UNIVERSITY FOR DEVELOPMENT STUDIES

EFFECTS OF HOUSEHOLD BIOMASS FUEL CONSUMPTION ON VEGETATION IN SISSALA EAST MUNICIPAL OF THE UPPER WEST REGION

ERIC DUNEBO ANG-NUMBAALA

2020

UNIVERSITY FOR DEVELOPMENT STUDIES

EFFECTS OF HOUSEHOLD BIOMASS FUEL CONSUMPTION ON VEGETATION IN SISSALA EAST MUNICIPAL OF THE UPPER WEST REGION

BY: ERIC DUNEBO ANG-NUMBAALA

B.A INTEGRATED DEVELOPMENT STUDIES

ID NUMBER: UDS/ MEM/ 0097/ 16

THESIS SUBMITTED TO THE DEPARTMENT OF ENVIRONMENT AND RESOURCE STUDIES, FACULTY OF INTEGRATED DEVELOPMENT STUDIES, UNIVERSITY FOR DEVELOPMENT STUDIES IN PARTIAL FULFILLMENT OF THE REQUIREMANTS FOR THE AWARD OF AN MPHIL IN ENVIRONMENT AND RESOURCE MANAGEMENT.

OCTOBER, 2020

DECLARATION

Students'

I hereby declare that this thesis is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere:

Candidate'

Signature: …………………………………… Date: ………………………………

Name: ……………………………………………………………………………….

Supervisors'

I hereby declare that the preparation and presentation of the thesis was supervised in accordance with the guidelines on supervision of thesis laid down by the University for Development Studies.

Name of Supervisor: …………………………………………………………

Signature of Supervisor: …………………… Date: …………………………….

ABSTRACT

Charcoal and fuel wood constitute the primary source of energy in developing countries. In Ghana, fire wood and charcoal are primarily collected from forest and savannah wood land. As population increases, pressure on the forest and wood land increase, leading to over exploitation and deforestation. Using a mixed- method approach, this study examined the implications of households' biomass consumption on deforestation in the Sissala East Municipal of Ghana. In particular, desk reviews, household survey, focus group and key informant interviews were employed to collect data among a cross-section of population in six (6) rural and urban communities. The study found that the primary source of energy for most households in the study area remains fire wood, which is mainly collected from forest, farm and the open savannah wood land. Furthermore, the study found that the use of firewood has severe consequences on the environment and health of the users, especially women. This is because they are more close to inhaling the smoke from cooking activities than men. The research further established that the most preferred alternative energy for households is LPG but the major factor hindering access is its affordability. Based on the research findings, the study concluded that continuous collection of fire wood poses a serious challenge for environmental sustainability. The study therefore recommended that, the ministry of agriculture, through the forestry commission should among other things institute education and sensitization programs to educate households on sustainable collection of wood fuel. Aside, the government should also initiate subsidy p1rograms to support households, especially rural population to be able to afford improved energy stoves as a way of reducing dependency on fuel wood.

Key words: Fuel Wood, Households, Charcoal, LPG and Sustainability

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

AFREPREN/FWD	The Energy, Environment and Development Network for Africa
CAR	Central AFRICAL Republic
CRES	Centre for Renewable Energy
ESMAP	Energy Sector Management and Assessment Programme
FAO	Food and Agriculture Organization
FRA	Forest Resource Assessment
FGD	Focus Group Discussion
GSS	Ghana Statistical Service
GHG	Greenhouse Gases
IEA	International Environmental Agency
IPCC	Inter-Governmental Panel for Climate Change
KII	Key Informant Interviews
KM	Kilometres
LI	Legislative Instrument
LPG	Liquefied Petroleum Gas
MDG	Millennium Development Goals
MMTDP	Metropolitan Medium-Term Development Plan
MoE	Ministry of Energy

PHC	Population and Housing Census
RA	Research Assistant
SSA	Sub-Saharan Africa
SPSS	Statistical Package for Social Sciences
SNRM	Sustainable Natural Resource Management IAP = International Assessment Programme
UN-DESA	United Nations Department of Environmental Sustainability Assessment
UNDP	United Nations Development Programme
UN	United Nations
UNDP	United Nations Development Programme
WB	World Bank
WEC	World Energy Council
WWF	World Wildlife Foundation

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

A third of the world's population uses biomass for cooking, heating, and lighting (Gordon et al, 2014). It is projected that in the developing world there are over 2.5 billion people who depend on the use of biomass for cooking (IEA, 2007; World Bank, 2011; Njong& Johannes, 2011). In Sub-Sahara Africa (SSA) and Central America, the phenomenon is very common with both rural and urban households (Kuunibe et al, 2013). As high as 77% of SSA's population identify biomass to be primary energy used (Bonjour et al, 2010) whiles about 63% of people in Ecuador used the same for household cooking and lighting (Kuunibe et al, 2013). In Ghana, like many other African countries, biomass fuel constitutes the main energy source among the entire population. Among rural households in Ghana, 97% use wood-based fuel in cooking, heating, and lighting (Amissah-Arthur and Amonoo, 2004). The Ghana Statistical Service (2012) report estimates had it that about 96% of households in Ghana use biomass fuel for various households' purposes (GSS report, 2012) is similar. The use of biomass fuel in Ghana in the year 2008 is barely reaching 11.7 million tonnes constituting about 66% of the entire energy sources (Moe, 2012). Firewood, charcoal including farm residue make up the bulk of biomass resources but charcoal constitutes the dominant energy source for urban households (Wright, et al., 2009). An estimated 2-2.5 billion tons of biomass are used yearly worldwide (Luo et al 2012). Out of this number, developing countries alone consumes an estimated 730 million tons of biomass annually (UNDP, 2008). Thus, a household in Africa consumes an average of 2 tons of biomass yearly; to cook, heat and light (World Bank, 2011). The main and preferred source of biomass for most households is forest and wood resources and not less than

90% of households in SSA depend directly on forest and natural woodlots for their biomass energy needs (World Bank, 2011).

The vegetation cover in Africa is fast depleting due to intense human activities. Unsustainable ways of harvesting fuelwood and charcoal processing are the main factors causing deforestation in most African countries (Butler, 2006). Statistics from 1990 to 2005 show that tree removal was very high. In Angola, it was 42%, 44% in Burundi and 51% in the Democratic Republic of Congo. Gabon and Ghana recorded 92% and 83% respectively. Rwanda recorded 35% which is quite low. The impact of deforestation/devegetation, especially on livelihood, environment and human health cannot be overemphasized. Deforestation/devegetation can lead to a high concentration of GHGs, especially carbon dioxide and cause rises in global temperature (World Bank, 2011; IPCC, 2007; Venkataraman et al, 2010). Additionally, climate change impacts are already being felt in most parts of SSA, and further deforestation could potentially endanger livelihoods and exacerbate food insecurity in the sub-region.

Despite the overwhelming evidence of the destructive impacts of man’s actions in the biosphere, much remains still unknown about the effects of households’ biomass consumption activities on the environment, particularly for forest resources, that remains the major biomass fuel supplier in most parts of SSA. However, households continued use of biomass fuel which could pose devastating impacts on sustainable forest, environmental resources as well as rural livelihoods, particularly in parts of the African continent where populations depend heavily on biomass fuel. This, therefore, underscores the need for an in-depth understanding of how households' biomass consumption impacts the environment, from informing strategic policy and programming to address unsustainable harvesting and use of biomass resources, particularly wood/wood-based resources in developing countries. Thus, this study was envisaged to provide an in-depth insight for understanding households' biomass consumption and the consequent effect on deforestation of forest reserves in Ghana.

1.2 Problem Statement

Wood, charcoal and agricultural waste constitute the main household's fuel source for cooking, heating, and lighting in rural Ghana (GSS, 2014). In particular, charcoal and fuelwood constitute about 95% of the household's energy in the Sissala East Municipal (GSS, 2014). Biomass energy in the municipality is sourced from forest wood resources. However, unsustainable harvesting of wood resources is fast depleting the forest and environment. Increasing population and commercialization of charcoal productions is putting unprecedented pressure on forest/vegetation wood resources in the Sisaala East Municipality. There is evidence of unsustainable exploitation of wood and forest resource as a potential threat to the Municipality's development agenda. The rate of exploitation far exceeds natural growth, leading to the destruction and depletion of environmental resources (Ghana Statistics Service Report (GSS), 2012: Medium Term Development Plan (MMTDP, 2014-17).

Deforestation is a known driver of global warming which leads to climate change, resulting in high levels of GHGs in the atmosphere (IPCC, 2007). If this phenomenon is not checked, it could have far-reaching consequences on the natural environment, climate change, and human health. Against this background, it is very crucial for climate researchers, development authorities and other stakeholders to begin to take urgent steps to address this problem confronting the Municipality. Even though previous studies such as Amissah-Author and Amonoo, (2004); Kuunibe et al, (2013) have investigated the subject, very little is known about the subject in the Sissala East Municipality. Additionally, other studies such as (Gordon et al, 2014; Puzzolo, 2013) have largely researched with focus on the health impact of biomass utilization on users, and improved cook stoves technology uptake but largely failed to examine how households' biomass consumption contributes to deforestation. Consequently, scanty knowledge is available on the subject matter, especially in Ghana. This is in spite of the over 90% of rural households in Ghana depending on the forest/vegetation resources for their biomass energy. The poor understanding of the effects of households' biomass consumption could adversely affect forest resources, especially for economies that depend heavily on wood fuels like Ghana. This, therefore, underscores the need for this study to unearth and deepen understanding of how households' biomass fuel consumption affects vegetation in the Sissala West Municipality of Ghana, where most households use biomass fuel to cook, heat and light (GSS, 2012).

1.3 Research Questions

1.3.1: Main research question

The main research question is; how does households' biomass fuel consumption contribute to devegetation in Sisala East Municipality?

1.3.2: Specific research questions

In an attempt to answer the overarching research question, the following specific questions have been explored in the study;

1. Which tree species are usually used for biomass fuel in the study area?
2. What factors determine households' decision to use biomass fuel in the study area?
3. What alternative sustainable energy sources are available for households in the study area?

1.4 Research Objectives

1.4.1: Main research objective

The overall goal of the study is to examine the household's biomass consumption and its contribution to devegetation in Sisala East Municipality.

1.4.2: Specific research objectives

Specifically, this study explored the following;

1. To identify the tree species that are used for biomass fuel production in the study area.
2. To examine the factors that determine households' biomass fuel choices in the study area.
3. To explore environmentally sustainable alternative energy sources for households use in the study area.

1.5 Significance of the Study

Studying households' biomass fuel consumption has many significances. Therefore, the relevance of this research cannot be overemphasized. First, the rationale of the study is to deepen understanding and provide useful statistics for better understanding, to inform policymaking, especially at the strategic level by offering alternative energy policy design, direction, and implementation for enhancing sustainable development. Second, the study contributes to a nuanced understanding of households' energy consumption by unearthing the micro-effect of households' biomass fuel consumption, especially on vegetation/forest. A nuanced understanding of the effect of households' biomass use will extend the energy debate further, by highlighting the micro-level effects of households' activities on deforestation/devegetation in the context of rural Ghana. Also, the outcome of this study will be used as secondary research materials in the field of deforestation research. While much is known about the connection between biomass use and deforestation, scanty knowledge exists about the effect of households' biomass use on vegetation/forests in developing countries. Third, the study adds significant new dimensions to knowledge and research because it is the first academic research in the study area (so far as my search is concerned) that focused primarily on household biomass consumption and its effect on depletion of forest/vegetation and woodlands. Many past studies in Ghana have largely focused on analysing the relationship between biomass and GHGs emissions and concentration without much attention to household-level activities that promote global warming. For instance, Kuunibe et al., (2013); Gordon et al., (2013) and Amissah-Arthur and Amonoo (2004) have examined the social impacts of energy intervention on rural communities and the implications of wood-based fuel consumption and implication on environmental sustainability. The limited literature on this subject underscores the need for a study that will focus primarily on examining the effects of households' biomass consumption on deforestation, especially among rural communities.

1.6 Scope of the Study

Contextually, the study examined the effect households' biomass consumption has on vegetation, using a mixed-method approach. The main categories of respondents in the study were; principal decision-makers in households, wood/charcoal vendors and processors. Thus, the study mainly sought to analyse the contribution of households' biomass consumption to devegetation. Additionally, vulnerability analysis was conducted to identify tree species that are most likely used in charcoal production, and the determinants of household biomass energy choices. The study also examined alternative sustainable energy source for households and proffered recommendations for achieving environmental sustainability in the Sissala West Municipality of Ghana.

The study spanned a period of one year; from August 2017 to May 2018. The first component of the study, which entailed a research proposal, was completed and approved by the supervisor in December 2017. Data collection, analysis, and report writing took place from January to April 2018.

1.7 Organization of the Study

The research account has been structured along with five chapters as prescribed in the University for Development Studies' graduate school guidelines. Chapter one entailed the background to the study, problem statement, research questions, research objectives, the significance of the study, the scope of the research and structure of the report. Chapter two (2) was dedicated to reviewing literature, theoretical and conceptual analysis. Chapter three (3) gives a detailed description of the research design and methodology, the sampling design, data collection methods, and present the profile of the study area. Chapter four (4) presents the research results and discussions. The results and discussions have been structured along with the research objectives. The concluding chapter (five) gives key research findings, the conclusion drawn from the study, recommendations for further research and policymaking.

1.8 Limitations of the Study

Despite a successful study conducted, there were a few limitations. First, the financial limitation was a barrier because of the Municipal's location, especially for transportation costs. Second, because the study was conducted in one Municipality, a generalization of the findings is problematic. However, the findings can be used for logical conclusions and generalization on issues of household energy consumption patterns. Furthermore, the language barrier was a challenge during the data collection process. To overcome this, the researcher engaged a research assistant who spoke the local dialect, and thus, acted as interpreter and translators during interviews.

Furthermore, enumerators were engaged from local communities to support the data collection and supervised by the researcher and his research assistants.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter entails a review of the literature on the thematic areas and concepts relevant to the study. The chapter also presents the theoretical and conceptual framework underpinning the study. The chapter has been sub-divided into three sections; section one defined terms and concepts relevant to the study. Section two discussed relevant thematic literature on the study; the last section presents the conceptual and theoretical framework of the study. These sections have been discussed as follows;

2.2 Definition of Key Terms

2.2.1: Biomass and Biomass Energy

The term "biomass" has been widely defined by different scholars, especially in the sustainability sciences. For instance, Duku, Gu and Hagan (2010) see biomass as the remains of organic matter from plants and animals. These can be in the form of wood products and their waste, agriculture products, and their by-products as well as waste from living things of all forms. The Schiffer (2018) also see biomass energy as energy from organic matter (biomass), not from geological formations. It can be used in its primary state as fuel or transformed into various states (Moriarty & Honnery, 2016). Industry, manufacturing, domestic and transport sectors all use this fuel. Biomass energy includes traditional biomass, contemporary biomass, and biofuels. It involves the changing of organic matter occurring in nature or cultivated into energy. Also, the term biomass is seen as remains from forests, agro-residues, and by-products from the processing of industrial wood products. This was captured sufficiently by Quaschning (2010) who defined the term as organic material that contains all sorts of life, dead organisms, and organic metabolism products. Bildirici and Özaksoy (2018) classified biomass as organic matter renewable over time, which might be used as a renewable energy supply, either directly by combustion to provide heat or indirectly, once conversion into varied sorts of processed biofuels (such as wood pellets or ethanol). Wood remains a critical form of biomass energy. From this definition, it can be stated that a large proportion of biomass materials is fuelwood and charcoal, which has often been referred to as traditional biomass. Traditional biomass is, therefore, the primary biomass fuel in most parts of Africa, including Ghana. According to FAO (2001), fuelwood, which is the commonest biomass materials used in households, is that energy sourced from the combustion of logs, straw, twigs and is mainly utilized by rural households in sub-Saharan Africa. The majority of the earth's populace uses this traditional energy. Bio-energy is therefore generated from the use of materials such as wood fuel, crop residue, and animal waste. As noted earlier, worldwide, biomass energy constitutes the prime foundation of energy for almost 2.7 billion individuals for household and domestic activities (Kersten, Wang & Swaaij, 2005; Wicke, et al., 2011) and the majority of them are found in Africa, especially in sub-Sahara (WEC, 2006).

