Mendel University in Brno
Faculty of Forestry and Wood Technology
Institute of Forest Ecology

Forests in Ghana-Ecosystem-Based Strategies and Climate Change Mitigation

DIPLOMA THESIS

2016/2017 Bc. MAAME ESI HAMMOND

STATUTORY DECLARATION

I hereby declare that I compiled the Diploma Thesis on the topic of Forests in Ghana-Ecosystem-based Strategies and Climate Change by myself and have stated all sources used.

I agree to my thesis being published in accordance with §47(b) of the Act No. 111/1998 Coll. on Higher Education Institutions including amendments to some other acts and in compliance with Mendel University Chancellor's decree on publishing final theses. I am fully aware that my thesis is subject to Act no. 121/2000 Coll., The Copyrights Act and that the Mendel University in Brno has the right to enter into licence agreements for use of this work as school work in accordance with §60 section 1 of the Copyrights Act.

I hereby agree to obtain a written statement from the University that any license agreement with a third party on the use of copyright does not contravene the rightful interests of the University prior to executing any such agreement, and agrees to disburse any compensation for costs incurred in association with the thesis compilation in compliance with the due calculation.

In Brno on: 14.4.2017 student's signature

ACKNOWLEDGEMENTS

I am very thankful to the Almighty God for my life and the opportunity to study in the Czech Republic. I am again, grateful to Mr Emmanuel Paul Kane, my husband, for his love, sacrifice, encouragements and support. Moreover, to CARIBU (Erasmus Mundus Action 2) for financing all costs regarding my education in Mendel University in Brno.

Also to my ever loving and caring daddy, Prof Daniel Theophilus Akwa Okae-Anti for his guidance, motivation and everything.

I am appreciable to Prof Jiri Kulhavy, who supervised my diploma thesis and to all who have contributed in diverse ways to make my dream a reality in achieving my MSc qualification.

Lastly, to my son, Zion Pavel Kane for making my life interesting.

ABSTRACT

Forests are the dominant terrestrial ecosystem on Earth. Ghana has its share of this rich renewable natural resource as it covers 27.8% of the total land area. The country is highly exposed to climate change and its variability due to its location in the tropics. Forests have significant influence on climate, hence have the potential to mitigate climate change. However, deforestation in Ghana is considered to be one of the highest in the world as between 1990-2015, an annual rate of 2 percent of the forest was recorded. The objective of the study was to characterise the historical and the present state of Ghana's forests and to explain the role of forestry in mitigating climate change in Ghana, including the comparison with the forestry policy in Europe. The study was conducted on Rainforest and Deciduous forests; Forest-Savanna forest and Coastal Savannah forest which engaged a 25 year time series specifically between the years 1990 and 2015. Secondary data employed were climatic factors such as temperature, rainfall and wind speed and on different forest classifications in Ghana. Similarly, on carbon stock biomass in both Ghana and Europe, forests, growing stock in both forests, the rate of deforestation in Ghana and CO_2 emissions were collected. Also, data on ecosystem-based strategy in mitigating climate change in Ghana and finally, forest policies in support of fighting climate change in Ghana and Europe were gathered. Deforestation was observed to be the primary factor of the deteriorating state of Ghana's forests since 1990-2015 as mining and mineral exploration became the most principle causes since 2011 but prior to that it was agriculture. Climate change was noticed as increasing temperatures and rainfall variability influenced the growth of forests in Ghana. REDD+ was found out to be the most effective mitigation tool against climate change in Ghana while Climate Smart Forestry in Europe. To Ghana and Europe being on the same level in curbing the situation, international forest policies like Paris and Kyoto Protocols were compared.

It was therefore concluded that deforestation typified the state of Ghana's forests from 1990-2015. It was detected that forests have role in mitigating climate change as they have a direct link with CO_2 sequestration and lastly, Paris Protocol to be used as a forest policy in both Ghana and Europe as it principally considers forest degradation in its climate change mitigation agreement.

Key words

Forests ecosystems in Ghana, Climate change mitigation, Forest policy, Comparison of European approaches

ABSTRAKT

Lesy jsou převažující pozemské ekosystémy na Zemi. Ghana se na tomto bohatém obnovitelném zdroji významně podílí, neboť lesy pokrývají 27,8% celkové plochy země. Tato země je vystavena silné změně klimatu a jeho proměnlivosti, a to proto, že se nachází v tropickém pásmu. Lesy mají na klima významný vliv a tudíž i potenciál zmírňovat změnu klimatu. Odlesňování v Ghaně se však považuje za jedno z nejvyšších na světě, neboť v období let 1990-2015 činil meziroční úbytek lesa v této zemi 2%. Cílem studie bylo charakterizovat historický i současný stav ghanských lesů a vysvětlit úlohu lesnictví při zmírňování důsledků změny klimatu v Ghaně včetně porovnání s lesniickou politikou v Evropě. Tato studie byla provedena v deštných a opadavých lesích, v lesích typu leso-savany a přímořských leso-savanách a zahrnovala 25-letou časovou řadu mezi léty 1990 a 2015. Sekundární použité údaje zahrnovaly klimatické factory jako teplotu, srážky a rychlost větru v lesních oblastech s různou klasifikací v Ghaně. Podobně byly rovněž sbírány údaje o obsahu uhlíku v biomase zásoby lesních porostů jak v Ghaně, tak v Evropě, zásobě na pni u obou lesů, podílu odlesňování v Ghaně a emisích CO_2. Kromě toho byly take shrommážděny údaje o ekosystémově založené strategii pro zmírňování klimatické změny v Ghaně a koneřčně take lesnické politiky podporující boj se změnou klimatu v Ghaně i v Evropě. Bylo zjištěno, že odlesňování je prvotní příčinou zhoršujícího se stavu ghanských lesů od období let 1190-2015, jelikož od roku 2011 byla nejvýznamnější příčinou tohoto stavu těžba a průzkum mineral, kdežto předtím to bylo zemědělství. Pozorována byla změna klimatu, neboť zvyšující se teploty vzduchu i variabilita srážek ovlivnily růst lesů v Ghaně. Program REDD+ byl shledán jako nejúčinnější nástroj pro zmírnění změny klimatu v Ghaně, zatímco v Evropě je to Climate Smart Forestry (chytré lesnictví). Aby byly při zvládání situace Ghana a Evroa na stejné úrovni, provedeno bylo srovnání mezinárdních lesnických politik jako např. Pařížského a Kjótského protokolu.

V závěru bylo konstatováno, že stav ghanských lesů v období 1990-2015 byl typický odlesňováním. Bylo rovněž konstatováno, že lesy mají svoji úlohu při zmírňování klimatické zěny, neboť mají přímou souvislost se sekvestrací CO_2, a konečně že by měl být v Ghaně i v Evropě přijímán jako lesnická politika Pařížský protocol, který v dohodě o zmírňování změny klimatu zmiňuje jako zásadní degradaci lesa.

Klíčová slova

Lesní ekosystémy v Ghaně, Zmírňování změny klimatu, Lesnická politika, Porovnání s evropskými přístupy

Table of Contents

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

1.1 Background

Forests are the dominant terrestrial ecosystem on Earth (Pan et al., 2013). Forest is an area with a minimum land coverage of 0.5-1.0 hectare with tree crown cover (or equivalent stocking level) of more than 10-30% with trees with the potential to reach a minimum height of 2-5 meters at maturity in situ (Rakonczay, 2002*)*. The tropical Africa forests cover more than half a billion hectares. Most of these forests are found in Central and Southern Africa, while the remaining proportion in West and North Africa is very limited. (Nair and Tieguhong, 2004). That is why the heart of Africa lies in the Congo Basin, as it contains the second largest tropical rainforest in the world (Mercer et al., 2011). Africa's forests are invaluable natural resources because they contain three Internationally Recognisable Biodiversity Hotspots and many varied non-timber products (Conservation International (CI); Food and Agriculture Organisation (FAO), 2008).

Ghana can boast of its share of this rich renewable natural resource. The total forest cover is 6,335,000 ha representing 27.8% of the total land area (Ministry of Lands and Natural Resources (MLNR), 2012). Ecologically, Ghana is divided into three major zones; the High Forest Zone (HFZ), Transition Zone (TZ) and the Savannah Zones (SZ) representing 8.2 million hectares, 1.1 million hectares and 15.7 million hectares respectively. HFZ is sub-divided into different sub-types as rain and deciduous forests, TZ into semi-deciduous forest in the middle belt and the SZ is fragmented into Coastal, Guinea and Sudan savannah (Ministry of Lands and Natural Resources (MLNR), 2016). These groupings are dependent on prevailing local climatic variation and soil differences in the country, according to Hall and Swaine (1981) and MLNR (2012).

1.2 Problem Statement

Despite the self-evident importance of forest in Ghana, its existence is being threatened by climate change. Ghana is highly exposed to climate change and its variability due to its location in the tropics (MLNR, 2016). Since 2002, the Intergovernmental Panel on Climate Change (IPCC) has provided a strong evidence of accelerated global warming as a result of increasing concentration of greenhouse gases (CO_2, methane, N O, etc.) in the atmosphere (IPCC, 2001; Forster et al., 2007; Moriondo et al., 2011). This phenomenon has become an important factor that shapes forests globally, especially in Ghana due to the total dependence of the forestry sector on weather (Walther, 2010).

Altered rainfall patterns, increasing temperature causing heat stress resulting in increases tree mortality or forest die-offs subsequently causing decrease in forest productivity, are all attributable to climate change (Allen et al., 2010; Kurz et al., 2008; Phillips et al., 2009). Climate change also triggers changes in disturbance regimes, such as increasing frequency and intensity of wildfires, windstorms, or insect outbreaks (Dale et al., 2001). Webb (1992) also reported of climate-induced migration of tree species successively leading to new geographic distribution of forests' communities. Deforestation is a major contributor to climate change in Ghana. Since the later years of 1940s, over 90 percent of the high forest has been deforested as records show in 5% in off-reserves and 2% in on-reserves respectively (Tamakloe, n.d). For fifteen years thus between 1990 and 2005, the country lost over a quarter of its total forest cover. Currently, looking at the rate of deforestation in Ghana, there is the fear of the country's forests could disappear entirely in less than 25 years (Boafo, 2013).

Forests have significant influence on climate, hence have the potential to mitigate climate change. Forest ecosystems play an important role in the global biochemical cycles because they serve as an essential link in the global carbon cycle and have the capacity to remove CO_2 from the atmosphere and to store it in its biomass (FAO, 2008; Standing Forestry Committee (SFC), 2010; Braatz et al., 2011). It is estimated by Braatz et al. (2011) that 17.4% of the world's GHG emissions are derived from the forests, in a large part due to deforestation. With the current rate of deforestation and forest degradation of 2% annual loss of forest cover in Ghana Forestry Commission (FC) (2016) hence the timely provision of Forest Ecosystem-based Strategy (FES) is crucially needed (Patosaari and Director, 2007).

In the wake of this, Ghana has joined the United Nations Framework Convention on Climate Change (UNFCCC) to formulate its own $REDD^+$ (reducing emissions from deforestation and forest degradation) called the National REDD+ Strategy. REDD+ denotes the set of interventions that seek to reduce emissions from deforestation and forest degradation whilst incorporating the role of conservation, sustainable forest management and enhancement of forest carbon stocks in developing countries. Ghana is committed to accomplishing REDD+ and changing the way that the country has historically thought about, used, and benefited (or not) from its forest resources (FC, 2016). Appiah (2003) stated that effective forest management is dependent on the availability of appropriate forest policies. In a reason of this, Ghana's $REDD^+$ Strategy is synched with the appropriate Climate change policies like National

Climate Change Policy (NCCP), National Climate Change Policy Action Programme for Implementation and others (FC, 2016).

1.3 Objectives

The above stated account gives a concise description of the motives behind this study and by so doing, serving as a guide for exploration in the chosen pathway of the research work. Hence, these objectives will help unravel the part Ghana's forests play in solving global climate change and also in comparison with Europe forest policies.

1.3.1 General Objectives

1. To characterise the historical and present state of Ghana's forests and to explain the role of forestry in mitigating climate change in Ghana including the comparison with the forestry policy in Europe.

1.3.2 Specific Objectives

1. To identify the principle cause of forest deforestation in Ghana.
2. To compare Ghana forest policy on climate change with that of Europe.

1.3.3 Research questions

1. What has caused the differences in the present and past situations among the various forest zones in Ghana from 1990-2015?
2. To what extent has deforestation degraded forests in Ghana and what are the causes of deforestation from 1990-2015?
3. What challenges does climate change pose on forests in Ghana? How can the forest ecosystem in Ghana be utilised in combating climate change menace?
4. What ecosystem-based strategies are useful in mitigating climate change in Ghana?
5. What forest policies in Ghana are in line with mitigating climate change? How can the various forest policies in Ghana and that of Europe be in parallel to curb climate change globally?

2.0 LITERATURE REVIEW

2.1 Climate Change Phenomenon within the World's Forests

Climate change is the change of the normal weather patterns around the world over an extended period of time, typically decades or longer (Stone and León, 2010). Climate Change presents a significant threat to the wellbeing of mankind, and it is driven by the ever increasing quantity of greenhouse gases (GHG) being emitted into the atmosphere from anthropogenic sources. The Intergovernmental Panel on Climate Change (IPCC) has called for intensive action by all nations to limit their global greenhouse gas (GHG) emissions. There is a global compromise that it will be practically impossible to limit the impacts of climate change without reducing emissions from the forestry and agricultural sectors; yet worldwide, forests continues to be lost at an alarming rate. Forests provide vast carbon sinks that when destroyed emit carbon dioxide (CO_2) into the atmosphere, either by burning or degradation of organic matter. CO_2 is one of the most potent greenhouse gases and the primary component of anthropogenic emissions. The conversion of forests to other land uses is responsible for around 10% of net global carbon emissions (IPCC, 2013).

European land temperatures in the decade 2006–2015 were around 1.5 °C warmer than the pre-industrial level. Precipitation has increased in most of northern Europe, in particular in winter and has decreased in most of southern Europe, in particular in summer. The projected changes in precipitation show the same pattern of regional and seasonal changes. Heavy precipitation events have increased in several regions in Europe over recent decades, in particular in northern and north-eastern Europe. Observations of wind storm location, frequency and intensity show considerable variability. Several studies have projected the risk of intense winter storms and its associated severe autumn storms will increase in the future of the North Atlantic and northern, north-western and central Europe. The number of hail events is highest in mountainous areas and the pre-Alpine regions (European Environment Agency (EEA), 2016).

Climate change and increasing CO_2 concentrations are affecting forest ecosystems, as they are causing range shifts of tree species towards higher altitudes and latitudes are leading to increases in the risk of forest fires, in particular in southern Europe and are resulting in an increased incidence of forest insect pests. Cold-adapted coniferous tree species are projected to lose large fractions of their ranges to broadleaf species. Generally, there is an anticipation of an increase in forest growth in northern Europe while a decrease in southern Europe but with substantial regional variation (EEA, 2016).

2.2 Climate Change Phenomenon within the other Tropical Zone in the World

The climate in the Tropics is changing, as it is in the rest of the world (Intergovernmental Panel on Climate Change (IPCC), 2013). Tropical climates have changed in the past, with the most recent major change being the several-degree warming at the end of the last glacial period, between 20,000 and 10,000 years ago. The effects of steadily rising concentrations of greenhouse gases on the climate are becoming more obvious to tropical residents (Corlett, 2008). The impacts of this phenomenon have largely been so by the interaction between the natural climatic variability and human systems (IPCC, 2014) like deforestation, population growth, increased urbanisation and pollution. Terrestrial impacts are more visible on high mountains, where both plants and animals have moved upslope in reaction to warming in several parts of the Tropics, while glaciers have shrunk on the highest peaks in the Andes, East Africa and New Guinea (Corlett, 2008).

Australian continent is also in vulnerability to the effects of global warming as projected for the next 50 to 100 years because of its extensive arid and semi-arid areas, an already warm climate, high annual rainfall variability and existing pressures on water supply. The continent's highest fire risk increases this susceptibility to change in temperature and climate. Additionally, Climate change threatens the Australian tourism industry and may result in the loss of coral reefs. This is because Australia's population is highly concentrated in coastal areas and its important tourism industry depends on the health of the Great Barrier Reef and other fragile ecosystems. The impacts of climate change in Australia will be complex and to some degree uncertain, but increased foresight may enable the country to safeguard its future through planned mitigation strategies (wikipedia.org).

In Asia, expected changes in climate embrace increases in temperature, precipitation and extreme weather happenings including heat waves, floods and droughts and seasonal changes in rainfall patterns. These impacts are expected to vary among sub-regions, with high altitude and high latitude areas most affected. Coastal areas are projected to encounter sea level rise of 32cm by 2050 and an increase in cyclone intensity and storm surge height. Indeed, expected impacts of climate change on forest ecosystems in Asia are complex. Forests are estimated to face increased incidence of fire, dieback, pests and pathogens, invasive species and landslides. Changes in climate will also affect tree physiology and phenology, forest growth and biodiversity, with knock-on impacts on forest-dependent people and wider society. The severity of these impacts will vary among sub regions and ecosystems (FAO (n.d.)).

South America has been experiencing several unprecedented weather-related events in the recent past, such as intense rainfall in Venezuela (in 1999 and 2005 especially), flooding in the Argentine Pampas, Amazon drought (in 2005) in Brazil, Hailstorms in Bolivia (in 2002) and Greater Buenos Aires area (in 2006) and the devastating hurricane Katrina in 2004.Studies have shown again that the causes of increased rainfall in south-eastern Brazil, Paraguay, Uruguay and some parts of Bolivia. This has had impacts on land use and crop yields and has led to increase the flood frequency in the region. On the contrary, a decreased trend in precipitation has been observed in southern Chile, southwestern Argentina, southern Peru, and western Central America. (Know Climate Change (KCC), 2017).

According to the 4th IPCC Assessment Report, there is already evidence that Africa is warming faster than the global average and this is likely to continue (IPCC, 2007). The temperature of African tropical forest increases by 0.29^{o}C since 1960 (Hulme et al., 2005; Boko et al., 2007). Collins (2011) reported significant increasing temperature trends in all African regions during the past two decades (1995-2010). In southern and eastern Africa, increase in temperature between 0.1-2°C was reported for the period 1900-1995 (Boko et al., 2007; Hulme et al., 2001). Contrary to this, temperature variability occurs as a decrease in temperatures has been observed in Cameroon and in parts of Malawi, Senegal and Nigeria (Hulme et al., 2001; Hulme et al., 2005). Hasanean (2001) found a temperature increase in Tripoli, Libya, but a temperature decrease in Alexandria, Egypt. Domroes and El-Tantawi (2005) observed temperature decrease in northern Egypt, but an increase in the southern Egypt. Odjugo (2010) reported a temperature increase of 1.2°C in Port Harcourt (a Coastal city) and 2°C in Nguru (a semi-arid city of Nigeria) between 1901 and 2005. Rainfall variable patterns have been noticed as well. For instance, rainfall has decreased in the Horn of Africa (Fischer et al., 2005), in Botswana, Zimbabwe, the Transvaal and in the Sahel during the period from 1961 to 1990 (Hulme et al., 2005), but significant increase in rainfall is reported in South Africa (Mason et al., 1999). In the Volta Basin encompassing six countries in West Africa, rainfall increased at the rate of 0.7 mm/yr2 or 49 mm/ yr between 1901 and 1969, whereas a decrease of 0.2 mm/yr was estimated for 1970-2002 sub-series (Oguntunde et al., 2006). In central Africa (Congo basin), precipitation reduced slightly (2-3%) but heavy rainfall events increased over Angola, Namibia, Mozambique, Malawi and Zambia between 1931 and 1990 (Sivakumar et al., 2005;

Boko et al., 2007). The Sahel has experienced a decrease in rainfall from 1970 to 2000, with recurrent droughts; a major drought lasted from 1972-1984 (UNEP, 2002). Rainfall in the Sahel has increased since the end of the 1990s, although the annual average rainfall is still as low as during the drought of the 1970s (Mahe and Paturel, 2009). The climate change phenomenon has also resulted in the inundation of low-lying lands, including coastal settlements and islands (KCC, 2017). Agricultural production and food security in many regions of African are likely to be severely compromised by this climate variability. Climate change will worsen the water stress currently faced by some countries, while some countries that are not at risk will become at risk of water stress. Changes in a variety of ecosystems are already being detected faster than anticipated, particularly in southern African ecosystems (African Ministerial Conference on Environment (AMCEN) AMCEN, 2011). Human health could be further negatively impacted upon by climate change, for example, there has been an increase in the prevalence of malaria in southern Africa and in the East African highlands. These adverse impacts, combined with poverty, poor policy and institutional frameworks make Africa one of the most vulnerable continents to climate change (AMCEN, 2011).

