCCTTGATCGTTACAAAGGGCGATGCTACCACATTGAGCCCGTTGCTGGAGAAGAAAATCAAT  
 ATATATGTTATGTAGCGTACCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTTCCAT  
 TGTGGGTAATGTATTTGGGTTCAAAGCCCTGCGCGCTCTACGTCTAGAGGATCTGCGAATCCCTACTTC  
 TTATACTAAAACCTTCCAAGGCCCGCCTCATGGCATCCAGGTTGAAAGAGATAAATTGAACAAGTACG  
 GTCGTCCTTATTAGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGAACTACGGTAGAGCA  
 GTTTATGAATGTCTACGTGGTGGACTTGATTTTACCAAAGATGATGAGAATGTGAACTCCCAACCATTT  
 ATGCGCTGGAGAGACCGTTTCTTATTTTGTGCCGAAGCAATTTATAAAGCACAGGCTGAAACAGGTGA  
 AATCAAAGGGCATTACTTCATGCATG

4.1.25.0 Species: *Tieghemella heckelii* Pierre ex A. Chev.

Family: Sapotaceae

Specimen: GH0296

Location: Ankasa Resource Reserve 123m 2°16.789'N °22.984'W

Description: It is an enormous tree throughout the forest zone, but most common in the moist ever green forest. Leaves are usually simple, alternate clustered and entire petiole approximately 1-3cm long. Flowers are small, scented yellow on 2cm stalks (Hawthorne & Gyakari, 2006).



Plate 25 *Tieghemella heckeli* Pierre ex A. Chev.

DNA barcode; rbcLa

CGACTAAGCAAGTGTTGGATTCAAAGCGGGTGTTAAAGATTACAAATTGACTTATTATACTCCTGACT  
 ATGAAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACTCCTCAACCTGGAGTTCCACCTGAA  
 GAAGCAGGGGCCGCGGTAGCTGCCGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGATGGACT  
 TACTAGCCTTGATCGTTACAAAGGGCGATGCTACCACATCGAGCCCGTTGCTGGAGAAGAAAATCAAT  
 ATATTGCTTATGTAGCTTATCCTTTAGACCTTTTTGAAGAAGGTTCTGTTACTAATATGTTTACTTCCAT  
 TGTGGGGAATGTATTTGGGTTCAAAGCCCTGCGCGCTTTACGTCTGGAAGATCTGCGAATCCCTCCTGC  
 GTATTCTAAAACCTTCCAAGGACCGCCTCATGGCATCCAAGTTGAAAGAGATAAATTGAACAAGTACG  
 GTCGTCCTCCTGTTGGGATGTACTATTAACCTAAATTGGGGTTATCTGCTAAAACCTACGGTAGAGCG  
 GTTTATGAATGTCTCCGCGGTGGACTTGATTTTACCAAAGATGATGAGAACGTGAACTCCCAACCATT  
 ATGCGTTGGAGAGATCGTTTCTTATTTTGTGCCGAAGCACTTTATAAAGCACAGGCTGAAACAGGTGA  
 AATCAAAGGGCATTACTTGAATGCACTG

4.1.25.1 Species: *Tieghemella heckelii* Pierre ex A. Chev.

Family: Sapotaceae

Specimen: GH0294

Location: Kakum National Park 176m 5°51.160'N 0°10.488'W

DNA barcode; rbcLa

CGACTAAGCAAGTGTTGGATTCAAAGCGGGTGTTAAAGATTACAAATTGACTTATTATACTCCTGACT  
 ATGAAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACTCCTCAACCTGGAGTTCCACCTGAA  
 GAAGCAGGGGCCGCGGTAGCTGCCGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGATGGACT  
 TACTAGCCTTGATCGTTACAAAGGGCGATGCTACCACATCGAGCCCGTTGCTGGAGAAGAAAATCAAT  
 ATATTGCTTATGTAGCTTATCCTTTAGACCTTTTTGAAGAAGGTTCTGTTACTAATATGTTTACTTCCAT  
 TGTGGGGAATGTATTTGGGTTCAAAGCCCTGCGCGCTTTACGTCTGGAAGATCTGCGAATCCCTCCTGC  
 GTATTCTAAAACCTTCCAAGGACCGCCTCATGGCATCCAAGTTGAAAGAGATAAATTGAACAAGTACG  
 GTCGTCCTCCTGTTGGGATGTACTATTAACCTAAATTGGGGTTATCTGCTAAAACCTACGGTAGAGCG  
 GTTTATGAATGTCTCCGCGGTGGACTTGATTTTACCAAAGATGATGAGAACGTGAACTCCCAACCATT  
 ATGCGTTGGAGAGATCGTTTCTTATTTTGTGCCGAAGCACTTTATAAAGCACAGGCTGAAACAGGTGA  
 AATCAAAGGGCATTACTTGAATGCACTG

4.1.26.0 Species: *Terminalia superba* Engl.& Diels

Family: Combretaceae

Specimen: GH0299

Location: Ankasa Resource Reserve 150m 2°16.789N' 0°22.984'W

Description: It is a large deciduous or practically evergreen tree, up to 40-60 m tall and 5 m in girth, bole cylindrical, long and straight with large, flat buttresses, 6 m above the soil surface; crown open, generally flattened, consisting of a few whorled branches. Leaves are simple, alternate, in tufts at the ends of the branches. Fruit are transversely winged, sessile, golden-brown and smooth nut (Orwa *et al.*, 2009).

Plate 26 *Terminalia surperba* Engl. & Diels

DNA barcode; rbcLa

GAAACTAAAGCAAGTGTGGATTCAAAGCTGGTGTTAAAGATTATAAACTGACTTATTATACTCCTGACTATCAAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACTCCTCAACCTGGAGTTCCGCCTGAGGAAGCAGGGGCTGCAGTGGCTGCTGAATCTTCTACTGGAACATGGACAACCTGTATGGACCGATGGCTTACCAGCCTTGACCGTTATAAAGGAAGATGCTACCACATCGAACCTGTTGCTGGAGAAGAAAATCAATATATATGCTATGTAGCTTACCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAATATGTTTACTTCATTGTGGGTAATGTATTTGGGTTCAAAGCCCTACGCGCTCTACGCTCTGGAGGATCTGCGAATTCCTACGGCTATATTA AAACTTTCCAAGGCCCTCCTCACGGGATCCAAGTTGAGAGAGATAAATTGAACAAGTATGGTCGTCCCCTATTGGGATGTA CTATTA AACCTAAATTGGGGTTATCCGCTAAGAACTACGGTAGAGCAGTTTATGAATGTCTTCGTGGTGGACTTGATTTTACGAAGGATGATGAGAACGTGAACTCACAAACCATTTATGCGTTGGAGAGACCGTTTCTTATTTTGTGCCGAAGAATTTATAAAGCACAAGCTGAAACTGTTGAAATCAAAGGGCATTACTTTGAATGCAACTG

4.1.26.1 Species: *Terminalia superba* Engl.& Diels

Family: Combretaceae

Specimen: GH0297

Location: Kakum National Park 176m 5°51.160'N 0°10.488'W

DNA barcode; rbcLa

GAAACTAAAGCAAGTGTTGGATTCAAAGCTGGTGTAAAGATTATAAACTGACTTATTATACTCCTGACTATCAAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACTCCTCAACCTGGAGTTCCGCCTGAGGAAGCAGGGGCTGCAGTGGCTGCTGAATCTTCTACTGGAACATGGACAACCTGTATGGACCGATGGCTTACCAGCCTTGACCGTTATAAAGGAAGATGCTACCACATCGAACCTGTTGCTGGAGAAGAAAATCAATATATATGCTATGTAGCTTACCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAATATGTTTACTTCATTGTGGGTAATGTATTTGGGTTCAAAGCCCTACGCGCTCTACGTCTGGAGGATCTGCGAATTCCTACGGCCTATATTA AAACTTTCCAAGGCCCTCCTCACGGGATCCAAGTTGAGAGAGATAAATTGAACAAGTATGGTCGTCCCCTATTGGGATGTA CTATTA AACCTAAATTGGGGTTATCCGCTAAGAACTACGGTAGAGCAGTTTATGAATGTCTTCGTGGTGGACTTGATTTTACGAAGGATGATGAGAACGTGAACTCACAAACCATTTATGCGTTGGAGAGACCGTTTCTTATTTTTGTGCCGAAGAATTTATAAAGCACAAAGCTGAAACTGGTGAAATCAAAGGGCATTACTTTGAATGCAACTG

4.1.27.0 Species: *Triplochiton scleroxylon* K. Schum.

Family: Malvaceae

Specimen: GH0300

Location: Ankasa Resource Reserve 103m 2°16.789'N 0°22.984'W

Description: A very common tree in semi-deciduous forests, Leaves are 5-7 lobed, hairless cordate; blade approximately 10-15cm but larger on saplings. Five flowers with 1cm petals which are very hairy, whitish, red to purple at the base (Orwa *et al.*, 2009).