Biomass use is widespread in SSA, estimated at 95%. The high figure registered for flammable renewable and waste energy use for Sub-Saharan Africa could be a reflection of its serious use on biomass energy primarily used at the social unit level (Gatama, 2014). As of 2001, the share of biomass intake was 18% in sub- Saharan Africa, 16.46% in South Africa and 4.06% in North Africa (Dasappa, 2011). Thus, till date, some 650 million of SSA's population use traditional biomass energy for domestic activities (Kersten, Wang, & Swaaij, 2005; Gustafson, 2001; Misana, 2001), though studies had projected this figure to increase to 720 million by the year 2030

(Bridgwater, Meier, & Radlein, 1999). In Kenya, just like many parts of the African continent, apart from cooking, heating, and lighting, wood is utilized in agro-processing as well as local industrial activities. Charcoal is utilized for cooking and sometimes ironing. According to the Zulu and Richardson (2013), the statistics about charcoal use are quite contrasting. Rural dwellers who use charcoal is 26% while for their urban counterparts, it is 85%. It is estimated that 67% and 99.5% buy charcoal this charcoal respectively. The rest of the households process it themselves and trade the rest. The distances covered to access charcoal is about 6km for rural inhabitants. Urban inhabitants manage a distance of about 1.8km on average. Also, in Albania 42. % of families utilized a form of biomass to heat space, cook or heat water. The statistics indicate that over 50% of rural dwellers in Albania use biomass to heat or cook. As stated earlier, most of the rural biomass use favours domestic activities such as cooking, heating lighting, and space conditioning. Whiles the majority of urban households used charcoal, rural households prefer firewood. Also, whiles, urban households often purchase their firewood or charcoal, their counterparts in rural areas usually collect it from the bush or farm (Gatama, 2014) Going into the future, biomass use in Africa would likely remain unchanged. Whiles some studies have shown a likely increase in biomass use in Africa, others project a downward trend in the continent. For instance, the International Energy Agency (IEA) has projected a decline in the entire energy share of biomass and wastes by 2035. However, the Intergovernmental Panel on Climate Change (IPCC) projects an upsurge within the near future. As cited in Sposito (2016) the IPCC envisages an increased utilization of biofuels alongside innovative technology, higher productivity in agriculture and increased acreage for farming purposes. This means that biomass energy use in Africa will remain an important energy resource for the majority of African households in the future (Dasappa, 2011).

The IEA also lists sub-Sahara Africa (SSA) and India as the two sub-regions with higher household portions reliant on traditional biomass for their energy. Berndes, Hoogwijk & Broek, (2003) indicated that it is important that modern biomass energy systems play a crucial part in maintainable energy supply in the coming years. This suggests that new biomass energy systems should not only be efficient but also be sustainable. Thus, all focus on future bioenergy development should be more concerned about sustainability and efficiency, taking into consideration current environmental and climate change concerns. It had also found that there exist great potentials for biomass energy development, especially for sustainability and energy supply in Africa. According to Smeets, (2004) sub-Sahara Africa has more than 750 hectors of farmland capable of cultivating bio-energy crops. This could easily produce 317 EJ of energy, on the back of increased productivity in agriculture. This potential alone could supply a significant proportion of sub-Sahara Africa's population with clean renewable energy for household uses. In another study, Hoogwijk (2004) analysed the energy potentials in Africa using a scenario analysis that projected that, biomass production potential for Africa could read up to 134 EJ/yr. Further studies in Mozambique by Dasappa (2011) reported that there are promising potentials in bioenergy production in Southern Africa. The availability of suitable land, climate, and a sparsely populated area support commercial production of biomass for energy.

Overall, there is ample evidence in the African continent that suggest huge potentials exist for biomass energy production, that could supply the regions' greater population with their energy needs, especially for domestic uses. However, the greatest challenge is the lack of investment in biomass energy production, and also partly due to the inefficient agricultural production systems that are largely used in production in Africa.

These inefficiencies in agriculture production thus limit large scale production and could be a greater challenge if Africa has to tap this great potential.

2.2.2: Types and Sources of Biomass used in Households in Africa

First and foremost, at the household level, it has been widely established that fuelwood remains the most used in most households in Africa. For example, according to a study conducted by Centre Renewable Energy Saving (CRES, 2012), about 99% of households in Africa use firewood and only a minute percentage (1.2) used pellets. To buttress this, research showed that in Botswana, fuelwood remains the most desired. LPG was next with kerosene closely following. Cow dung was the last on the preferred list of energy for cooking. The people relied on kerosene or a candle for light. Electricity was used in a small proportion of cases in a related Zimbabwean study, Bazilian (2012) went further to investigate the utilization of different fuels as energy. Their study's results showed that a significant population of the country relied on biomass energy, with a majority in the urban areas depending on charcoal whiles those in the rural areas depending on fuelwood. It further found that access to biomass was high across the country. Urbanised areas recorded 79% and rural recorded 98% access rates. This points to a high reliance on biomass and charcoal by the majority of the households. biomass obtained from wood sourced as the primary energy in households makes up to 95% in both Eritrea and Ethiopia. In Zambia, it is 70%. Uganda recorded 92%, respectively. Additionally, in Tanzania, the energy requirement is met by the use of biomass. The capital city reports 71% of households to rely on charcoal. That translates to 50% of the nation's charcoal use (Owen, 2103).

Across Ghana, about 74% of the total population relies on traditional biomass for their energy needs (GSS, 2014; Piedrahita, et al., 2016). However, in the countryside, logs remain the main basis of cooking fuel with 73.4% population depending on fuelwood whiles in the urban areas, only 13.8% of the population, rely on firewood fuel. In urban localities, charcoal was the most common energy source for cooking with 47.9% (GSS, 2014). Given current trends of increase, urbanization, economic process, and relative value developments of different energy sources. It is possible that wood based biomass can stay a vital supply of energy particularly for several states for several decades (World Bank, 2011). Energy consumption is driven by domestic consumption in Tanzania and undertaken by women just as in other African countries. Most households utilized kerosene or candles to light their homes. Charcoal was mainly utilized to cook. Furthermore, farm residues: including both crop and animal wastes also account for a significant proportion of biomass materials in Africa. These replace firewood in cooking in most households, especially in rural areas. According to Sikei, et al. (2009), increased firewood scarcity in Kenya has seen increasing unavailability of firewood leading to more frequent utilization of agro-waste for household's energy needs. In his study, about three-quarters of rural dwellers rely on combustible waste from agro processes as energy. A negligible percentage does the same in the urban environment (Sikei, et al., 2009), Also, electricity has been used in some households to cook, light, operation of small gadgets, etc. However, considering the cost component, and widespread energy insufficiencies in Africa, electricity is only used by wealthier households, notably in urban areas. For instance, electricity coverage is very low in Kenya. It is 20% in cities and towns, and lower than 5% in the countryside. This proportion is a resulted from access to electricity, the inability to afford the cost of electricity is a major impediment to using it for domestic purposes, especially for cooking.

More so, the emergence of lignified petroleum gas (LPG) has also become common household energy in especially urban households who can afford to purchase a cylinder and regularly pay for a refill. However, LPG is mainly used for cooking in households, although commercial entities such as restaurants and other cooking ventures are increasingly using LPG. LPG is largely an urban households' energy source. According to Sikei, et al. (2009), cited by Ondraczek (2013), less than one percent of rural dwellers in Kenya use Liquefied Petroleum Gas, as compared to 0.8% among urbanized homes (Ondraczek, 2013). Additionally, large numbers of processors, buyers, sellers, and transporters are involved in a complex web of wood wood-based biomass. A whole mix of livelihood and profiteering is activated in this local industry. On the contrary, apart from mainland China, biomass is used in a quarter of all cases as energy. Latin America boasts similar statistics, though slightly lower. While it is foreseen that by 2030, energy derived from wood in the continent can still account for about one third of total residential energy use serving one billion individuals, it presently accounts solely for 10% of the world energy offer (Dasappa, 2011). Notably, the majority of the people (95%) in various states in West Africa and Central Africa report a huge deficit in terms of access to modern energy. Unsurprisingly, rural homes depend largely on biomass to cook.

The main method for collecting household fuel is either from the forest or sometimes from land resources. Also, 63% of firewood used in urban households is supplied from biomass supply centres, whiles 22% come directly from forestry. In Tanzania, it was reported that about 91% of households' fuel is biomass and in some cases the use of stoves which are used for heating and cooking while about 6.5% of them satisfy their heating needs from electricity using electrical appliances such as air conditions and electric stoves (Soneye, et al., 2017). Also, a similar study conducted by Soneye, et al.

(2017) revealed that a larger proportion of the population in Dar es Salaam, Tanzania representing more than 85% be contingent rely on charcoal as a source of energy for cooking. However, this is affected by less availability of trees in the nearby surroundings which has increased coverage of longer distances to obtain charcoal, thus about 150km or more.

Secondly, agriculture is one major source of energy consumption in Africa. Energy is an important component in many agriculture production activities at all levels. This energy is needed for agricultural production-related functions in many rural settlement areas in the form of intensive use, transport, watering of crops and process of produce, land preparation, planting purposes, nursing of seeds and transplant of seedlings. In the processing of food products and processing of fisheries are some of the major uses of firewood, for instance, has been used for. However, one notable challenge in Africa is that the data set that is related to energy is not taken into consideration, considering the important role that energy especially, household energy plays in processing and transporting agriculture products which make use of more energy in recent times. To overcome this loss, FAO's (1995) valuation using comprehensive Tanzanian and Zimbabwean survey data in estimating the energy consumption of households in these nations revealed that agro-processing and agricultural-related transport activities are more significant in bio-fuel usages. It was therefore settled on the processing and this accounted for about 45% of energy uses in the agriculture sector and this is followed by on-farm an agricultural activity which also is close to about 32% and agriculture-related transport activities are about 23%. Many of these agro-processing industries need a lot of mechanized energy in undertaking all forms of activities.

In Africa for instance, biomass energy alone used by agro-processing industries is about 60%, oil products about 17% and that of coal is about16%. These serve as the main sectors of the industrial front that make use of energy in the agricultural subdivision. This is to say that, biomass energy provides some sort of heating in the agricultural processing, oil sector, power, and non-motive processing equipment and is used for transportation services as well, this supplement with the use of coal (Karekezi, et al., 2006). It is also enough to add that energy consumption is manifested in the fishing and livestock industries as these sectors can be isolated from the industrial sectors due to the unique characteristics they possess because, in certainty, departure of fisheries and livestock from agriculture is anxious with complications (Karekezi, et al., 2006).

2.2.3: Deforestation

The term deforestation is a broad concept often used commonly in forestry and natural resources management. The use of the term connotes destructions of the natural environment, especially the removal of forest resources or vegetation. The term has been variedly defined in different disciplines but the commonest and widely accepted definition is one given by the United Nations' Food and Agriculture Organization (FAO). The FAO put deforestation as the permanent destruction (or removal) of vegetative and forests cover to make land available for other uses (Food and Agriculture Organization, 2015). It thus means that deforestation implies the removal of trees from the forest, especially by human activities. The process is gradual in nature and the destruction caused either permanent or takes a long time to reclaim. The thrust of deforestation is that the removal of trees is often done by human beings to pave way for other land uses such as agriculture, housing, industry, and other permanent development. Typically, deforestation implies clearing a lot of trees without the intention of establishing future growth.

Generally, deforestation is caused by a wide range of human activities but in Africa, the phenomenon is commonly caused by agriculture and farming activities in which inappropriate methods are often been employed. Deforestation is a fast-growing phenomenon globally, and particularly in Africa. It is common in Africa because of the continents' high dependence on agriculture and nature for their livelihoods. Between 70-90% of agriculture in Africa rely on traditional and inappropriate methods for cultivating, planting and harvesting that pose potentially injurious impacts on the environment. Again, more than 81% of the sub-Sahara African population depends on forest and wood resources for their household energy needs, which directly depend on existing forest and woodlots. On average, sub-Saharan Africa (SSA) has the largest per capita wood fuel use in the world in 2011 per region having an overall average of about 0.69 m^3/year (Iiyama, et al, 2013), and the trend is unlikely to change in the next few.

This situation put considerable pressure on existing forest resources, leading to fast-pace depletion. Thus, the rate of exploitation (especially wood resources) in most situations far exceeds the rate of natural re-growth; hence deforestation has become a problem in most countries in the African sub-region. The United Nations' Food and Agriculture Organization (FAO) indicates that, globally, forests resources cover an estimated 31% of the entire land area on our earth but there is an estimation to about18 million acres (7.3 million hectares) of forest resources are misplaced annually due to a combination of human activities, topmost among them is industrialization. Currently, the world loses between 6 to 12% of its forest cover yearly. Hence, if this trend continues, in less than three decades, there will be very few forest reserves in the world. The sustainable development goals seven (7) search to increase accessibility, affordability, reliability, sustainability and modern energy demands for all. However, this overall goal will remain a mirage if sustainable household energy strategies are not pursued. Therefore, if African countries want to achieve the sustainable development goals, it is important to for national government and multilateral agencies to focus attention on the provision of cleaned and renewable energy service, this is because on average, people who pollute the environment with fuelwood for cooking amount to about 40% of all users, and over 90% of them are from the African continent ((Peerzado, et al., 2019).

Past studies have shown that there are varied causes of deforestation; including industrial development, agriculture activities and urbanization, especially common phenomena in developing countries. Although somewhat disputable, deforestation in Africa has been closely linked to inappropriate and inefficient household fuelwood consumption. According to the World Wildlife Foundation (WWF), it is on records that about half of the trees that are illegally removed from forests are used as fuel at various homes. Although a chunk of it ends up in the industry, a significant proportion of it is used up in household domestic activities; including cooking, heating, and lighting. However, MacDicken (2015) link deforestation to infrastructure development and expansion than household energy fuel consumption. They believe household consumption alone is not sufficient to cause depletion of the forest because natural regeneration will always replenish the lost trees. Estimates indicate that between 1990 and 2000, and 2000 and 2005 forest losses were 135,000 and 115,000 ha, respectively (Keenan, 2015). From the figures, though there has remained a lessening in the depletion speed, the amount of damage is still significant and this underscores the need for effective strategies to combat. In the past, excessive depletion of the forest has been attributed to extreme illegal taking down of trees, unmaintainable agricultural practices such as the bush burning of the vegetation, mining and quarrying activities, settlement expansion due to population increase and movement of people across regions and places in the forest zones (Duku et al., 2011). The consequences of deforestation are immeasurable. First, the direct impact of deforestation is felt in global warming due to increased greenhouse gas emissions. Increased GHGs emissions consequently lead to the formation of acidic rain and oceans, and loss of tree and fish species, flooding and erosion, and decline in life quality. Deforestation not only affects the climate and weather, but it also affects the biodiversity and ecosystems, leading to imbalances.

2.2.4: Forest resources

Forest resources encompass all resources found within the forest reserves; including trees, wild fruits, wildlife, and vegetation. Forest resources provide for a significant part of human needs, including food, health and wellbeing, and livelihoods. They serve as a strategic source of natural reserves and the preservation of wildlife. Forest constitutes the main source of traditional biomass in most developing countries including in Ghana. Traditional biomass which is in the form of charcoal, fuelwood, and sawdust, has been used in households since history, purposely for cooking as well as heating and lighting of homes. According to the FAO (2009), it has been estimated that yearly use of wood is roughly 4106 m3 with a volume of about 55% utilization as fuelwood, chiefly in developing countries. In Ghana, the main source of fuelwood is from forest reserves but in the guinea savannah regions, the source of supply is the natural wood lots scattered around the vegetation.