2.3 Climate Change Induced Challenges in Ghana

The nation is particularly vulnerable to climate change and variability due to reliance on sectors that are sensitive to climate change, such as forestry. It is believed that the depth of vulnerability is correlated with the pace of environmental degradation exacerbating climate change impacts. Ghana's climate has been tough to foretell and the country can expect more intense weather events, such as torrential rains, excessive heat and severe dry winds as a result of the situation ((Ministry of Environment, Science, Technology and Innovation (MESTI), 2013). Evidence of some extreme climate events that the country has experienced over the years includes: floods, drought, bush fires, erratic rainfall patterns, sea level rise along the eastern coast, increased desertification or land degradation, consistent loss of forest cover, loss of some biodiversity and severe soil erosion and siltation of water bodies (MLNR, 2016). Biodiversity loss is very high with more than 10 species projected to become extinct in less than a decade. Most of the indigenous species like, *Milicia excels* and *Milicia regia*, the mahoganies (*Khaya* and *Entandrophragma* species), *Pericopsiselata, Naucleadiderrichii* and *Triplochiton scleroxylon* which mainly generate substantial revenues for Ghana's economy, have drastically reduced. The timber stocks in the off-reserve areas are disappearing at faster rates, leaving the forest reserve areas as "vulnerable small, isolated islands" with limited populations of trees and animals and no possibilities for genetic exchange (MLNR, 2016).

Again, in most forest dependent communities, the life of “the poor” is a life of vulnerability, which reflects the deeper problem of insecurity (MESTI, 2014). The poor depend heavily on environmental goods and services and their livelihoods are punctuated by dependence on agriculture, fisheries and forestry (which revolve on the use of land and water resources) and on the capacity of ecosystems to provide the services vital for environmental balance, without which food production and other productive activities cannot be carried out on a sustainable basis. This trend puts the poor at risk in both rural and urban forest Ghana (MLNR, 2016).

2.4 Greenhouse Gas (GHG) Effect on Forest Productivity

Greenhouse gases are atmospheric gases, which have been accumulating in an unprecedented fashion in recent years. Most important among these gases are carbon dioxide (CO_2) and methane (CH_4) (rainforestconservation.org). Climate change is happening according to IPCC (IPCC, 2007). If there is no effort to limit CO_2 emissions, Melillo et al. (1990) reported that CO_2 concentration will reach 500 ppmv and 800 ppmv by 2040 and 2100 respectively. The continuous addition of the greenhouse gases such as CO_2 and other greenhouse gases to the atmosphere may exacerbate the climate change in the future (Dhiaulhaq, 2011). Climate, the plant and the carbon cycle are interrelated in a number of ways. Firstly, plants are sensitive to climatic change. Plants have adapted to climatic conditions such as temperature, CO_2 concentration and precipitation over long periods of time to become better suited to its ecosystem (Streck et al., 2008). Changes in those climatic factors, therefore have the potential effect of the plant productivity (McGuire and Joyce, 2005; Hawkins et al., 2008). Plant productivity and the carbon cycle are likely to be altered by these climatic changes. Various studies on the possible effect of climate change on plant productivity reveals that too high temperature and severe drought may decrease plant productivity (Dhiaulhaq, 2011). Secondly, plant productivity is interrelated with the carbon cycle. Aside, this carbon cycle, plants take part in the transfer of carbon through converting carbon dioxide (CO_2) from the atmosphere and water (H_2O) into carbohydrate ($C_6H_{12}O_6$) using solar energy. This is part of the process called photosynthesis. Conversely, plants release carbon to the atmosphere when they respire (Ajtay et al., 1979; Garnaut, 2008). Photosynthesis by terrestrial vegetation accounts for about half of the carbon that annual cycles between Earth and the atmosphere (Hawkins et al., 2008). The ability of plants to photosynthesize explains the fact that terrestrial plants have been influencing the carbon cycle and become increasingly greater carbon sinks over the past 50 years (Dhiaulhaq, 2011). The effect of CO_2 to plant productivity may be limited by factors, such as plant acclimatization, nitrogen availability and water availability.

Under low nitrogen conditions, plants will have complications in transforming higher CO_2 into production. In an extended period of time, accumulation of carbohydrates in the plant tissues may occur from higher CO_2 conditions which may eventually reduce the photosynthetic rates or decrease photosynthetic response to elevated CO_2 (Dhiaulhaq, 2011). The exchange of carbon between the plant and the atmosphere may be explained by four related terms, namely Gross Primary Productivity (GPP), Net Primary Productivity (NPP), Net Ecosystem Productivity (NEP) and Net Biome Productivity (NBP). These definitions vary in different literatures. In the account of Grace and Zhang (2006), GPP is the rate at which plant capture and store atmospheric carbon and use it in the photosynthesis process. NPP is GPP minus autotrophic respiration (Ra). NEP or sometimes called as Net Ecosystem Exchange (NEE) is the result of GPP minus autotrophic and heterotrophic respiration (Rh). NBP is the term used to measure the flux at a broader spatial and time scale (1 km2 upwards and 1 year upwards), which also take the disturbances into account (Dhiaulhaq, 2011).

These terms are interconnected as follows (Grace and Zhang 2006):

$GPP = P$

$NPP = P - Ra$

$NEP = P - Ra - Rh$

$NBP = P - Ra - Rh - D$

The existing studies show that the direct effect of temperature changes are expected to be more significant than any other climatic variables (Kehlenbeck and Schrader, 2007). An increase in temperature may affect photosynthesis, respiration, soil nutrients and development which all relate to plant growth (Lewis, 2005). Grace and Zhang (2006) predicted the effect of temperature on plant productivity in boreal forest under both normal and doubled CO_2 concentration. Lloyd and Farquhar (1996) conclude that there are axioms in various literatures related to plant responses to elevated CO_2.

Water is a crucial element needed for photosynthesis and the main chemical component of plants (Boisvenue, 2006). So the impact of rising CO_2 to plant productivity may depend on the balance of water in the soil (McGuire and Joyce, 2005). Many drought events are identified in a period of 2000-2009 (Dhiaulhaq, 2011). For example, high temperature driven drought has caused a 30 % reduction in GPP over Europe in 2003 (Ciais et al., 2003). It is predicted that future changes in precipitation may impact water availability and substantially impact plant productivity. One of the explanations for such changes is that when water availability in the soil declines, it can reduce water uptake by plants and also restrict nutrient absorption by roots and its transportation to the plant cells (Hanson, 2000).

2.5 Climate Change Mitigation

Climate change mitigating strategy aims at reducing greenhouse gas emissions and or removing CO_2 from the atmosphere with the intent of stabilizing CO_2 concentrations by dealing with the causes of forest depletion, which has a major support in climatic occurrence (Patosaari and Director, 2007).

The threat of climate change is being addressed globally by the United Nations Framework Convention on Climate Change (UNFCCC, 1992). Its long-term running objective is to stabilise atmospheric GHG concentrations at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner (EEA, 2016).

The main policy instrument for guiding and supporting the maintenance and expansion of forest area within the region is forest law (FE, 2015). EU climate change mitigation policy aims to put the EU on track towards a low-carbon economy and to reduce EU greenhouse gas emissions by 80 to 95 % by 2050. The EU is on track towards its 2020 climate targets (EEA, 2015d), but to achieve the long term goals of the EU in 2030 and 2050 new policies and a more fundamental change are needed in the way the EU produces and uses energy, goods and services. All EU Member States are required to monitor their emissions under the EU's greenhouse gas monitoring mechanism, which sets the EU's own internal reporting rules on the basis of internationally (UNFCCC) agreed obligations. The EU climate change mitigation policy has targets for reducing its greenhouse gas emissions progressively up to 2050. Key relevant EU policies are the legally binding 2020 'climate and energy package' which comprises the EU Effort Sharing Decision and the revised EU emissions trading scheme; the 2030 'framework for climate and energy policies' (not yet adopted); and the 2050 low-carbon roadmap. The Effort Sharing Decision establishes binding annual greenhouse gas emissions targets for Member States for the period 2013–2020. These targets concern emissions from most of the sectors that are not included in the EU Emissions Trading System. The 2020 package is a set of climate safe conscious binding legislation to ensure that the EU meets its climate and energy targets for 2020 (EEA, 2016).

Forests are the most important terrestrial storehouses of carbon and play an essential role in controlling our climate. For that matter, forests have a key role in addressing climate change: by storing carbon they help to off-set the effects of anthropogenic greenhouse gas emissions (Streck, 2007). Deforestation, forest degradation, and land-use change are a major source of carbon emissions. The Intergovernmental Panel on Climate Change (IPCC) estimated that 1.6 billion tonnes of carbon are released annually due to land-use change, of which the major part is traced to tropical deforestation (Denman et al., 2007). The forestry sector represents about 15–20% of current global carbon emissions (IPCC 2007, Houghton, 2008, Werf, 2009), which is more than what comes from the fossil fuel-intensive global transport sector (Kanninen et al., 2010). Forest ecosystems contain the majority (approx. 60 percent) of the carbon stored in terrestrial ecosystems (IPCC, 2000) and account for 90 percent of the annual carbon flux between the atmosphere and the Earth's land surface (Winjum et al., 1993).

The Stern Review (2006) emphasizes the prevention of further deforestation as one of four “key elements” of future international climate frameworks. The arguments for inclusion of forests in a future climate agreement are that (a) the forestry sector is the second largest anthropogenic source of carbon dioxide (CO_2) to the atmosphere, after fossil fuel combustion, but avoided deforestation is not included in the Kyoto Protocol, and (b) the costs of reducing emissions from forests compare favourably with most other sectors (Kanninen et al. 2007, Lubowski 2008, Werf 2009).

Understanding these external causes is crucial to identifying appropriate incentives to curb deforestation. Financing REDD+ may require significant international funding to target these underlying causes of deforestation and forest degradation, e.g., those described above (Kanninen et al., 2007). Other reform processes or good governance initiatives (for example Forest Law Enforcement, Governance and Trade, FLEGT) in the forest sector confirm the above needs and offer many lessons to learn for a successful implementation of REDD+ (Kanninen et al., 2010). Putz et al. (2008) estimated that carbon stocks in forests with improved management are predicted to be about 30 MgC/ ha higher than those in conventionally logged forests (Kanninen et al., 2010).

2.6 Kyoto Protocol

The Kyoto Protocol is an international agreement that interconnect the United Nations Framework Convention on Climate Change in committing it**s** Parties to set internationally binding emission reduction targets (UNFCCC). In 1997, the Kyoto Protocol was adopted, which legally bound the participating developed countries to achieving greenhouse gas emissions reduction targets by 2008–2012, the first commitment period. A number of countries, as well as the EU, agreed to take on mitigation commitments until 2020 for a second commitment period running from 2013 to 2020 (Briner and Prag, 2013). In 2010, the international community agreed on the need to reduce emissions in order to prevent global temperature increases from exceeding 2°C compared with pre-industrial levels ('Cancun agreements') (Vautard et al., 2014).) This would require global emissions to be cut by 40 to 70 % compared with 2010 by 2050 (Edenhofer et al., 2014).

2.7 Paris Protocol

At the Paris Climate Conference (COP21) in December 2015 (UNFCCC, 2015), 197 countries adopted the first-ever universal, legally binding global climate deal. The agreement is due to enter into force in 2020 or earlier, depending on the process of ratification. The Paris Agreement targets to connect today's policies and climate-neutrality before the end of the century, and, with regard to mitigation, the governments agreed (EEA, 2016). Thus the Agreement tends to establish the core framework for cooperative action on climate change beyond 2020 and will replace the Kyoto Protocol (Climate Forum (CF), 2015). On 5 October 2016, the inception for entry into force of the Paris Agreement was attained. The Paris Agreement entered into force on 4 November 2016. The first session of the Conference took place in Marrakech, Morocco from 15-18 November 2016 which served as the meeting of the Parties to the Paris Agreement (CMA 1) (EEA, 2016).

2.8 Climate Smart Forestry (CSF)

An approach that primarily focus on climate mitigation by using forests and its related policies by utilising the different regional characteristics and circumstances of the EU Member States. It also looks for synergies with other policies impacting the forest sector. The fact that the EU Member States have very dissimilar mitigation potentials in the forest sector should not prevent us from taking advantage of the opportunities for using EU policy to enhance forestry's role in mitigation. Example of CSF is; enhanced CO_2 sequestration by using improved tree genetic resources (through tree breeding), or the selection of species and provenances more resilient to climatic change is regionally specific measures. Again, having synergies between different forest polices like rural policies, industrial policies, energy policies and biodiversity policies meet climate mitigation targets. An example of synergies with regional development can be found in central European regions where outgrown coppice is only used for non-commercial fuel wood and burned in local stoves at low energy efficiency. Furthermore, these synergies can also be found by the mitigation of the projected disturbance risks from fire or storms, but also by the enhanced implementation of forest reserves and halting forest degradation. In addition, the Forest Management Reference Level is very different from country to country, based on past historical growth and on future forest use potential (Nabuurs et al., 2015).

2.9 Deforestation in Ghana

Deforestation is the situation whereby forest is transformed into an alternative use mostly into permanent non-forested land use such as agriculture, grazing or urban development (van Kooten and Bulte, 2000). Deforestation is primarily a concern for the developing countries of the tropics (Myers, 1994) as it is shrinking areas of the tropical forests (Barraclough and Ghimire, 2000) causing loss of biodiversity and enhancing the greenhouse effect (Chakravarty et al., 2012). In this regards, deforestation in Ghana is considered to be one of the highest in the World. At an annual rate of 2 percent, equivalent to 135,000 hectares per annum, remnant forests outside of the gazetted forest reserves are likely to be completely liquidated in the next 10 years and the forest reserves will be under a more acute threat of encroachment and other illegal activities if very serious and concerted action to eliminate the threats is not taken (FC, 2015a).

Forest degradation and deforestation pose a significant threat to Ghana for two main reasons: forests provide many unseen ecosystem services and functions that support the country's predominantly agricultural economy. As Ghana loses its forest ecosystem, it threatens the security of supply of some of the most important foreign exchange earners in the country. In addition, deforestation is a major global contributor to climate change (FC, 2015b).

The causes of deforestation are differentiated across the various forest zones in the country. In the south, excessive logging, unsustainable agricultural practices, bush burning, mining, quarrying and settlement and related infrastructure construction, timber exploitation have been identified as predominant causes (Boafo, 2013), while in the north, unsustainable charcoal and firewood production, forest fires and agriculture expansion are the major causes (Domson and Vlosky, 2007; Agyeman et al., 2012). It is also indicated that increased population growth and migration in forest fringe communities have exerted undue pressure on biological and wildlife populations in Ghana especially in the high forest zone (National Development Planning

Commission, 2010,). According to Mahapatra and Kant (2003), the size of the forest could be a factor that influence the process of deforestation. Tamakloe (n.d.) also argues that, off-reserves have been seriously degraded and fragmented to less than 5% of the forested area of 83,500 km^2. This is corresponding with Insaidoo et al. (2012) who noted that the country current reserves stand at only 5%, 395,000 hectares. It is evident that there is rapid forest-cover loss in many humid and sub-humid tropical areas, but that notwithstanding, there is much debate on the rate and extent of deforestation (Adams, 2009).

Deforestation increases the concentration of carbon dioxide in the atmosphere and causes energy changes in the globe through micrometeorological processes (Pinker, 1980), affects wind flows (Chomitz et al., 2007) and disrupts normal weather patterns creating hotter and drier weather and displacement across the major vegetation regimes in the country (Dregne, 1983).

Consequently, addressing the problem of deforestation is a prerequisite for any effective response to climate change (FC, 2015b).

2.10 REDD+ Strategy in the tropical Forests

Reducing Emissions from Deforestation and forest Degradation (REDD+) is an international initiative that was formally launched in 2007 as part of the Bali Action Plan. REDD+ seeks to support and reward developing countries for reducing their emissions from deforestation and forest degradation. Ghana joined the international REDD+ Readiness Programme through the World Bank's Forest Carbon Partnership Facility (FCPF) in 2008 and its REDD+ Readiness Preparation Proposal (R-PP) was approved in 2010 (FC, 2015b).

The Ghana National REDD+ Strategy (GNRS) is evidence that Ghana is committed to achieving REDD+ and changing the perception of the use of forest resources in the country. Ghana's Vision for REDD+ is to significantly reduce emissions from deforestation and forest degradation by 40% over the next ten years, whilst at the same time addressing threats that undermine ecosystem services and environmental integrity. By so doing, Ghana will become a pillar of action for the national climate change agenda and a leading pathway for sustainable, low carbon emissions development. The objectives for REDD+ in Ghana align with key National Development Plans for green growth. This includes reducing emissions from deforestation and forest degradation, while preserving Ghana's forest resources and at the same time, transforming the agricultural sector, expanding platforms for cross-sector and publicprivate collaboration and generating innovative, substantial and sustained economic and non-economic incentives to improve livelihoods across all regions in Ghana (FC, 2015b).

Ghana's REDD+ strategy is also in alignment with other international treaties and conventions including, Convention on International Trade in Endangered Species (CITES) and the Convention on Biological Diversity (CBD) (FC, 2016).

2.11 Scope of REDD+

The concept was introduced for the first time in 2005 at the COP 11 in Montreal, Canada. The original notion of REDD+ focused only on RED—reducing emissions from deforestation. However, within the last decade, the scope has been expanded to include degradation (REDD) and the Plus which refers to carbon stock enhancement (CSE), sustainable forest management (SFM) and biodiversity conservation (FC, 2015b).

REDD+ is basically made up of five sub-mitigation strategies as Avoided Deforestation (AD), Avoided Forest degradation (ADD), Carbon Stock Enchancer (CSE), Sustainable Forest Management (SFM) and Biodiversity Conservation (BC) (FC, 2016).

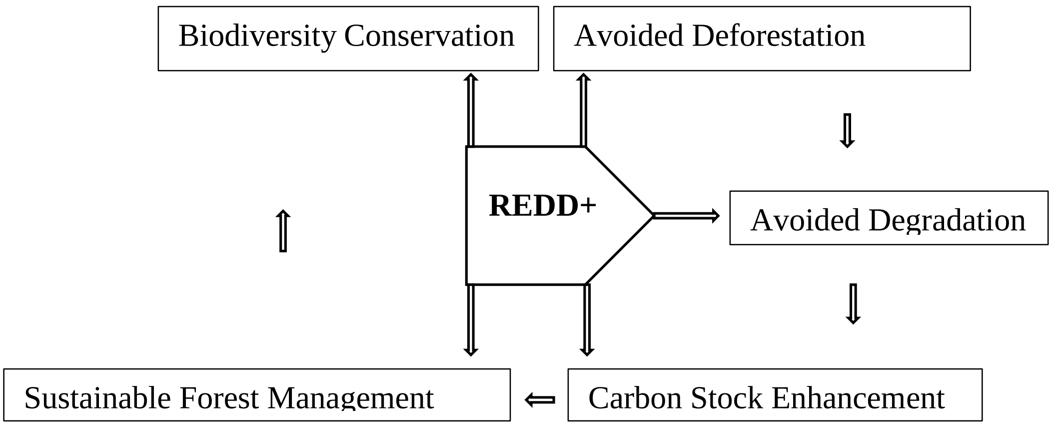

Figure 1: Elements of REDD+

Source: FC (2015b)

2.12 General Recommendations aimed at Study Research Priorities

The consequences of efforts are now getting set for the implementation of REDD+ activities hinge on a number of important issues and the resolution of the uncertainties surrounding these issues. These relate to: (1) the ecological impacts of climate change and their influence on REDD+ strategies; (2) policy approaches adopted towards REDD+; (2) forest governance, tenure rights, livelihoods and local communities; and (4) how REDD+ activities will integrate systems for measurement, reporting and verification (e.g., of carbon stock changes). These issues were the focus of the International Conference in Hong Kong on Adopting REDD+ for Conservation, Sustainable Community Livelihood and Climate Change Mitigation held in Hong Kong in 13-15 December 2013 (IUFRO, 2014).