Plate 27 *Triplochiton scleroxylon* K.Schum.

DNA barcode; rbcLa

GAAAACATAAGCTTTTGTGGATTCAAAGCGGGTGTTAAAGAGTATAAATTGACTTATTATACTCCTG  
 AATATCAAGTCAAAGATACTGATATCTTGGCAGCCTTCCGAGTAACTCCTCAACCCGGAGTTCCGCCT  
 GAGGAAGCAGGGGCCGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGATGG  
 GCTTACCAGCCTTGATCGTTACAAAGGGCGATGCTACCACATTGAGCCCGTTCCTGGAGAAGAAAATC  
 AATATATATGTTATGTAGCTTACCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTTC  
 CATTGTAGGTAATGTATTTGGGTTCAAAGCCCTGCGCGCTCTACGTCTAGAGGATCTGCGAATCCCTGT  
 TTCTTATATTAATACTTTCCAAGGCCCGCCTCATGGCATCCAGGTTGAAAGAGATAAATTGAACAAGT  
 ATGGTCGCCCCTTATTAGGATGTAATAAACCTAAATTGGGGTTATCCGCTAAGAACTACGGTAGA  
 GCAGTTTATGAATGTCTACGTGGTGGACTTGATTTTACCAAAGATGATGAGAATGTGAACTCCCAACC  
 GTTTATGCGTTGGAGAGACCGTTTCTTATTTGTGCCGAAGCTCTTTTTAAAGCACAGGCTGAAACAGG  
 TGAAATCAAAGGGCATTACTTGAATGCAACTG

4.1.27.1 Species: *Triplochiton scleroxylon* K. Schum.

Family: Malvaceae

Specimen: GH0301

Location: Ankasa Resource Reserve 176m 5°51.160'N 0°10.488'W

DNA barcode; rbcLa

GAAAACATAAGCTTTTGTGGATTCAAAGCGGGTGTTAAAGAGTATAAATTGACTTATTATACTCCTG  
 AATATCAAGTCAAAGATACTGATATCTTGGCAGCCTTCCGAGTAACTCCTCAACCCGGAGTTCCGCCT  
 GAGGAAGCAGGGGCCGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGATGG  
 GCTTACCAGCCTTGATCGTTACAAAGGGCGATGCTACCACATTGAGCCCGTTCCTGGAGAAGAAAATC  
 AATATATATGTTATGTAGCTTACCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTTC  
 CATTGTAGGTAATGTATTTGGGTTCAAAGCCCTGCGCGCTCTACGTCTAGAGGATCTGCGAATCCCTGT  
 TTCTTATATTAATACTTTCCAAGGCCCGCCTCATGGCATCCAGGTTGAAAGAGATAAATTGAACAAGT  
 ATGGTCGCCCCTTATTAGGATGTAATAAACCTAAATTGGGGTTATCCGCTAAGAACTACGGTAGA  
 GCAGTTTATGAATGTCTACGTGGTGGACTTGATTTTACCAAAGATGATGAGAATGTGAACTCCCAACC  
 GTTTATGCGTTGGAGAGACCGTTTCTTATTTGTGCCGAAGCTCTTTTTAAAGCACAGGCTGAAACAGG  
 TGAAATCAAAGGGCATTACTTGAATGCAACTG

4.1.28.0 Species: *Tectona grandis* L.f.

Family: Lamiaceae

Specimen: GH0305

Location: Bia Biosphere Reserve 195m 6°34.522'N 0°07.437'W

Description: This species naturally occurs in deciduous forests, but is planted commonly along roadsides and in large plantations throughout the tropics. Flowers are small, about 8 mm across,

mauve to white and arranged in large, flowering heads, about 45 cm long; found on the topmost branches in the unshaded part of the crown. Fruit is a drupe with 4 chambers; round, hard and woody, enclosed in an inflated, bladder-like covering; pale green at first, then brown at maturity (Orwa *et al.*, 2009).



Plate 28 *Tectona grandis* L.f.

DNA barcode; rbcLa

```
CGAACTAAAGCAAGTGTTGGATTCAAAGCGGGTGTTAAAGAGTACAAATTGACTTATTATACTCCTGA
ATACGAAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACTCCTCAACCTGGAGTTCCGCCTG
AAGAAGCAGGGGCCGCGGTAGCTGCCGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGATGG
ACTTACCAGCCTTGATCGTTACAAAGGGCGATGCTACCACATCGAGCCCGTTCCTGGAGAAAAAGATC
AATATATCTGTTATGTAGCTTACCCTTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTTC
CATTGTAGGAAATGTATTTGGATTCAAAGCCCTACGTGCTCTACGTCTGGAAGATCTGCGAATCCCTAC
TGCTTATATTA AAACTTTCCAAGGCCCGCCTCATGGGATCCAAGTTGAGAGAGATAAATTGAACAAGT
ACGGTCGTCCTCTGTTGGGATGTA CTATTA AACCGAAATTGGGGTTATCTGCTAAAACTATGGTAGA
GCAGTTTATGAATGTCTTCGCGGTGGACTTGATTTTACCAAAGATGATGAGAACGTGAACTCCCAGCC
ATTTATGCGTTGGAGGGATCGCTTCTTATTTGTGCCGAAGCAATTTATAAAGCACAGGCTGAAACAG
GTGAAATCAAAGGCCATTACTTGATGCACG
```

4.1.28.1 Species: *Tectona grandis* L.f.

Family: Lamiaceae

Specimen: GH0303

Location: Kakum National Park 130m 5°10.416'N 0°22.984'W

DNA barcode; rbcLa

```
CGAACTAAAGCAAGTGTTGGATTCAAAGCGGGTGTTAAAGAGTACAAATTGACTTATTATACTCCTGA
ATACGAAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACTCCTCAACCTGGAGTTCCGCCTG
```

AAGAAGCAGGGGCCGCGGTAGCTGCCGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGATGG  
 ACTTACCAGCCTTGATCGTTACAAAGGGCGATGCTACCACATCGAGCCCGTTCCTGGAGAAAAAGATC  
 AATATATCTGTTATGTAGCTTACCCTTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTTC  
 CATTGTAGGAAATGTATTTGGATTCAAAGCCCTACGTGCTCTACGTCTGGAAGATCTGCGAATCCCTAC  
 TGCTTATATTA AAACTTTCCAAGGCCCGCCTCATGGGATCCAAGTTGAGAGAGATAAATTGAACAAGT  
 ACGTTCGTCCTCTGTTGGGATGTA CTATTA AACCGAAATTGGGGTTATCTGCTAAAACTATGGTAGA  
 GCAGTTTATGAATGTCTTCGCGGTGGACTTGATTTTACCAAAGATGATGAGAACGTGAACTCCCAGCC  
 ATTTATGCGTTGGAGGGATCGCTTCTTATTTTGTGCCGAAGCAATTTATAAAGCACAGGCTGAAACAG  
 GTGAAATCAAAGGGCATTACTTGATGCACG

4.1.29.0 Species: *Terminalia ivorensis* A. Chev.

Family: Combretaceae

Specimen: GH0308

Location: Bia Biosphere Reserve 228m 6°32.672N' 3°01.959'W

Description: A pioneer tree, common in upland and semi-deciduous forests. Leaves are simple, alternate, entire clustered with 1-2 cm reddish petiole. Flowers are yellow in erect spikes (Hawthorne & Gyakari, 2006).



Plate 29 *Terminalia ivorensis* A. Chev.