Apart from being the main source of household biomass energy, forest resources contribute a lot to the socio-economic development of Ghana. The forestry sector has contributed enough to the growth of Ghana's economy, for instance, in 2006 alone, labour offered by the forest subsector is about 0.4%. Considering these figures, the role of forest resources in Ghana's socio-economic development cannot be overemphasized. Thus, underscoring the need for the country to fashion ways to forestall destructions to forest reserves. The reliance on ancient biomass energy is extremely high in the region, accounting in some countries for up to 95% of the total consumption. The high figure registered for combustible renewable and waste energy consumption for the region could be a reflection of its serious reliance on biomass energy that's chiefly used at house level (Gatama, 2014). As of 2001, the share of biomass consumption was 81% in sub- Saharan continent, 16% in state and 6% at intervals in the region (Dasappa, 2011). Thus, to date, some 653 million individuals in this geographical are dependent on ancient biomass. In Kenya, a bit like several components of the African continent, except for cooking, heating, and lighting, fuel is additionally utilized in the agricultural areas for the agricultural process, thus solidifying most agriculture produce like tobacco and smoking of fish. On average, a rural human travels half-dozen metric linear units to supply charcoal whereas urban resident travels one 9 metric linear units (Zulu and Richardson, 2013). Also, in Albania, some 5% of the households use some form of biomass for house heating, cookery or water heating.

The share is higher in rural areas, where quite over half of the households (51%) reportedly use biomass for his or her heating desires, compared with solely (35%) in urban areas. As declared earlier, the majority of energy disbursed in countryside areas is employed in households' domestic activities like cookery, heating and lighting. Whiles the majority of urban households used charcoal, rural households like fire wood (World Energy Council, 1999; Karekezi & Kithyoma, 2002). Also, while urban households usually purchase their fuel or charcoal, their counterparts in rural areas typically collect it from the bush or farm (Gatama, 2014). Going into the long run, biomass use in the continent would seemingly stay unchanged. Whiles some readings have given an indication of high consumption of biomass fuel, some can seemingly have been exaggerated in the continent, others project a downtrend within the continent. As an example, the International Energy Agency (IEA) has projected a decline within the entire energy share of biomass and litters by 2035. However, the Intergovernmental Panel on temperature change (IPCC) projections show the trend can increase within the future. As cited in Sposito (2016), the IPCC create a mental rising use of biofuels amid scientific invention, exaggerated agricultural efficiency and cultivation of additional land. This implies that biomass energy use in the continent can stay a vital energy resource for the majority of African households within the future (Bulsink, 2020). Bulsink listed sub-Sahara Africa (SSA) continent among the two sub-regions with the greatest proportion of its population obsessed with ancient biomass for his or her energy. Berndes, Hoogwijk and Broek (2003) indicated that its important and fashionable biomass energy system that can offer a vital contribution to future energy systems. This means that new biomass energy systems must not solely be economical, however, conjointly offer a property supply energy for future use. Different studies have conjointly found that there exist nice potentials for biomass energy development, particularly for property and energy providers in the continent. As an example, per Smeets et al. (2004) sub-Sahara Africa's has would-be left-over land-living of up to 700 million hectares (Mha) that might be used to grow bio-energy produce with yearly yields of up to 317 EJ, assumptive enhancements in agricultural output of up to eight times. This potential alone may provide a major proportion of sub-Sahara Africa's population with clean renewable energy for home uses. In another study, Hoogwijk (2004) analyzed the energy potentials in the continent employing a state of affairs analysis that projected biomass production potential for continent may rise up to 134 EJ/yr.

Other studies by Dasappa (2011) report that there are promising potentials for biomass energy production among Southern continent, because of the relative profusion of natural possessions, favourable ecological circumstances and low population concentration, that change massive scale production. Overall, there's ample evidence within the African continent that counsel vast potentials exist for biomass energy production, which would provide the regions' bigger population with their energy wants, particularly for domestic uses. However, the biggest challenge is the lack of investment in biomass energy production, and conjointly because of the inefficient agricultural production systems that are for the most part employed in production in the continent. These inefficiencies in the agricultural production system limit large scale production and likely will be a bigger challenge if the continent needs to exploit this huge potential.

2.2.5: Types, sources, and Sources of Biomass employed in Households in the continent

First and foremost, at the management level, it's been widely established that fuelwood is that the main energy employed in the majority of households incontinent. As an example, in line with a study conducted by Centre Renewable Energy Saving (CRES, 2012) stated that about 99% of households' in Africa use wood fuel while about (1.2%) rumoured to use pellets. To buttress this, the results of African countries in the year 2000 point to the view that there is a high demand for firewood in the rural parts of the continent which is followed by the use of LPG at the households' level while lighting is done by using candles and electricity. In a very connected study, Davidson & Mwakasonda (2004) went more to summarize the utilization of varied fuels for energy functions in African nations. Their study found that a greater proportion of population of the country relied on biomass energy, with the majority within the urban areas relying on charcoal whiles those in the rural areas depending on fuelwood. Their study discovered that inurban areas, about 78% of the residents depend on biomass fuel at home and in the agriculture and rural surrounding about 98% depends on it.

Moreover, Owen (2103) reports showed that about 70% of dwellers in Dar Es Salaam, Tanzania depends heavily on biomass energy. In Ghana, about 74% of the entire population depends on traditional biomass for his or her energy wants (GSS, 2010; Piedrahita, 2016). In urban localities, charcoal was the foremost common energy supply for preparation with 47% (GSS, 2014). Given the present trends, developmental issues and economic growth coupling with rapid urbanization, biomass in the form of wood can stay a vital supply of energy especially, for preparation for several decades (World Bank, 2011). Similarly, the results from some selected countries in Africa portrayed that many households lighting is done using Candles, fuel or electricity as well as charcoal and kerosene including the remains of crops (Karekezi & Majoro, 2002). Moreover, flammable agricultural residues: together with crop and animal wastes conjointly account for a big proportion of biomass materials in the continent. Sikei, et al. (2009), growing fuel insufficiency in the Republic of Kenya has led to increased use of agricultural residue for household's energy wants. Also, electricity has conjointly been employed in some households, for preparation, lighting, house conditioning, ironing and the use of other electrical appliances.

However, considering the value element, and widespread energy insufficiencies in the continent, electricity is simply utilized by wealthier households, notably in urban areas. As an example, 20% of Kenya's inner-city families have contact with electricity whereas only 2% can get it within the rural settings. Of the proportion with access to electricity, inability to afford the value of electricity could be a major impediment to utilizing it for domestic functions, particularly for preparation of food.

However, LPGs is especially used for the preparation of food in wealthy households, although business entities like restaurants also utilize LPG. LPG is essentially an urban households' energy supply in line with Sikei, et al. (2009), cited by Ondraczek, (2013) (2003), but one-hundredth (0.01%) of rural households in the Republic of Kenya use LPG, as compared to 0.8% of the urban households Ondraczek, (2013). Massive numbers of traders are involved in shopping for, transporting, and re-selling of wood-based biomass and this is often wherever most of the added are obtained within the informal sector. In contrast, all of Asia (excluding China), biomass represents 25% of the first energy provide and in the geographical region (World Bank 2011). Whereas it's expected that by 2030 energy derived from wood in the continent can still account for a conservative three quarters of total residential energy consumption serving almost one billion individuals (Dasappa, 2011). Specifically, over 95% of the population in countries like Burundi, Central African Republic (C.A.R.), Chad, Liberia, Rwanda, Republic of the Gambia and Sierra Leone lack access to modern energy, with the agricultural population relying virtually completely on wood-based biomass energy for preparation (Pachauri, 2013).

The main technique for assembling fuelwood is either from the forest or lands. Huge numbers of traders are involved in buying, conveying, and re-selling of wood-based biomass and this can be often where most of the information is obtained among the informal sector (Dasappa, 2011). Precisely, over 95% of the population in countries like Burundi, Central African Republic (C.A.R.), Chad, Liberia, Rwanda, Republic of the Gambia and Republic of Sierra Leone lack access to modern energy (World Bank 2011), with the agricultural population relying just about fully on wood-based biomass energy for preparation (Pachauri, 2013). the most technique for aggregation fuelwood is either from the forest or lands. Also, 63% of fuel employed in urban households is provided from biomass provide centres, whiles 22% return directly from biological science. Most of the rumoured households that use biomass (91%) use it in stoves whereas the remainder in fireplaces. 6.5% of the biomass users use another style of heating appliance e.g. air con, gas/electric fire, among others. Most of the households that use biomass for heating indicate that they use it for cooking also whereas a big 10% uses biomass also for water heating.

Agro-processing industries need massive parts of mechanized energy (motive and shaft power) for heating. In Africa, biomass (60%), oil product (17%) and coal (16%) are the most sources of energy for the agricultural sector. Thus, biomass provides heat for the agricultural process and machinery including transport whereas coals is employed for transport only (Karekezi, et al., 2006). Another complication is energy consumption in fisheries and farm animals. Though these sectors might, in strict, definitional terms, be excluded from the agricultural sector, in reality, separation of fisheries and farm animals from agriculture is fraught with difficulties (Karekezi, et al., 2006).

2.2.6: Property management of natural resources

The idea of "sustainability" and "sustainable management" are widely used and applied in various spheres of development, together with resource management. The term "sustainability" may be a goal that a lot of within the ecology discipline aim to attain as a result of it being vital for the resolution of the many environmental issues together with degradation. The term sustainability has been take differently by different people connotes continuity and permanency for making certain future use of natural resources. though the property has been widely employed in the natural sciences, to date, there's no absolute agreement concerning what this term precisely suggests that.

In resource management, the idea of property management of natural resources is widely used and sometimes employed interchangeably with property to imply the usage of resources in a very approach that ensures its continues existence and uses the term as used in the natural resource management refers to mistreatment natural possessions in a manner and at a degree that upholds and improves the elasticity of ecosystems and therefore the advantages they supply to societies.

2.3 Summary of Biomass Use

2.3.1: Biomass North American nation in the continent

Globally, 2.8 billion individuals place confidence in solid biomass fuel (Wicke, et.al. 2011); out of this, more than three quarters of them live in developing countries (Johannes, et al., 2011). In this geographic region, the utilization of biomass energy is common among each rural household especially for burning and alternative domestic energy wants (Bailis et al., 2007; Mekonnen & Kohlin, 2008). As an example, in Ghana, Amissah-Arthur & Amonoo (2004) found that 84% and 13.0% of rural households use fuel and charcoal respectively. There are variations between the use of biomass among the various regions in the world.

On regional basis, Sub-Saharan Africa has about 76%, North Africa (3%), India (69%), China (37%), Indonesia (72%), Rest of Asia (65%), Brazil (13%) and Rest of Latin America (33%) (World Bank, 2011). This composed by suburbanisation that will increase the speed of wood fuel (charcoal) that is essentially utilized in most elements of independent agency urban residents. In contrast, rural areas with no energy access, wood remains a key provider of domestic primary energy despite the health and environmental problems associated with its inefficient burning (World Bank, 2011). In region (SSA), biomass energy demand is influenced by several factors besides increase, accelerated urbanization, economic development and relative worth changes of different energy selections (Africa Renewable Energy Program, 2011). Studies have shown that there's a positive relationship between increasing rates and energy demand (Kebede et al., 2010). In 2009, Africa's population exceeded one billion, of that 395 million (or 40%) lived in urban areas and by 2030, the urban population is anticipated to attain concerning 780 million (UN setting, 2010). This number result shows that urbanization usually leads to small families in the urban centres and significantly accumulated consumption by businesses and public facilities, like small restaurants and hospitals, schools, universities, prisons, and for brick sweltering for housing construction (Nzeadibe & Anyadike, 2012).

2.3.2: Biomass Consumption in African nations

There is growing proof that links family biomass consumption to deforestation and environmental degradation. For example, the international organisation REDD+ programme found that in the Kingdom of Cambodia 11% of all wood fuel is collected from the forest, and 42% of fuelwood collected within the country is employed inefficiently. This underscores the requirement to understand however and why forest space changes over time for the needs of managing forests sustainably (MacDicken, 2015). Understanding the dynamics with regards to the changes occurring within the forest can facilitate policy formulation. Forest resource is crucially a part of human living. Aside from being the supply of wood fuel, forests additionally give the majority of the world's forest product and variety of natural and eco-friendly services, like water, sanitisation, erosion managing and carbon sequestration.

Forests additionally act as basins and sources of carbon. Therefore, exploring the drivers of forest gains and losses can facilitate scientists and decision-makers to measure the forests' ability to scale back gas emissions. Although comparatively new dimension, the potential result of family wood fuel consumption on deforestation is gaining ground as a result of new proof (World Bank 2011). Though the result of households' biomass consumption on deforestation has been downplayed by the Food and Agriculture Organization (2015), there's reasonable proof to point out that biomass and deforestation, particularly in areas that depend extremely on wood fuel for their energy wants. For example, 11% of wood fuel utilized in households in the Kingdom of Cambodia is collected from the forest by wood customers. what is more, over 62% of the pressure on the forest resource of the Kingdom of Cambodia is attributed to pressure from Charcoal burning for business functions.

More so, the overall quantity of wood fuel harvested within the country of Cambodian is calculable at 400,000t, Olympian the annual offer of 380, 000t (UN REDD, 2015). In step with the Forest Resources Assessment (FRA) Country Report Nigeria 2005 (cited in Food and Agriculture Organization, 2005), shows that about a total wood of forest were removed in 2005 amounted to 86626,797 m3, and exclusions for wood fuel from forests within the year 2005 were 710,935 m3, the distinction being created up by manufacturing spherical wood, that accounted for 915,862m3. This suggests that the annual offer of wood fuel falls below annual demand resulting in overexploitation. This can be a result of unsustainable ways in which gathering of fuel and how these method is changing forest lands to agriculture lands (Peerzado, et al., 2019).

Currently, 42% of the wood fuel consumed in the Kingdom of Cambodia is unsustainable. Over the past twenty-five years, the world's forest space has declined from 1 billion HA to merely beneath four billion ha, a significant decrease. From 2010 to 2015 international forest space has decreased by 8% annually, totalling 3% though the speed of world forest space loss has slowed by over 50% stuck between the periods 1990 to 2000 and 2010 to 2015. Vital efforts are still required to reverse deforestation, particularly in developing countries. There are still staggering high rates of depletion of forest resources in most developing countries, a worrying trend that might exacerbate inequalities and environmental property. For example, between 1990 and 2000, West Pakistan lost a median of,100ha of its forest per annum. This amounts to a median annual deforestation rate of 63%. In total, between 1990 and 2005, West Pakistan lost 7% of its forest (Tahir, 2010). In line with Tahir et al (2010) United Nations agency conducted a study to live the impact of 6000 brick kilns on deforestation, their study found that projected annual wood consumption and sequent deforestation is calculable to be 298000 M3 and 1378000 m3 per annum respectively. However, the study found varying consumption levels and deforestation rates existed within the different declared contribution in the study. Thus, the study showed that consumption of woody biomass and its sequent effects varies with population density and dynamics. Overall, the results of those studies indicate a robust affiliation between family biomass consumption and therefore the rate of forest depletion. In countries that rely heavily on biomass resources for their domestic energy wants, population expansions can place respectable pressure on forest resources, leading to overexploitation and depletion of reserves. What is more, analysis indicates a stronger link between the financial condition (poverty) and the exploitation of natural resources. Thus, Africa's high dependency on biomass resource is partially explained by the continents high level of poverty.

In Ghana, a bit like alternative African countries, the consumption of wood fuel or charcoal is influenced by many factors together with affordability and accessibility by households. However, it was reportable that households don't merely substitute one fuel for one more as financial muscle increase, however, instead add fuels different types of energy for specific services (such as electricity for radio and television, or LPG for making tea and coffee) rather than total replacement of an existing variety of energy that already provides a service adequately. The foremost energy-consuming as the family change of state and heating are the last to vary. The use of multiple fuels provides a kind of energy security, since complete dependence on one fuel or technology leaves households prone to variations and unreliable service. Some reluctance to discontinue modification of fuelwood may additionally be due to vogue preferences and thus the familiarity of change of state with ancient technologies.

2.3.3: Ancient biomass utilized on the continent

Traditional wood fuel has been used for change of state since the start of human history. However, as society progressed, totally different sources of other households' energy have emerged as alternative sources of households' fuel in recent times, comparatively economical technologies and benefits over the standard systems. It has been realised that the gradual transition from ancient ways to improved technologies provides opportunities for not solely environmental sustainability, but improved health.