Addressing the local relevance of REDD+, the Conference presentations and discussions highlighted a number of important conclusions similar to those of the recent (2012) IUFRO-led Global Forest Expert Panel assessment "Understanding Relationships between Biodiversity, Carbon, Forests and People: The Key to Achieving REDD+ Objectives". These include, among others, the importance of understanding the effects of climate change itself as well as other factors driving forest and biodiversity loss and degradation and how these changes are affecting the livelihoods and development prospective for forest-dependent communities (IUFRO, 2014).

3.0 MATERIALS AND METHODOLOGY

This chapter was focused on the criteria on how the data of the research were gathered thus research methodology used in the study. The studies specifically looked at the factors that are deemed to have characterised the state of Ghana's forests from 1990-2015 with its relation to the climate change phenomenon.

3.1 Organization of the Thesis

The thesis is divided into six parts; Introduction, Literature Review, Materials and Methodology, Results, Discussion, Conclusion and Recommendations. The introductory part gives a general overview of this thesis topic with the direction of its aims. The Literature part reviews the various studies on the concept on forests in Ghana and ecosystem-based strategies and climate change mitigation and forest policy in Ghana and the corresponding policy in the European region. The section gave a concise description of Ghana's forestry and the importance of the sector to the development of the Ghana. The factors which affect the growth of forests in Ghana were also looked at in this section of the study. The methodology part describes the analysis tools that were employed in the thesis. Results and Discussion showed the results of the thesis and describes a qualitative analysis of the results obtained. The final part concludes the findings of the thesis and its implication for practice and further studies in the research area.

3.2 Study Region

Ghana's forests forms part of the Guineo-Congolean Phytoecological region. Broadly, forests fall into two major biomes, each with different vegetation and forest types: the High Forest Zone covers 34% and the Savannah Zone covers 66% of the land area (MLNR, 2012). The southern part of the country, approximately south of the Kwahu Plateau, supports the closed forest and the northern part supports savanna and woodland vegetation. Within these major vegetation types, there are many variants (e.g., swamp forests in the forest zone, gallery forests along rivers in the savanna) (Ministry of Science and Environment (MSE), 2002). These regions are largely influenced by the two main regimes of seasonal rainfall (Stanturf et al., 2011). The first is the double maximum rainfall regime occurring south of about latitude 8°30'N, affecting the closed forest region and coast. The two major periods occur commonly from May to August and from September to October (Dickson and Benneh, 1988; Benneh and Agyepong, 1990). The single maximum regime occurs north of 8°30'N in the savanna biome where the single rainy season occurs from May to October, followed by a long dry season from November to May (Stanturf et al., 2011). The forest zone extends over a major part of the southwest of Ghana and comprises the eastern end of the Upper Guinean forest block, one of Africa's two major lowland rainforest blocks (Stanturf et al., 2011). Biodiversity is high in the High Forest Zone, as the zone falls within the West African Biodiversity Hotspot (Myers et al., 2000).

For purposes of addressing the issue of climate change in this work, the study was carried out in the forest areas of the middle belt to the southern parts to some areas of the eastern corridor of Ghana. With that, four subtypes of forests within the three major ecological forest zones were taken into consideration in the research.

They are as follows; Rainforest and Deciduous forests in the HFZ; Forest-Savanna forest in the TZ and Coastal Savannah forest in the SZ. Contrary, Guinea and Sudan Savannah forests (all in the SZ) were exempted from the studies because they did not meet the criteria for forest by Ghana's definition (FC, 2015a). Rainforest, Deciduous, Transition and Coastal forests cover 7 percent, 3 percent, 28 percent and 2 percent respectively of the total area in Ghana (Statistics, Research and Information Directorate (SRID), 2001).

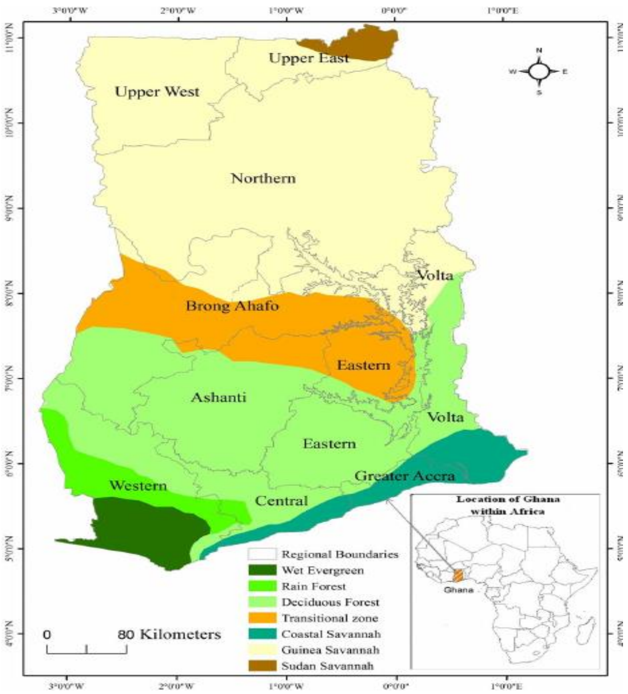

Figure 2: Ecoregions of Ghana

Source: Antwi et al. (2014)

3.3 Research Design and Data Sources

The study mainly focused on the factors affecting the growth of forest in Ghana. Notable climatic factors such as temperature, rainfall and wind speed and on different forest classifications in Ghana. Similarly, on carbon stock biomass in both Ghana and Europe, forests, growing stock in both forests, deforestation in Ghana and CO_2 emissions. Also, data on ecosystem-based strategy in mitigating climate change in Ghana and finally on forest policies in support of fight climate change in Ghana and Europe. Secondary data were principally the data source for the research. Journals, articles, books, reports, statistical bulletin and other important internet sources were used to achieve the set objectives of the study. However, the use of internet literature was limited by the researcher as it is not a reliable source of data information for proper research work. Data used for the analysis was obtained from the Ministry of Food and Agriculture (MoFA), Ministry of Lands and Natural Resources (MLNR), Ghana Forestry Commission, Forest Research Institute, Global Forest Resources Assessment and other relevant online database.

3.4 Data Sampling and Analysis Procedure

Quantitative data were obtained from the Ministry of Food and Agriculture (MoFA); Ghana Forestry Commission; Forest Research Institute and Global Forest Resources Assessment. The research engaged a 25 year time series specifically between the years 1990 and 2015. This period was chosen for the study because it reflects the trend in the relationship among the variables employed in the study.

In terms of analysis, the study used a multiple regression analysis model to empirically analyze the relationship between the variables used for the study. Following the use of a regression model analysis, the following assumptions were made;

1. There is a significant relationship the growth of the forest and the rate of temperature in Ghana.

2. There is a significant relationship between the growth of forest and the rate of rainfall.

3. There is a significant relationship between growth of forest and wind speed.

4. There is a significant relationship between growth of forest and carbon stock.

3.5 Choice of Variables

In my own evaluation to make a choice in such variables in the empirical analysis of the study in answering the set hypothesis above were made.

The impact of temperature, the impact of rainfall, the impact of wind speed, the impact of CO_2, and the impact of growing stock.

The impact of deforestation

The annual average rate of deforestation was calculated by establishing the total deforestation between two points in time (i.e. from land cover data from the years 2000 and 2010) and then dividing the total area deforested by the number of years between the two points in time (i.e. 10 years) to get an annual area deforested (FC, 2015a).

3.6 Comparison of Forest Policies in Ghana and Europe

For such evaluation, main conclusions from Kyoto and Paris meeting were used.

3.7 Model Specification

In order to investigate and analyze the factors that affect the growth of forest and test of the proposed hypothesis, a multiple regression model and Pearson correlation was used. Therefore, our baseline model could be specified as follows:

$Y^*it = \beta 0 + \quad \beta i\ Xti + \varepsilon t$……………………………………………………Eq. 1

Extending Eq.1 to reflect all the explanatory variables, the following regression model is obtained: $Y^*t = \beta_0 + \beta_1 X + \varepsilon t$……………..Eq.2

Where;

Y*= the dependent variable (s)

X = the independent variable (s)

$\beta 0$ = A constant

β 1,...... n are regression coefficients to be estimated.

t= time

For the purpose of simplicity, the model is broken down as follows Y= f(x)

The multiple regression model was adopted following the studies done by Lischke et al. (1998); Robledo et al. (2005); Toledo et al. (2011) and Pereira et al. (2013).

3.8 Analysis of Production Factor Model

To analyze the factors that affect the growth of the forest areas in Ghana as measured in forest cover per hectare, the specified model given in (2) above was expanded to have the following model below.

TFA = f (TEMP, RAIN, WIND, RD) ……………….. (3)

Thus, the econometric model 3 is mathematically expressed as follows;

In TFA = $\beta_0 + \beta_1$ In $TEMP$it + β_2 In $RAIN_{it}$ + β_3 In $WIND_{it}$ + β_4 In RD + ε_{ti}............. (4)

Where: TFA is the total forest area, β_0 is the intercept of the regression line and the Y axis, RAIN is Total amount of rainfall, *WIND* is Wind speed recorded and RD is the rate of deforestation.

Correlation analysis was done using Pearson correlation to analyze if there exists any impact on the amount of carbon stock in living biomass significantly affects the growth of forest in Ghana.

3.9 Model Estimation Tools

Knowing and establishing the specification of the model to suit the variables employed in the study, the following estimation tools would be used following the rules inscribed by economic research laws;

1. Multiple regression theory as established above.

2. Statistical test significance (Ordinary Least Square for hypothesis under confidence level 0.05).

3.10 Data Analysis Techniques

Statistical tools such as Excel (version 2010) and Statistical Package for Social Sciences (SPSS version 20) would be used for the data analysis. Data obtained will be analyzed with the use of standard statistical software using descriptive statistics. The objectives will be tested using multiple regression method. Data would be analyzed using frequencies with mode, mean and median indicated. Percentages will be estimated to indicate positions with measures of central tendencies and measures of dispersions. Dependent and independent variables will be used for regression analysis. Statistically, other data will be treated for scientific, objective interpretations. Deriving from the above, data will be presented in tables. Findings will be deduced from these followed by logical conclusions which will form the basis for appropriate recommendations.

4.0 RESULTS

4.1 Description of Forest Ecosystems in Ghana

Two main ecosystems exist in Ghana; the high forest and savannah ecosystems (MLNR, 2012). They are fundamentally defined by the rainfall pattern, degree of humidity, geology, soils and fire regime (Hall and Swaine, 1981). Almost all vegetation cover within the high forest zone qualify as forest as they meet all the requirements of the forest definition (FC, 2015a). Similarly, the forest definition allows the inclusion of savannah woodlands and other vital landscapes such as gallery forest within the savannah environment to be captured, measured and reported as forest, thus the ecosystem constitutes about two thirds of the entire land mass of Ghana (FC, 2015a). A closer look at Ghana’s vegetation cover reveals a pronounced environmental gradient from the evergreen rainforest of the western coasts through to the dry, semi-deciduous forest of the forest-savannah transition to the savannah environment of the northern regions. This ecological difference in Ghana has been well classified by Hall and Swaine (1981).

4.1.1 Rainforest Zone

The Rainforest also known as the Evergreen Forest Zone is located in the southwestern corner of Ghana in the Western Region (Menczer and Quaye, 2006). The forest subtypes in the zone are wet evergreen and moist evergreen (Hall and Swaine, 1976). According to SRID (2010) the wet evergreen forest type occurs in the southeastern (most corner of the country) in an area of about 750,000 ha, where rainfall is highest at 1500-2100 mm/year (Menczer and Quaye, 2006), averages 2,092 mm/year and occurs on the average of 143 days/year by Minia (2008). The moist evergreen forest type conversely, lies between the area of wet evergreen forest to the southwest and the moist semi-deciduous forest to the northeast; the area receives an annual rainfall of 1500-1750 mm (Stanturf et al., 2011).

4.1.2 Deciduous Forest Zone

This zone includes two primary forest types: moist semi-deciduous forest and dry semi-deciduous forest (Hall and Swaine, 1976). The northern boundary of the zone follows the Kwahu Plateau and the southern edge blends into the moist evergreen forest type. This zone is known to be a drier season than the evergreen forest types (MSE, 2002). Moist semi-deciduous forest occurs in a region receiving a total annual rainfall of 1,250-1,700 mm/year and adjoins the moist evergreen forest type to the south. To the northeast position of the Kwahu Plateau, the narrow belt of dry, semi-deciduous forest type is in an area receiving annual rainfall of 1,250-1,500 mm. Here there is a pronounced dry season (Stanturf et al., 2011).

The dry, semi-deciduous forest has two subtypes based mainly on the amount of rainfall and occurrence of fire, a wetter inner zone and a drier fire zone subject to frequent fires (Hall and Swaine, 1976). This type is described as forests containing clearings of savanna or savanna with clumps of forest trees (Ministry of Science and Environment (MSE), 2002).

4.1.3 Transition Zone

Transition Zone is alternatively called the Forest-Savanna Transitional Zone. As the name implies, is an area largely of derived savanna between the Dry Semi-deciduous Forest Zone along the Kwahu Plateau and the Guinea Savanna to the north (Stanturf et al., 2011). The region encompassed 6,630,000 ha of central Ghana (SRID, 2001). The area is expanding along forest fringes with grassland replacing forest as stated by Oppong-Anane (2001) and is believed to have been derived from forests (Dickson and Benneh, 1988). Minia (2008) delineated a transitional eco-climatic zone as being farther north (about 7.5-8.5° North) with an average annual total rainfall of 1,301 mm with rain occurring an average of 101 days/year. Within this transitional area, most of the tree species are similar to those in the forest zone to the south (Dickson and Benneh, 1988), and occur in association with tall to medium tall grasses (Stanturf et al., 2011).

4.1.4 Coastal Savanna Zone

The area widens to about 80 km inland and along its width includes the southern parts of the Central, Greater Accra, and Volta regions (Stanturf et al., 2011). In southeastern Ghana, the region encompasses much of the Accra Plain and Keta Plain (Volta Delta) as well as the southern third of the Ho Plain (Jenik and Hall 1976, Oppong-Anane, 2001; Minia, 2008). Mean annual rainfall is 800 mm (Dinar et al., 2008; Statistics, Research and Information Directorate (SRID) 2001). The zone consists of a coastline strand of vegetation along the seashore, mangrove vegetation (mostly degraded) associated with lagoons and coastal estuaries, and inland vegetation, primarily of scrub, grasses, and scattered trees (Stanturf et al., 2011). The main vegetation types are categorised as southern marginal forest from about Accra westward, southern outlier forest in the Accra Plains and savanna in the Ho Plains (Hall and Swaine, 1976; Menczer and Quaye, 2006). The southern marginal forest type occurs in a narrow strip from Cape Coast to Akosombo within the vegetation zone classified as coastal savannah (Stanturf et al., 2011).

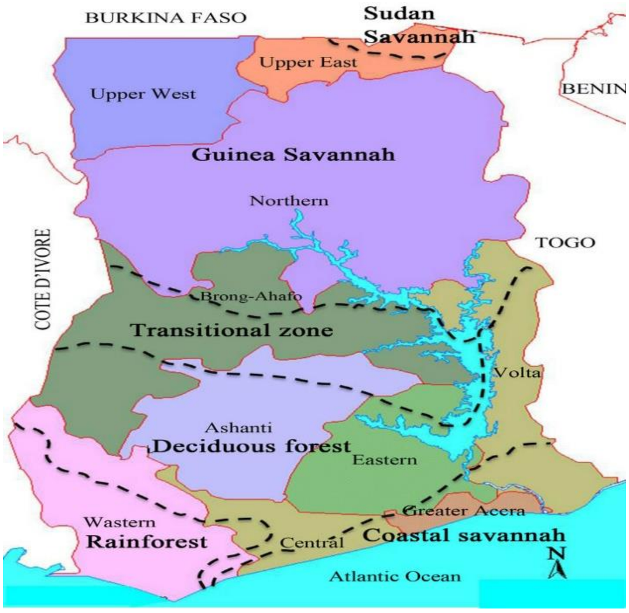

Figure 3: Agro-Ecological Zone Classification in Ghana

Source: Kemausuor et al. (2013)

In addition, all forestlands in Ghana are considered "Managed" according to the IPCC definition of managed (FC, 2015a).

4.2 Climate Overview in Ghana

The climate of Ghana is mainly subjected to the interaction of the Inter-Tropical Convergence Zone (ITCZ) and the West African Monsoon. The ITCZ, also called the Equatorial Convergence Zone or Inter-Tropical Front, is an area of calm winds separating the northeast and southeast trade winds. Annually, the location of the ITCZ reaches its northernmost extent during the northern hemisphere summer and its southernmost extent during the northern hemisphere winter. The principal feature of the climate of Ghana is the alternate wet and dry seasons caused by the movements of the ITCZ and West African Monsoon. In southern Ghana there are two distinct wet seasons, but Northern Ghana has only one (Stanturf et al., 2011).

The average daily range in the forest zone is 8 ^{o}C-9 ^{o}C and the seasonal range of daily mean temperature is 3 ^{o}C-4.5 ^{o}C. The mean monthly maximum in the hottest months is 31^{o}C-34 ^{o}C, and the mean monthly minimum in the coldest months is 19^{o}C-21^{o}C (Boakye, 2010). The principal feature of rainfall in Ghana is its seasonal character and variability from year to year. Very considerable variations exist between successive rainy seasons in time of onset, duration and amounts received. The rainy season begins in April and lasts until September. Annual rainfall ranges from about one thousand and one hundred (1,100) mm in the north to about two thousand and one hundred (2,100) mm in the southeast. The southern zone is characterized by a bi-modal rainfall pattern with peaks in May-June and September- October followed by a short dry spell. The mean annual rainfall for the forest zone ranges between 1000-2150 mm (Boakye, 2010). In Ghana, average wind speeds are 6.4-7.5 metres per second (m/s), corresponding to wind class categories 3 and 4 shown in the table of Gross Wind Resource Potential of Ghana (International Renewable Energy Agency (IRENA), 2015).

4.3 Historical State of Ghana's Forest from 1990-2015

The below figures show the characteristics of Ghana's forest in the past 25 years

The figure below shows data for the characterisation of forest in Ghana from 1990-2015

Looking at the forest trends in figure (3), it is clearly shown that naturally regenerated forests have increased over the years, whereas planted forests keep losing its area and primary remaining constant.

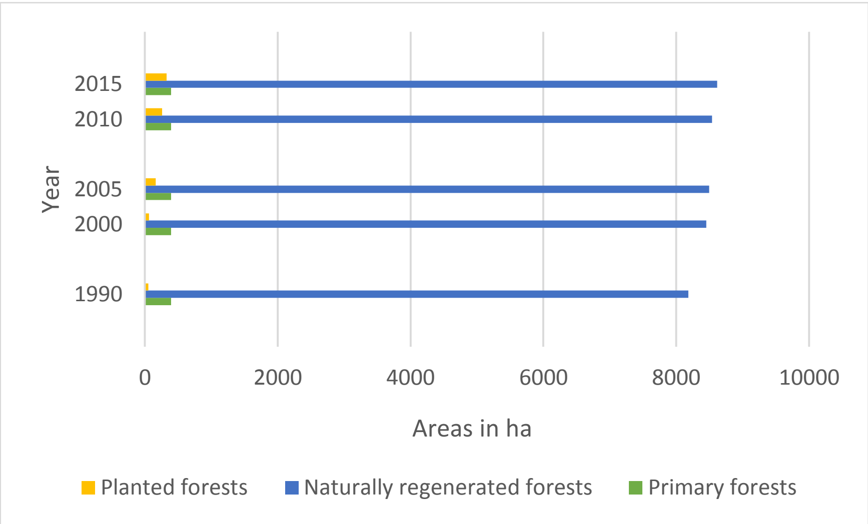

Figure 4: Forest Trends in Ghana from 1990-2015

Source: Global Forest Resources Assessment (GFRA) (2015)

The figure shows an explicit state of the forest types by function from 1990-2010 in Ghana.