DNA barcode; rbcLa

CAGAACTAAAGCAAGTGTGGATTCAAAGCTGGTGTTAAAGATTATAAACTGACTTATTATACTCCTG  
 ACTATCAAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACTCCTCAACCTGGAGTTCGCCT  
 GAGGAAGCAGGGGCTGCAGTGGCTGCTGAATCTTCTACTGGAACATGGACAACCTGTATGGACCGATG  
 GGCTTACCAGCCTTGACCGTTATAAAGGAAGATGCTACCACATCGAACCTGTTGCTGGAGAAGAAAAT  
 CAATATATATGCTATGTAGCTTACCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAATATGTTTACTT  
 CCATTGTGGGTAATGTATTTGGGTTCAAAGCCCTACGCGCTCTACGTCTGGAGGATCTGCGAATTCCTA  
 CGTCTATATTA AAACTTTCCAAGGCCCTCCTCACGGGATCCAAGTTGAGAGAGATAAATTGAACAAG  
 TATGGTCGTCCCCTATTGGGATGTA CTATTA AACCTAAATTGGGGTTATCCGCTAAGA ACTACGGTAGA  
 GCAGTTTATGAATGTCTTCGTGGTGGACTTGATTTTACGAAGGATGATGAGAACGTGAACTCACAAAC

ATTTATGCGTTGGAGAGACCGTTTCTTATTTTGTGCCGAAGCAATTTATAAAGCACAAGCTGAAACTGG  
TGAAATCAAAGGGCATTACTTGAATGCACT

4.1.29.1 Species: *Terminalia ivorensis* A. Chev.

Family: Combretaceae

Specimen: GH0306

Location: Kakum National Park 130m 5°10.416'N 0°22.984'W

DNA barcode; rbcLa

CAGAACTAAAGCAAGTGTTGGATTCAAAGCTGGTGTTAAAGATTATAAACTGACTTATTATACTCCTG  
ACTATCAAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACTCCTCAACCTGGAGTTCGCCT  
GAGGAAGCAGGGGCTGCAGTGGCTGCTGAATCTTCTACTGGAACATGGACAACCTGTATGGACCGATG  
GGCTTACCAGCCTTGACCGTTATAAAGGAAGATGCTACCACATCGAACCTGTTGCTGGAGAAGAAAAT  
CAATATATATGCTATGTAGCTTACCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAATATGTTTACTT  
CCATTGTGGGTAATGTATTTGGGTTCAAAGCCCTACGCGCTCTACGTCTGGAGGATCTGCGAATTCCTA  
CGTCTATATTA AAACTTTCCAAGGCCCTCCTCACGGGATCCAAGTTGAGAGAGATAAATTGAACAAG  
TATGGTCGTCCCTATTGGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGA ACTACGGTAGA  
GCAGTTTATGAATGTCTTCGTGGTGGACTTGATTTTACGAAGGATGATGAGAACGTGAACTCACAACC  
ATTTATGCGTTGGAGAGACCGTTTCTTATTTTGTGCCGAAGCAATTTATAAAGCACAAGCTGAAACTGG  
TGAAATCAAAGGGCATTACTTGAATGCACT

4.1.30.0 Species: *Turraeanthus africanus* (Welw.ex C.DC.) Pellegr.

Family: Meliaceae

Specimen: GH0311

Location: Bia Biosphere Reserve 194m 6°34.522'N 3°07.436'W

Description: *Turraeanthus africana* is described as a tree of the rain forest and having a trunk diameter of 0.6-0.9m. It is commonly creamy white or pale yellow but will darken upon exposure to ultra-violet light to a golden yellow color. It has an interlocked wood grain producing various figures: striped, curly, or mottled. This plant was not successfully sequenced at the rbcLa region (Orwa *et al.*, 2009).



Plate 30 *Turraenthus africanus* (Welw.ex C.DC.) Pellegr.

4.1.31.0 Species: *Zanthoxylum leprieurii* Guill.&Perr.

Family: Rutaceae

Specimen: GH0374

Location: Ankasa Resource Reserve 103m 2°16.789N' 0°22.984'W

Description: *Zanthoxylum leprieurii* is a low-branching tree with aromatic leaves that forms a spreading crown and grows up to 24 m tall, though it is often much shorter. The branches are prickled, these prickles becoming bosses on the bole. Leaves are alternate, imparipinnately compound with 8–16(–24) leaflets (Hawthorne & Gyakari, 2006).



Plate No 31 *Zanthoxylum leprieurii*

DNA barcode; rbcLa

CAGAAACTAAAGCGAGTGTTGGATTCAAAGCCGGTGTTAAAGATTATAAATTGACTTATTATACTCCT  
 GACTATGTAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAASTCCTCAACCCGGAGTTCCACCC  
 GAGGAAGCGGGGGCTGCGGTAGCTGCGGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGATG  
 GGCTTACCAGCCTTGATCGTTACAAAGGGCGATGCTACAACATTGAGCCCGTTGCTGGAGAAGAAAAT  
 CAATATATATGTTATGTAGCTTACCCGTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTT  
 CCATTGTGGGTAATGTATTTGGTTTCAAAGCCCTGCGCGCTCTACGTCTAGAGGATCTACGAATCCCTC  
 CCGCGTATWCTAAAACCTTCCAAGGCCCGCCTCACGGCATCCAAGTTGAGAGAGATAAATTGAACAA  
 GTATGGACGTCCCCTGTTGGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGAATTACGGTA  
 GGGCAGTTTATGAATGTCTACGCGGTGGACTTGACTTTACCAAAGATGATGAGAACGTGAACTCCCAA  
 CCATTTATGCGTTGGAGGGACCGTTTCTTATTTTGTGCGGAAGCAATTTATAAATCGCAAGCTGAAACA  
 GGTGAAATCAAAGGTCATTACTTGATGACG

4.1.31.1 Species: *Zanthoxylum leprieurii* Guill.&Perr.

Family: Rutaceae

Specimen: GH0312

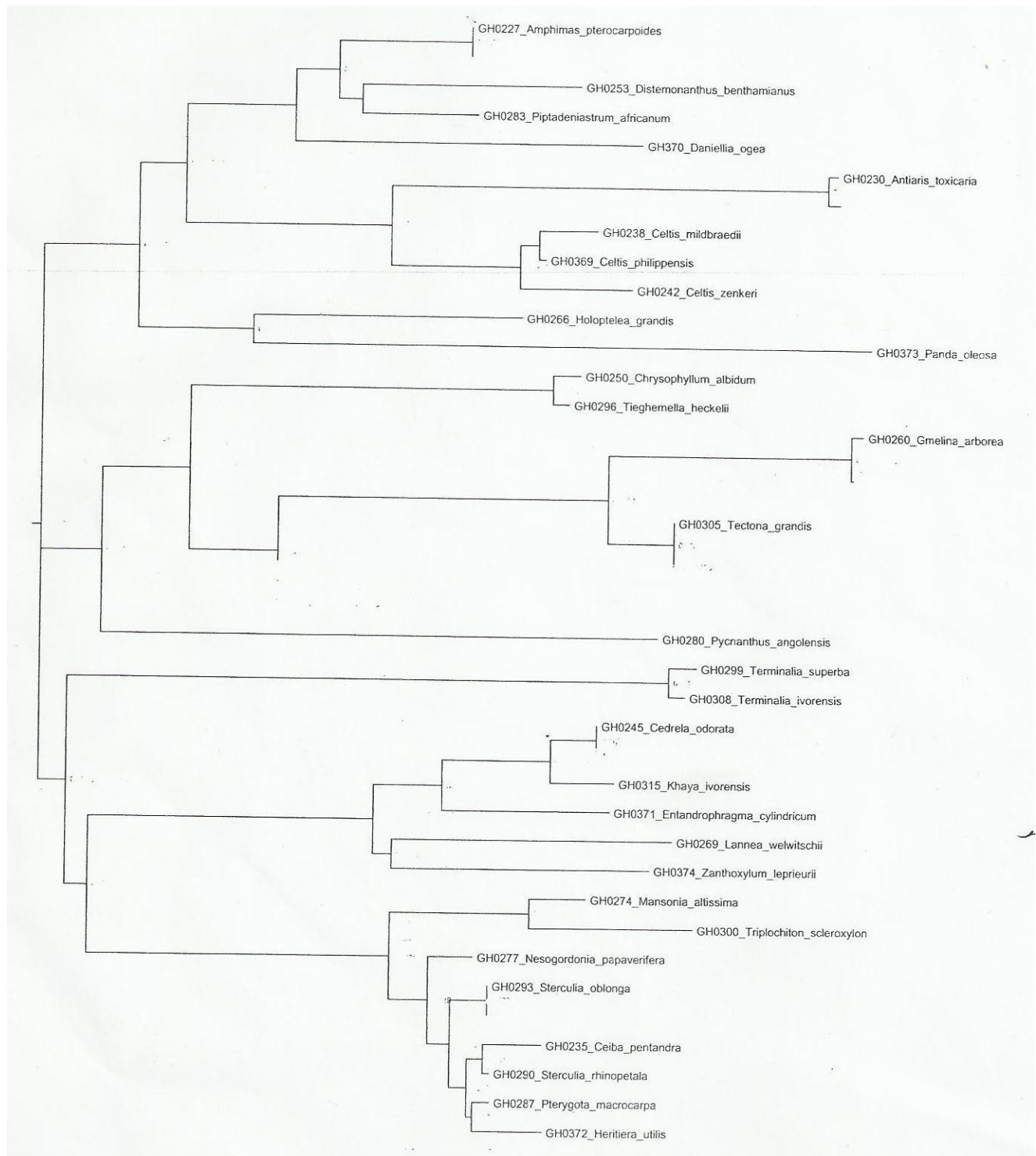
Location: Ankasa Resource Reserve 100m 2°16.689N' 0°22.884'W