Over the last 3 decades, there has been growing proof linking indoor pollution to many health issues, particularly for girls and youngsters. The situation has led to respectable efforts from national and international agencies to boost household clean energy sources. This proof has reinforced efforts to demand quality cook stoves for households to boost interior air quality, increase fuel potency, and acquire stove receipt over the future. This led to the push of improved cook stoves technologies to produce higher and additional economical cook stoves for households in developing countries. In line with the planet Bank, (2011), there's no unanimously accepted definition of cook stoves connected to routine or technical standards. They but, maintained that the definition of improved stove depends on many factors including; kind of ancient stove thought of, the aim of the look improvement, and affordability problems. They intimated that ancient cook stoves will vary from three-stone open fires to substantial brick-and-mortar models and ones with chimneys. The improved stove is designed to spice up energy efficiency, remove smoke from the indoor way, or scale back the plodding of modification of state duties (World Bank, 2011). In line with studies by world health organization, ladies and kids in developing countries are exposed each day to pollution from indoor stove smoke, at intervals the sort of small particulates, up to twenty times over the utmost counselled levels of the world Health Organization (WHO) and various environmental agencies around the world (WHO 2005). Smoke from modification of state fuels is estimable to account for nearly 2 million deaths, over 99% of that occur in developing countries (WHO and Pachauri, 2013). This implies that a giant proportion of the annual burden of the malady is caused by the modification of state smoke. As a result of mothers and children and their young ones breathe in such smoke makes them disproportionately sick with the connected health issues.

Children are significantly vulnerable; therefore, durable proof supports the linkages between biomass combustion emissions and acute tract infection (ARI) is common in among households that make use of biomass fuel especially, among children. There are many disadvantages related to the use of ancient biomass energy. First, these energy sources are found to be fairly inefficient at changing energy into heat for change of state (Kammen, Bailis & Herzog 2002). World Bank, 2011).

Secondly, assembling this fuel generally will be arduous and take tons of ladies' and children's time. what is more, there are known health effects of smoke emitted from an indoor change of state activities, particularly for metabolic process connected diseases. Moreover, in the state of affairs where demand for native biomass energy outstrips the natural re-growth of native resources, environmental problems like deforestation and degradation could be widespread.

There's ample proof that biomass fuels burned in ancient ways contribute to a build-up of greenhouse gases (GHGs) (Venkataraman et al. 2010), additionally, as various climate forcers, along with black carbon (BC), inside the atmosphere (Ramanathan and Hoagland Howard songwriter 2008 as cited in United Nations agency 2011). The rising health and environmental problems with traditional biomass energy compelled the United Nation's Food and Agriculture Organization (FAO) to see the Energy Sector Management facilitate Program (ESMAP) inside the 1980s, to reduce the challenges and provide cheap to run alternative energy for households. This approach for increasing interest and funding for programmes and boosting households' energy efficiency is thriving.

2.4 Potentials of biomass in the continent

It has been established that the African continent has plentiful potentials for biomass development. Thus, biomass is commonly referred to as "the inexperienced gold" of the continent. However, Africa's underdevelopment and low technological advancement have usually resulted in the resource being underutilized or used inefficiently to a large extent. 90% of individuals in this geographic area use biomass, but not in economical ways. Similarly, Batidzirai et al. (2006) studied the potential role of biomass fuel production in the country. The authors estimate that a country may manufacture up to six kilogram of bio-energy annually with structured agricultural technology practices and respecting considerably the matter of food versus energy property. Comparing many technologies and production regions, the study establishes that the conditions and vital factors for a prospering bio-energy program in the country are promising. Karekezi and Kithyoma (2003) highlight that biomass is first in each of the biggest renewable energy resources in the region.

Batidzirai et al (2006) studied the potential role of biomass fuel production in the country. The authors derived that country may manufacture up to 7 kilogram of bioenergy annually with structured agricultural technology practices and respecting considerably the matter of food versus energy property. Further, a degree estimate of 380 kg of oil equivalent is employed per capita for preparation practice fuelwood (Chambwera, 2004). These estimates conclude that around 530 million make the most use of the wood equivalent of energy required for cooking. Another supply on the provision of biomass resources for energy purposes is that the non-valued residues from non-edible oil extraction. Presently, several activities are geared towards the uptake of biodiesel targeted in the African region. It should be noted that the oil could even be a small amount fraction of the seed used for the extraction. The residue from oil extraction is important in quantity and would be accessible for various uses. Type of those foods contemplated uses is food like soy meal, fertilizer, pesticide, etc., whereas most of it's accessible as fuel because of the toxic nature of the cake generated as is the case of Jatropha. Aside from the seed, various plant residues are substance-based that require attention to disposal and handling.

Analysing the knowledge from the administrative body (2005), the continent has about 650 million hectares (Mha) of land covereded by forests and this corresponds to 17% of the world's total forest area. The forest cover is about a fifth of the continent's expanse and unpredictably distributed, with the Congo basin accounting for the biggest share. Interestingly, the forest-rich countries of West and Central African Republic, production of economic spherical wood and wood merchandise could even be a major provider of employment. it's fascinating to look note that African forests amount to 85ha per capita of population, and this value is around the world average. The continent has about one-quarter of all tropical rain forests. Only one of the forest areas in the continent is classed as forest plantations. The expanse is about3,000 Mha at intervals in the region and almost 645 Mha amounting to 21% of the expanse has biomass cover. Of the expanse of 650 Mha, concerning 280 Mha is covereed with forest in Western and Central African Republic, which amounts to about 44% (FAO, 2005). Whereas the forest cover is low at areas in the Northern region, fuel resources are high there compared to at areas in the selected regions. It's at areas in the selection regions that one should address solutions of practicing biomass-derived fuels within the energy systems. In Africa for instance, the following countries; Nigeria, Republic of South African, Morocco, Tanzania, Sudan, Madagascar, Niger, Mali, Uganda, Egypt, Ethiopia, Algeria account for a generation potential of about 4000 MW. On the concept of the biomass offered in agency and assuming a small amount fraction (30% availability) of residues is obtainable from the forests and agriculture production, the power potential is about 15,000 to 20,000 MW. With a conservative estimate of the biomass residues accessible as indicated on prime of, potential to return up with concerning 100 TWh a year of electricity exists. However, Biomass as a provider of generating electricity has not been extensively explored in the African region. There are efforts in recent times by different countries of the region to determine outcomes. A good example of this might be the recent effort by the Ministry of Energy and Mineral Development, Uganda, for an action system package being implemented to satisfy heat and power needs of little capacities (Owen, 2103). There are many efforts by some action development groups to initiate programs in African countries for demonstration outcomes, but these haven't created the necessary impact. Biomass has been in use as a provider of energy in majority of the African continent, principally for preparation and various thermal uses, with low conversion efficiency. Economical use of biomass in the continent can meet every need with electricity generation playing a small role. The use of economical distributed power generation technology through action may facilitate in meeting the electricity demand. Important barriers, like resource mapping, capability building, and technology demonstration, to the introduction of biomass energy in the system, are brought out. Recent surges in world petroleum prices and problems concerning energy and action from gas (GHG) emissions have prompted every developed and developing countries alike to pursue a course for biofuels production. Many Sub-Saharan African countries see biofuels as a way to stimulate rural development, manufacture jobs, and avoid wasting resources.

To date, the transport sector has been the key area for large-scale efforts in biofuel use worldwide. The two primary biofuels consumed are alkyl radical alcohol and biodiesel. Currently, the US and Brazil, which build alkyl radical alcohol from maize and sugarcane, are the world's two largest biofuel markets. In the African continent especially, there are prospects of bilateral or many-sided aid transfer for action mitigation through the development of biofuels. Ghana, for example, could sell a vicinity of her carbon credits to countries with high reduction commitments beneath the Clean Mechanism a part of the metropolis Protocol and collectively profit off biofuel production to extend the consumption of energy (Bekunda et al 2009; Dasappa, 2011).

In Ghana, a large scope exists for the exploitation of assorted kinds of biomass, like energy crops, agricultural and biology residues, wood method wastes, and municipal solid waste for conversion to biofuels via totally different routes. Thus, biomass conversion to energy and fuels might even be gratifying areas in the country given the massive handiness of these biomass resources. The subsections, in brief, describe biomass conversion technologies that are applied or tested in the country over the past years. The assembly and use of liquid biofuels as totally different fuels and are often a recent development in the country. Generally, in some countries, the foremost interest has been on biodiesel derived from rosin genus, fat, and soybean. Some initiatives on biofuel development have already been taken by the govt., the private sector, non-governmental organisations (NGOs), and thus the UNDP (Amigun et al 2008). it's derived that just about 129,200 tonnes of organic matter are available. These waste materials are also a potential feedstock for biofuel production. In Ghana, over 240 digesters with various capacities are in place. Through the Bio-sanitation programme, the Institute of economic analysis of the Council for Scientific and Industrial analysis of (CSIR-IIR) has placed in several biogas systems for various faculties, prisons, hospitals, and district assemblies.

It is collectively promoted the utilization of the solid residue as a natural fertilizer. Biogas has collectively been used to fuel a combustion engine to power electricity at Appolonia, a rural community, as an illustration project of the Ministry of Mines and Energy under the Renewable Energy Programme (Amigun et al, 2008; Dasappa, 2011). The shift is that the thermal degradation of organic matter at a temperature vary of 400–800 8C. The first shift product of biomass is usually named as condensable (tars) and non-condensable volatiles, and char. The condensable volatiles (tars) are usually classified as liquids (bio-oil), and non-condensable volatiles is gassed primarily, CO,

CO_2, H_2, and C1–C2 hydrocarbons primarily, the shift is usually classified into typical, slow, and fast or flash shift. Typical shift, that happens beneath a slow heating rate, has been used for the assembly of charcoal (Bouwman & Leemans, 1995). In flash or fast shift, method conditions include: (1) an extremely high heating rate and warmth transfer rate, (2) finely ground biomass feed.

2.4.1: Result of unit biomass consumption

Traditional wood stoves usually utilized in Social Security Administration burn fuel inefficiently, with smoke and gases created by incomplete combustion that cause long metabolism health problems and deaths. Per unit reports, smoke from primitive indoor stoves oxyacetylene by wood, coal, crop waste, and dung, kills a minimum of 1.5 million people worldwide, disproportionately poignant ladies and children (Bulsink, 2020). Solid biomass fuel use in households to boot) 10-50 times quite the executive unit permissible guideline values (Pennise et al., 2009). There's sturdy scientific proof linking indoor pollution (IAP) from the employment of solid fuels to preventable diseases like disease in young youngsters (Dharani et al., 2008), accounting for associate enumerable 10% of disease-related deaths incontinent (Pope, 2010) and chronic clogging pneumonic diseases like respiratory illness and respiratory disease in ladies (Pope, 2010). Further, daily discomfort in ladies from coughs, headaches, stinging eyes, and backaches are usually related to traditional cooking ways which (WHO,2008). Moreover, the impact of IAP from solid fuels in the Social

Security Administration is even worse if the number of years lost because of ill-health, incapacity or early death is thought of. Applying the incapacity adjusted life year (DALY) as a recognized live of overall healthiness burden, 44% of all the IAP-cased DALYs worldwide occur in Social Security Administration (Pachauri, 2013). This implies that indoor pollution related to biomass use is directly responsible for further deaths than infection, nearly as many as HIV/AIDS (Pachauri, 2013). Ladies and children suffer most from indoor pollution as a result of the fact that they 'are traditionally responsible for preparation and various household chores, that involve long hours by the stove/hearth exposed to smoke. Youngsters are considerably vulnerable too, which accounts for his or her predominance in the statistics for premature deaths because of the use of biomass for cooking.

A study undertaken found that girls who do most of the cooking were exposed to double the highest quantity of particulate emission as their male counterparts, and were twice as likely to suffer from metabolism infections (Karekezi & Kithyoma, 2002; Karekezi & Ranja, 1997). As an example, the executive unit (2006) said that infection accounted for 1.2% of deaths in the continent, followed by smoke (1.3); disease (1 .6); HIV (2.8). In developing countries, exclusively disease, unprotected sex, and lack of pure water and sanitation were larger health threats than IAP (Pachauri, 2013). When the extent of dependence on polluting fuels and inefficient stoves varies wide round the world, so can the toll because of indoor smoke. The number of premature deaths is highest in the geographical region because of these regions' high dependence on, and inefficient use of fuel. The results of exposure to indoor pollution have faith within the provision of pollution (fuel and stove type), however, pollution is distributed (housing and ventilation) and also the approach lots of their amount members pay within. the sort of fuel used and individuals' participation in food preparation have consistently been the foremost important indicators (WEC, 2006).

The prevalence of indoor pollution is significantly higher in residential areas where gain is below $1 per day per capita (Pachauri, 2013), and being way more addicted to biomass, poor households consider low-quality preparation instrumentation and sleep in poorly ventilated housing, gathering the negative health impact, as there are incomplete combustion and non-dissipation of smoke. It is enumerable that indoor pollution causes 36% of lower metabolism infections and 22% of chronic disease (UNEP, 2006). A young person exposed to indoor pollution is 2 to a few times more likely to catch the disease, that's one of the world's leading killers of young youngsters. Further, there's proof to link indoor smoke to low birth weight, death rate, disease, cataracts, and disease. to boot has direct effects on health, indoor pollution worsens the suffering and shortens the lives of these with every disease like infection, disease, and HIV/AIDS, and chronic diseases, notably vas diseases and chronic metabolism diseases, that are out and away from the world's worst killers. Four out of 5 deaths because of chronic diseases are in low and middle-income countries (Pachauri, 2013 Ward, 2002).

The results of fuelwood and inefficient use of it is not exclusively restricted to human health. It put together poses serious consequences for land and thus the setting. Other than the direct environmental degradation, full use of fuelwood affects gas emission. as Associate in Nursing example, meeting the fundamental energy desires of Senegal's households with fuelwood and/or charcoal has been creating problems for natural forest resources and at intervals the immediate surroundings of human settlements (FAO, 2006). The study noted that this case has step by step contributed to deforestation, the increasing insufficiency of traditional fuels, and contributed to the activity. The emissions of oxide, hydrocarbons, and material are rumoured (Smith et al., 2000). Matter emissions are highest from the burning of dung for fuel, whereas particulate emissions are highest from agricultural residues. Biomass harvest ends up in slashed vegetation, erosion effects, slashed soil fertility, loss of soil wet, and loss of heterogeneity. Further, reliance on biomass (especially at intervals the type of charcoal) encourages land degradation. In some areas (for example around major cities like

Lusaka, Zambia capital, Kenya; and, Dar E Salaam in Tanzania) charcoal demand looks to contribute to degradation of the encompassing woodlands and forests (Desanker & Zulu, 2001; Soneye, et al., 2017).

Unsustainable charcoal production practices contribute to the current degradation. As In between growing seasons, agricultural residues are sometimes left at intervals the sphere as a ground cover to enrich the most effective soil. They will be tilled back to the soil or burnt on top of the soil to return nutrients to the soil. Once the residues are used for fuel, they, at placed the top of the soil, in the reduction of the soil fertility and leave the soil unprotected so in danger of abrasion (Farrell, et al., 2007). There is a practice in which animal manure is used as fuel which takes away valuable fertilizer decreasing soil fertility and resulting in lower yields. It put together forces the households to consider costlier inorganic fertilizers (Farrell, et al., 2007). What is more, besides these health impacts, ladies in rural areas generally use long hours gathering wood-based biomass; time that will rather have been used for child-care, agricultural production, education, and various activities. Whereas the distances in cosmopolitan environment, people use to assemble fuel wood vary greatly, looking the countryside is worse, distances increase extremely in the Countryside-Case studies suggest up to 10 miles (International Environmental Agency, 2006). This demonstrates that gathering fuelwood is additionally physically exerting and put together within the centre of various negative attributes, like sexual assaults and snake bites. However, it should be noted that grouping fuelwood sometimes happens as a "by-product" of various activities, e.g. walking to and from the fields, grouping water, and various daily activities. Fuel use at the agricultural and concrete households in varied African countries is either collected or purchased (Malimbwi, et al., 2010). As an example, fuel assortment in the Republic of the state is commonly the responsibility of women and children. at intervals, the agricultural areas, 90% of the population use collected fuel as compared to exclusively 20% at intervals the urban areas. In the Republic of Botswana, the quality distance cosmopolitan to fuelwood assortment points was 6 metric long measure and thus the time taken was regarding 3.3 hours (Zhou, et al., 2001). The distance to fetch fuel in the State of Eritrea is 10 kilometres and in most cases (80-90%) it is the responsibility of women and children (Semere, 2001). Per Klunne and Mugisha (2001), because of increasing sugarcane areas in the state, there has been a decline in fuelwood grouping areas resulting in longer distances cosmopolitan to access fuelwood. Because of moving long distances to assemble fuel, ladies and children in the rural continent are sometimes left with restricted time for various activities leading to low agricultural productivity and inadequate time to pursue educational opportunities.