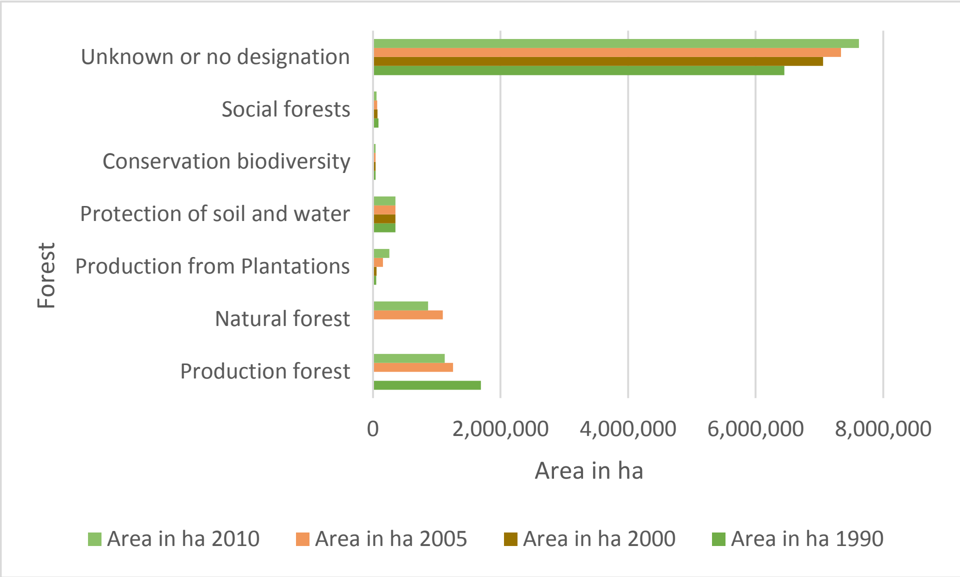

Figure 5: Forest Classification by Function in Ghana from 1990-2010

Source: MLNR (2012)

The figure shows a clear state of the forest types by management from 1990-2015 in Ghana.

Open forest appreciated a gradual growth from 1990-2015 while closed forest depreciated in growth at the same period of study.

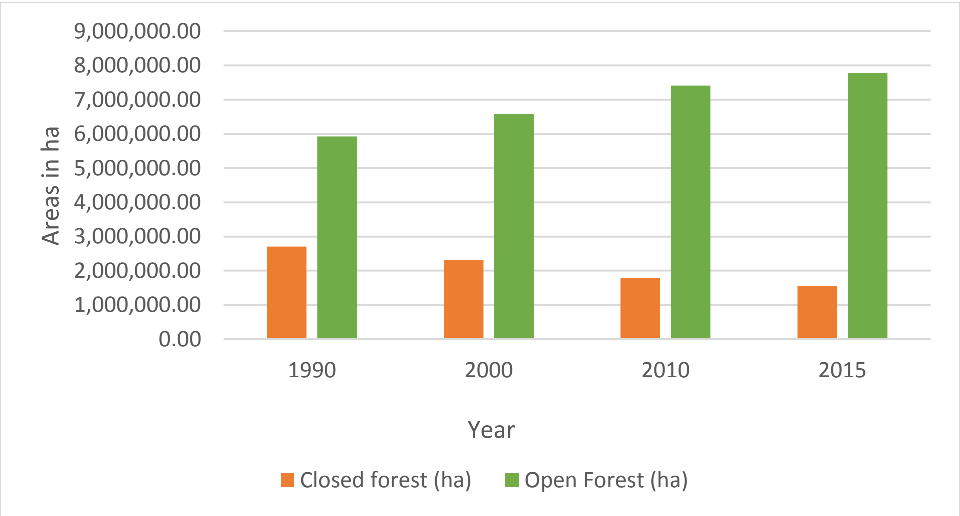

Figure 6: Comparison of Closed and Open Forests in Ghana from 1990-2015

Source: MLNR (2012)

4.4 Drivers of Deforestation in Ghana

The pie chart below shows the statistical data on the rate in percentage of the key drivers (causes) of deforestation in Ghana.

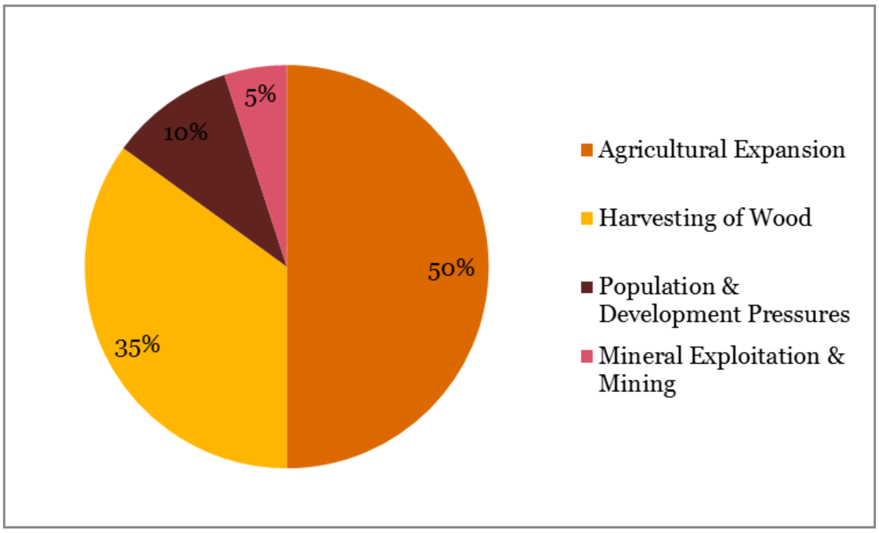

Figure 7: Principal Drivers of Deforestation

Source: FC (2015b)

Table 1: Drivers of deforestation in Ghana that caused differences among the various forest zones from 1990-2015

The table below provides a detailed description of drivers of deforestation that caused differences in the present and past situations among the various forest zones from 1990-2015 in Ghana. Direct drivers are activities or actions at the forest frontier that explicitly impact forest cover, whereas indirect drivers are the socioeconomic processes that shift the way that people behave at a macro level and would affect the direct driver (FC, 2015b).

Direct drivers	Associated indirect drivers
Agricultural Expansion	• Cocoa farming • Other tree crop systems: Rubber, Citrus, Oil Palm, Coffee, Cashew, Mango • Food crop farming: Plantain, cassava, maize, yam; farmed under shifting cultivation using slash-and-burn.
Wood Harvesting	• Illegal logging: timber companies and chainsaw operations • Charcoal production: Unregulated • Other fuel wood harvesting
Population Growth and Development	• Population growth • Urban and rural settlement and expansion • Expansion of roads and infrastructure
Mining and Mineral Exploitation	• Mining inside Forest Reserves • Illegal small-scale mining: commonly known as galamsey
Population Growth and Development:	• Increasing demand for food crops, firewood, charcoal, and construction materials

Low price of timber on domestic market	Unknown
Global markets	• Increasing demand for high value timber species. • Growing global demand for chocolate and other cocoa products. • Increasing global and regional demand for palm oil.
Weak law enforcement	• Weak institutional capacity • Corruption
Land and tree tenure regimes that create perverse incentives	• Tree tenure policies that create perverse incentives to remove on-farm trees
Timber industry over-capacity:	• Proliferation of chainsaws and small-scale mills

Source: FC (2016)

4.4.1 The Extent of Deforestation in Ghana among various forest sub types from 2000-2010

From the figure below, the rate of deforestation in the Southern marginal (coastal savannah) is highly significant than all the forest sub types. Moist evergreen is highly significant different from upland evergreen but significantly than wet evergreen. Significantly, wet evergreen is different from upland evergreen. Moreover, dry, semi deciduous (fire) is significantly different from a dry, semi deciduous (inner), moist deciduous (NW) and moist deciduous (SE). However, moist deciduous (NW) and moist deciduous (SE) were not significantly from each other and upland evergreen was also not significant from them.

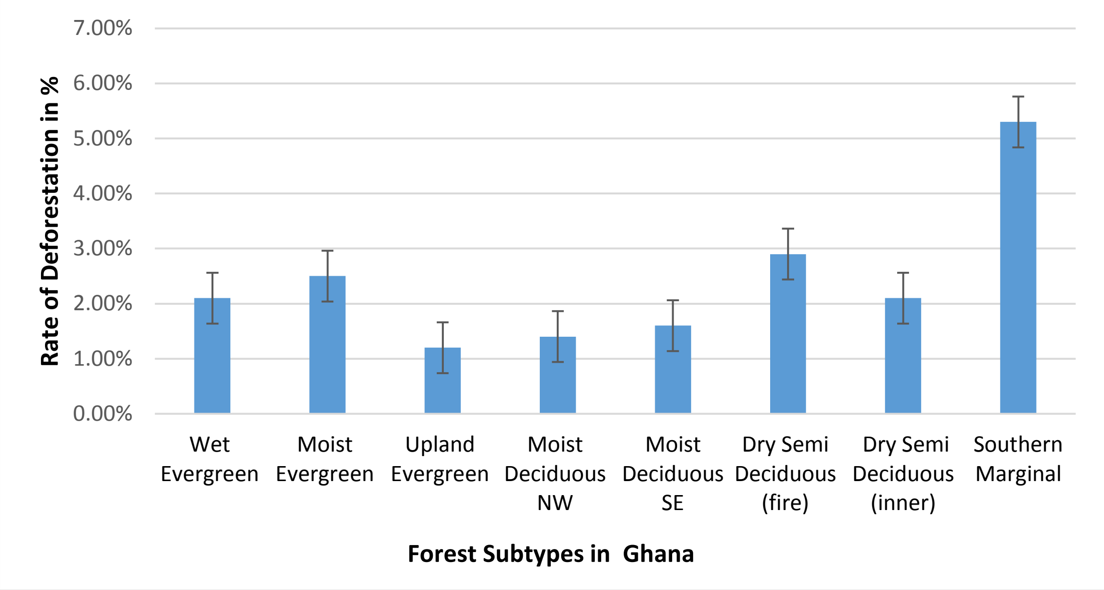

Figure 8: Extent of Deforestation from 2000-2010

Source: Authors own from secondary data collected.

4.4.2 The impact of deforestation

Deforestation increases the concentration of carbon dioxide in the atmosphere and causes energy changes in the globe through micrometeorological processes (Pinker, 1980), affecting wind flows (Chomitz et al., 2007) and disrupts normal weather patterns creating hotter and drier weather and displacement across the major vegetation regimes in the country (Dregne, 1983).

4.5 Analysis of Model, Results and Interpretation

Based on our model specification as shown in (Chapter 4), the following null and alternative hypotheses are proposed;

Hypothesis, one (Null and Alternative)

H_o: a_1=0 There is no significant relationship between temperature and forest growth.

H_1: $a_1 \neq 0$ There is a significant relationship between temperature and forest growth.

Hypothesis two (Null and Alternative)

H_o: a_1=0 There is no significant relationship between the amount of rainfall and forest growth.

H_1: $a_1 \neq 0$ There is a significant relationship between the amount of rainfall and forest growth.

Hypothesis three (Null and Alternative)

H_o: a_1=0 There is no significant relationship between wind speed and forest growth.

H_1: $a_1 \neq 0$ There is a significant relationship between wind speed and forest growth.

Hypothesis Four (Null and Alternative)

H_o: a_1=0 There is no significant correlation between carbon stock and forest growth.

H_1: $a_1 \neq 0$ There is significant correlation between carbon stock and forest growth.

4.5.1 Decision Rule:

If p calculated < p at 0.05 significance level, I reject the null hypothesis (Ho) and accept the alternative hypothesis, otherwise, I accept it.

Also, if F- calculated > f- table (4.747), I conclude that the entire or overall regression result is statistically significant, otherwise it is not.

4.6 Regression Results of the Factors that affect Growth of Forest in Ghana

The table below shows the regression model results for the impact of the factors that impact the growth of forest in Ghana.

Table 2: Regression Model Summary

From the table above, a look at the coefficient of determination (R^2) = 0.980, it indicates that, the regression model was able to explain 98% of the explanatory variables whiles 2% is explained by other factors which were not part of the model and are taken care of by the error term. The coefficient of determination for the model can therefore be said to be high and hence this shows that, the regression is significant and the data best fits the model used.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000[a]	.980	1.000	79.4923283

a. Predictors: (Constant), Wind Speed, Temperature, Rate of Deforestation, Rainfall

Source: Authors own from secondary data collected.

Table 3: Results obtained from the analysis

From the table, it can be deduced that, temperature, rainfall and the rate of deforestation has a significant impact on the growth of forest in Ghana. Yet, wind speed was shown to be insignificant on the growth of forest in Ghana. This brings out the fact that the wind speed climate has no appreciable effect on the growth of forest in Ghana and does little or no support to the climate change situation.

Factors that affect growth of forest in Ghana	Constant B	T-test	Sig.
Rate of Deforestation	-2001.78	-5.901	**0.00****
Temperature	-14.7	6569.01	**0.00****
Rainfall	-2424.157	-47.086	**0.00****
Wind speed	-0.729	-0.498	**0.624**

a. Dependent Variable: Forest lands in Ghana.

Significant at p (0.05) **

Source: Authors own from secondary data collected.

4.6.1 The impact of temperature

Temperature being an abiotic factor tends to have a great impact on the growth and promote the sustainability of forest ecosystems as it supports the various physiological processes in trees as stated clearly by Chambers and Silver (2004). For example, Sato et al. (2006) said that reproductive processes such as flowering and fruit set in trees may be especially sensitive to high temperatures. Clark (2004) and Wright (2005) also suggested that an increase temperatures which resulted in some form of tropical forest decline. Thus, temperature has an effect on the growth of forests in Ghana.

4.6.2 The impact of rainfall

There have been changes in rainfall patterns in the forest areas of Ghana as some regions are receiving less rainfall and suffering longer and more droughts, other regions are experiencing much higher levels of rainfall. In many places the seasons or times of year when rain falls are changing. Rain is falling at different times and for shorter or longer periods than in the past. This has affected the growth of forests in the country as well so therefore the need to investigate the impact of rainfall on the ecosystem (Stone and León, 2010).

4.6.3 The impact of wind speed

Wind is a climate parameter which is known to have an effect on the anchorage of trees in the forest ecosystem. There is, however an uncertainty prediction of changes to the wind climate (Hulme and Jenkins, 1998) by the effect from climate change occurrences. In some cases, the speed of wind has caused adverse effects in the forest like total devastation of the forest as reported by (Mayer and Schindler, 2002; Hubrig, 2004; WSL and BUWAL; 2001).

4.7 The following data in table presentations show the role of forest in mitigating climate change in Ghana and Europe.

Table 4: Pearson Correlation between Carbon Stock and Forest Growth in Ghana

The table below shows the Pearson correlation results for impact of carbon stock on the growth of forest in Ghana. Results from the correlation analysis show a significant, but negative correlation between carbon stock and the growth of forest in Ghana. This gives a positive impression on Ghana's forest to have stored and has the potential to hoard more carbon in its living biomass, which otherwise, would have been emitted to cause to global climate change.

Carbon Stock and Forest Growth	Value	Sig.
Pearson's R	**-0.750**	**0.00******
Spearman correlation	**-0.735**	**0.00****

Significant at p (0.05) **

Source: Authors own from secondary data collected.

Table 5: Table 5: Carbon Stock in biomass 1990-2015 (Ghana)

From the results there was an appreciable loss of carbon stock in biomass in the Ghanaian forests from 1990-2015 giving a value of -0.6%.

	Living forest biomass (million tonnes)					**Annual change (%)**
	1990	**2000**	**2010**	**2015**	**1990-2015 Mt C**	**1990-2015**
	820	765	724	713	-4300	-0.6%

Source: Authors own from secondary data collected.

Table 6: Table 6: Emissions levels among the various sub-forest types in Ghana

The table below shows the role of the various sub-forest types contribution to the total emission in Ghana from 2000-2010.

Negative emission values were recorded across the various sub-forest types in Ghana. This clearly explains the results that some human intervention actions like afforestation, reforestation etc. were purposely taken to remove CO_2 from the atmosphere so as to stabilize the climate as desired (Fuss et al., 2014). The various sub-forest types serving as a carbon sink character is an important role they can play to help grab the problem to a more comfortable climate state. Hence, the upland evergreen emitted less CO_2 emissions compared to moist evergreen. In summary, there was a slight difference between the sub-forest types emissions and the national emissions with forest as reference. This acknowledges the fact that negative emissions will be an undeniable component of a wider climate change mitigation effort (Fuss et al., 2014).

Forest sub types	Total Emissions ($t\ CO_2$-e)	Forest Reference Emission Level as average annual emissions ($t\ CO_2$-e / yr)
Wet Evergreen	-10,030,601	-1,003,060
Moist Evergreen	-20,000,917	-2,000,092
Upland Evergreen	-363,915	-36,392
Moist Deciduous NW	-5,990,629	-599,063
Moist Deciduous SE	-10,635,075	-1,063,507
Dry Semi Deciduous (fire)	-6,720,080	-672,008
Dry Semi Deciduous (inner)	-4,680,185	-468,018
Southern Marginal	-2,049,259	-204,926
Savannah	-14,131,347	-1,413,135
Total	**-74,602,008**	**-7,460,201**

Source: Authors own from secondary data collected.

4.7.1 The impact of CO_2

Forests influence climate change largely by affecting the amount of carbon dioxide in the atmosphere (FAO, 2005). The carbon sink function of a forest increases with the forest's rate of growth and the permanence with which it retains carbon. Climate change has both direct and indirect effects on forests (FAO, 2013). Since half the dry weight of biomass is carbon (IPCC, 2003), therefore the need to analytically address carbon stocks in forest biomass (FAO, 2005) to achieve the objective of the study. So quantifying the substantial roles of forests as carbon stock (sink) is one key component in understanding the empirical analysis of the study and getting solutions to the set stated hypothesis.

4.8 The following data shows the impact of climate change on the growth of forests in Ghana

Table 7: Table 7: Trends in forest growing stock 1990-2015 (Ghana)

Results from the table shows that from 1990-2015, there was a decrease in forest growing stock in Ghana.

Country/Territory	**Growing stock (million m^3)**					**Annual change rate**	
	1990	**2000**	**2005**	**2010**	**2015**	**1990-2015**	
						1 000 m^3/yr	**%**
Ghana	434	406	397	389	378	-2.2	-0.6

Source: Authors own from secondary data collected.

4.8.1 The impact of growing stock

Forest growth counteracts rising greenhouse gas (GHG) concentrations in the atmosphere by providing an important carbon sink (FAO, 2008; SFC, 2010).

4.9 Ecosystem-based Strategy for combating Climate Change in Ghana

REDD+ Implementation Strategies in Ghana adopted a nested approach. The strategic focus on the implementation of large scale, sub-national programmes, which follow ecological boundaries or eco-zones and are defined by major commodities and the drivers of deforestation and degradation, within a set of over-arching, national activities and the encompassing national REDD+ framework. For formulation stages and the analysis of strategic options for Ghana's National REDD+ Strategy (NRS), three (3) national and sub-national REDD+ programmes have emerged as being the main areas of focus for the coming five-plus years of REDD+ implementation (FC, 2015b).

Table 8: Table 8: REDD+ Strategic Interventions in Ghana

The table displays the ecosystem-based strategy Intervention useful in mitigating climate change in Ghana under REDD+

Strategic Intervention	Improving Land-use and socioeconomic development in the High Forest Zone and cocoa growing areas	Addressing wood harvesting and agricultural practices in the 'transition' and savannah zone	Policy and legislative reforms to support REDD+ and a sustainable Forestry sector
Title:	Ghana's Emission Reductions Program for the Cocoa Forest Mosaic Landscape (Cocoa Forest REDD+ Programme)	Emission Reductions Programme for the Shea Landscape of the Northern Savanna Woodland (Shea Savanna Woodland REDD+ Programme)	
Nesting Level	Sub-national	Sub-national	National
Eco-Zone	High Forest Zone	Savanna Woodland Zone	
Commodity Focus	Cocoa, oil palm and other tree crops	Shea (scientific name) and possibly Cashew	Addressing indirect drivers
Drivers	Cocoa, other tree crops, Galamsey, Illegal is logging	Charcoal, illegal logging, agricultural expansion	
Leverages			National level interventions will leverage the funding and activities being implemented under the VPA-FLEGT

			process and eventual implementation as well as the projects under Ghana's FIP

Source: (FC, 2015b).