DNA barcode; rbcLa

CAGAAACTAAAGCGAGTGTTGGATTCAAAGCCGGTGTTAAAGATTATAAATTGACTTATTATACTCCT  
 GACTATGTAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAASTCCTCAACCCGGAGTTCCACCC  
 GAGGAAGCGGGGGCTGCGGTAGCTGCGGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGATG  
 GGCTTACCAGCCTTGATCGTTACAAAGGGCGATGCTACAACATTGAGCCCGTTGCTGGAGAAGAAAAT  
 CAATATATATGTTATGTAGCTTACCCGTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTT  
 CCATTGTGGGTAATGTATTTGGTTTCAAAGCCCTGCGCGCTCTACGTCTAGAGGATCTACGAATCCCTC  
 CCGCGTATWCTAAAACCTTCCAAGGCCCGCCTCACGGCATCCAAGTTGAGAGAGATAAATTGAACAA  
 GTATGGACGTCCCCTGTTGGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGAATTACGGTA  
 GGGCAGTTTATGAATGTCTACGCGGTGGACTTGACTTTACCAAAGATGATGAGAACGTGAACTCCCAA  
 CCATTTATGCGTTGGAGGGACCGTTTCTTATTTTGTGCGGAAGCAATTTATAAATCGCAAGCTGAAACA  
 GGTGAAATCAAAGGTCATTACTTGATGACG

### 4.3 Relationship between the tree species in commercial trade in Ghana

Though the sequences were generated in duplicate only one of each species was used to generate the cladogram. The cladogram generated was used to show the relationship between the species (Fig.4). The cladogram shows that specimens of the same species have similar DNA sequences. Each of the tree species that were successfully sequenced were separated to the species level.



**Figure 4: Cladogram of timber trees collected from the three study areas**

#### 4.4 Verification of DNA database

Six species were randomly selected from the database to test the validity of the database. Below are the GPS coordinates, families and the sequences of the six species randomly selected for the verification of the database.

##### 4.2.1 Species: *Amphimas pterocarpoides* Harms.

Family: Leguminosae

Specimen: GH 0226

GPS coordinate: 454m N05°51.784'W000°10.036'

DNA barcode; rbcLa

```
CAAAC TAAAGCAAGTGTGGATTCAAAGCTGGTGTTAAAGATTATAAATTGACTTATTATACTCCTGA  
CTATGAAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACTCCTCAACCTGGAGTTCCGCCTG  
AAGAAGCAGGTGCCGCGGTAGCTGCCGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGATGGG  
CTTACCAGTCTTGATCGTTACAAAGGACGATGCTACTACATCGAGCCCCTTGCTGGAGAAGAAAATCA  
ATATATTGCTTATGTAGCTTATCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTTCC  
ATTGTAGGTAATGTATTTGGGTTCAAGGCCCTGCGCGCTCTACGTCTGGAGGATTTGCGAATCCCTACT  
TCTTATATTA AAACTTTCCAAGTCCGCCTCACGGCATCCAAGTTGAGAGAGATAAATTGAACAAGTA  
TGGCCGTCCCCTATTGGGATGTACTATTA AACCTAAATTGGGGTTATCCGCTAAGAATTACGGTAGAG  
CAGTTTATGAATGTCTCCGCGGTGGACTTGATTTTACCAAAGATGATGAAAATGTGAATTCCCAACCAT  
TTATGCGTTGGAGAGACCGTTTCTTATTTGTGCCGAAGCACTTTATAAAGCACAGGCCGAAACAGGT  
GAAATCAAAGGGCATTACTTGAATGCACTG
```

##### 4.2.2 Species: *Antiaris toxicaria*

Family: Moraceae

Specimen: GH0229

GPS coordinate: 439m N05°51.837'W000°10.041'

DNA barcode; rbcLa

```
CAGAAACTAAAGCTTTTGTGGATTCAAAGCTGGTGTTAAAGATTATAAATTGACTTATTACACTCCTG  
AATATGAAGTCAAAGATACTGATATCTTGGCAGCATTTTCGAGTAACTCCTCAACCTGGAGTTCCCTCCTG  
AAGAAGCAGGGGCTGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCTGTATGGACTGACGGG  
CTTACCAGTCTTGATCGCTACAAAGGTCGATGCTACAACATCGAGCCCCTTGCTGGAGAAGAAAATCA  
ATATATTGCTTATGTAGCTTACCCTTTAGACCTTTTTGAAGAGGGTTCTGTTACTAACATGTTTACTTCC  
ATTGTGGGTAATGTATTTGGGTTCAAAGCTCTGCGGGCGTTACGTCTGGAAGATTTGCGAATCCCTCCT
```

TCTTATTCTAAAACCTTTCCAAGGACCACCCCATGGTATCCAAGTTGAGAGAGATAAATTGAACAAGTA  
TGGCCGTCCCCTATTGGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGAATTACGGTAGAG  
CAGTTTATGAATGTCTTCGCGGTGGACTTGATTTTACCAAAGATGATGAGAACGTGAATTTCCAACCCCT  
TTATGCGTTGGAGAGACCGTTTCTTATTTTGTGCCGAAGCACTTTATAAAGCACAAAGCTGAAACAGGT  
GAAATCAAAGGACATTACTTGAATGCAACTG

#### 4.2.3 Species: *Cedrela odorata* Linn.

Family: Meliaceae

GPS coordinate: 218m N05°57.360'W000°10.641'

Specimen: GH0244

DNA barcode; rbcLa

GAAACTAAAGCAAGTGTTGGATTCAAAGCCGGTGTTAAAGATTATAAATTGACTTATTATACTCCTGA  
CTATGTAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACTCCTCAACCCGGAGTTCCGCCCG  
AGGAAGCAGGGGCTGCGGTAGCTGCGGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGATGG  
GCTTACTAGCCTTGATCGTTACAAAGGACGATGCTACAACATTGAGCCAGTTGCTGGAGAAGAAAATC  
AATATATATGTTATGTAGCTTACCCTTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACGTC  
CATTGTGGGTAATGTATTTGGGTTCAAAGCCCTGCGCGCTCTACGTCTAGAGGATCTACGAATCCCTCC  
CGCGTATTCTAAAACCTTTCCAAGGGCCGCCTCATGGCATCCAAGTTGAGAGAGATAAATTGAACAAGT  
ATGGTCGTCCCCTATTGGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGAATTACGGTAGA  
GCAGTTTATGAATGTCTACGCGGTGGACTTGACTTTACCAAAGATGATGAGAACGTGAACTCCCAACC  
ATTTATGCGTTGGAGAGACCGTTTCGTATTTTGTGCCGAAGCAATCTATAAAGCGCAAGCTGAAACAA  
GGTGAAATCAAAGGTCATTACTTGAATGCAACTG

#### 4.2.4 Species: *Gmelina arborea* Roxb.

GPS coordinate: 187m N06°06.618'W000°18.130'

Specimen: GH0259

DNA barcode; rbcLa

CAGAACTAAAGCAAGTGTTGGATTCAAAGCGGGTGTTAAAGAGTACAAATTGACTTATTATACTCCT  
GAATACGAAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACTCCTCAACCTGGAGTTCCGCC  
TGAAGAAGCAGGGGCCGAGTAGCTGCCGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGATG  
GACTTACCAGTCTTGATCGTTACAAAGGGCGATGCTACCACATCGAGCCCGTTCTTGGAGAAAAGAT  
CAATATATCTGTTATGTAGCTTACCCTTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTT  
CCATTGTAGGAAATGTATTTGGATTCAAAGCCTTACGTGCTCTACGTCTGGAAGATCTGCGAATCCCTC  
AGGCTTATATTAACCTTTCCAAGGCCCGCCTCATGGGATCCAAGTTGAGAGAGATAAATTGAACAAG  
TATGGTCGTCTCTGTTGGGATGTACTATTAACCAAATTTGGGGTTATCTGCTAAAACTATGGTAGA  
GCAGTTTATGAATGTCTTCGCGGTGGGCTTGATTTTACCAAAGATGATGAAAACGTGAACTCCCAGCC  
GTTTATGCGTTGGAGAGATCGCTTCTTATTTTGTGCCGAAGCAATTTATAAATCACAGGCTGAAACAGT  
GAAATCAAAGGGCATTACTTGAATGCAACTG