Besides, ladies and children are the foremost vulnerable cluster in terms of energy insufficiency and adverse environmental impacts related to energy production and use (WEC, 1999). Ladies are the key users of ancient energy sources for unit activities as Associate in Nursing example, the preparation of food in most rural areas is that the responsibility of women ladies have smart interest and applied expertise at intervals the burning properties of various fuels, hearth and warmth management, fuel-saving techniques, and thus the advantages and downsides of various fuels and stoves. Ladies put together purchase (or influence the obtaining patterns of) fuels, stoves, and various unit energy appliances. further considerably, ladies influence the direct and indirect energy consumption patterns of their households (Reddy et al, 1997).

Since ladies are at the centre of unit energy use in rural areas, if ancient biomass energy use in Social Security Administration was progressive, it's uptake will bring sweeping changes in the short run and future and elevate unit living standards. Per girl's practice improved cook stoves meant free time, time gained from faster preparation was used for farming, income-generating activities, girls' education and women's participation in community life (Werner, 2009); 220 ladies interviewed mentioned they very much valued the chance to avoid trifling, way more than saving fuel (Vermeulen, 2001). However, since this greatly depends on opportunities offered at the community, proof from larger studies has shown mixed results once it involves whether or not or not the time saved goes towards productive uses or gain generation, like with improved access to water (Najman, 2010). Producing cook stoves can provide business opportunities for several entrepreneurs, whereas various operations like formalizing the charcoal sector and creating fuelwood markets can bring a variety of monetary gain generating edges. In Kenya, reports counsel that on every day, 337 improved cook stoves were created monthly per producer, unit earned a median monthly gain of US$120-US$240 (Werner, 2009).

Moreover, fuel, time and money savings may be an element for several businesses like restaurants that will be able to profit from newer technologies: as an example, households can save an enumerable half-ton of fuelwood annually if they own one amongst the new generation of improved stoves, that well affects their gain (Adkins et al., 2010) it is so important that girls and children are involved in property energy comes (Desanker & Zulu, 2001; Ward, et al., 2002). This may be often as a result of, improved energy technologies could in the reduction of the time and plodding related to energy acquisition tasks performed by poor ladies, e.g. assortment of fuelwood and water. Improved stoves, designed to chop back heat loss and increase combustion efficiency could significantly reduce indoor pollution, and guarantee economical fuelwood use (Karekezi & Kithyoma, 2002; Zhou, et al., 2001; ITDG-EA, 1999; Desanker & Zulu, 2001). Adopting energy efficiency measures at intervals the unit can in the reduction of the amount of fuelwood required. this may finish during very reduced fuelwood assortment journeys, so cathartic up a brief time for various activities (Bellerive Foundation, undated; Muguti et al, 1999). Additionally, improved energy services are Associate in Nursing input to gain generating activities (IGAs) of poor ladies.

2.5 Theoretical and Conceptual Framework

2.5.1: Theoretical framework

The theoretical and analytical framework of the study is underpinned by the idea of property resource management. The study adopted the Sustainable Natural Resource Management and Hardin (1968) theory of “the tragedy of the commons” the theories are combined in an exceedingly manner that attracts from the strengths of each theory for analysing the result of unit biomass consumption on the deforestation.

Sustainable resource management merely refers to the method of handling the natural resources in an exceeding approach that will be able to meet the wants of this generations while not compromising the needs of the longer term populations. Thus, doing, we tend to can accomplish a balance within the satisfaction of current and future generation’s wants. Hardin’s tragedy of the commons is equally wide applied in analysing natural resources management, particularly for understanding common environmental issues. Hardin’s theory analyses the implications or seemingly effects of common resources that access is unrestricted to individual members. Hardin (1968) argues that a typical resource is condemned to disappear once there is a level of free access. Thus, wherever individual members of the cluster have unchained access in the usage of these resources and therefore accept the common resource for his or her gains with none type of restrictions. A “common” could be a resource shared by several people in society or the community. Hence, everybody within the community has free access to a similar resource. During this framework, "shared" implies that everyone does not have entitlement to any a share of the reserve; however relatively to the utilization of some of it for his/her profit (Ponce, 2006). Hardins argued that within the non-appearance of the guideline, every individual can have some advantage of the playgrounds to his/her gain, typically while not limit. Beneath this state of dealings, the commons are exhausted and ultimately tumbledown; that he delineated because of the “tragedy of the commons”. The thrust of the thought of tragedy of the commons is that unrestrained self-interest of some people with regards to free access resources will lead to common things that have an effect on each population within the society. The underlying reasoning is that if the commons is eventually planning to run down, whoever effects the best use stands to learn the foremost. Beneath this circumstance, it is seen that the benefit/cost magnitude relation is astronomical. Whereas the advantages accrue only to the user, the prices are unfolding among all others sharing the commons. These theories are combined for the analysing the results of household’s biomass fuel consumption of the vegetation of the surrounding areas.

2.5.2: Conceptual framework

The conceptual framework demonstrates the implications of households’ biomass consumption, deforestation and associated health risk to the users. The figure shows that traditional biomass consumptions by households can leads to a number of direct and indirect effects, including; deforestation, CO2 emission and environmental and health risk to users. The commonest biomass fuel used by most households in the study area includes; wood fuel, crop residues, and charcoal. However, most households still use traditional cooking stoves which are largely inefficient and produce extensive heat and smoke that poses health risk to users. The world health organization reports that indoor residual smoke causes approximately 2 million deaths per year, due to the IAP. Globally, Gordon et al, (2014) reports that, indoor air pollutions (IAP) accounts for about 3·5–4 million deaths every year. This situation is more common among women and children in developing countries, who are more connected to domestic cooking and household chores. Aside the direct health effect of IAP, households' biomass consumptions also causes deforestation and depletion of forest because forest is the main sources of wood fuel to most households in developing countries. As a result of population expansion and urbanization, the use of charcoal and wood fuel is expected to expand, leasing to over exploitation, depletion and deforestation. This will consequently increase the presence of green households' gases such as carbon dioxide in the atmosphere.

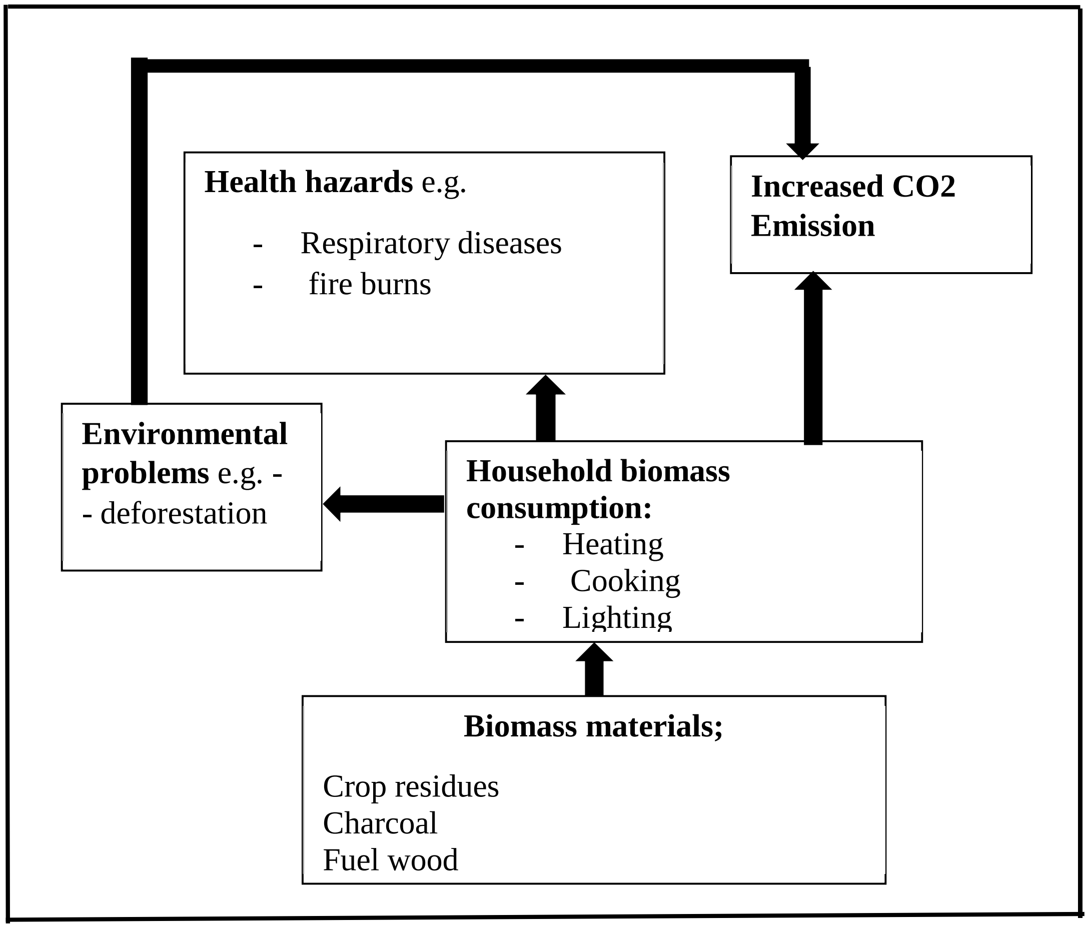

Figure 2.1: Implications of households' biomass consumption

Source: Authors construct, 2018.

From (Figure 2.1), households' biomass use can result in a number of risk: health and environmental risk that can have serious implications for sustainable development. First, the cause of households' fuel wood can cause serious health problems especially for those who regularly engage in cooking. Women and girls are at greater risk because they are the once involved in the cooking and household making. Excessive heat and smoke inhalation is a known cause of several respiratory diseases and disorders (WHO, 2005), and responsible for the death of several women and children yearly. Aside this, the continues cutting of fire wood influences environmental degradation and deforestations, especially in areas the main source of energy is the fuel wool. For instance, the continues cutting of trees, especially when it exceeds natural regenerative capacity will lead to the deforestation. Furthermore, the unsustainable logging of fire wood can lead to increased greenhouse gas emission and exacerbate climate change in the long run. This could pose serious consequence for the livelihood sustainability, especially in rain-fed dependent environments.

2.6 Conclusion

Overall, the review revealed considerable research has been conducted in the field of biomass consumption and environmental sustainability as well as health. However, not much has been done, especially for understanding the impact of households' biomass consumption on deforestation. The review covered a wide range of themes; around the research objectives. The first covered the theme "historical overview of biomass consumption". The review indicates that wood fuel forms the major source of domestic energy for cooking, heating and lighting in most households worldwide, and particularly in developing countries such as Africa. Thus, although a significant proportion of households have transitioned to the use of improved cooking stoves, a considerable majority of them in Africa still burn wood fuel in the traditionally ways. The use of traditional system of using wood fuel is associated inefficiency, and emission of smoke that have health implications for the users, especially women and children. Fortunately, technological advancement in improving households' cooking methods have emerged and currently been adopted in many countries including Ghana. These improved cooking stoves technologies have the potentials not only to eradicate the health hazards associated with the traditional methods, but also enhances efficiency in the way fuel wood is burned. Secondly, biomass consumption and deforestation has also been covered in the review. The review revealed that households' biomass consumption has significant effect on deforestation. For instance, 11% of wood fuel collected in Cambodian comes from forest reserves. In particular, deforestation is more common among areas where conversion of lands from forest to agriculture uses occurs.

Furthermore, deforestation has implication for GHG emission and consequently climate change. Thirdly, the review also examined the various improved household cooking stoves. There are several improves stoves technologies available in the market. These technologies were developed in responses to the growing health and environmental concerns associated with the traditional methods of cooking. These technologies have been improved upon as technology progress, and currently there are more sophisticates and highly efficient cooking stoves available in the markets.

CHAPTER THREE

STUDY AREA AND METHODOLOGY

3.1 Introduction

Chapter three comprises two main themes; descriptions of the study area and the research methodology employed. Hence, the first part of this chapter presents the profile of the Sissala East Municipal in the context of the upper west regional geography, and part two presents a detailed description of the research methodology; source of data, data collection methods, and data analysis techniques.

3.2 Description of Study Area

The study was undertaken within the Sissala East Municipality which is one the eleven districts within the upper west region of the Ghana. The Municipal was created in the year 2004 by the Legislative Instrument (LI.) 1766 with Tumu as its capital. The municipality is found within the northern part of the upper west region of Ghana. It falls between Longitudes 1 degree west and Latitude 10-degree north and 11-degree north. It shares boundary on the north with Burkina Faso, on the east with KassenaNankana West and Builsa District, to the south-east with West Mamprusi District, south-west with Wa East and Daffiama-Bussie-Issah districts and the west by Sissala West District. The Municipality has a land size of about 5,092.8 sq. Kilometres.

The Sissala East Municipality was chosen due to the fact that it has been so far the area with high production of charcoal in the upper west region relative to other districts in the region. First, the level of charcoal and fuelwood supply/production in the Municipality is one of the highest in the upper west region and the location of Gbelle forest reserve (the only forest reserve in the upper west region) makes it strategically suitable for this study. Thus, the availability of forest reserve in the Municipality serves as the main source of fuel and charcoal fuel supply not only to the municipality but the entire region. In the municipality's Medium Term Development Plan (MTDP 2014-17) charcoal and fuelwood production/supply were identified as a major source of income to a significant proportion of the population, an indication that the sectors play an important part in the socio-economic development of the Municipality.

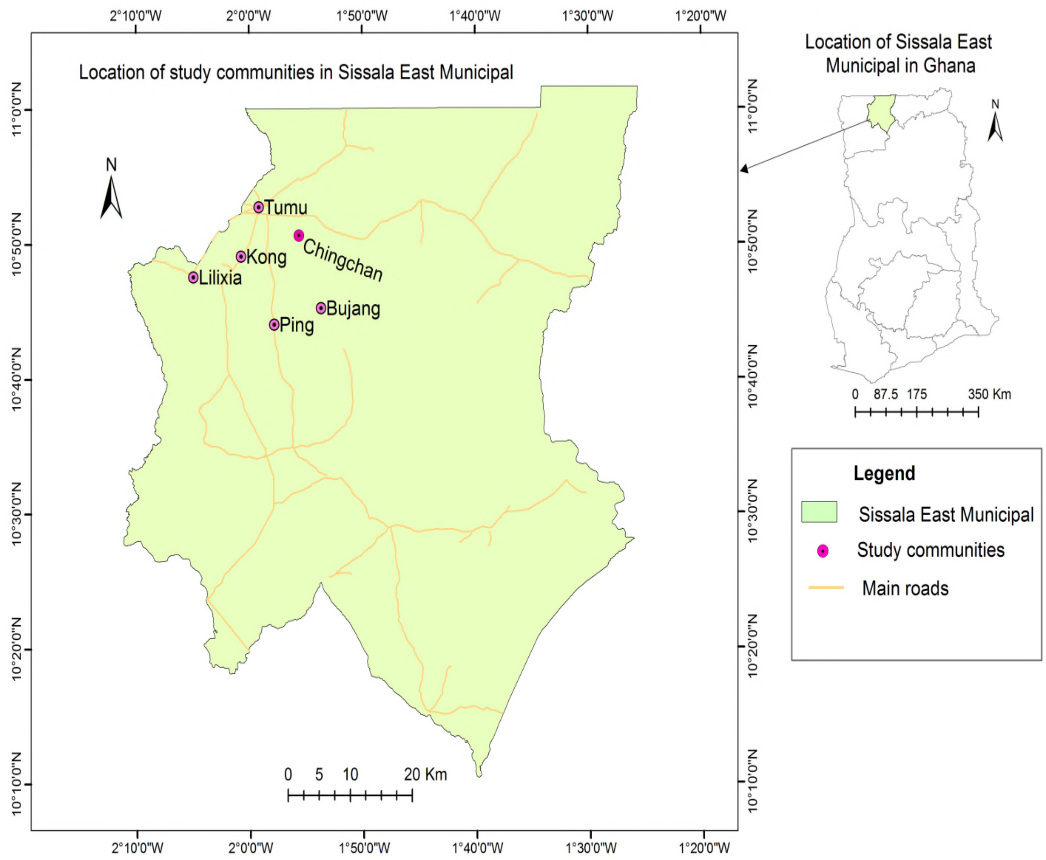

Figure 3.1: Study area Map of Sisala East Municipality
Source: Authors Construct, 2018

The total population of the Municipality is 56,528 (with 8,652 households) representing 8.1 percent of the Upper West Region's total population (GSS Regional Analytical Report, 2013). Out of this number, 48.7% of them are male and 51.3% female. Like the rest of the upper west region, the Municipality is largely rural, with a majority of the population living in the rural areas (81.2%) and 18.8% living in urban. The Municipality has a relatively young population as the majority of the population in the

Municipality fall within the age group of 5-9 years, representing 15.2%. On the other hand, the population within the age group 80-84 years constitutes the least population of the Municipality, representing 0.8%.