Nonetheless, there are some potential programmatic areas or landscapes that require further investigation for future implementation:

4.9.1 Mangrove Eco-Zone Emission Reduction REDD+ Programme

Is a natural forest ecosystem along Ghana's coasts and inland waterways. The magnitude of carbon stocks coupled with the existing threat to these unique and environmentally important forest types creates a strong imperative that for REDD+ action (FC, 2015b).

4.9.2 Togo Plateau and the dry, demi-deciduous forests zone REDD+ Intervention

Along Ghana's mid-eastern border with Togo, there is an area of the Volta Region, commonly referred to as the Togo Plateau, which contains some of the highest carbon stocks in the country due to a mosaic of protected forests, off-reserve forest patches, high biomass cocoa farms and other complex Agroforestry systems (FC, 2015b).

4.10 Forest Policies in Ghana

The government of Ghana recognizes that climate change is already negatively affecting Ghana in myriad ways and that it is likely to continue to hamper Ghana's environmental and socioeconomic prospects in the coming decades (FC, 2016) and that matter, various forest policies in direct relations to climate change mitigation have been formulated.

Table 9: Table 9: Forest Policies that are in line with Climate Change Mitigation

The table below shows the various forest policies in Ghana that are in line with a climate change mitigation agenda

Policy	**Overview**
National Climate Change Policy (NCCP) 2012	The NCCP was developed in 2012 with the vision of ensuring a climate resilient and climate compatible economy while achieving sustainable development through equitable low carbon economic growth.
National Climate Change Policy Action Programme: 2015-2020	The purpose of the national climate change master plan is to put in place robust measures needed to address the challenges posed by climate change and climate vulnerability. Policy Focus Area 4 seeks to design and implement intervention that increase carbon sinks.
The 2012 Forest and Wildlife Policy (2012)	This is the parent sector policy aimed at the conservation and sustainable development of forest and wildlife resources in Ghana.
The National Land Policy (1999) with the associated Land Administration	The policy outlines specific actions that are consistent with the Mission and Vision of the Forestry Commission and goals of REDD+. Under security of tenure and protection of land rights, it clearly states that decision-making with respect to the disposal of land should take into consideration: • The natural resources of the land; • Conservation of land for future generation; • Protection of land rights of the present generation; and • Accountability of the subjects for whom the land is held in trust.
National Environment Policy (NEP) 2014	The NEP commits to the principle of optimum sustainable exploitation of the ecosystem resources. The policy recognizes serious environmental challenges, including loss of biodiversity, land

	degradation, deforestation and desertification, wildfires, illegal mining, air and water pollution facing Ghana.
Low Carbon Development Strategy	The overall objective of this strategy is to contribute to global climate change mitigation through the development of an economically efficient, comprehensive Low Carbon Development Strategy a monitoring reporting and verification system
Forest Law Enforcement, Governance and Trade (FLEGT)	FLEGT initiative (as part of the Voluntary Partnership Agreement (VPA)), and the projects under Ghana's FIP all provide a strong set of complementary channels for addressing the major drivers of deforestation and degradation in the ERP landscape and for moving forward performance-based and climate-smart manner.

Source: FC (2016)

4.11 The State of Europe's Forests from 1990-2015

More than one third of Europe`s land area is forest and it has continued to increase since 1990. An area of 215 million ha is known to be the coverage of the forest given 33 percent of total land area in the continent which is heterogeneously distributed among countries. Northern Europe (53 percent) is the most forested region while South-East Europe is the least forested region (23 percent). Within the space of 25 years, thus from 1990-2015, the forest area in Europe has expanded by 17.5 million ha. Averagely, 0.33 percent accounting for 700,000 ha of forest area is added every year. This annul upward forest increment is as the results of afforestation, natural forest expansion and low turnout of deforestation (FE, 2015).

Table 10: Carbon Stock in Biomass (Europe)

The table below shows the carbon stock in the living forest in Europe from 1990-2015.

From the above results (table 6) shows that the highest carbon stock in biomass of 2.9% was recorded in South-West Europe, while North-Europe recorded the least of 1.0%. Sequentially, Central-East (2.2%), South-East (1.9%), Central-West (1.5%) were attained for the various regions in Europe.

Region	**Carbon stock in biomass**					**Annual change**	
	1990	2000	2005	2010	2015	1990-2015	
	Mt C					Mt C	%
North Europe	2414	2680	2829	2950	3029	24.6	1.0%
Central-West Europe	2519	2871	3068	3225	3447	37.2	1.5%
Central-East Europe	1917	2236	2376	2622	2960	41.7	2.2%
South-West Europe	725	950	1063	1157	1251	21	2.9%
South-East Europe	1265	1442	1535	1736	1854	23.6	1.9%
Europe	8840	10178	10870	11691	12541	148	1.7%
EU28*	6977	7998	8559	9128	9826	114	1.6%

Source: Authors own from secondary data collected.

Table 11: Trends in forest growing stock 1990-2015 (Europe)

Over the last five years (2010-2015) with that for the previous five-year period (2005-2010) reveals that the Central-East Europe region, was the only region in Europe with a higher rate of growing stock accumulation in the recent 2010-2015 period (1.94%) compared to the 2005-2010 period (1.77%) according to the results. Again, In all other regions of Europe, the rate of growing stock accumulation for the last five-year period 2010-2015 was lower than in the previous five-year period 2005- 2010: the growing stock accumulation rate decreased from 2.35% per year to 1.23% in the South-East Europe region, from 0.95% to 0.54% in the Northern Europe region, from 1.61% to 1.48% in the South-East Europe region and from 0.89% to 0.87% in the Central-West Europe region.

Region	Total growing stock in forest (million m3)					Annual change of growing stock 1990-2015	
	1990	2000	2005	2010	2015	million of m^3/yr	%
North Europe	6,486	7,225	7,660	8,029	8,247	70.50	0.97
Central-West Europe	6,847	7,910	8,411	8,794	9,185	93.50	1.18
Central-East Europe	7,021	8,281	8,772	9,577	10,541	140.80	1.64
South-West Europe	1,722	2,172	2,386	2,585	2,783	42.40	1.94
South-East Europe	2,923	3,364	3,609	4,054	4,309	55.40	1.56
Europe	24,999	28,952	30,838	33,039	35,065	402.70	1.36
EU-28	19,169	21,956	23,420	24,935	26,526	284.30	1.31

Source: Authors own from secondary data collected.

4.12 Conclusions of the Climate Mitigation Treaties in the World

4.12.1 Kyoto Protocol

The Protocol's key character is it’s has obligatory targets on greenhouse-gas emissions for the world's leading economies which have accepted it. Commitments under the Protocol vary from nation to nation. To compensate for the sting of "binding targets," as they are called, the agreement offers flexibility in how countries may meet their targets. The Kyoto Protocol is a complicated agreement that has been slow in coming--there are reasons for this. The Protocol not only has to be an effective against a complicated worldwide problem, but it also has to be politically acceptable. There is a delicate balance to international treaties. Some mechanisms of the Protocol had enough support that they were set up in advance of the Protocol's entry into force (UNFCCC).

4.12.2 Paris Protocol

Parties are urged to ratify and implement the second commitment period of the Kyoto Protocol up to 2020, to make and implement a mitigation pledge and improve measuring and reporting processes. Parties resolve to strengthen the existing technical examination process on mitigation, which means increased cooperation with non-country stakeholders, increased consultations and dissemination of results (Climate Focus (CF), 2015).

5.0 DISCUSSION

This section discusses in detail the understanding of the purposes of this research study and hopefully come out with a possible answers and solutions to counteract the study problem effectually. This is to know the impacts of temperature, rainfall, wind speed and rate of deforestation factors on forest growth in Ghana and the role of forests in mitigating climate change in the ecosystem-based strategy (REDD+). Also, to have a comparison between the various forest policies in Ghana and that of Europe in dealing meritoriously with the climate change phenomenon globally.

The rate of deforestation influenced the growth of forest in Ghana from 1990 to 2015 and this vindicate the studies of Amisah et al. (2009); Chakravarty et al. (2012); Boafo (2013) who stated that economic globalization combined with the looming global land scarcity have increased the need for land use change for the future pathways. This suggests that there are some land use activities which are contributing to the causes of forest depletion in Ghana. This assertion falls in line with the findings of Mohammed (2014) and FC (2016) which stated that the principal drivers of deforestation and degradation are: agriculture expansion, logging, fuel-wood harvesting or charcoal production, wildfires, infrastructure development, mining and sand winning. Furthermore, illegal mining has become a recent problem in Ghana. Artisanal gold mining has occurred for more than 500 years and indeed, gave Ghana its colonial-era name "Gold Coast". Pit mining locally termed "Galamsey", has contributed mostly to forest degradation in the country and this has opened to industrial mining that has shifted from underground to surface mining. Though mining within forest reserves was briefly banned in 1997 (Hansen et al., 2009), surprisingly, its success could rarely be seen in the growth of Ghana's forests. In 2013 especially, mining impact on the forest landscape shot up largely due to spikes in the global price of gold (FC, 2016). This menace continues to erupt irresponsibly in the country. Firewood also accounts for two-thirds of the energy consumption of Ghana; 84 percent of households use firewood and 13 percent use charcoal (Hansen et al., 2009). Overall, fuelwood is estimated to consume 25-28 million m^3/yr of raw wood (Hansen et al., 2009), which is about 7.5 to 8.5 times the estimated national volume of harvested timber. Charcoal is produced primarily in the transition and savanna zones, but due to declining resources, more wood is coming from the high forest zone (HFZ) (Hansen et al., 2009). However, according to Amisah et al. (2009), Ghana's growing population is a considering factor in deforestation because it demands more forest products and land area for settlements, construction, energy and food as the population continue to multiply. In that, in 1990, 14.63 million people existed, conversely, in 2015 there were 27,409,893 people (Ghana Statistical Service (GSS)). This shows an upward growth of almost 50%. This unimaginable faster growth rate is causing the country in experiencing increasingly more rural to urban migration as people seek for greener pastures and avenues for to better their lives and future. The growing urban population has increased domestic demand for construction wood, charcoal and agricultural products; this demand is met essentially by increasing the area of productive land rather than increasing the productivity of already cleared land. As noted above, most of the domestic demand for construction material comes from illegal harvesting (Hansen and Treue, 2008).

From figure (7), the rate of deforestation in the southern marginal (coastal savannah) was highly significant than all the forest sub types. This is because on that particular occasion, there are high densities of multiple species, according to FC (2015a) so therefore a lot of deforestation activities which go on there causing the uncontrollable depletion of the forest cover. Location of the nation's capital city (seat of government) within the area is also contributing to the high ascendency of rural-urban migration and industrialisation. Wardell et al. (2003) also supported by stating that migration from the poorer savanna zones to the south has long been a reality in rural Ghana, dating from colonial days and before. These factors are attracting a lot of people in that particular zone and this has a direct relationship with the rampant infrastructure which is claiming a lot of forest land and the fact that everyone wants to live in the capital city (the largest cosmopolitan city in Ghana). As reported by Stanturf et al. (2011) that the southern marginal forest type occurs in a narrow strip from Cape Coast through Accra to Akosombo within the vegetation zone.

Moist evergreen forest is highly significant different from upland evergreen but significantly different from the wet evergreen forest. This is because in the moist evergreen forest, there are about 505 trees per hectare (FC, 2015a) and this attracts a lot of illegal loggers and the occurrence of over exploitation of timber extraction are also frequent. Commercially demanding of a limiting number of species were selectively logged, effectively contributing to forest degradation. An estimated 32 percent of forest reserves (exclusive of timber production and protection areas) in the HFZ were classified as degraded (Donkor and Vlosky, 2003). Over-exploitation of a number of species led to an export ban on 14 commercial species in 1979 that was expanded with an additional four species in 1987 (Abugre and Kazaare, 2010). These figures under-estimate actual removals; the current actual harvest is estimated to be greater than 3 times the official tally at about 3.3 million m^3/yr (Hansen and Treue 2008) because of under-reporting and illegal logging. 75 percent of logging is regarded as illegal in Ghana and is mostly engaged by the informal sector who produce for the domestic market locally called the chainsaw operators or pit-sawyers (Hansen and Treue, 2008). Hansen and Treue (2008) estimated that much of the illegal timber is taken from forest reserves, less than or equals to 1. 5 million m^3/yr, which is clearly unsustainable. Commercial species are favored by the illegal loggers, who selectively harvest the higher-value species (Hansen and Treue, 2008; Abugre and Kazaare, 2010; Marfo, 2010). To add up, the weak enforcement of forest law and the weak nature the Forestry Commission are relevant to the situation as well. Significantly, wet evergreen is different from the upland evergreen forest because it has very rich species diversity with about 200 tree species with a mean density of 445 stems per hectare of all trees more than or equals to 10 cm diameter at breast height (dbh) are found in this zone (FC, 2015a), thus representing the richest zone with a higher plant diversity (MLNR, 2012) but in the upland evergreen it houses three major forest reserves hence deforestation is carefully controlled (FC, 2015a).

Moreover, dry, semi deciduous (fire) is significantly different from a dry, semi deciduous (inner), because the zone has about 156 tree species and is heavily degraded because of frequent fires which leads to frequent salvage logging of its economic species. Again, most of the forest reserves in this zone are being converted to plantation forest (FC, 2015a). To move on, dry, semi deciduous (fire) and dry semi deciduous (inner) are significantly different from moist deciduous (NW) and moist deciduous (SE). In the moist deciduous (NW) due to its dry nature, there are regular outbreaks of wildfires which cause various degrees of damages to the forest reserves found in the zone, especially the northern portions of this zone are noticeable for that. Secondly, these fires tend to cause great loss to the country as the majority of the nation's forest reserves are found there. Nevertheless, in the moist deciduous (SE), due to the productive nature of the kind of tree species, it has, forest depletion is becoming a daily affair there. These findings are in support of FC (2015a) which state that this particular area is the most productive zone among the forest zones. Aspect is always an important factor in forest site classification and site index estimation. Changes of aspect have different effects on forest growth owing to its influence on solar radiation, air temperature, wind speed, and so on. Worrell and Malcolm (1990b) studied factors influencing forest growth in northern Britain and found that south-west-facing slopes have the lowest productivity, owing mainly to the strong winds. In the Taihang Mountains, drought is the most serious problem for south-facing slopes. In earlier forest classifications (Yang et al., 1993; Liu et al., 1996; Li et al., 2002), south-facing aspects were recognized as unfavourable for forest growth, suggesting a more serious limitation by drought on south-facing slopes. Both closed and open forests are found within the forest ecosystems have had their share of deforestation as evidences are clearly indicated in all sub-forest types with reserves.

However, moist deciduous (NW) and moist deciduous (SE) were not significant from each other because collectively they form one Ecozone hence they may exhibit similar characters. Again, they are distinguished by their prevailing climatic conditions, aspects and their geographical direction as indicated in FC (2015a). Both zones host similar species as reported by FC, 2015a that, they both harbour deciduous species. One unique point is the fact that, while in the moist deciduous (NW), the deforestation rate is largely attributed to the indiscriminate wildfire outbreaks however, in the moist deciduous (SE), deforestation is attributed to the kind of species it harbours majority of commonest tree species in Ghana (FC, 2015a) and this tends to attract the various wood extractors there. All these have less or no effect on the rate of deforestation in their individual ecozones. Upland evergreen was also not significant from them (moist deciduous (NW) and moist deciduous (SE)) because it contains some forest reserves, which are protected against any phenomenon of deforestation or any form of forest degradation as stated by (FC, 2015a). In each specified forest zone, one or two forests by function exist. Looking at the forest trends in figure (3), it is clearly shown that naturally regenerated forests have increased over the years, whereas planted forests keep losing its area and primary remaining constant. The government of Ghana has started investing more resources in the naturally regenerated forests since 1990 because it was foresight in those early days of the circumstances of deforestation and however lost focus on plants forests but kept an eagle eye on remaining primary forests in Ghana. By dealing capitally with any unscrupulous forest offenders.

Generally, the common cause of deforestation from 1990-2015 among the various forest zones, namely; costal savannah, transition, deciduous and rainforest in Ghana is currently being illegal mining and its present and future repercussions are quantified. On the other hand, in many cases, drivers of deforestation (figure 6) are mostly aggravated by difficulties connected with land ownership, management and use in Ghana. Customarily, forest lands are solely owned by communities which is spearheaded by chiefs or reagents, but managed by the Forestry Commission of Ghana (MLNR). Yet again, depending on what use the forest land will be put to, as some lands contain precious minerals like gold and diamond: its management will be different. This is because if the land is used for mining activities, then the Minerals Commission and Chamber of Mines will coordinate the affairs. However, each institution has its own constitutional mandate. Broadly, Minerals Commission, Chamber of Mines and the Forestry Commission are all under the Ministry of Lands and Natural Resources. A report by FC (2016) attests to the point that a lack of a holistic and effective land use plan for Ghana poses a significant challenge to the successful implementation of interventions that seek to limit unsustainable environmental practices such as unregulated or unsustainable agriculture expansion, illegal mining activities and infrastructure development which drive the loss of forest cover in the country.

The temperature was seen as a significant climatic factor which affected the growth of forest in Ghana from 1990-2015 (Kehlenbeck and Schrader, 2007). As indicated by Zhou and Zhang (1996) that temperature rise possibly result in a decrease of forest cover in China in a climate–vegetation relationship studies. This gives some thought that there was a negative effect of temperature on the growth of forest as stated by Yang et al. (2006). The negative effect was possibly caused by drier conditions under a warmer climate. All this evidence suggests that the negative effect of temperature rise on forest growth is caused by the drier situation under warmer conditions in the Taihang Mountains Yang et al. (2003). By model simulation, Bonan et al. (1990) showed that the effect of climate change on forest is not only a simple response to temperature rise, but also a response to increased evapotranspiration demands accompanying global warming. Similarly, many studies showed that Net Primary Produces (NPP) of ecosystems are related to evapotranspiration (Chong et al., 1993). As climate change scenarios make predictions for tropical forests an increase in annual temperature and a stronger dry season (IPCC, 2007), we may expect potentially large shifts in the distribution of tropical forest trees. In Bolivia, for example, 65% of the species evaluated decline with a stronger dry season, whereas 39% of the species decline with a further increase in temperature (Toledo et al., 2011).

Temperature is an essential environmental factor which supports all plant physiological activities from photosynthesis, respiration, absorption of water, transpiration, germination, growth and to even reproduction (Kumar, n.d.; Lewis, 2005). All these processes contribute to the growth of plants and their continued existence in their habitats. In the forest, once the expected temperature range is fluctuated, its immediate adverse effect is expressed in the depreciation of forest ecosystem growth as the various physiological processes will halt or slow down. As according to Mellilo, (1990); Hawkins et al. (2008) and Kumar (n.d.) high temperature tremendously increases the rate of respiration and plant may die of starvation as plants growing in extremely warmer regions are usually succulent, their leaves very much reduced and stomata are sunken and covered with hairy outgrowths.

Temperature is an important feature in causing tree survival. By the studies of Kumar, (n.d.), plants greatly vary in their tolerance to withstand a particular range of temperature and its fluctuations. Furthermore, Toledo et al. (2011) stated that temperature supports 72% of species survivability, preferably given a small difference in their mean annual temperature between sites (24.2–26.4^{o}C), however, they went ahead to state that tropical tree species could be sensitive if seasonal monthly temperature variation goes beyond 27 ^{o}C. This was the case in Ghana's forest, as the monthly temperature was much beyond what was expected so many tree mortality situation was observed. By the findings of Stanturf et al, (2011), they predicted categorically that, Ghana's mean annual temperature is projected to increase by 1.0 to 3.0°C by the 2060s and 1.5 to 5.2°C by the 2090s. Consequently, the forestry sector is at risk. Temperature operates indirectly through its influence on soil factors and other climatic factors like rainfall and wind. For instance, the rise in atmospheric temperature accelerates the rate of transpiration through its action on saturation-deficit of the air. Along with the increase of temperature, the possible average increase in precipitation will be about 3.4 percent globally per 1°C (Allen and Ingram, 2002).