4.2.5 Species: *Sterculia oblonga* Mast.

Family: Malvaceae

Specimen GH0292

GPS coordinate: 439m N05°51.839'W000°10.040'

DNA barcode; rbcLa

CGACTAAGCAAGTGTGGATTCAAAGCTGGTGTAAAGAGTATAAATTGACTTATTATACTCCTGAAT  
 ATGAAGTCAAAGATACTGATATCTTGGCAGCCTTCCGAGTAACTCCTCAACCCGGAGTTCCGCCTGAG  
 GAAGCAGGGGCCGCGGTAGCTGCTGAATCTTCTACTGGTACATGGACAACCGTGTGGACCGATGGGCT  
 TACCAGCCTTGATCGTTACAAAGGGCGATGCTACCACATTGAGCCCGTTGCTGGAGAAGAAAATCAAT  
 ATATATGTTATGTAGCGTACCCCTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTTCCAT  
 TGTGGGTAATGTATTTGGGTTCAAAGCCCTGCGCGCTCTACGTCTAGAGGATCTGCGAATCCCTACTTC  
 TTATACTAAAACCTTCCAAGGCCCGCTCATGGCATCCAGGTTGAAAGAGATAAATTGAACAAGTACG  
 GTCGTCCTTATTAGGATGTACTATTAACCTAAATTGGGGTTATCCGCTAAGAACTACGGTAGAGCA  
 GTTTATGAATGTCTACGTGGTGGACTTGATTTTACCAAAGATGATGAGAATGTGAACCTCCAACCATTT  
 ATGCGCTGGAGAGACCGTTTCTTATTTGTGCCGAAGCAATTTATAAAGCACAGGCTGAAACAGGTGA  
 AATCAAAGGGCATTACTTCATGCATG

4.2.6 Species: *Tectona grandis* L.f.

Family: Lamiaceae

Specimen: GH0304

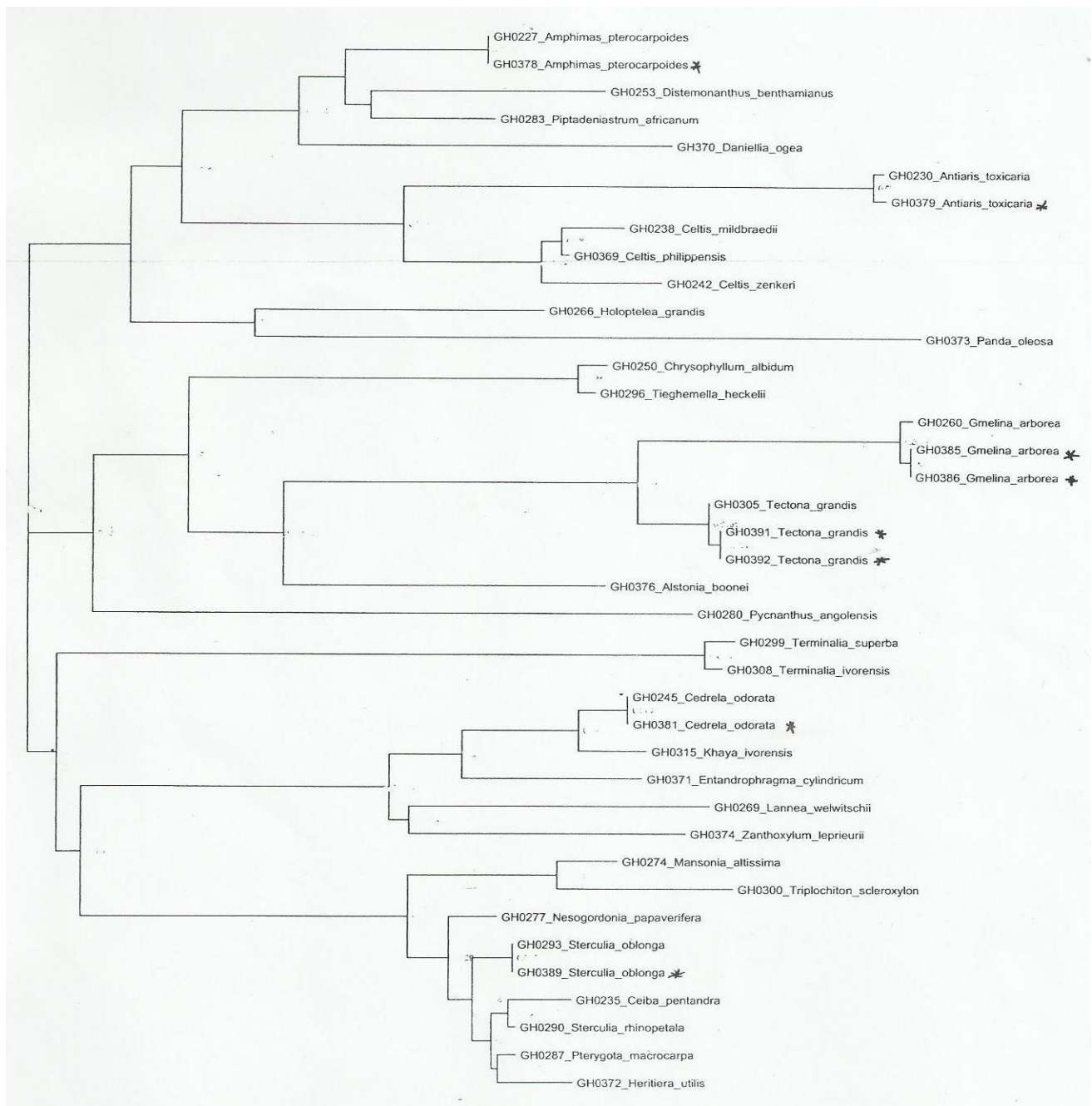
GPS coordinate: 437mN05°50.26'W000°10.640'

DNA barcode; rbcLa

CGAACTAAAGCAAGTGTGGATTCAAAGCGGGTGTAAAGAGTACAAATTGACTTATTATACTCCTGA  
 ATACGAAACCAAAGATACTGATATCTTGGCAGCATTCCGAGTAACTCCTCAACCTGGAGTTCCGCCTG  
 AAGAAGCAGGGGCCGCGGTAGCTGCCGAATCTTCTACTGGTACATGGACAACCTGTGTGGACCGATGG  
 ACTTACCAGCCTTGATCGTTACAAAGGGCGATGCTACCACATCGAGCCCGTTCCCTGGAGAAAAAGATC  
 AATATATCTGTTATGTAGCTTACCCTTTAGACCTTTTTGAAGAAGGTTCTGTTACTAACATGTTTACTTC  
 CATTGTAGGAAATGTATTTGGATTCAAAGCCCTACGTGCTCTACGTCTGGAAGATCTGCGAATCCCTAC  
 TGCTTATATTAACCTTCCAAGGCCCGCTCATGGGATCCAAGTTGAGAGAGATAAATTGAACAAGT  
 ACGGTCGTCCTCTGTTGGGATGTACTATTAACCGAAATTGGGGTTATCTGCTAAAACCTATGGTAGA  
 GCAGTTTATGAATGTCTTCGCGGTGGACTTGATTTTACCAAAGATGATGAGAACGTGAACCTCCAGCC  
 ATTTATGCGTTGGAGGGATCGCTTCTTATTTGTGCCGAAGCAATTTATAAAGCACAGGCTGAAACAG  
 GTGAAATCAAAGGGCATTACTTGATGCACG

The sequences of the randomly selected six timber species for the verification of the database from the 30 timber species were superimposed with that of the database to generate a cladogram

which presents a pictorial view of the validity of the database. The superimposed cladogram of the two sequences is presented in fig 5.



**Figure 5: Superimposed cladogram of both database sequences and verification sequences**

## **4.5 Social Survey**

The social survey of respondents in the timber market was categorized into four main schematic areas including personal data of respondents, timber species used for commercial trade commonly found on the Ghanaian timber market, timber resource situation and level of awareness of forest conservation and the respondents' perception about it.

### **4.5.1 Demographic Characteristics of respondents**

Results of the demography of respondents who use or sell timber species and timber products on the market were dominated by males with 98% and females were 2% (Table 1). The age distributions of the study population were grouped into 15-25 years, 26-35 years, 36-45 years and 46-55 years, showed that 88% of the respondents fell within the active working groups which are between 26–35 years and 36–45 years (Table 2). The early adult group, which is 15–25 years, had 2% out of the total respondents interviewed.