Historically, the people of Sisaala East Municipal are the Sisala tribes, although there are other settler tribes such as the *Dagaaba, Waala, Frafra, Akan*, and *Moshie* who co-exist peacefully in the Municipality. The people speak *Sisaala* language and like most tribes in Ghana, celebrate a cultural festival known as the *Paare-Gbiele* (traditional festival) which is celebrated by the chief and people every year to thank the gods and ancestors for a successful harvest. The "*Tumu kuoro*" is the overlord of the Sissala traditional council and all sub-chief owe allegiance to the *Tumu kuoro* kinship. The staple crops grown in the Municipality include cereals such as maize, millet, sorghum, and tubers such as yam and cassava.

According to the Ghana applied mathematics Service Report (2014), the Municipality is found within the Guinea Savannah vegetation belt and its vegetation consists of grasses and scattered heat-resistant trees just like the Shea, the Baobab and Dawadawa. The heterogeneous collections of these trees support domestic necessities for preparation fuel, constructing homes, constructing cows' kraals and fencing of gardens. The shorter shrubs and grasses offer fodder for stock. The climate of the municipality follows a general pattern known with the three northern regions. Its rainy season from June to September with a mean annual downfall of about 121 mm. This is often followed by Harmatan thus, a chronic season characterized by cold and hazy weather from early December month to March. The Harmattan season followed by intense weather conditions that end with the onset of early rains. The mean monthly temperature ranges between 21ºc and 32ºc. Temperatures rise to their most (42ºc) in

March, just before the onset of the rain season, and fall to their minimum (12ºc) in December throughout the due to the cold air that's brought by the north-east trade winds. Like different elements of the Republic of Ghana, the foremost supply of domestic cooking fuel within the Municipality is wood, representing 74% of the whole supply of cooking fuel within the Municipality. This is followed by charcoal (19.3%), and LPG (2.1%). For wood fuel, the figures are higher for rural dwellers (94.1%) as compared to urban dwellers (21.8%) however with regards to charcoal, the reverse is that the case. Thus, additional households in urban areas use charcoal for preparation (64%) than in rural areas that recorded (2.8%). Moreover, wood fuel serves a serious range of homes within the Municipality (2.5%) as the of the supply lighting within the night.

The Municipality is rural with about 8% of the individuals living in rural settlements. Therefore, the Municipality's economic scenario is typically farming, dominated by farming and agricultural connected activities (GSS, 2010 PHC). Agriculture, the foremost leader within the Municipality is usually subsistence with solely some engaged in business like cotton farming. About 69% of households within the Municipality are engaged in agriculture and associated activities and 6% of those in agriculture are into crop farming, cultivating staple crops like millet, maize, sorghum, and rice. The rest are groundnut, cowpea, yam, and cotton. Livestock farming additionally represents a heavy supply of monetary gain as 49% of the households keep livestock. Thus, livestock rearing is the second most vital agricultural activity. Animals are reared to supplement the income of households. Households keep each ruminant and non-ruminants such as birds. Among the ruminants, the commonest are cows, goats, and sheep. Within the bird class, they include; chicken, guinea fowls, doves, ducks, and ostriches. Generally, the physical characteristics of the Municipality reflect that of the upper west region and guinea savannah to an even bigger extent. The types of rock that underlie the Municipality include the Birimian and granite. These rocks hold a considerable quantity of water. This suggests that boreholes and hand-dug wells will simply be successful to create water on the marketplace for domestic and other functions. There are numerous varieties of soils within the Municipality that support plant growth and agriculture production. The foremost ones are the savannah ochrosols, the tropical brown earth and also the terrace soils. The savannah ochrosols are typically poor in organic matter and nutrients.

This can be often being as a result of the absence of dense vegetation caused by bush burning, overgrazing and poor farming practices within the Municipality. The service and commerce sector constitutes solely 15% of employment within the Municipality. The commerce sector is dominated by buying and marketing of agricultural produce, regionally factory-made things and used items. Business activities are high throughout the weekly market days. There are 2 weekly markets within the Municipality: *Tumu and Bugubelle.* Besides these weekly markets, there are outlets within town centers wherever a decent vary of factory-made merchandise and basic home goods are oversubscribed. Business activities within the Municipality are outstanding as a result of it sharing a border with the state.

Thus, several traders return from the state with a decent variety of products like onions, potatoes, cattle, sheep and high yielding mango seedlings. The industrial sector that's dominated by producing constitutes solely 16% of total employment within the Municipality. The planet is dominated by small-scale industries like shea butter and different oil and fat extractive industries, production of native drinks, blacksmithing, metalwork, weaving, etc. Others are producing farm implements like donkey carts, chairs, and school-play instrumentality. there's a big cotton ginnery industrial outfit, placed in *Tumu* that employs over 5 hundred individuals from and outdoors the Municipality. The rest of the manufacturing activities embody weaving and craft, pottery and trade. Different industrial activities embody trade, masonry, building and construction, and repairman.

3.3 Research Design

A mixed research design was used in this study, which combined both qualitative and quantitative research approaches in the data collection and analysis. A composite research approach is appropriate for this study because of its numerous advantages. The advantages of such a holistic research design cannot be overemphasized (Creswell, 2009; Brian, 2012 and Bryman, 2016). First, a composite research approach allows the researcher to draw from the strengths of both approaches for a robust and detailed study. Also, the systematic application of both qualitative and quantitative methods enhances complementarities in the study. Integrating both qualitative and quantitative research methods ensure the researcher explored the issues from multiple perspectives of a deeper understanding of the issues regarding the exploitation, uses, and effects of households' wood fuel.

Furthermore, the triangulation of data sources is equally achieved, which enhances data quality and validity of the research. The overall advantage of a mixed-method design is that it enhances both in-depth (detailed) and breadth in the study. Whiles, it enhances deeper understanding; generalization of the research findings is equally possible. Considering these advantages, the researcher chose a mixed-method design that combined focus group discussions (FGDs), key informant interviews and a household survey for collecting and analysing the data. These methods were systematically applied to enhance data validity and reliability.

3.3.1: Type and sources of data

The study sourced data from primary and secondary sources. First, the desk review method was employed to analyses relevant data for understanding the context of the study. Thus, relevant literature from books, journals, and articles and online resources were utilized for the design and development of the data collection tools.

3.3.2: Sample method and design

Based on the study design, a multi-stage sample design was adopted. Whiles the purposive sampling technique was applied in the qualitative study, the household survey utilized a systematic random sampling technique. Thus, at each stage of the study, the appropriate sampling technique (s) was applied. First, the research settings (communities) were purposively chosen with the help of a community development officer at the Sissala East Municipal Assembly. Ten communities where charcoal production/fuelwood harvesting is predominant were identified with the support of the Municipal community development officer. These six (6) communities were also sub-divided into urban and rural, and a simple random sampling technique was applied to select four (4) rural and two (2) urban areas for the study. These communities include; *Tumu, Lilixia, Ping, Bujang, Kong, and Chingchang* (Fig. 3.1). A multistage sampling design was adopted, to ensure that the study finding represents the views of both rural and urban settings, for a holistic understanding of the issues under study.

For the qualitative study, a purposive sampling technique was employed in the assortment of participants and discussants for interviews. The targeted respondents include; charcoal sellers, charcoal producers, wood fuel suppliers, and sellers. Participants were sampled with the assistance of community contact persons (Assembly members, unit committee members). Before the data collection, these target respondents in each of the sampled communities were identified with the help of community contact persons. Overall, six (6) FGDs and seven (7) key informant interviews were conducted for this study. There were 12 participants in each section six (6) males and six (6) females. The distribution of interviews is as distributed as follows; FGD sessions with processors of charcoal/wood fuel (1); FGD with charcoal sellers (1); FGDs with consumers of charcoal/wood (3); key informant interviews with community leaders and Environmental Protection Agency (EPA) (7). In the case of the household survey, a representative sample of 397 households was statistically determined, using the Yamine(1978) formula, ($n = \frac{N}{1+Ne^2}$) (Where; *n = Sample size; N = Population (3012); e = Level of precision or Sampling error (±5%) at 95 confidence level).*

Therefore, the households interviewed were **335**

This was proportionally distributed among the six (6) communities selected (Table 3.1).

Table 3.1: A sampling of responding households

Community	Number of households	Number sampled
Lilixia	86	10
Ping	74	8
Bujang	102	11
Kong	72	8
Chingchang	122	14
Tumu	2556	284
Total	3012	335

Source: Authors construct, 2018

A systematic random sampling technique was then applied to identify respondents for conducting interviews. The target respondents at the household level were female heads or their adult representatives in the households. Females were strategically targeted because they are deeply involved in household domestic activities including cooking and homemaking which is directly dependent on wood fuel and charcoal products.

3.*3.3: Data collection methods and tools*

The empirical data collection process utilized two main methods. First, focus group discussions (FGDs) and key informant interviews (KIIs) were conducted among charcoal sellers, charcoal producers, and wood fuel sellers across the six (6) sampled communities. FGDs and KIIs were facilitated by the researcher using interview guides and supported by a trained Research Assistant (RA). FGD sessions comprised between seven (7) to twelve (12) participants per session and lasted between 45 minutes to one (1) hour. All interviews were written manually in field notebooks and digitally in audio tape recorders and later transcribed into detailed field notes. Qualitative interviews transcribed were later categorized and classified for further analysis. Throughout the data collection process, the observation was critical in understanding certain practices at the household level for complementing and validating field data.

A household survey was also conducted as part of the study design. The survey was conducted among three hundred and thirty-three (335) sampled household respondents across all six sampled communities. The instrument used was a semi-structured interview questionnaire, administered by three (3) trained enumerators. The survey questions were structured along with the major research questions with available response options. Responses were recorded in the hard copies using pencils. All responses were later coded with numeric codes into the Statistical Package for Social Scientist (SPSS) for further analysis. A geographic information system(GPS) handheld device was used to pick locations of both standing trees and felled tree stumps in six (6) designated plots in the study area. This georeferenced data was used to develop maps using ArcGIS and other software to aid further analysis.

3.3.4: Data quality and validity measures

Internal data validity in the study was done through several measures: First, the data collection instrument was reviewed by the academic supervisor and friends to ensure that the tool was relevant. Secondly, the data collection tool was pre-tested and feedback incorporates into the tool. Furthermore, the data collection process was strategically staggered in two phases; starting with the household survey, followed by the in-depth interviews, this was deliberately done to draw lessons from the first phase to enrich the next stage. More so, because the data collection process employed both qualitative and quantitative methods, triangulation of data sources was possible which enhanced cross-validation of information, and thus enhance data quality and validity.

3.3.5: Data analysis and presentation

The data analysis process also utilized two main methods. Qualitative data were analysed using qualitative processes. First, raw field notes and audio files were transcribed, harmonized, synthesized and classified under the main research themes for easy reporting. Detailed direct quotations from discussants were also used to enrich the data. On the other hand, household survey data was first coded into SPSS software (version 20.1). Using descriptive statistics in the SPSS software, frequency tables, graphs, pie and bar charts and cross-tabulations were generated for presenting the results. Direct quotations paraphrasing and interpretations was used intermittently to enrich the discussion.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the results and discussion of the study. The results are presented in simple tables, crosstabs, graphs, and charts for easy reading. Furthermore, the results are discussed and organized around three main themes. These include; characteristics of household respondents, access and utilization of biomass energy in households and implications of households' biomass consumption on environment and health. In each of these domains, some sub-themes have been discussed.

4.2 Socio-demographic characteristics of household respondents

4.2.1: Sex /age distribution

Overall, three hundred and thirty-five (335) respondents who participated in the household survey. Out of this, 57% were females and 43% males (table 4.1). Thus, there were more females than men in the households' survey. More females were strategically selected because, in Ghana and particularly northern Ghana, women are more involved in domestic activities than men, hence were more placed to be able to respond to issues with regards to the subject under study than their male counterpart. Men were however involved to understand their views of the same issues, for comparative and detailed understanding.

In terms of age (Table 4.1), the results show that majority of the survey respondents were between the age brackets of 21-30, which represents (33.6%), followed by those within the ages of 31-40 (32.0%) and the least being those above age 60 years (0.8%). Cumulatively, those within the youthful ages (15-40) constitute 69.1% of the entire population of the study. This result reflects Ghana's demographic trends, which suggest youthful population is in the majority. The implication is also that, this shows great potential for labour, especially for households' productivity in agriculture.

Table 4.1: Sex /Age distribution of survey respondents

	Sex of respondent		
Age categories of respondents	**Female**	**Male**	**Average (%)**
15-20	6.1	0.0	3.5
21-30	33.5	33.8	33.6
31-40	26.9	38.8	32.0
41-50	25.9	25.6	25.8
51-60	6.1	1.9	4.30
above 60 years	1.4	0.0	0.8
Total (%)	**100.0**	**100.0**	**100.0**

Source: Field survey (March 2018)

4.2.2: Distribution of occupation

Table 4.2 presents the distribution of occupations of households' respondents involved in the study. From the table, the major occupation of most respondents is farming/agriculture work, representing about 93% of the survey participants. The remaining 7% is distributed among; trader/entrepreneurship (1.4%); public/civil servants (1.9%). The occupational distribution depicts a typical rural agrarian economy, with the majority of its population engaged as farmers and agriculture workers. This typically reflects the Ghanaian economy, where over 44.3% of the population is into agriculture (GSS, 2014).

The result reveals a significant insight with regards to sources of fuelwood for households in the study area. The major economic activity of respondents (agriculture) is the main source of fuelwood supply for most households. In the process of farming, some trees were cut down for farming activities, which will be used subsequently as fuelwood for the households' use.

Table 4.2: Primary occupation of household respondents

Occupation	Frequency	(% of respondents)
Farming/Agric	324	96.7
Trade/Entrepreneur	5	1.4
Civil Servant	7	2.0
Artisans	1	0.2
Unemployed	3	0.8
Others	10	2.9
Total	335	100

Source: Field Survey, 2018

4.2.3: Household size

From figure 4.1, households involved in the study have larger household sizes. Households' sizes ranged between 1-21 persons per household. The findings demonstrated that the majority of the households in the study area have members between 6-9 persons, representing 45% of the total respondents' households, followed by 2-5 persons (24%) and the least being those with household members 18-21 (2%) (Figure 4.1).