In the long term, temperature fluctuations contribution to climate change condition will cause deforestation in the forest region of Ghana. This supports the research of Tang et al. (1998) who studied that the effect of temperature on vegetation types in northeast China and showed the possibility of decreases in wet forest by 38.1 per cent and of moist forest by 13.6 per cent and in an increase of desert shrubs by 26.3 per cent, suggesting a drier condition under higher temperature. Available temperature data indicate a warming climate in Ghana with the drier northern area warming more rapidly than southern Ghana. From 1960 for Ghana as a whole, mean annual temperature rose by 1.0°C. The rate of increase had generally been more rapid in the northern than southern regions (Minia 2008; McSweeney et al., n.d.; Stanturf et al., 2011). By 2100, further increases of greenhouse gases in the atmosphere are expected to increase the global average surface temperature by about 1.4–5.8°C (Houghton et al., 2001), Conclusively, five-year moving averages from 1961 to 2000 indicated about a 1°C increase in the Deciduous Forest (~0.8°C), Rain Forest (~0.4°C), and Coastal Savanna (~0.6°C) zones ((Stanturf et al., 2011; Minia, 2008; Idinoba et al., 2010).

Rainfall was a strong essential climatic element which impacted the forest growth in Ghana from 1990-2015. This means that rainfall played a part in the growth of forest in the country during that period of time. Ghana relies heavily on rainfall for source of water for its forest growth. Unfortunately, the impact of this important weather parameter has not been well felt in forest growth due to its unexpected seasonal variability as reported by Stanturf et al. (2011) that annual rainfall in Ghana is inherently variable causing erratic rainfall patterns. This problem is largely the result of global climate change menace. As far as African continent is considered to be among the most likely to suffer adverse impacts of climate change because of vulnerable social and natural systems (Dixon et al., 2003), then Ghana is automatically very vulnerable to climate change as well (MESTI, 2013) due to the presence of the multiple interacting stresses and low adaptive capacity (Boko et al., 2007). Repercussion of this has manifested greatly in the growth of forest in Ghana and it alters the natural growing patterns of trees. For example, in the Coastal Savanna and the Forest-Savanna Transition zones, rainfall are bimodal, but the minor wet season is unreliable. In these areas considerable variation exists between successive rainy seasons in time of onset, duration, spatial distribution, amount of rainfall and number of rainy days. These conditions contribute to reductions in vegetative cover in the affected areas (Environmental Protection Agency (EPA), 2003).

Ghana spans a range of climatic and edaphic zones from coastal mangroves and rainforests along the coast to savanna in the north. Floods can be said to have caused consistent loss of forest cover through severe soil erosion in the forest (MLNR, 2016). Between 1991 and 2008 Ghana experienced six major floods (Global Facility for Disaster reduction and recovery (GFDRR n.d). Highest erosive rainfall occurring just after the prolonged dry period predisposes areas, which have erodible and low infiltration soils, to a high risk of land degradation, particularly from erosion (EPA, 2003). This is the evidence of the prevailing extreme climate events that the country has experienced over the years. On the other side, too much rainfall in a particular region determines the type of vegetation not only pertaining to that of humid climate, but also types of plants with adaptation to soil percolated with water and against heavy showers. For instance, the leaves of the plants growing in equatorial forests have drip-tip and furrows so that an excess of water can immediately be removed. The moist climate increases the longevity of plants and their leaves, whereas the dry climate shortens the vegetative period, checks blooming, setting of fruits and maturation of seeds (Kumar, n.d.).

Despite advances in the understanding of the complex mechanisms driving rainfall patterns, much uncertainty remains (Stanturf et al., 2011). Drought, is therefore a manifestation of extreme rainfall variability, which has been a long feature of forest cover loss. Drought is the most important limiting rainfall factor in forest growth (Bongers et al., 1999; Engelbrecht et al., 2005). Climate change scenarios predict that global warming will result in reduced annual rainfall and longer dry seasons. Experimental studies in the shade house (Poorter and Markesteijn, 2007) and the field (Engelbrecht et al., 2005) suggested that seasonal drought has a stronger effect on growth and survival over other factors, as it immediately affects cellular processes and plant physiology (Chaves et al., 2003). Drought driven climate change effects on trees are unavoidable. Seasonal evergreen forests which depend on the use of soil, water reserves will be replaced by more drought-tolerant, semi deciduous forests, once rainfall becomes insufficient to replenish soil water reserves regularly Borchert (1998). Sometimes, as a result of drought conditions, forest lands are converted into other land use and this really contributes to the depreciation of forest growth in Ghana. As concluded by Gonzalez (2001) that decline in rainfall southward shift of the savanna zone with the loss of grassland and woodland with displacement of human populations. During the drought period, trees tend to be of the low humidity and high evapotranspiration and forest cover very susceptible to frequent forest fires because of the dryness of the atmosphere as a result of the very long dry season (EPA, 2003).

Rainfall determines the distribution of tree species and prevents species extinction. So if this weather factor becomes unpredicted in the forecast and expectation, then the forest cover will be reduced. A studies conducted by Holmgren and Porter (2007) showed that 59% of 89 rare and endemic West-African rainforest plant species responded to rainfall. Climate factor 'rainfall' was a stronger driver of species distribution as revealed in a study conducted by Toledo et al., (2012) showed that 91% of the species were affected by rainfall. Plant water availability and drought sensitivity are, therefore, important determinants of the distribution of tropical tree species Borchert, (1998).

For future projections by 2100 further increases of greenhouse gases in the atmosphere are expected to increase the global average rainfall to about 3.4 percent globally per 1°C (Allen and Ingram, 2002).

Wind speed had no impact on the growth of forest in Ghana from 1990-2015 in my study research. This source to back the reports of Yang et al. (2006) and FC (2016) which stated that, ecological zones are delineated basically by rainfall and temperature, hence relevant climatic parameters which affect the growth of forest in Ghana and conversely disputing the findings of Kumar, (n.d.) that, effect of wind often prevents the growing of larger trees above a certain height.

In predicting future climatic conditions, developing different scenarios of anthropogenic influences on different levels of GHG emissions in the climate system should not be ignored (IPCC, 2007). There were some indications of the impacts of human actions such as afforestation, reforestation and proper land-use management, which enhanced the carbon sink character of the various sub-types of forests by emitting very appreciable lower levels of CO_2 from these different zones (Raupach et al., 2008). From the year 2000, Ghana's forest has experienced gradual increment in its growth as the results from employing the various forest growth interventions. These actions played a role in capturing most free CO_2 molecules from the air, hence contributing to this negative emissions figure recorded in the results. This tows in a positive direction in mitigating climate change subject (Fuss et al., 2014).

A significant element which contributed to the results was the type of land use management technique employed. In 2001, Ghana introduced a forest-based strategy called Modified Taungya System (MTS) and since then has helped increase forest growth in the country (Ledger et al., 2011). Acheampong et al. (2016) have pointed out that MTS has restored the country's forest cover. Again, according to Kanninen et al. (2007), one strategy for reducing emissions from land conversion is to pay for maintaining and enhancing carbon stocks with the added benefit of halting deforestation. This recognized the role of conservation and sustainable forest management in enhancing carbon stocks as reported by Mayers et al. (2010). Additionally, voluntary carbon markets and the Clean Development Mechanism or Afforestation and Reforestation mechanism programmes also contributed to the negative emission values in Ghana (Westholm et al., 2009). There was a deliberate effort in avoiding emissions of GHG in Ghana by using the various forest subtypes as the barrier in achieving climate change mitigation. In support of this, McGlashan et al. (2012) suggested that emissions prevention efforts should remain the main focus in addressing climate change mitigation measure portfolio.

The growth of forest in Ghana influenced carbon stock concentration in the atmosphere from 1990-2015. This gives a good indication that Ghana's forest has a potential role in mitigating climate change. As Keenan, (2012) mentioned that forests have a role in the carbon cycle and the potential impacts of climate change on forest structure and composition. In this sense, the higher the forest cover, the lower carbon stock in the atmosphere, hence the lesser the occurrence of the climate change predicament. In effect, the forest will sequestrate the atmospheric carbon into its biomass and through proper forest management, an increase in carbon storage in the forest will occur. This makes the forests the substantial contributor to national and global mitigation portfolio which reduce the rate of carbon dioxide (CO_2) increases in the global atmosphere (Larsson, 2007).

Consequently, reducing emissions from deforestation and degradation (REDD+) in the tropical forests is one means for mitigating the effects of increased CO_2 on global climate as reported by (IPCC, 2007). In Ghana, for instance, the greatest potential for REDD+ is in carbon enhancement, which means better management of the remaining small amount of forest and in restoring degraded forests. This prospective so far has been considered as mostly within the High Forest Zone (HFZ), including shade-grown cocoa (cocoa culture is primarily carried out in the HFZ) because most of the forest types are found in this zone (Stanturf et al., 2011; MLNR, 2016). Yet, all the five sub-mitigation strategies of REDD+ namely; Avoided Deforestation (AD), Avoided Forest degradation (ADD), Carbon Stock Enchancer (CSE), Sustainable Forest Management (SFM) and Biodiversity Conservation (BC) are seriously being executed to increase the growth of forest which will eventually cause a decrease of carbon stock in the forest ecosystem hence making a strong ecosystem-based mitigation strategy against climate change in Ghana (FC, 2016).

Similarly, comparing tables (5) and (10) disclosed that carbon stock in Ghana is very low to that in Europe. This is mainly attributed to the extent of forest growth in Europe compared that of Ghana. Naturally, forest growing stock is directly proportional to carbon stock. This is because the more the forest growth is increased the higher the carbon stock stored in the forest biomass. Carbon may also be gained by increasing the area of forest land through afforestation of farmland or restoration of degraded forest land. There are also fluxes associated with timber harvesting and regrowth (Stanturf et al., 2011). This is a warning signal for the climate change because CO_2 is a persistent greenhouse gas (IPCC, 2007). Limiting cumulative CO_2 emissions, therefore, is key if global temperature rises are to be kept below the 2°C above pre-industrial level target (Allen et al., 2009). Looking at the turnout effects of leaving this dangerous GHG freely atmosphere is in the bad taste as it contribute ominously to climate change. Hence the need to remove CO_2 from the atmosphere (McGlashan et al., 2012). Forest policy implementation challenges is also an associated factor in the low levels of carbon stock in the forest biomass of Ghana (Fuss et al., 2014).

With table (11) ant table (7), it was very obvious that trends in forest growing stock for the past twenty-five years (1990-2015) in Europe was comparatively higher than of Ghana. In Europe, each successive year from 1990-2015, an average of 0.33 percent of forest growth was attained (FE, 2015) while in Ghana, an annual 2 percent of forest was lost since 1990-2015 (FC, 2015a). This disparity is the result of the presence of strict obedience of forest law in Europe, whereas the case in Ghana is quite opposite (Stanturf et al., 2011). Macroeconomic, technological, demographic and governance factors are substantially contributing to lower rate of forest growth in the Ghana as concluded by Kanninen et al. (2007). Macroeconomic factors include the global demand for primary resources; for Ghana this has been cocoa, timber, and minerals (Asante, 2005; Hansen et al., 2009). Some policies, incentives and tax exemptions from the government have one way or the other favoured these industries. Technological advancements in these industries have also influenced the rate of deforestation and degradation in Ghana. New "sun-tolerant" cocoa varieties requiring less shade than the traditional varieties have prompted the clearing of trees on farms, especially in the cocoa-expanding western region of the HFZ (Hansen et al., 2009). As noted above, the industrial, mining industry has adopted new technologies for surface mining, thereby increasing the amount of forest removed in their operations (Stanturf et al., 2011).

REDD+ Strategy is in direct orientation with Ghana's current environment and natural resource policy framework and is very well positioned to catalyse key actions and investments on the ground to bring about many of the needed changes and performance-based results for both mitigation priorities. REDD+ and the Cocoa Forest REDD+ Programmes feature significantly in Ghana's Intended Nationally Determined Contribution (INDC) to the UNFCCC, which commits to reducing the country's emissions, across all sectors, by 40% (FC, 2016). Furthermore, Mangrove Eco-Zone Emission Reduction Programme implementation is also championed in the REDD+ strategy because of the recent works that suggested the approximately 2,000 Mg/ha which are stored in the mangrove system thus one hundred fold more than in tropical high forests (FC, 2015b). Togo Plateau and the dry, demi-deciduous forest zone is also a special strategy placed under REDD+ because of the zone richest in biodiversity hence its capacity in trapping hazardous CO_2 from the atmosphere (FC, 2015b). Nevertheless, key relevant European Union (EU) policies are the legally binding 2020 'climate and energy package' are EU Effort Sharing Decision (ESD) and the revised EU Emissions Trading Scheme (ETS); the 2030 'Framework for Climate and Energy Policies' (FCEP) and the 2050 Low Carbon Roadmap (LCR) (EC, 2011). Still, survey studies conducted by (SFC, 2010) indicated that many responding EU countries have some form of forestry and or climate change plan within their national policies, with many creating synergistic links between the two.

More so, the climatic variation across Europe (table 11) has resulted in the occurrence of dissimilar types of forests as well. Different forest types have distinct forest settings all together and the purpose to which these forests are up to. For that matter, different forest policies are enacted across parts of the region, however, their "global eyed" similarities still exist like sustainable forest management. Climate Smart Forestry is a contemporary forest management system employed in Europe, which streamlines climate change mitigation at different areas within the continent and also tries to find synergies among the various forest policies (Nabuurs et al., 2015). Through sustainable forest management (SFM), Europe's forests have been part of the solution to world-wide climate change condition (SFC, 2010). Europe climate change mitigation policy has targeted the reduction of its greenhouse gas emissions progressively up to 2050 (EC, 2011). In the call to this, climate change mitigation has been factored in the various forest policies in Europe in a strategy called Climate Smart Forestry (CSF). The core of CSF is to find ways in which the area physiognomies of EU Member States forests can be best harnessed for climate change mitigation because 'one-size-fits all' policy is unlikely to achieve this (Nabruus et al., 2015).

Therefore, to bridge the gap between Europe and Ghanaian forests in mitigating climate change, the various forest policies existing in these two distinct areas are paralleled in this discussion. For Ghana, forest policies in line with REDD+ will be used while in Europe those in the lining in the bosom of CSF will be utilized. To set the ball rolling;

Firstly, comparing high forest stocked central European country with Forest and Wildlife Policy (WP) in Ghana:

A resilient demands for increased biodiversity protection co-exist with climate policy targets is championed with multi-purpose forestry intentions (Nabuurs et al., 2015) and yet WP aims at the conservation and sustainable development of forest and wildlife resources in Ghana (FC, 2016).

Secondly, comparing an industrial forestry-oriented country in Europe and National Environment Policy (NEP) 2014 in Ghana:

Policies are focussed on forest reserves and the preservation peat carbon (Nabuurs et al., 2015) but the NEP recognizes serious environmental challenges, including loss of biodiversity, land degradation, deforestation and desertification, wildfires, illegal mining, air and water pollution facing Ghana (FC, 2016).

Thirdly, comparing a fire-prone European country and Low Carbon Development Strategy Policy (LCDSP) in Ghana:

Fire risk management is its target for carbon mitigation strategy in combination with regeneration with drought-resistant species (Nabuurs et al., 2015) while in LCDSP is to contribute to global climate change mitigation through the development of an economically efficient, comprehensive Low Carbon Development Strategy a monitoring, reporting and verification system as its global climate change mitigation (FC, 2016)**.**

Fourth, comparing European Balkan country and National Climate Change Policy Action Programme in Ghana:

Stimulating rural development as part of the rural forestry policy in Europe (Nabuurs et al., 2015) but the national climate change master plan is put in place robust measures needed to address the challenges posed by climate change and climate vulnerability. (FC, 2016).

Fifth, comparing European urbanised region and Forest Law Enforcement Governance and Trade (FLEGT) in Ghana:

Urbanised regions measures are aimed at stopping deforestation, establishing new forests and providing recreation opportunities for a healthy society (Nabuurs et al., 2015) whereas the FLEGT initiative provide a strong set of complementary channels for addressing the major drivers of deforestation and degradation in climate-smart manner (FC, 2016).

Nonetheless, internationally, two climate change oriented protocols exist. Both Ghana and Europe must adhere to them to ensure a mitigation roadmap to this Globally Environmental Challenge. To this effect, they will be compared as well.

Kyoto Protocol aims at achieving greenhouse gas emissions reduction targets by 2020 while the Paris Agreement aims at bridging the gap between today's policies and climate-neutrality before the end of the century and, with regards to climate change mitigation (EEA, 2016). With the long term effect of the climate change situation, Paris protocol will continue the agenda of the Kyoto protocol in 2020 as Kyoto ends in that particular year. This is because different challenges continue to sprout up and it is likely that new ones may also evolve unexpectedly so as the need to prepare adequately for that. As atmospheric CO_2 residues for a very long time, even reduced emissions will have a large cumulative effect; therefore the carbon budget will eventually be exceeded (Erbach, 2015). It is, again, observed that Paris protocol looks into the varied forest policies which have connection with climate mitigation across the world in order to meet its intentions but Kyoto only focus on greenhouse gas emissions reductions. In effect, Paris agreement is a long term mitigation protocol, while Kyoto is a short term climate protocol. This is Paris targets today’s condition to solve future climate change effects while Kyoto looks at the present atmospheric emissions which contribute to climate change.

Collectively, both agreements should concentrate their attention on the best mitigation approach that will cause the reduction of CO_2. This is because carbon dioxide (CO_2), is the most important GHG which persists in the atmosphere for thousands of years, making it the largest GHG impact in climate change intensifies. In 2014 alone, the average atmospheric concentration of CO_2 was almost 400 parts per million (ppm), up from 280 ppm in pre-industrial times (Erbach, 2015). Interestingly, both protocols are internationally legal tools employed to curb global challenging climate change predicament.

6.0 CONCLUSIONS

From 1990-2015, deforestation was a major feature that characterised the state of forests in Ghana. There were clear observations of the various degrees of forest degradation in the studied area. Different drivers of deforestation caused the differences in situations among the various forest zones in Ghana from 1990-2015. Between 1990-2010, agriculture was the principal cause of deforestation in Ghana whereas since 2011-2015, mining and mineral exploration became the most principle causes of deforestation. Consistent 2% annual loss of Ghana's forests from 1990-2015 has caused a great deterioration in the state of this renewable ecosystem. Ghana should treat deforestation as a national environmental security threat looking at its long term harmful contribution to the climate change phenomenon. Loss of biodiversity is the major challenge climate change pose on forests in Ghana as there had been cases of warmer temperatures coupled with altered rainfall patterns.

Plummeting the impacts of future climate change by reducing GHG emissions by increasing the sinks ability of forests is a good climate-change mitigation strategy. This is because forests have the capability to store an appreciable amount CO_2 in their ecosystems. For this reason, REDD+ was considered to be the best ecosystem-based strategic tool against climate change in Ghana looking at the key cause of forest loss in the country. Conversely, European approach in climate change mitigation was Climate Smart Forestry.

Looking at the alarming evidences of the global risks to natural and human systems from climate change, mitigation will have to be considered as a responsibility for all international bodies. Reaching a binding international agreements that will limit future GHG emissions is a worthy pursuance to establish. In view of this, all hands must be on deck in promoting low-carbon alternatives preferably using the forest mitigation approach. Ghana and Europe in this prospective, have to be on the same scale in forest policies in mitigating climate change globally. Therefore, Paris Protocol has to be strictly adhered because it considers the eradication of forest degradation as a key component of the agreement whereas Kyoto Protocol does not but only looks deeply into GHG emissions. Again, the Kyoto Protocol will be ending in 2020 and Paris Protocol, however will remain after that period.