The educational background of the respondents was also investigated. Fifty seven percent of the respondents have had at least basic level of education and those who had secondary level of education contributed 31% (Table 2). The tertiary education as observed in the community was low with 6% as well as other forms of education.

The respondents that were interviewed were identified to have lived or worked in communities such as Botwe Timber Market, Ofankor Timber Market, Accra Timber Market, Ashaiaman Timber Market, East Legon and Adentan municipality. It was discovered that the period in which they have lived or worked in these communities' ranged from 1 - 30 years. Sixty five percent of

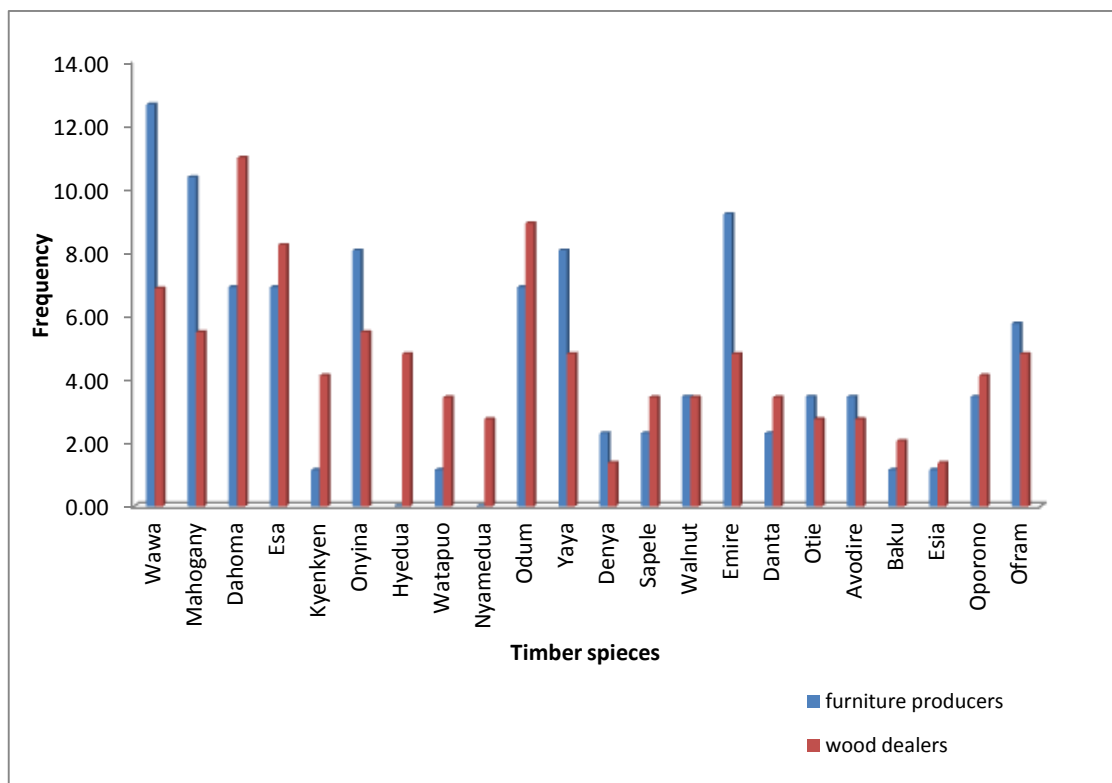
the respondents who have worked in these communities fell within the range of 1-10; with 8% being in the range of 21-30. A detailed demographic characteristic of the respondents are shown in table two.

**Table 2: Demographic characteristics of respondents.**

Variable	Item	Frequency	Percentage
<b>Gender</b>	Male	50	98
	Female	1	2
<b>Age</b>	15-25 years	1	2
	26-35 years	19	37
	36-45 years	26	51
	46 -55 years	5	10
<b>Educational level</b>	Basic	29	57
	Secondary	16	31
	Tertiary	3	6
	Others	3	6
<b>Occupation</b>	Wood dealers	30	60
	Furniture producers	21	40
<b>Period of practicing</b>	1-10 years	33	65
	11-20 years	14	27
	21-30 years	4	8

#### **4.5.2 Timber species used for commercial trade commonly found on the Ghanaian timber market used by wood dealers and furniture producers.**

It was found that the respondents use or sell more than one timber tree species on the market (Fig. 6). A total number of 22 timber species were found on the markets that were used by respondents. It was also observed that the wood dealers sell more *Piptadeniastrum africanum* (Dahoma) followed by *Milicia excelsa* (Odum) in the market and the furniture producers' often use *Triplochiton scleroxylon* (Wawa) to make their products.



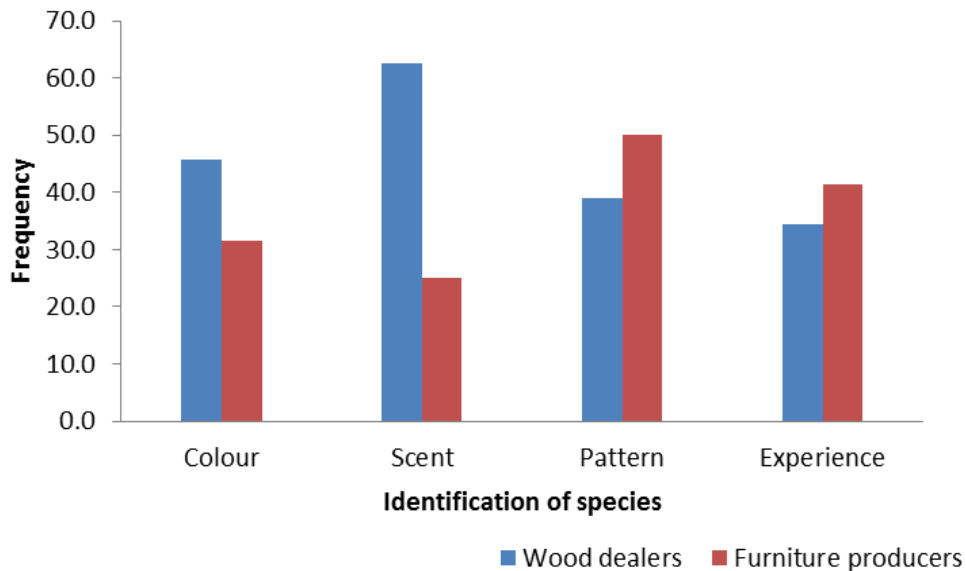
**Figure 6: Common timber species found on the market used by furniture producers and wood dealers.**

The study also found out why the respondents used or sell some of the timber species on the market. The furniture producers were of the view that these species are durable and are able to withstand bad weather and insect attack and it is easy to work with these wood materials compared with others. The wood sellers on the other hand based their preference on customer demand and durability (Table 3).

**Table 3: Preference of timber species used by furniture producers and wood dealers.**

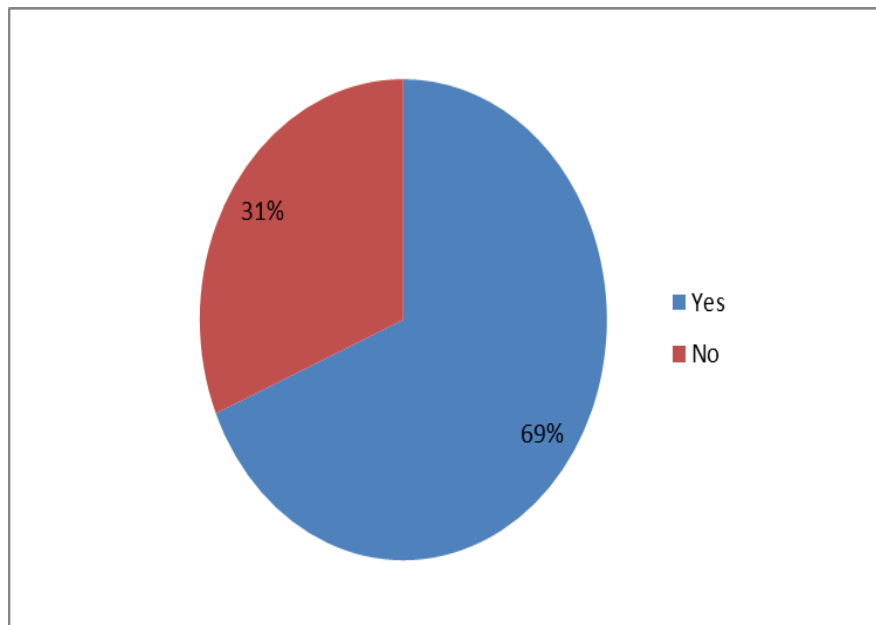
Criteria	Wood dealers	Percentage	Furniture producers	Percentage
<b>Durability</b>	5	25	7	40
<b>Workability</b>	5	25	12	36
<b>Customers demand</b>	20	50	2	24

The interview sought to find out the various methods used by respondents in the identification of timber species they use or work with. It was recognized from (Fig.7) that 62.5% of the wood dealers used scent for the identification of their species, followed by colour 45.7%, pattern 38.9% and from experience 34.5%. In addition, the furniture producers used pattern more in the identification of their species.