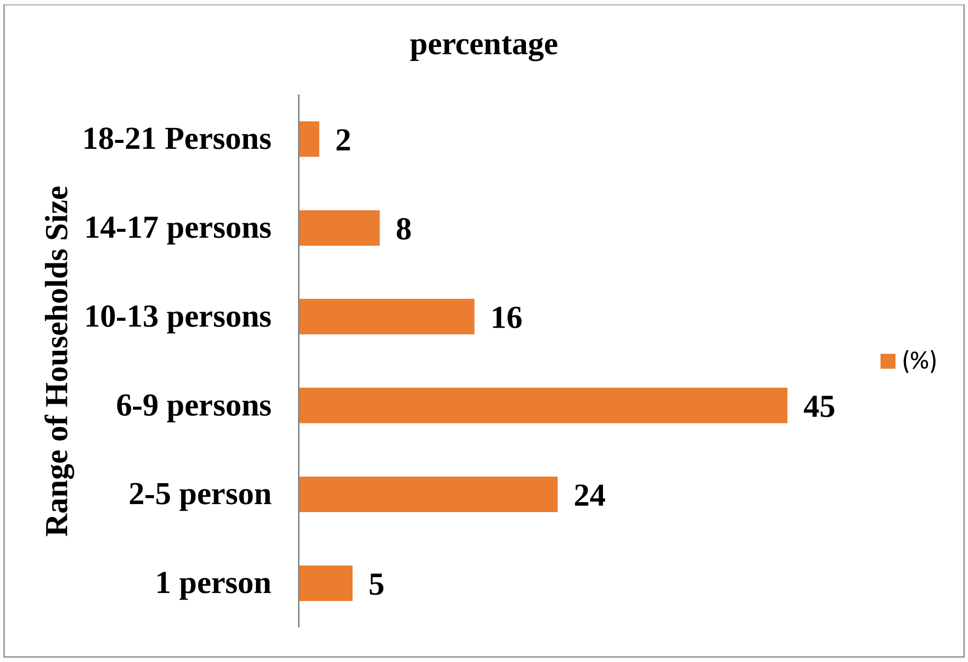

Figure 4.1: Household sizes in the study area
Source: Fieldwork, 2018

From figure 4.1, the result generally shows that households in the study area have larger sizes; a typical reflection of household sizes in rural Ghana. Large household sizes have both advantages and disadvantages depending on the perspective it is viewed. From a cultural and social point of view, large family sizes are sources of family labour, especially for agriculture activities, and for cultural purposes such as inheritance. Additionally, they are very important sources of social and economic support, especially during "difficult times" such as loss of loved ones. Hence, they are widely appreciated and valued in cultures that value social relations such as one prominent in the study area, and the wider Ghanaian society. From an economic perspective, large household sizes are real sources of burden and dependency. They increase the social burden of having to care for a large proportion of the inactive population, such as children and the elderly. From this perspective, it thus holds that large household sizes are undesirable because it breeds high dependency ratios, and reinforces extreme poverty, especially among already impoverished households. In effect, culturally, larger households are cherished but economically undesirable.

Earlier studies conducted in the Upper West Region and Sisal East District in particular generally corroborate these findings. In Ghana, especially northern Ghana, larger households' sizes are common, particularly in rural areas. According to the Ghana Statistical Service report (GSS, 2012), Ghana's national average household size is about 4 persons in a household. This figure, however, varies urban to rural; and from region to region. For instance, in the Upper West Region, the average household size is about 6 persons, which is the same in the Sissala East District (GSS, 2012). In another study conducted by Kuunibe et al (2013) in the Upper West Region, they found that the average household size in the Wa Municipality was about 7 members in a household.

These findings generally suggest that large household sizes are a characteristic feature of families in the Upper West Region, and Sisaala East District in particular. This has been attributed to the extended family systems which are very common in northern Ghana; the matrilineal inheritance systems, and the widespread polygamous marriage systems practiced in northern Ghana. Dividing the total fuel timber intake of 39,700,206 t/yr. through the number of inhabitants, which is 140,003,542 (Census, 2006), we get approximately 0.284 t/person/12 months, that is, approximately 0.776 kg/day.

Similar figures of biomass fuel usages are stated in several publications by many people. The distinction among urban and rural families was explained by the truth that urban households frequently have additional resources of power at their disposal, like kerosene, gas, charcoal, and electricity. As State-specific consumption figures are not available, we multiply the countrywide per-head timber fuel intake (countrywide average) of 0.284 t/person/12 months with the range of the population of Kaduna State, which is 6,066,562 (Census, 2006) and we get consumption of 1,722,904 t/year). According to Yahaya (2002), there exists an immediate relationship between the human population and wood fuel demand, hence, the cutting down of wet wood can be said to be at the increase. The rate of intake of gasoline wooden in Nigeria for instance exceeds the production in the country. Dividing the total fuel timber intake of 700,206 t/yr. through the number of inhabitants, that's 100 to 4,003,542 (Census, 2006), we tend to induce near zero.284 t/person/12 months, that is, near776 kg/day. Similar figures are expressed in many publications. the excellence among the town and rural families could even be explained by the fact that urban households oftentimes have further resources of power at their disposal, like kerosene, gas, charcoal, and electricity. As State-specific consumption figures aren't obtainable, we tend to multiply the countrywide per-head timber fuel intake (countrywide average) of zero.284 t/person/12 months with the vary of population of Kaduna State, which is 6,066,562 (Census, 2006) which we get consumption of 1,722,904 t/year). In step with Yahaya (2002), there exists an on the spot relationship between human population and wood fuel demand, hence, the reduction of wet wood is also aforesaid to be at the increase. The speed of intake of gas wood in the African nation exceeds the fee of production. It is so correct to mention this renewable provider of electricity would after be scarce, ought to this quite an exploitation continues.

4.2.4: Education and household energy sources

Further analysis of the result revealed a negative association between the level of education of household respondents and the use of fuelwood. From table 4.3, a majority (73.7%) of those without any form of education used fuelwood as their primary source of energy. As the level of educational attainment of respondents increases, their dependency on fuelwood (% of households using fuelwood) begins to generally tend to decrease. From the results, 20% of household respondents who had basic education used fuelwood as their primary energy source compared to 73.7% of those without any form of education. The remaining percentage (6.3%) is distributed among those with non-formal education (1.5%), secondary education (3.8%) and tertiary education (0.90%). Thus, the majority of those who relied on fuelwood as their primary sources of energy either do not have or have very little education. Conversely, in all households that used charcoal as their primary source of energy, the households' heads had basic education qualification. Differently put, all households' respondents with basic education used charcoal as their primary source of energy. Those who used LPG are equally distributed among those without any form of education (50%) and those with secondary education (50%) (Table 4.3).

Table 4.3: Level of education/biomass fuel source

Primary energy source	Level of education (%)					Total (%)
	None	Non-formal	Basic	Secondary	Tertiary	
Fuelwood	73.70	1.50	20.20	3.80	0.90	100.00
Charcoal	0.00	0.00	100.00	0.00	0.00	100.00
LPG	50.00	0.00	0.00	50.00	0.00	100.00
Average	**41.23**	**0.50**	**40.07**	**17.93**	**0.30**	**100.00**

Source: Field survey, 2018

Averagely, a significant proportion (41%) of respondents who used all three sources was not educated. This is followed by those with basic education (40%), and secondary education (17.9%). Non-formal and tertiary education shares were less than 1% each (Table 4.3). Again, these results essentially support the finding of earlier studies by Kuunibe et al (2013). In all these studies, the linkage between education and the choice of energy sources in households has been established, especially for rural households. For instance, Kuunibe et al (2013), analysed households' energy decision making among 200 households in the Wa municipality of the Upper West Region. They subsequently concluded that there is a negative association between the level of education of the heads of households and the likelihood of households using fuelwood for cooking and other household activities. They report that an additional increase in years of completed education of the head of households will make the household less likely to use firewood for cooking. In other words, like the level of education increase, the chances of a household using firewood generally tend to decline, because they will prefer improved modern methods such as LPG and electric cook stoves. In a similar study conducted by Heltberg (2003) in India and Brazil, it was found that as people gain more education, they are more likely to use modern energy sources such as LPG and electricity. These studies have been confirmed in several other studies including Mekonnen and Kohlin (2008) and Njong and Johannes (2011). This means a lot for public policy, especially for enhancing governments' goal of improving households' access to improved energy such as LPG and cooking stove. In the rural areas of Ghana where levels of education are generally low, it is, therefore, useful to pay more attention to the education of the citizens, if the government wants to reduce households' dependency on firewood.

4.3 Trees/plants species used for wood fuel/charcoal production in the study area

This section answers objective two of the study which seeks to identify the types of trees that are used as fuel by households in the study area. This portrays numerous tree species that are used by households to satisfy their households' energy consumption needs. There are many biomass products used as fuel worldwide. However, the common ones in Ghana include; wood fuel (firewood), charcoal and crop residue (crop remains). The primary source of energy for most households remains firewood, and secondly charcoal. Primarily, these two biomass products are (fuelwood and charcoal) are produced from wood resources, harvested or collected from the forest, savannah woodland or farm clearing. As part of the research objectives, the study sought to identify the types of trees most often used for charcoal production and firewood in households.

From the results (Figure 4.2), the predominant type of trees/plant species used for fuelwood and charcoal production in the study area include; from the results (Figure 4.2), the most prominent plant materials used for fuelwood are; rosewood (27%); mahogany (26%); Shea (23%) and dawadawa trees (20%). The remaining put together is less than 5% (figure 5). This means that a large proportion of fuelwood and charcoal produced in the study are made of wood from these tree species. Altogether, rosewood and mahogany trees constitute more than half (53%) of the entire composition of charcoal and firewood in the study area. As a result, indiscriminate fuelwood harvesting and charcoal productions in the study would post severe consequences for these tree species. Thus, if indiscriminate harvesting of wood is unchecked, the existence of these tree species (Rosewood, Mahogany, Shea, And Dawadawa trees) would be seriously under threat, especially that the use of unsustainable collection methods is widespread in the study area (Figure 4.2)

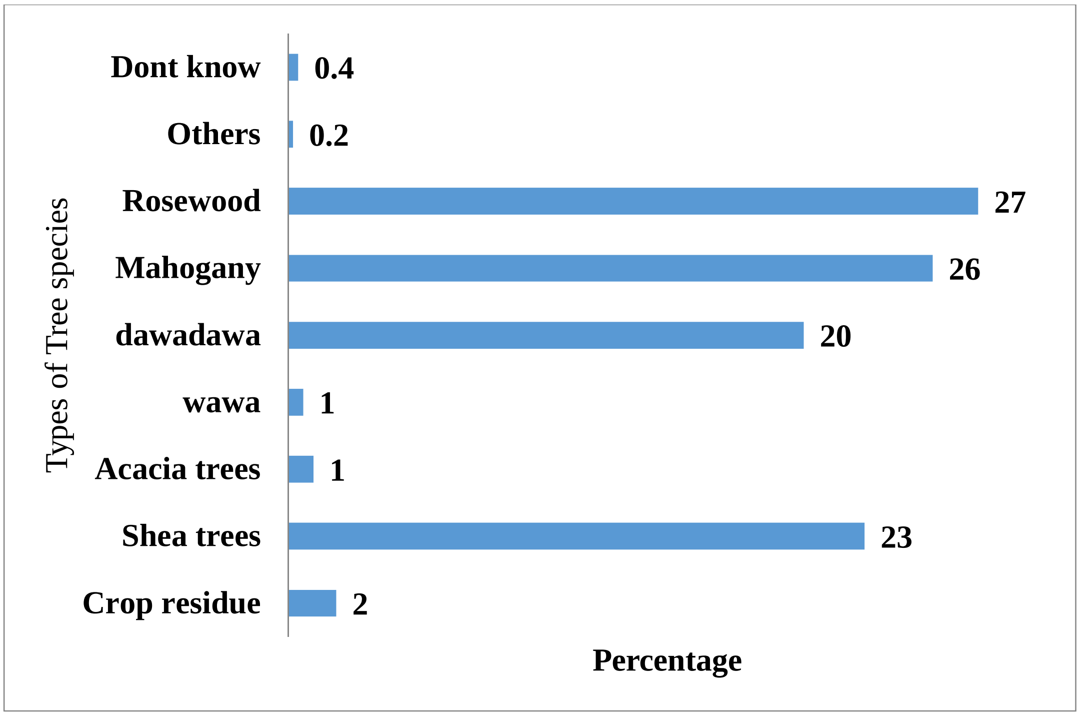

Figure 4.2: Materials for domestic energy
Source: Field survey, 2018.

From in-depth interviews, however, it was revealed that charcoal production uses trees species differently from firewood. Key informant interviews with charcoal producers indicate that specific trees species (such as Shea trees) are particularly desirable for charcoal production because they produce high-quality charcoal. According to them, charcoal produced from Shea trees gives a very "fine and efficient fire" as compared to other woods. Ultimately, every charcoal producer prefers to use the Shea tree for their charcoal production. This situation is partly driven by customers'/consumers' preference for Shea charcoal (charcoal produced from Shea trees). As a result of this situation, excessive exploitation of the Shea tree is happening; to the extent that some charcoal produces tend to cut fresh Shea trees for their production. Hence, putting the Shea tree in particular, under serious threat, and potentially endangering the livelihoods, nutrition, and income sources of the majority of the rural population, especially women. This is because, the Shea tree not only serves as a source of nutrition for many households but also a majority source of income for a considerable proportion of rural women, especially in northern Ghana. Thus, apart from being a major source of nutrition, the Shea tree is also an important economic tree that must be protected from over-exploitation. According to FGD interviews, due to the existential threat of charcoal production on Shea tree, stakeholders in most communities (Chiefs, Elders, Tindanas, and Assembly Members) have instituted bylaws for protecting the Shea tree in particular. For instance, it was widely reported across most communities that cutting of fresh Shea trees for any reason is prohibited and punishable by the customary and by-laws. These punishments range from outright payment of fines (maximum - GHC1000), livestock and facing of law court prosecution. However, the punishment for indiscriminate cutting of Shea trees varied from community to community. However, on the whole, these punishments are not deterrent enough to curb the situation, considering the lucrative nature of charcoal business in the area. Excerpts from key informants' interviews with a charcoal producer in the Lilixia community were reported as follows;

> *.... among all trees, the Shea tree is the best for charcoal production. However, we are not allowed to cut them. This is because, apart from being a source of food and nutrition for us, it is also a source of income to women in particular. that cutting them down for charcoal will deprive our women of their livelihoods. Because of this, in some communities, it is not allowed to cut*

Shea trees. In fact, in this community, the chief has decreed that, and if you dare cut fresh trees, you will be held responsible… (Male Key informant Lilixia community, 03.2018)

4.3.1: Reasons for using specific trees species for fuelwood/charcoal

Different reasons informed households' choices for using specific trees/plants for firewood or charcoal production. The most common reasons include; availability, efficiency, and affordability (cost). From table 4.4, an average (29%) of households chose to use rosewood for firewood in their households. This is followed by mahogany (26%), Shea (22%) and Dawadawa tree (20%). Thus, overall, more than half (55%) of households in the study area used rosewood and mahogany for firewood. the reasons for choosing these particular trees varies from one species to the other. For instance, 33% of households who chose to use rosewood trees as firewood in their households did so, because of its efficiency (producing good fire).

Table 4.4: Preferred trees for fuelwood

Type of materials used	**Reasons for using it (%)**			
	Readily available	**Fuel efficient**	**Affordable**	**Average**
Crop residue	2.30	0.00	1.20	1.00
Shea trees	23.60	19.30	22.2%	22.00
Acacia trees	1.00	0.00	2.10	1.00
Wawa	0.40	0.00	1.00	0.00
Dawadawa	20.80	19.30	20.30	20.00
Mahogany	24.40	28.40	26.60	26.00
Rosewood	27.20	33.00	25.50	29.00
Others	0.40	0.00	0.0.00	0.00
Don’t know	0.00	0.00	1.00	0.00
Total	**100.00**	**100.00**	**100.00**	**100.00**

Source: Field survey, 2018

Furthermore, 27% choose rosewood because it was readily available within their reach. Another 25% chose it because it was cheaper to acquire. Similarly, 28% of households chose the mahogany tree as firewood in their households. After all, it is efficient, followed by 26.6% who chose it because it was affordable and 24% chose it because it is readily available. On the contrary, the majority of households that chose Shea tree did so because it is readily available (23.6%), followed by affordability (22.2%) and the least with efficiency (19%). From the results, it is evident that cost/affordability (which is critical in household energy decision making) has less influence on households' decision making with regards to the particular tree/plant to use for fuelwood. This, therefore, means that, when it comes to firewood selection, efficiency and availability of the wood product is much more critical than the cost.