7.0 SUMMARY

For the past 25 years (1990-1015), the state of Ghana's forests has experienced loss of cover by 2% annually. Deforestation has therefore, characterised the state the forest ecosystems all these years. Severally drivers of deforestation mostly anthropogenic, have caused the diverse degrees of forest loss in the various forest sub-types within the studied area. Notably are; agriculture, which was a predominate driver in 1990-2010 while mining and mineral exploration from 2011-2015 as the most principle causes of the forest calamity. Deforestation has contributed to the fast rising effects of climate change in Ghana of which evidences are clearly shown in rising temperatures and drought and flooding cases resulting from unannounced rainfall patterns.

In my diploma thesis, I formulated basic research questions aimed at looking at drivers that caused the differences in the present and past situations among the various forest zones in Ghana from 1990-2015; the extent deforestation has degraded forests in Ghana and the causes of deforestation from 1990-2015; the challenges climate change pose on forests in Ghana; how Ghana's forest ecosystems can be utilised in combating climate change menace; ecosystem-based strategies useful in mitigating climate change in Ghana; forest policies in Ghana that are in line with mitigating climate change and how the various forest policies in Ghana and Europe can be at parallel to curb climate change globally.

In summary, REDD+ program was found out to be most effective ecosystem mitigation strategy in halting this menace in Ghana. European forests, however, increased in growth within the same era (1990-2015). Once the risks from climate change is experienced globally, there is the need to compare the various forest policies in these distinct destinations. To this effect, Paris Protocol was concluded to be used as a forest policy in support of climate change mitigation in both Ghana and Europe.

7.1 SOUHRN

V průběhu uplynulých 25 let (1990-2015) zaznamenávaly ghanské lesy 2% meziroční ztrátu pokryvnosti. Po všechna tato léta, charakterizovalo stav lesních systémů hlavně odlesňování. Vážné příčiny odlesňování, zejména ty antropogenní, způsobily ve studované oblasti v různé míře ztrátu lesa v různých lesních subtypech. Jsou to zejména zemědělství, které bylo hlavní příčinou této kalamity lesa v období let 1990-2010, zatímco v letech 2011-2015 byly hlavními příčinami těžba a průzkum minerálů. Odlesňování přispělo v Ghaně k rychle narůstajícím vlivům klimatické změny, které se projevují zvyšujícími se teplotami vzduchu i případy suchých období střídajících se se záplavami v důsledku nepředvídatelných režimů srážek.

Ve své diplomové práci jsem formulovala otázky základního výzkumu v oblasti. A program REDD+ byl vyhodnocen jako nejúčinnější strategie pro zmírnění problémů lesních ekosystémů a zastavení tohoto zla v Ghaně. Evropské lesy však ve stejném období (1990-2015) vykazovaly růst. Jakmile dojde k celosvětovému uvědomení si změny klimatu, bude zapotřebí porovnat v těchto významných destinacích různé lesnické politiky. V tomto smyslu bylo rozhodnuto o přijetí Pařížského protokolu jako lesnické politiky podporující zmírnění důsledků klimatické změny jak v Ghaně, tak i v Evropě.

REFERENCES

Abugre, S. & Kazaare, F.P., (2010). Trends and status of illegal timber logging in three forest districts of the Brong-Ahafo region of Ghana. Ghana Journal of Forestry, 26: 89-100.

Acheampong, E., Insaidoo, T. F., & Ros-Tonen, M. A. (2016). Management of Ghana's modified taungya system: challenges and strategies for improvement. Agroforestry Systems, 90(4), 659-674.

Adams, W.M. (2009). Green Development: Environment and Sustainability in the Third World, 3rd Edition, Routledge, London and New York.

Adiku, S. G. K., Yangyuoru, M., Mawunya, F. D., & Jones, J. W. (2007). Climate Prediction and Agriculture Advances and Challenges, edited by Mannava VK Sivakurnar and James Hansen. In: Chapter 20;" Can ENSO help in agricultural decision making in Ghana?"-Berlin Heidelberg.

African Ministerial Conference on Environment (AMCEN) (2011). Addressing Climate Change Challenges in Africa; A Practical Guide Towards Sustainable Development.

Agurgo F. B. and R. K. Bamfo (2000). Proceedings of Sub-Regional Workshop on Forestry Statistics and Outlook Study For Africa/Fosa Ecowas Sub-Region. FAO Country Report-Ghana.

Agyeman, K. O., Amponsah, O., Braimah, I., and Lurumuah, S. (2012). "Commercial Charcoal Production and Sustainable Community Development of the Upper West Region, Ghana." Journal of Sustainable Development, 5 (4).

Ajtay, G.L., Ketner, P. & Duvigneau, P. (1979), 'Terrestrial Primary Production and Phytomass', in B Bolin, ET Degens, S Kempe & P Ketner (eds), The Global Carbon Cycle, Wiley, U.K.

Allen, C. D., Macalady, A. K., Chenchouni, H., Bachelet, D., McDowell, N., Vennetier, M., & Gonzalez, P. (2010). A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. Forest ecology and management, 259(4), 660-684.

Allen, M. R., Frame, D. J., Huntingford, C., Jones, C. D., Lowe, J. A., Meinshausen, M., & Meinshausen, N. (2009). Warming caused by cumulative carbon emissions towards the trillionth tonne. Nature, 458(7242), 1163-1166.

Allen, M. R., & Ingram, W. J. (2002). Constraints on future changes in climate and the hydrologic cycle. Nature, 419(6903), 224-232.

Amisah, S., Gyampoh, A. B., Sarfo-Mensah, P., & Quagrainie, K. K. (2009). Livelihood trends in response to climate change in forest fringe communities of the Offin Basin in Ghana. Journal of Applied Sciences and Environmental Management, 13(2).

Antwi, E. K., Boakye-Danquah, J., Asabere, S. B., Yiran, G. A., Loh, S. K., Gyekye, K. A. & Owusu, A. B. (2014). Land Use and Landscape Structural Changes in the Ecoregions of Ghana.

Appiah, D.O.(2011). Essentials of Climatology, Meteorology and Biogeography (Handout).

Appiah, M. (2003). Domestication of an indigenous tropical forest tree: Silvicultural and socio-economic studies on Iroko (Milicia excelsa) in Ghana. University of Helsinki, Viikki Tropical Resources Institute (VITRI).

Asante, M.S., (2005). Deforestation in Ghana: explaining the chronic failure of forest preservation policies in adeveloping country. Univ Press of America.

Ayensu, E. S., Adu, A., & Barnes, E. (1996). Ghana: biodiversity and tropical forestry assessment. USAID Report (Contract P1O/T641-0110-3-50035), Accra, Ghana.

Barraclough, S. & Ghimire, K. B. (2000). Agricultural Expansion and Tropical Deforestation. Earthscan.

Benneh G & Agyepong G.T. (1990). Land Degradation in Ghana. Commonwealth Secretariat/University of Ghana. London. 33-53.

Benneh, G., & Agyepong G. T., (1990). Land degradation in Ghana. Food Production and Rural Development Secretariat, Marlborough House, Pall Mall, London, and Department of Geography and Resource Development, University of Ghana, Legon, Ghana. Berlin Heidelberg, 205-212.

Briner, G., & Prag, A. (2013). Establishing and Understanding Post-2020 Climate Change Mitigation Commitments.

Boafo, J. (2013). The Impact of Deforestation on Forest Livelihoods in Ghana. Africa Portal online Library.

Boakye, N. (2010). Kwame Nkrumah Universitiy Of Science And Technology Kumasi, Ghana (Doctoral Dissertation, College Of Science Faculty Of Physical Sciences Department Of Mathematics Factor Analysis Of Tree Distribution Patterns Of Six Forest Reserves In

Ashanti Region By Nancy Boakye (Bsc. Mathematics) A Thesis Submitted To The Department Of Mathematics, Kwame Nkrumah University Of Science And Technology).

Boateng, E. (1998). Proceedings of workshop on land use planning. FAO Land Use Planning Project. TCP/GHA/6715/A.

Boisvenue, C. & Running, S.W (2006), 'Impacts of climate change on natural forest productivity – evidence since the middle of the 20th century', Global Change Biology, 5 (12), 862-82.

Boko M, Niang I, Nyong A, Vogel C, Githeko A, Medany M, Osman-Elasha B, Tabo R &Yanda P. (2007). Africa. Climate Change: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry M L, Canziani O F, Palutikof J P, van der Linden P J and Hanson C E (eds). Cambridge University Press. Cambridge UK. 433–467

Bonan, G. B., Shugart, H. H., & Urban, D. L. (1990). The sensitivity of some high-latitude boreal forests to climatic parameters. Climatic Change, 16(1), 9-29.

Bongers, F., Poorter, L., van Rompaey, R.S.A.R. & Parren, M.P.E. (1999) Distribution of moist forest canopy tree species in Liberia and Coˆte d'Ivoire: response curves to a climatic gradient. Journal of Vegetation Science, 10, 371–382.

Borchert, R., (1998) Responses of tropical trees to rainfall seasonality and its long-term ch Repanges. Climatic Change, 39, 381–393.

Braatz, S., Rametsteiner, E., & Thunberg, J., (2011). Climate change for forest policy-makers. An approach for integrating climate change in forest programmes in support of sustainable forest management.

Briner, G., & Prag, A. (2013). Establishing and Understanding Post-2020 Climate Change Mitigation Commitments.

Burslem, D.F.R.P., Garwood, N.C. & Thomas, S.C. (2001) Tropical forest diversity—The plot thickens. Science 291: 606-607.

Calvert, J.B., (2000). Weather: Wind [online] Available at: http://mysite.du.edu/~etuttle/weather/wind.htm

Canadell, J. G., & Raupach, M. R. (2008). Managing forests for climate change mitigation. science, 320(5882), 1456-1457.

Chakravarty, S., Ghosh, S. K., Suresh, C. P., Dey, A. N., & Shukla, G. (2012). Deforestation: causes, effects and control strategies. Global perspectives on sustainable forest management, 1, 1-26.

Chambers J.Q, & Silver W.L (2004). Some aspects of ecophysiological and biogeochemical responses of tropical forests to atmospheric change. Phil. Trans. R. Soc. B. 359,463–476.

Chapin, F.S., T.V. Callaghan,Y. Bergeron,M. Fukuda, J.F. Johnstone, G. Juday & S.A. Zimov, (2004). Global change and the boreal forest: thresholds, shifting states or gradual change? Ambio, 33, 361-365.

Chaves, M.M., Maroco, J.P. & Pereira, J.S. (2003) Understanding plant responses to drought – from genes to the whole plant. Functional Plant Biology, 30, 239–264.

Chibeze S. Ezekeil (2015) The National Climate Change Policy (NCCP) of Ghana: Policy paper, Ghana.

Chomitz, K. M., Buys, P., Luca, G. D., Thomas, T. S. & Wertz-Kanounnik, O. S. (2007). At loggerheads? Agricultural expansion, poverty reduction and environment in thetropical forests. World Bank Policy Research Report.World Bank, Washington DC

Chong L. S., D., Mougin, E., & Gastellu-Etchegorry, J. P. (1993). Relating The Global Vegetation Index To Net Primary Productivity And Actual Evapotranspiration Over Africa. Titleremote Sensing, 14(8), 1517-1546.

Christensen, J. H., Hewitson, B., Busuioc, A., Chen, A., Gao, X., Held, I., & Magaña Rueda, V. (2007). Regional climate projections. Climate change 2007: the physical science basis.

Ciais, P, Reichstein, M, Viovy, N, Granier, A, Oge, J, Allard, V, Aubinet, M, Buchmann, N, Bernhofer, C, Carrara, A, Chevallier, F, De Noblet, N, Friend, A, Friedlingstein, A, Grünwald, P, Heinesch, B, Keronen, P, Knohl, A, Krinner, A, Loustau, D, Manca, G, Matteucci, G, Miglietta, F, Ourcival, J, Papale, D, Pilegaard, K, Rambal, S, Seufert, G, Soussan, J, Sanz, E, Schulze, E, Vesala, T & Valentini, R (2003). 'Europe-wide reduction in primary productivity caused by the heat and drought in 2003', *Nature*, 22 (437).

Clark D.A (2004) Sources or sinks? The responses of tropical forests to current and future climate and atmospheric composition. Phil. Trans. R. Soc. B. 359, 477–491.

Climate Forum (2015). International Journal of Climatology, 25: 51-63.

Collins, J. M. (2011). Temperature variability over Africa. Journal of climate, 24(14), 3649-3666.

Colls, A., Ash, N., & Ikkala, N. (2009). Ecosystem-based Adaptation: a natural response to climate change. IUCN.

Conservation International http://www.conservation.org/How/Pages/Hotspots.aspx. Accessed on 18.2.2017

Corlett, D. (2008). Stormy Weather: The Challenge of Climate Change and Displacement. UNSW Press.

Dale, V. H., Joyce, L. A., McNulty, S., Neilson, R. P., Ayres, M. P., Flannigan, M. D., & Simberloff, D. (2001). Climate change and forest disturbances: climate change can affect forests by altering the frequency, intensity, duration, and timing of fire, drought, introduced species, insect and pathogen outbreaks, hurricanes, windstorms, ice storms, or landslides. BioScience, 51(9), 723-734.

Denman, K. L., Brasseur, G. P., Chidthaisong, A., Ciais, P., Cox, P. M., Dickinson, R. E., ... & Lohmann, U. (2007). Couplings between changes in the climate system and biogeochemistry. In Climate change 2007: The physical science basis. Cambridge University Press.

Dhiaulhaq A. (2011). How Will Climate Change Influence Plant Productivity and the Carbon Cycle? https://dhiaulhaqreview.wordpress.com/2011/09/27/how-will-climate-change-influence-plant-productivity-and-the-carbon-cycle/

Dickson, K. B. & Benneh, G. (1988) A new geography of Ghana. Longman Group UK Limited. Longman House, Burnt Mill, Harlow, Essex, England.

Dinar, A., Seo, S. N., Mendelsohn, R. O., Hassan, R. M., & Kurukulasuriya, P. (2008). A Ricardian analysis of the distribution of climate change impacts on agriculture across agro-ecological zones in Africa.

Dixon, R.K., Smith, J. & Guill, S., (2003). Life on the edge: vulnerability and adaptation of African ecosystems to global climate change. Mitigation and Adaptation Strategies for Global Change, 8(2):93-113.

Domroes, M., & El-Tantawi, A. (2005). Recent temporal and spatial temperature changes in Egypt. International journal of climatology, 25(1), 51-63.

Domson, O. & Vlosky, R.P. (2007) A Strategic Overview of the Forest Sector in Ghana, Louisiana Forest Products Development Center, Working Paper 81, Baton Rouge.

Dregne, H. E. (1983). Desertification of Arid lands .Harwood Academia Publishers, London.

Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Farahani, E., Kadner, S., Seyboth, K., & Kriemann, B. (2014). Climate change 2014: Mitigation of climate change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 511-597.

Engelbrecht, B.M.J., Kursar, T.A. & Tyree, M.T. (2005) Drought effects on seedling survival in a tropical moist forest. Trees, 19, 312–321

Environmental Protection Agency (2003). National action programme to combat drought desertification, April 2002. Environmental Protection Agency, Ministry of Environment and Science, Accra, Ghana.

Erbach G. (2015) Negative greenhouse gas emissions Assessments of feasibility, potential effectiveness, costs and risks : Briefing paper EPRS | European Parliamentary Research Service

Europe, F., & Unece, F. A. O. (2011). State of Europe's forests 2011. Status and trends in sustainable forest management in Europe, 978-82. ISBN 978-82-92980-05-7

European Environment Agency (EEA) (2015d). The European environment — state and outlook 2015: Assessment of Global Megatrends.

European Environment Agency EEA (2016). Climate change, impacts and vulnerability in Europe 2016 an indicator-based report No 1/2017 ISSN 1977-8449

FAO (no date) Forests and climate change adaptation in Asia For further information, please visit: www.fao.org/asiapacific/forestry-adaptation

FAO 2005 Global forest resources assessment

FAO 2008 Strategic framework for forests and climate change. Collaborative Partnership on Forests.

FAO. 2010. Global Forest Resources Assessment 2010. Rome (available at www.fao.org/forestry/fra/fra2010/en/)

FAO. 2013. Climate change guidelines for forest managers. FAO Forestry Paper No. 172. Rome, Food and Agriculture Organization of the United Nations.

FAO. 2015. Global Forest Resources Assessment 2015 Rome. (available at www.fao.org/forestry/fra/fra2010/en/) ISBN 978-92-5-108826-5.

Feeley, K. J., Joseph Wright, S., Supardi, N., Kassim, A. R., & Davies, S. J. (2007). Decelerating growth in tropical forest trees. Ecology letters, 10(6), 461-469.

Fischer, G., Shah, M., Tubiello, F. N., & Van Velhuizen, H. (2005). Socio-economic and climate change impacts on agriculture: an integrated assessment, 1990–2080. Philosophical Transactions of the Royal Society B: Biological Sciences, 360(1463), 2067-2083.

Forest Europe (2015): State of Europe's Forests 2015.

Forestry Commission (2015b). Ghana National REDD+ Strategy.

Forestry Commission (2016). Ghana REDD+ Strategy.

Forestry Commission, Republic of Ghana (2015a). Development of Reference Emissions Levels and Measurement, Reporting and Verification System in Ghana Final Report FC/FCPF/MRV/REL/RFP/01/2013.

Forster, P., Ramaswamy, V., Artaxo, P., Berntsen, T., Betts, R., Fahey, D. W., & Nganga, J. (2007). Changes in atmospheric constituents and in radiative forcing. Chapter 2. In Climate Change 2007. The Physical Science Basis.

Frenken, K. (Ed.). (2005). Irrigation in Africa in figures: AQUASTAT Survey, 2005 (Vol. 29). Food & Agriculture Org.

Fuss, S., Khabarov, N., Szolgayova, J., & Obersteiner, M. (2014). REDD options as a risk management instrument under policy uncertainty and market volatility. Proceedings of the XXIV IUFRO World Congress, 5-11 October 2014, Salt Lake City

Garnaut, R. (2008). The Garnaut Climate Change Review: The Final Report, Cambridge University Press, Port Melbourne, VIC , Australia.

Gaston, K. J., Jones, A. G., Hänel, C., & Chown, S. L. (2003). Rates of species introduction to a remote oceanic island. Proceedings of the Royal Society of London B: Biological Sciences, 270(1519), 1091-1098.

Ghana Statistical Service http://www.statsghana.gov.gh/statistics

Global Facility for Disaster Reduction and Recovery (no date).

Global Forest Resources Assessment 2010 Country Report Ghana.

Gonzalez, P. (2001). Desertification and a shift of forest species in the West African Sahel. Climate research, 17(2), 217-228.

Grace, J. & Zhang, R. (2006). ‘Predicting the effect of climate change on global plant productivity and the carbon cycle’, in JIL Morison & MD Morecroft (eds), *Plant Growth and Climate Change*, Blackwell, Oxford.

Hall, J. B., & Swaine M. D.. (1976). Classification and ecology of closed-canopy forest in Ghana. Journal of Ecology 64:913-951.

Hall, J. B., & Swaine, M. D. (1981). Distribution and ecology of plants in tropical rain forest. Junk, The Hague.

Hansen, C.P. & Treue, T., (2008). Assessing illegal logging in Ghana. International Forestry Review, 10(4):573-590.

Hansen, C.P., Lund, J.F. & Treue, T., (2009). Neither fast, nor easy: the prospect of Reduced Emissions from Deforestation and Degradation (REDD) in Ghana. International Forestry Review, 11(4): 439-455.

Hanson, P.J. & Wetzin, J. F. (2000). ‘Drought disturbance from climate change: response of United States forests’, *The Science of the Total Environment*, vol. 262, pp. 205-20.

Hasanean, H.M., (2001). Fluctuations of surface air temperature in the East Mediterranean; Theoretical and Applied Climatology 68(1–2): 75–87.

Hawkins, B., Sharrock, S. & Havens, K. (2008). *Plants and climate change: which future?*

Hoad, D. (2015). Reflections on small island states and the international climate change negotiations (COP21, Paris, 2015). Island Studies Journal, 10(2), 259-262.