**Figure 7: Identification of timber species used by furniture producers and wood dealers.**

### 4.5.3 Timber Resource Situation

The interview sought to find out whether respondents had observed changes in a dwindling trend in the timber resource situation. Sixty nine percent of the respondents had observed changes in the availability of some timber plants species while the remaining 31% think there were no changes in availability of any of the timber species they deal in (Fig. 8).



**Figure 8: Changes in timber species observed by furniture producers and wood dealers.**

According to the respondents, the causes of the observed changes and measures to alleviate the problems are presented in (Table 4) below. Forty percent of the respondents attributed the dwindling timber resource situation to illegal logging activities while 24% attributed it to persistent to wild fire.

Although 39% of the respondents think controlled logging can aid solve the situation, 24% of the respondents were of the view that tree planting can contribute to the restoration of timber species in the long term.

**Table 4: Perceived causes and solutions to loss of timber plants species as suggested by furniture producers and wood dealers.**

Variable	Item	Frequency	Percentage
Causes	Wild fire	12	24
	Illegal Logging	20	40
	Illegal mining	5	8
	Unsustainable farming practices	4	8
	Chain sawing operations	10	20
Mitigation	Controlled logging	20	39
	Tree planting	12	24
	Creation of reserves	5	10
	Education	10	19
	No idea	2	4
	All of above	2	4

#### 4.5.4 Level of awareness of forest conservation methods

The interview also found out the level of awareness of respondents about forest conservation. Eighty percent of the respondents were aware of forest conservation methods but only 20% of the respondents think it is of no significance to ensure the sustainability of timber plants species in Ghana. The level of awareness, source of awareness and the significance of forest conservation to respondents are presented in Table 5.

**Table 5: Level of awareness, source of awareness and the significance of forest conservation to respondents.**

<b>Variable</b>	<b>Item</b>	<b>Frequency</b>	<b>Percentage</b>
<b>Level of awareness</b>	Aware	46	80
	Not Aware	5	20
<b>Source of awareness</b>	Print media	16	32
	Radio/television	35	68
<b>Significance</b>	Very important	5	10
	Important	10	20
	May be	14	27
	Not important	22	43

## CHAPTER FIVE

### 5.0 DISCUSSION

#### 5.1 DNA Barcoding of tree species in commercial trade in Ghana

According to Bafeel *et al.* (2011), DNA barcoding relies on the information encoded in the nucleotide sequences of a standard region of the genome as a tool for species identification. This study supports the usefulness of DNA barcoding as a bridge between species identification and wildlife conservation. The study achieved a success rate of 96.77% at the *rbcLa* gene region which is comparable to that of Bafeel *et al.*, (2011) who achieved a success rate of 88% at the same gene region. These findings corroborate a previous report on evaluation of the seven main candidate plastid regions (*rbcL*, *matK*, *rpoC1*, *rpoB*, *trnH-psbA*, *atpF-atpH*, and *psbK-psbI*) which demonstrated that no single locus has high levels of universality and resolvability (Hollingsworth *et al.*, 2009). The 96.77% success rate may also be explained by primer mismatch at the annealing site making sequencing of some of the tree species impossible. Furthermore, poor DNA extracted owing to plants metabolite and their chemotypic nature which can affect the polymerized chain reaction can also be a reason for not achieving 100% success (Khanuja *et al.*, 1999).

According to Altschul *et al.* (1997), the central concept in species identification is to match the sequence of the evidence item to a reference sequence. This study matched the sequence of six different timber tree species with the reference DNA database produced from thirty different timber trees. A hundred percent success matching was achieved which means that DNA barcoding can be used to identify correctly all commercial timber tree species with the reference DNA database.

According to Nielsen & Kjær (2008), DNA obtained from dried wood samples can be amplified and matched with the DNA database. This makes it possible for DNA of sawn timber to be identified correctly and even linked from the source to the consumer. Hence timber from protected species can be clearly identified and distinguished, thereby making it possible to prosecute offenders. Currently, even the Forestry Commission of Ghana finds it difficult to give distinct names to individual timber species which has resulted to some names as red wood which refers to all timber species with brownish or reddish colour such as *Melicia excelsa*, *Piptadeniastrum africanum*, among others. With DNA barcoding this problem of identification can be solved and boost the confidence of the Commission to prosecute offenders of illegal logging. This therefore makes DNA barcoding the ideal tool for tracing illegal logging. Proper identification of sawn timber is very important in ensuring sustainable use of forest resources and also strengthens conservation measures (Hayman & Brack, 2002). Not only will proper identification of sawn timber help to keep proper records on seized illegally logged timber but will also contribute to the successful prosecution of illegal loggers.

According to Bokhari *et al.* (1990) and Kamal *et al.* (2010), plants produce several compounds and genetic diversities in adapting to harsh climatic conditions and anthropogenic forces. These genetic diversities are translated in the DNA of the plant species which account for the production of unique barcodes which are slightly different from the same plant species under different climatic conditions. These characteristics of plants can produce a lot of information on the source of any suspected logging from protected or unauthorized areas and also to conservationists in tracking and prosecuting loggers who log from protected areas. This makes

DNA barcoding a successful tool in tracing illegal logging from the source even to the consumer provided enough data on such species exist (Nielsen & Kjær, 2008).

With these numerous benefits produced by DNA barcoding, it will be very important that the scientific community and other industries whose operations involve the identification of species, to acknowledge and use this technology. This tool will be useful to the Forestry commission in their quest to track and prosecute illegal loggers of protected trees and also from the three protected areas; Ankasa, Bia and Kakum by the use of the reference data developed from this study.

## **5.2 Characteristics of the Respondents**

The unequal number of males and females in the timber market may be indicative of the fact the timber business is perceived to be a male activity. This is in agreement with previous study by Sarfo-Mensah, (2005). It was also realized from the study that most of the respondents in the industry are in active age group. This could be due to the fact that selling timber demands a lot of strength to carry the timber. Most of the respondents are not academic achievers and this is in line with Okrah (2002) who found that most of the people who engaged in the timber industry are not academically inclined.

### **5.2.1 Common timber species found on the market used by respondents**

The respondents use or sell more than one timber species on the timber market depending on the availability and the kind of project at stake. Most wood sellers sold the plants that are commonly used by the users in order to get quicker sales and generate more revenue. The choice of wood by

the wood dealers depends much on the preference of their customers and also the kind of work involved. This trend may perhaps be explained by the fact that customer satisfaction is the core for profit oriented business people (Okrah, 2002).

Over the last four decades, rapid population growth and high demand of timber by the housing and construction industries have spear headed illegal logging in almost all economic tropical trees like *Milicia excelsa* (Odum), *Entandrophragma cylindricum* (Sapele), *Khaya ivorensis* (Mahogany), and *Triplochiton scleroxylon* (Wawa) among others (Ghana web, 2013). According to Sarfo-Mensah, (2005), due to growing interest of individuals owing their own houses, there is a high demand on the sawn timber industries. To address this issue, the Forestry Commission has designated some formal processing firms to supply twenty percent of their total output to the local market (TIDD, 2004). Sarfo-Mensah (2005), argued that, the supply from these firms are too expensive and out of reach to the ordinary Ghanaian. Moreover the saw mill and timber industries target only the foreign market leaving a high deficit hence making illegal logging attractive to potential loggers as there is always a high demand for wood in the local timber market. This is also a major contributing factor to illegal logging in such species even though they are vulnerable. 16 timber species commonly logged have been listed as vulnerable by the International Union for Conservation of nature red list of endangered species ([www.iucnredlist.org](http://www.iucnredlist.org)). However, majority of them have not been assessed and this is a hindrance to spearheading conservation and management plans towards our timber species.

The methods of identification of timber techniques used by wood dealers and furniture producers are not different from that used by the Forestry Commission (FC) in identifying and tracking of logged timber species. In an interview with the selected key managers of the Forestry

Commission, some challenges were encountered in identifying ceased timber species using the available methods; pattern, experience scent and colour, in the sense that a ceased timber truck can contain a mixture of hard woods thereby is very difficult to distinguish one species from the other. Also most of the tracking activities are done manually with a lot of paper work causing delays in delivery, duplication of activities and documentation along the chain of custody among various organizations within Forestry Commission making reconciliation cumbersome and difficult. The entire process is subject to human discretion, errors and abuses are detected late along the chain making corrections and punishment ineffective. The observation made from this study is comparable to Andel *et al.* (2012), who reported that in African markets, where roots, bark and wood are much more common, plant identification is much more cumbersome and recommended molecular identification methods.

### **5.2.2 Timber resource situation and awareness of forest conservation**

Ghana is said to be losing millions of dollars from its timber industry due to corruption, inefficiency, illegal logging activities and pricing (<http://www.ghanabusinessnews.com>). 90% of timber sold domestically is obtained illegally leading to huge revenue losses to the state (Abbey, 2012). IIED, 1993 argue that over 50% of total timber harvest in Ghana comes from off-reserve areas through illegal chainsaw activities. Evidence on the ground suggests that the greater part of the lumber on the local markets is supplied through illegal means predominated by itinerant chainsaw operators and their urban financiers (Sarfo-Mensah, 2005). The Forestry Commission of Ghana since 2000 calls for a national plantation development programme with a target of 20000 ha a year to be a replacement of timber plant species in the wild (FAO 2010). However with the rate at which we are losing our timber species it is impossible for the cultivation alone to replenish the loss.

Tang (n.d) appeals for a better understanding of the scope of the problem in order to deal with the over-exploitation of timber plants effectively. Tang (n.d) argues that in halting forest loss, one should rather tackle both the direct causes and indirect causes, i.e. both prevention and cure. For example, one direct cause of deforestation is illegal logging. In trying to fight deforestation, we may not go very far if we are merely trying to stop illegal logging. We might be better off solving the underlying cause of illegal logging which may be weak institutions or corruption or both.

Monitoring causes like wild fires, illegal logging, etc. that propels the over exploitation of timber plants will be the drive in ensuring the sustainability of the dwindling trend in the timber resource situation. Even though majority of my respondent are aware of forest conservation, only 20% of my respondents consider it can have any impact on the decreasing timber plants population. This might be due to the fear of losing their source of income since all those interviewed in the survey directly or indirectly depend on forest resources.

## CHAPTER SIX

### 6.0 CONCLUSION AND RECOMMENDATIONS

This study delved into the use of DNA barcoding as a tool in the identification of timber tree species that are in commercial trade to enhance sustainable forestry in Ghana.

DNA barcoding is an efficient tool to identify timber trees to the species level. The study achieved a 100% matching success of timber tree species. This method when use can identify both dried and fresh sawn timber trees to their respective species which is important in prosecuting loggers of protected timber species and from protected areas alike since species can be traced to their sources.

Most common illegally logged species included *Piptadeniastrum africanum* and *Ceiba pentandra* among others. Some vulnerable species such as *Cedrela odorata*, *Khaya ivorensis*, *Lophiria alata* and *Azelia africana* among others were among the commonest trees sold on some timber markets. Most of the timber species had not been assessed by the Intentional Union for Conservation of Nature red list of endangered species and thus hinders their conservation and management.

Morphological identification which is based on the scent, colour, pattern and experience was the only timber identification method used by the timber industry. The identification of illegally logged timber species by the Commission was also based on the use of morphological characteristics which was found to be quite tedious. There was no electronic tracking of illegal

logging. The commission set their guards in target places which does not only put the life of the guards at risk but is also inefficient.

Cultivation of timber trees species is one way to ensure the sustainability of timber plants species in Ghana. Most timber trees are dwindling due to unsustainable farming practices, illegal mining, and illegal logging of the timber species and transportation of the logged timber through the forest. Most of the respondents were aware of forest conservation but only 30% acknowledged that it can contribute to forest sustainability.

In the light of the findings of this study, the following are recommended:

1. DNA barcoding should be accepted for use by the Forestry Commission so as to ensure accurate and efficient identification of all timber tree species.
2. Efforts should be made to barcode all tree species in Ghana for effective management and conservation of biodiversity.
3. The Forest Division Management of the Forestry Commission should carry out frequent sustainable forestry management education in the markets while also strengthening the law enforcement unit to ensure compliance of the timber regulation.

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## APPENDICES

## Appendix A List of timber species used in creating DNA data base

Family	Genus	Species
Leguminosae	<i>Amphimas</i>	<i>pteroarpoides</i>
Moraceae	<i>Antiaris</i>	<i>Toxicaria</i>
Malvaceae	<i>Ceiba</i>	<i>Pentandra</i>
Ulmaceae	<i>Celtis</i>	<i>Mildbraedii</i>
Ulmaceae	<i>Celtis</i>	<i>Philippensis</i>
Ulmaceae	<i>Celtis</i>	<i>zenkeri</i>
Meliaceae	<i>Cedrela</i>	<i>odorata</i>
Sapotaceae	<i>Chrysophyllum</i>	<i>albidum</i>
Leguminosae	<i>Distemonanthus</i>	<i>benthamianus</i>
Leguminosae	<i>Daniellia</i>	<i>ogea</i>
Meliaceae	<i>Entandrophragama</i>	<i>cylindricum</i>
Verbenaceae	<i>Gmelina</i>	<i>arborea</i>
Ulmaceae	<i>Holoptelea</i>	<i>grandis</i>
Malvaceae	<i>Heritiera</i>	<i>utilis</i>
Meliaceae	<i>Khaya</i>	<i>ivorensis</i>
Anacardiaceae	<i>Lannea</i>	<i>welwitschii</i>
Malvaceae	<i>Mansonia</i>	<i>altissima</i>
Malvaceae	<i>Nesogordonia</i>	<i>papaverifera</i>
Myristicaceae	<i>Pycanthus</i>	<i>angolensis</i>
Leguminosae	<i>Piptadeniastrum</i>	<i>africanum</i>
Pandaceae	<i>Panda</i>	<i>oleosa</i>
Malvaceae	<i>Pterygota</i>	<i>macrocarpa</i>
Malvaceae	<i>Sterculia</i>	<i>rhinopetala</i>
Malvaceae	<i>Sterculia</i>	<i>oblonga</i>
Sapotaceae	<i>Tieghemella</i>	<i>heckelli</i>

<b>Family</b>	<b>Genus</b>	<b>Species</b>
Combretaceae	<i>Terminalia</i>	<i>superba</i>
Malvaceae	<i>Triplochiton</i>	<i>scleroxylon</i>
Lamiaceae	<i>Tectona</i>	<i>grandis</i>
Combretaceae	<i>Terminalia</i>	<i>ivorensis</i>
Meliaceae	<i>Turraenthus</i>	<i>africanus</i>
Rutaceae	<i>Zanthoxylum</i>	<i>leprieurii</i>

## Appendix B

### QUESTIONNAIRE

#### **Title: Sustainable forestry in Ghana: tracing illegal logged timber species through DNA barcoding**

Please this questionnaire is specifically for academic work. Respondents are assured that information provided will be treated as confidential as possible. Please tick the appropriate boxes that suit your views, and fill in the spaces required.

#### **(A) Personal Characteristic**

1. Sex: Male  Female

2. Which age group do you belong?

a. 15-25

b. 26-35

c. 36-45

d. 46-55

e. 55+

3. What is your educational level?

a. Uneducated

b. 1st Cycle (primary-middle school/ primary-J.S.S)

- c. 2nd Cycle (secondary/technical/SSS)
  - d. Tertiary (post-sec/poly/university)
4. What is your position in the timber market?
- a. Wood trader
  - b. furniture producer
  - c. saw mill operator
  - d. others
5. How long have you lived or worked here?
- a. 0-5 years
  - b. 6-10years
  - c. 11-15years
  - d. 16-20years
  - e. 20+

**B Timber species on the market**

6. How do you identify the timber species you use/ sell?
- a) physical observation
  - b) previous knowledge about the product
  - c) lab test

7. What type of timber species do you use, sell or work with?

.....  
.....  
.....

8. Rank the timber species listed in question 7 in order of importance to your occupation.

1. ....
2. ....
3. ....
4. ....
5. ....

9. How often do you get the timber species on the market?

- a) Regularly
- b) Occasionally
- c) Not at all

### **C State of the timber industry**

10. Can you estimate the quantity of each timber species you use /work with or sell per week/month?

11. Have you observed any changes in availability and quantity of the timber species you use or work with? Yes/No

If yes what in your opinion is the cause of the changes you perceive

**D Awareness of forest conservation**

12. How can timber plants be conserved?

13. Have you heard of forest conservation?

Yes [ ] B. No [ ]

14. Where did you hear of it?

.....

15 Is forest conservation of any importance to the conservation of timber species?

A. Important B. Very important C. May be D. Not important