Houghton, R. A. (2008). Carbon flux to the atmosphere from land-use changes 1850–2005 [en línea]. TRENDS: A Compendium of Data on Global Change. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, US Department of Energy, Oak Ridge, Tenn, Estados Unidos.

http://www.rainforestconservation.org http://www.rainforestconservation.org/rainforest-primer/3-rainforests-in-peril-deforestation/f-consequences-of-deforestation/8-climate-change-and-increase-in-greenhouse-gases/ accessed on 12.4.17

https://en.wikipedia.org/wiki/Effects_of_global_warming_on_Australia Accessed on 8.4.2017

Hubrig M. (2004). Analyse von Tornado- und Downburst-Windsch¨adenan B¨aumen. [Analysis of Tornado and Downburst wind damage to trees]. Forst und Holz 59: 78–84.

Hulme M., Doherty R., Ngara T., New M., & Lister D., (2001): African climate change; 1900–2100. Clim Res 17:145–168

Hulme, M., Doherty R.,Ngara T., M. New, (2005): Global Warming and African Climate Change; are assessment in Low, P. S., Climate Change and Africa, Cambridge University Press, 29-40.

Idinoba, M.; Nkem, J.; Kalame, F.B.; Tachie-Obeng, E.; Gyampoh, B. (2010). Dealing with limitation of forest ecosystem services through a vulnerability assessment and planed adaptation actions. In: April 26-30 International Human Dimensions Programme Open Meeting. Bonn, Germany: International Human Dimensions Programme on Global Environmental Change. 20.

Insaidoo, T. F.G., Ros-Tonen, M. A.F., Hoogenbosch, L. and Acheampong, E. (2012) Addressing Forest Degradation and Timber Deficits in Ghana, ETFRN News 53: April 2012,

Int. Gov. Panel Clim. Change (IPCC). 2007. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switz.: IPCC. 104 pp.

Intergovernmental Panel on Climate Change (IPCC), 2001. Climate Change: The Scientific Basis. Working Group 1 Contribution to the IPCC Third Assessment Report.

International Renewable Energy Agency (Irena). Ghana Renewables Readiness Assessment 2015 Mechanical engineering

IPCC (2000). Land Use, Land-Use Change, and Forestry. A Special Report of the IPCC, (eds. Watson, R.T., Noble, I.R., Bolin, B., Ravindranath, N.H. Verardo, D.J., Dokken, D.J.), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. 3

IPCC (2013). Climate Change 2013: The Physical Science Basis. Working Group 1 contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

IPCC (2014). Climate Change 2014: Impacts, Adaptation, and Vulnerability. Working Group 2 contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

Jenik, J., &. Hall J. B. (1976). "Plant communities of the Accra plains, Ghana." Folia Geobotanica 11(2), 163-212.

Kanninen, M., Brockhaus, M., Murdiyarso, D., & Nabuurs, G. J. (2010). Harnessing forests for climate change mitigation through REDD+ (Vol. 25, pp. 43-54). IUFRO (International Union of Forestry Research Organizations) Secretariat.

Kanninen, M., Murdiyarso, D., Seymour, F., Angelsen, A., Wunder, S. & German, L. (2007). Do Trees Grow on Money? The implications of deforestation research for policies to promote

REDD. Forest Perspectives No. 4, Center for International Forestry Research (CIFOR), Bogor, Indonesia. 61.

Keenan, R. J. (2012). Adaptation of forests and forest management to climate change: an editorial. Forests, 3(1), 75-82.

Kehlenbeck, H. & Schrader, G. (2007). 'Climate Change, Happy future for plant pests?', in Secretariat.of.the.Convention.on.Biological.Diversity (ed.), Emerging Issues for Biodiversity Conservation in a Changing Climate, CBD, Montreal, Canada, vol. Technical Series 29.

Know Climate Change (KCC), (2017).

http://know.climateofconcern.org/index.php?option=com_content&task=article&id=110

Kumar Sriniba (no date). Ecological Factors that Affect the Growth of Plants.

Kurz, W. A., Dymond, C. C., Stinson, G., Rampley, G. J., Neilson, E. T., Carroll, A. L., & Safranyik, L. (2008). Mountain pine beetle and forest carbon feedback to climate change. Nature, 452(7190), 987-990.

Larsson, T. B., Barbati, A., Bauhus, J., Van Brusselen, J., Lindner, M., Marchetti, M.,& Petersson, H. (2007). The role of forests in carbon cycles, sequestration, and storage. IUFRO Newsletter, 5, 1-10.

Lewis, S. L., Malhi, Y. & Philips, OL (2005), 'Predicting the impacts of global environmental changes on tropical forests', in Y Malhi & OL Philips (eds), Tropical Forests & Global Atmospheric Change, Oxford University Press, Oxford, UK.

Li, Y. S., Liu, J., Kang, G. L., & Guo, Z. J. (2002). Techniques for the development of forest in the Taihang Mountains. Prot. For. Sci. Technol, 53, 87-89.

Lischke, H., Guisan, A., Fischlin, A., Williams, J., & Bugmann, H. (1998). Vegetation responses to climate change in the Alps: modeling studies (pp. 309-350). MIT Press, Boston, Massachusetts.

Liu, D. Z., Bi, J., Ma, Z. W., & Hou, Q. (1996). Site classification of natural Pinus tabulaeformis stands in the Taihang Mountains. Hebei For. Sci. Technol, 3, 27-31.

Lloyd, J. & Farquhar, G. D. (1996). 'The CO2 Dependence of Photosynthesis, Plant Growth Responses to Elevated Atmospheric CO2 Concentrations and Their Interaction with Soil Nutrient Status', *Functional Ecology,* 1 (10), 4-32.

Lubowski. (2008). What are the costs and potential of REDD? In: Angelsen. A. (ed). Moving ahead with REDD: issues, options and implications. Center for International Forestry Research (CIFOR), Bogor, Indonesia. 23–30.

Mahapatra, K. and Kant, S. (2003) Tropical Deforestation: A Multinomial Logistic Model and some Country-specific Policy Prescriptions, Journal of Forest Policy and Economics 7 (2005), Elsevier, pp.1-8

Mahé, G., & Paturel, J. E. (2009). 1896–2006 Sahelian annual rainfall variability and runoff increase of Sahelian Rivers. Comptes Rendus Geoscience, 341(7), 538-546.

Marfo, E., Halladay, P., Zagt, R. and Wit, M., (2010). Chainsaw Milling in Ghana: Context, drivers and impacts. Tropenbos International, Wageningen, the Netherlands, 12: 64.

Mason, S.J., Waylen, P.R., Mimmack, G.M., Rajaratnam, B., Harrison, J.M., (1999). Changes in extreme rainfall events in South Africa; Climate Change 41, 249–257.

Mayer H, Schindler D. (2002). Forstmeteorologische Grundlagen zur Ausl¨osung von Sturmsch¨aden im Wald in Zusammenhang mit dem Orkan "Lothar". Allgemeine Forst- und Jagdzeitung 173: 200–208

McGlashan, N., Shah, N., Caldecott, B., & Workman, M. (2012). High-level techno-economic assessment of negative emissions technologies. Process Safety and Environmental Protection, 90(6), 501-510.

McGuire, A. D. & Joyce, L. A. (2005). 'Responses of Net Primary Production to Changes in CO2 and Climate', in LA Joyce (ed.), *Productivity of America's Forest and Climate Change,* US Department of Agriculture (USDA), USA.

McSweeney, C., M. New, and G. Lizcano.(no date). UNDP Climate Change Country Profiles: Ghana. UNDP Climate Change Country Profiles, School of Geography and Environment, University of Oxford, Oxford, United Kingdom. Available from: http://country-profiles.geog.ox.ac.uk.

Melillo, J. M., Callaghan, T. V., Woodward, F. I., Salati, E. & Sinha, S. K. i. (1990) 'Effects on Ecosystems', in JTea Houghton (ed.), *Climate Change: The IPCC Scientific Assessment*, Cambridge Univ. Press, Cambridge, 283−310.

Menczer, K. & Quaye E. (2006). USAID/Ghana Environmental Threats and Opportunities Assessment (FAA 118/9 Assessment). USAID, Accra, Ghana.

Mercer, B., Finighan, J., Sembres, T., & Schaefer, J. (2011). Protecting and restoring forest carbon in tropical Africa. A guide for donors and funders. Forest Philanthropist Action Network (FPAN), UK, 2-5.

Minia, Z. (2008). Climate change scenario development. Pages 2-13 *in* W. K. Agyemang-Bonsu, editor. Ghana Climate Change Impacts, Vulnerability and Adaptation Assessments. Environmental Protection Agency, Accra, Ghana.

Ministry of Environment, Science, Technology and Innovation (MESTI): Ghana National Climate Change Policy (2014).

Ministry of Environment, Science, Technology and Innovation (MESTI): Ghana National Climate Change Policy (2013).

Ministry of Lands and Natural Resources (MLNR) (2012). Annual Forest Report. Ghana

Ministry of Lands and Natural Resources (MLNR) (2016). Ghana Forestry Development Master Plan (2016-2036).

Ministry of Lands and Natural Resources (MLNR) http://www.mlnr.gov.gh/

Mohammed, A. S. (2014). Deforestation and its effect on livelihood patterns of forest fringe communities in the Asunafo North Municipality (Doctoral dissertation, school of graduate studies, Kwame Nkrumah University of Science and Technology).

Moriondo, M., Giannakopoulos, C., & Bindi, M. (2011). Climate change impact assessment: the role of climate extremes in crop yield simulation. Climatic Change, 104(3-4), 679-701.

Ministry of Science and Environment (MSE) (2002). National biodiversity strategy for Ghana. Ministry of Science and Agriculture. Accra, Ghana.

Myers, N. (1994). Tropical deforestation: rates and patterns. The causes of tropical deforestation, 27-40.

Myers, N. and Mittermeier, R. A. (2000). Biodiversity hotspots for conservation priorities. Nature 403: 853-854.

Nabuurs, G. J., Delacote, P., Ellison, D., Hanewinkel, M., Lindner, M., Nesbit, M., & Savaresi, A. (2015). A new role for forests and the forest sector in the EU post-2020 climate targets (No. 2). European Forest Institute.

Nair, C. T. S., & Tieguhong, J. (2004). African Forests and Forestry: an overview. A report prepared for the project. Lessons Learnt on Sustainable Forest Management in Africa. Royal Swedish Academy of Sciences, African Forest Research Network (AFORNET) and FAO.

National Development Planning Committee of Ghana (2010).

Odjugo, A. O., (2010). Regional evidence of climate change in Nigeria; Journal of Geography and Regional Planning, 3(6), 142-150.

Oguntunde P.G., Friesen, J., van de Giesen N., Savenije, H.H.G., (2006). Hydroclimatology of the Volta River Basin in West Africa; Trends and variability from 1901 to 2002, Physics and Chemistry of the Earth, 31,1180-1188.

Oppong-Anane, K. (2001). Ghana: Country Pasture/Forage Resource Profiles. Grassland and Pasture Crops Group, Food and Agriculture Organization

Pan, Y., Birdsey, R. A., Phillips, O. L., & Jackson, R. B. (2013). The structure, distribution, and biomass of the world's forests. Annual Review of Ecology, Evolution, and Systematics, 44, 593-622.

Parrotta J. & Marafa L. (2014). Can REDD+ Achieve Conservation, Livelihoods And Climate Change Mitigation Goals? IUFRO http://blog.iufro.org/2014/02/20/can-redd-achieve-conservation-livelihoods-and-climate-change-mitigation-goals/#more-1688.

Patosaari, P., & Director, U. N. (2007). Forests and climate change: mitigation and adaptation through sustainable forest management. In Remarks presented to the 60th annual DPI/NGO conference, Climate change: How it impacts us all. UN, New York (6).

Pereira, M. G., Calado, T. J., DaCamara, C. C., & Calheiros, T. (2013). Effects of regional climate change on rural fires in Portugal. Climate research, 57(3), 187-200.

Phillips OL, Arag˜ao LEOC, Lewis SL, Fisher JB, Lloyd J, et al. 2009. Drought sensitivity of the Amazon rainforest. Science 323:1344–47

Pinker, R. (1980). The microclimate of a dry tropical forest. Agricultural Meteorology 22: 249-265.

Poorter, L. & Markesteijn, L. (2007) Seedling traits determine drought tolerance of tropical tree species. Biotropica, 40, 321–331.

Putz, F.E., Zuidema, P.A., Pinard, M.A., Boot, R.G.A., Sayer, J.A., Sheil, D., Sist, P., Elias, & Vanclay, J.K. (2008). Improved tropical forest management for carbon retention. PLoS Biology 6: 1368–1369

Rakonczay, Z. (2002). Biome-specific forest definitions, Document de travail FCCC. TP/2002/1, UNFCCC.

Raupach, M. R., & Canadell, J. G. (2008). Observing a vulnerable carbon cycle. In The Continental-Scale Greenhouse Gas Balance of Europe (pp. 5-32). Springer New York.

Robledo, C., Kanninen, M., & Pedroni, L. (2005). Tropical forests and adaptation to climate change: In search of synergies. CIFOR.

Sato S, Kamiyama M., Iwata T., Makita N., Furukawa H., Ikeda H. (2006). Moderate increase of mean daily temperature adversely affects fruit set of Lycopersicon esculentum by disrupting specific physiological processes in male reproductive development. Ann. Bot. 97, 731–738.

Standing Forestry Committee (2010). Ghana Climate Change and Forestry Report to the Standing Forestry Committee Ad Hoc Working Group III on Climate Change and Forestry.

Stanturf, J. A., Warren, M. L., Charnley Jr, S., Polasky, S. C., Goodrick, S. L., Armah, F., & Nyako, Y. A. (2011). Ghana climate change vulnerability and adaptation assessment. Washington: United States Agency for International Development.

Statistics, Research and Information Directorate (SRID). (2001). Agriculture in Ghana. Facts and figures. Ministry of Food and Agriculture. Accra. Ghana.

Statistics, Research and Information Directorate SRID (Statistics, Research and Information Directorate). (2001). Facts and figures. Ministry of Food and Agriculture. Accra. Ghana.

Statistics, Research and Information Directorate (SRID). (2010). Agriculture in Ghana. Facts and figures. Ministry of Food and Agriculture. Accra. Ghana.

Stern, N. (2006). Stern Review: The economics of climate change. London: UK Treasury.

Stone, S., & Chacón León, M. (2010). Climate Change and the Role of Forests: A Community Manual. Conservation International.

Streck, C. (2007). Protecting forests to mitigate global climate change. In Meeting on Forest Governance and Trade: Exploring Options. Chatham House, Royal Institute of International Affairs, London, UK (24).

Streck, C., O.'Sullivan, R., Smith, T. & Tarasofsky, R. (2008). 'Climate Change and Forestry: an introduction', in C Streck, R O'Sullivan, T Smith & R Tarasofsky (eds), *Climate Change and Forest: Emerging Policy and Market Opportunities*, The Royal Institute of International Affairs, London, UK.

Tamakloe, W. (n.d). State of Ghana's Environment: Challenges of Compliance and Enforcement, Ghana Environmental Protection Agency

Tang, H., Chen, X., & Zhang, X. (1998). A preliminary study on the biome classification and the response of biomes to global change along northeast China transect (NECT). Acta Phytoecolog. Sin, 22, 428-433.

Tilman, D. (2000) Causes, consequences and ethics of biodiversity. Nature 405: 208-210.

Toledo, M., Peña-Claros, M., Bongers, F., Alarcón, A., Balcázar, J., Chuviña, J., & Poorter, L. (2012). Distribution patterns of tropical woody species in response to climatic and edaphic gradients. Journal of Ecology, 100(1), 253-263.

Toledo, M., Poorter, L., Peña-Claros, M., Alarcón, A., Balcázar, J., Leaño, C., & Bongers, F. (2011). Climate is a stronger driver of tree and forest growth rates than soil and disturbance. Journal of Ecology, 99(1), 254-264.

Trewin, B. (2014). The climates of the Tropics and how they are changing. In: State of the Tropics. James Cook University. Australia.

UNEP, (2002): Africa Environment Outlook; Past, present and future perspectives, http://www.unep.org/dewa/Africa/publications/AEO-1/002.htm

United Nations Environment Program (UNEP)(2008). Africa: Atlas of our changing environment (on line). URL: www.unep.org/dewa/africa/AfricaAtlas

United Nations framework convention on climate change. UN, U. (1992). In United Nations Framework Convention on Climate Change).

United Nations framework convention on climate change. (2011). In United Nations Framework Convention on Climate Change.

United Nations framework convention on climate change. UN, U. (2005). In United Nations Framework Convention on Climate Change.

Van Kooten, G. C., & Bulte, E. H. (2000). The economics of nature: managing biological assets (p. 512). Blackwell Publishers.

Vasconcelos, H.L. & Lawrence, W.F. (2005) Influence of habitat, litter type, and soil invertebrates on leaf-litter decomposition in a fragmented Amazonian landscape. Oecologia 144: 456-462.

Vautard, R., Gobiet, A., Sobolowski, S., Kjellström, E., Stegehuis, A., Watkiss, P., & Jacob, D. (2014). The European climate under a 2 C global warming. Environmental Research Letters, 9(3), 034006.

Visser, S. (1985). Role of the soil invertebrates in determining the composition of soil microbial communities. In: Atkinson D, Fitter AH, Read DJ, Usher MB (eds) Ecological interactions in soil. British Ecological Society's Special Publication Service, Blackwell, Oxford, 4: 297-317.

Walker, J.K. &Jenkins, N., 1997. Wind Energy Technology. John Wiley & Sons Ltd.

Walther G. R. (2010). Community and ecosystem responses to recent climate change. Philos. Trans. R. Soc. B 365:2019–24

Wardell, D.A., Reenberg, A. & Tøttrup, C., (2003). Historical footprints in contemporary land use systems: forest cover changes in savannah savanna woodlands in the Sudano-Sahelian zone. Global Environmental Change, 13(4): 235-254.

Way, D. A., & Oren, R. (2010). Differential responses to changes in growth temperature between trees from different functional groups and biomes: a review and synthesis of data. Tree Physiol, 30(6), 669-688.

Webb III, T. (1992). Past changes in vegetation and climate: lessons for the future. Global warming and biological diversity, 59-75.

Werf, G.R. van der, Morton, D.C., DeFries, R.S., Olivier, J.G.J., Kasibhatla, P.S., Jackson, R.B., Collatz, G.J. & Randerson, J.T. (2009). CO2 emissions from forest loss. Nature Geoscience 2: 737–738.

Westholm, L., Henders, S., Ostwald, M., & Mattsson, E. (2009). Assessment of existing global financial initiatives and monitoring aspects of carbon sinks in forest ecosystems–The issue of REDD. rapport nr.: Working Papers in Economics 373.

Winjum, J. K., Dixon, R. K., & Schroeder, P. E. (1993), Forest management and carbon storage: An analysis of 12 key forest nations, Water, Air, & Soil Pollution, 70(1 - 4), 239-257.

Worrell, R., & Malcolm, D. C. (1990). Productivity of Sitka spruce in Northern Britain 2. Prediction from site factors. Forestry, 63(2), 119-128.

Wright, S. J. (2005). Tropical forests in a changing environment. Trends in ecology & evolution, 20(10), 553-560.

WSL, B. (2001). Lothar. Der Orkan 1999. Ereignisanalyse. Birmensdorf, Bern, Eidg. Forschungsanstalt WSL und Bundesamt für Umwelt, Wald und Landschaft BUWAL.

www.foresteurope.org retrieved 6.2.17

Yang, J. G., Wang, G. X., Hua, W. S., Song, C. S., Chen, Y. F., & Chen, Z. S. (1993). Evaluation of site quality and suitability of trees in the Taihang mountains.

Yang, Y., Watanabe, M., Wang, Z., Sakura, Y., & Tang, C. (2003). Prediction of changes in soil moisture associated with climatic changes and their implications for vegetation changes: WAVES model simulation on Taihang Mountain, China. Climatic Change, 57(1), 163-183.

Yang, Y., Watanabe, M., Li, F., Zhang, J., Zhang, W., & Zhai, J. (2006). Factors affecting forest growth and possible effects of climate change in the Taihang Mountains, northern China. Forestry, 79(1), 135-147.