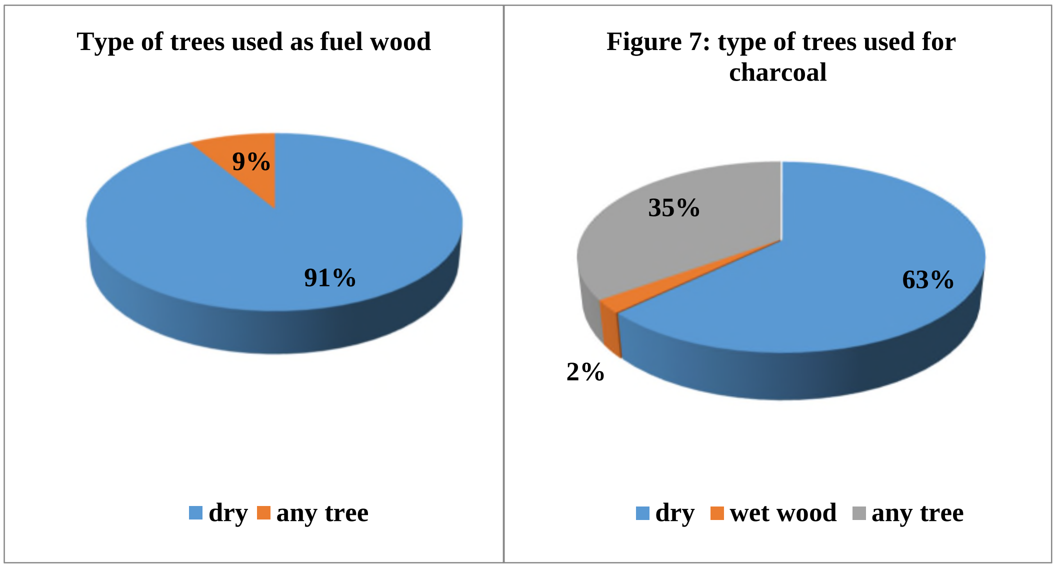

Figure 4.3: Types of tree species used as fuel for rural and urban household
Source: Field survey, 2018

The results further show that dry woods are often used for fuelwood. However, other woods from fresh trees are used for charcoal production. From figures (6) and (7), 91% of wood products used as fuelwood in the household are dry wood, as compared to 63% for charcoal production (Figure 4.3). Furthermore, about 35% of charcoal producers use wet wood in the production of charcoal fuel. This means that firewood used in households is mainly made up of dry wood, but those used for charcoal production is made up of both wet and dry planks of wood.

Furthermore, half of the respondents reported that they used dry trees as fuel because it is readily available. Another 69% used dry wood because of its efficiency, whiles another 74.2% does so because dry wood is very cheap to afford. However, only 3.8% use fresh wood essentially because is readily available. Others also used any tree available (46.2%) because it is readily available, 30.6% used any tree because of efficiency, whiles 25.8% used any tree they found for fuelwood because it is very cheap.

Key informant interviews with sampled charcoal producers across study communities largely corroborate the foregoing results. According to the key informant, charcoal production utilizes both wet and dry kinds of wood. Most producers would have preferred using wet wood because it gives high-quality charcoal than dry wood. However, there are restrictions from the forestry commissions and community leaders concerning using fresh/wet wood for charcoal production. A key informant summarises it in the following statements;

> *"...for charcoal production you can use both wet and dry trees but we are not allowed to use the wet or fresh trees because of the law. But the fresh wood even properly and gives high-quality charcoal" (Key Informant, Ping Community, 03.2018).*

The conversion of wood to charcoal may be barely but determiner inside the charcoal worth chain. Generally, ancient kilns are used, that finish in low conversion efficiencies. Interventions abound in many government agency countries have tried to beat this challenge by promoting a lot of economical kilns for charcoal production, but the adoption rate has been restricted. The explanations for this are primarily found inside the informal and infrequently illegal nature of charcoal production as of times pictured throughout this paper. Higher material costs inflated labour input, but additionally, lack of information all represents disincentives for charcoal burners to adopt improved technologies in things where they are not rewarded with inflated prices or wherever the danger of discovery may need abandoning the assembly information processing system (compare Hedon, 2010).

Besides structure enhancements and conjointly the organisation of charcoal production and mercantilism, charcoaling technologies are altogether likelihood the key drive to cut back the quantity of woody biomass required per unit of charcoal created. Policies, which can promote improved household appliance technologies, are essential for property charcoal production. Moreover, if the entire charcoal chain is reformed throughout a comprehensive manner, adoption of improved and wide accepted household appliance technologies has to be a piece of revised restrictive frameworks in form of standards for oven technology to be applied. A core challenge once enhancing the household appliance technology is that it would love a modification inside the socio-organization structure of charcoal production. At present, ancient and improved kilns are created inside the forest where the wood is harvested; once improved kilns are used, producers desire an awfully little chimney which can be merely transported by bicycle or on foot. However, semi-industrial ovens are a lot of permanent structures that need the wood to be transported to the oven. Given already the challenges individual charcoal producers face for creating stripped technology enhancements like chimneys, semi-industrial technology can entirely be established through larger-scale personal investments or once joint investments by former individual charcoal producers is expedited, as an example by forming producer associations or cooperatives. If larger-scale personal investors establish or industrial household appliance technology, the wood-sourcing has to ideally return throughout sodbuster schemes of different benefit-sharing arrangements allowing the native population to continue earning a gradual gain through the charcoal sector.

A key element for promoting improved household appliance technology desires to provide cash resources to potential investors. As a result of the inflated costs of improved household appliance technology, seed funding in form of "one-time" input subsidies is, also a policy alternative, although subsidies don't appear to be most well-liked, given the necessity for external inputs and also the prospect that funds are misallocated. If they're applied, however, they have to not be a permanent element of any network. Also, micro-credit schemes could provide cooperatives and individual producers with the finances needed. The potential for reducing GHG emissions by promoting the appliance of improved household appliance technology is tremendous, not entirely as a result of higher charcoaling efficiencies, but additionally as a result of the appliance of GHG reducing technologies and conjointly the prospect of electricity co-generation. A coupled impact of inflated remodelling efficiency and better GHG management reduces GHGs significantly.

As an example, current industrial kind kilns have entirely however 10% of gas emissions compared to ancient kilns. additionally, larger-scale charcoaling facilities may might also the energy generated throughout the charcoaling methodology to co-generate electricity an idea that may presumably contribute additionally to extending off-grid electricity generation in rural areas of the varied desert African countries (ESMAP, 2010). Mode of an assortment of wood/charcoal fuel. In developing regions enthusiastic about biomass, women and children are in control of fuel assortment, a protracted and exhausting task. The common fuelwood load in the nation-state is around twenty kilos but varied 38 Kilos (Rwelamira, 1999) have additionally been recorded.

women can suffer serious long physical injury from strenuous work whereas not ample recovery. This risk, however as a result of the prospect of falls, bites or assault, rises steeply the removed from home women have to walk, as an example as a result of the conversion of land to agricultural uses. The everyday distance is highest inside the central region of Singida, at over ten kilometres per day, followed by the western regions on the brink of Lake Tanganyika, where it's larger than five kilometres per day.

Assortment time incorporates an important price, limiting the chance for ladies and children to strengthen their education and move in income-generating activities. Many children are drawn from schools to attend to domestic chores associated with biomass use, reducing their accomplishment and limiting their economic opportunities. Fashionable energy services promote economic development by enhancing the productivity of labour and capital. Many economical technologies provide higher-quality energy services at lower costs and unlock unit time, significantly that of girls and children, for many productive functions. There are vital development edges to be gained from increasing access to fashionable energy services. The worldwide organization Millennium Project (2005) has made it emphatic that there are links which exist between energy and every 1/8 of the Millennium Development Goals (MDGs). Usually, the energy services facilitate deflate financial condition (MDG 1) and liable to play a necessary role in rising tutorial opportunities for kids, empowering women and promoting gender equality (MDGs 2 and 3). The supply of adequate clean energy is important in reducing child mortality (MDG 4). Reducing the carrying of greatly varied fuelwood improves maternal health (MDG 5). Inefficient combustion of fuelwood exacerbates metabolism diseases and different diseases (MDG 6). Fuel substitution and improved stove efficiencies would facilitate alleviate the environmental injury of biomass use (MDG 7). Finally, the widespread substitution of the latest energy for ancient biomass might be a purpose for world partnerships (MDG 8).

4.4 Access and Utilization of Biomass Energy in Households

This section presents the results of sources and utilization of biomass by the various households and individuals interviewed in the study. This sort meets the requirements in objective which seeks to examine the factors that determine households' biomass fuel choices in the study area. Specific issues considered are sources of the biomass, the uses, and quantity that are consumed.

4.4.1 Sources and uses of fuelwood/charcoal energy

Results from the survey, it was reported that there are differences in terms of the main source of households among rural and urban dwellers. Evidence showed that about 94% of rural households drive their fuel from mainly fuelwood. Meanwhile, just a few of these households get their fuel from charcoal and LPG, which is very minor, representing about 3% each of the responses.

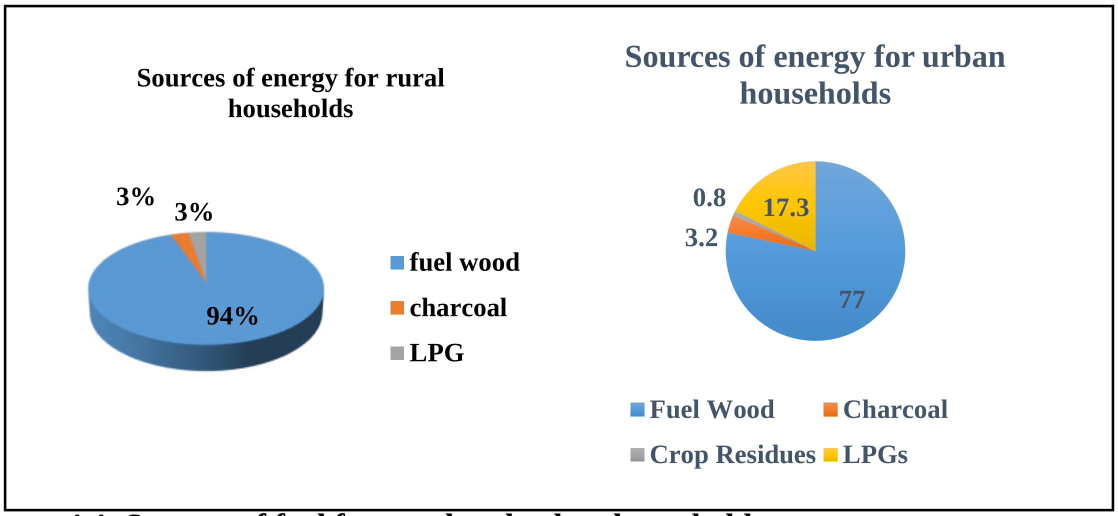

Figure 4.4: Sources of fuel for rural and urban households

Source: Field survey, 2018

There is a contrary view among urban dwellers. In these settings, households drive their fuel from mainly charcoal representing about 77% of the responses. Results from in-depth interviews similar to the results from the survey. According to However, others get their main household fuel from LPG (about 17.3%). Details are shown in (Figure 4.4). The results from the FGDs and key informant interviews (KIIs), the primary source of energy in most households is the fuelwood, and often being complemented by charcoal fuel. Further discussions revealed that it is a result of; 1) fuelwood is readily available and accessible 2) there is no or very little cost; 3) the need to cook large quantities of food daily for the large family sizes. These reasons were widely corroborated by almost all discussants across all six (6) research communities. In particular, a female discussant at Lilixia community reported in the following narratives;

> *"I can say all households in this community use fuelwood for domestic cooking activities. Although we produce charcoal in this community, very few people use it. This is because of owe of the fact that charcoal fire cannot cook large quantities of food we often cook here due to the large household sizes. Firewood is more useful than charcoal here. Also, because of the monetary value of charcoal most households prefer to sell it than use it themselves. We have firewood in abundance here and there is no need to be struggling with charcoal if firewood can do the cooking faster…" (Female discussant, Lilixia, 03.2018)*

Primarily, fuelwood/charcoal is used in households for cooking, heating, lighting and other domestic household chores. Wood fuel provides for about 2 billion persons in emerging nations (FAO, 2011), and in greatest of these states, wood fuel is not only necessary for domestic nutritional needs but also for the growth and development of local businesses and industries such as brewing, local chop bar cooking, baking, smoking, curing and electricity production (Trossero, 2002; Boampong, et al., 2015).

4.4.2: Uses of fuel woods in households

From the study, fuelwood has several uses at the household level including, cooking, heating, and lighting. However, its primary use, fuelwood is equally used for other none-domestic activities such as commercial chop bar operations, *Pito* brewing, baking of bread, smoking and electricity generation for industrial activities.

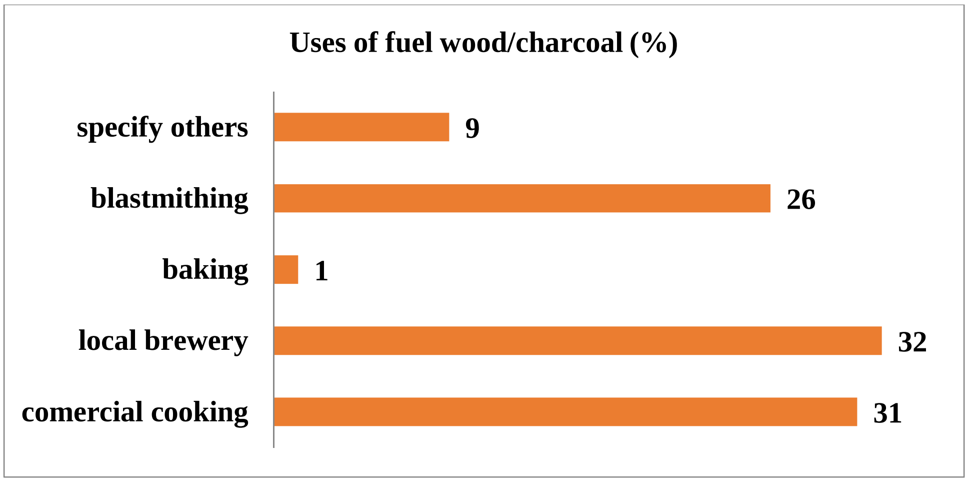

Figure 4.5: Uses of fuelwood/charcoal in households

Source: Field survey, 2018.

From the survey results, about 30.9% of household respondents reported that aside domestic cooking; fuelwood is also used for chop bar cooking, followed by local *Pito* brewery (32.2%), baking of bread (1.3%), blacksmithing activities (26.3%) and others such as smoking and heating (9.3%) (Figure 2). From Key informant interviews, it was revealed that brewing of local wine (*Pito*) consumes a lot of fuelwood because it takes three days to prepare. According to the key informant, each stage of boiling could use up to 30-50kgs of wood. This means that by the time the *Pito* is ready for consumption, between 90-150kgs of firewood would have been used.

From literature, the Food and Agriculture Organization (FAO), reports that at least 280 000 of 2.2 billion users of fuelwood in Africa use it for other none-domestic activities. Ghana's Energy, Commission (2010) reportable that aside domestic uses, fuelwood is additionally used for minor process activities, fish smoking, *Mandioca* creating, *Pito* production, *Akpeteshi* distillation, pottery creating, and oil extraction (from palm fruits, coconut, groundnut, shea butter). These activities contribute considerably to each Ghana's GDP and employment, particularly for girls in rural areas., aside from, that it's conjointly creating a big involvement in solving issues related to food security and preservation and money financial gain for the countryside and concrete individuals. also, the Ghana energy commission estimate that there are some 600 000 limited enterprises in industrial happenings, like chops bars, street food, and grills, that rely upon fuelwood or charcoal as their chief sources of energy.

4.4.3: Type and quantities of fuel wood consumed by households

The study results suggest there is a connection between household size and the quantity of fuel wood/charcoal they consumed. From table 4.4, the results show the largest household size (18-21 persons) consumes the largest quantity of wood fuel/charcoal products (above 21kg) daily. Thus, all quantities of charcoal/fuelwood above 21kgs were consumed in households that have members between 18 and 21.

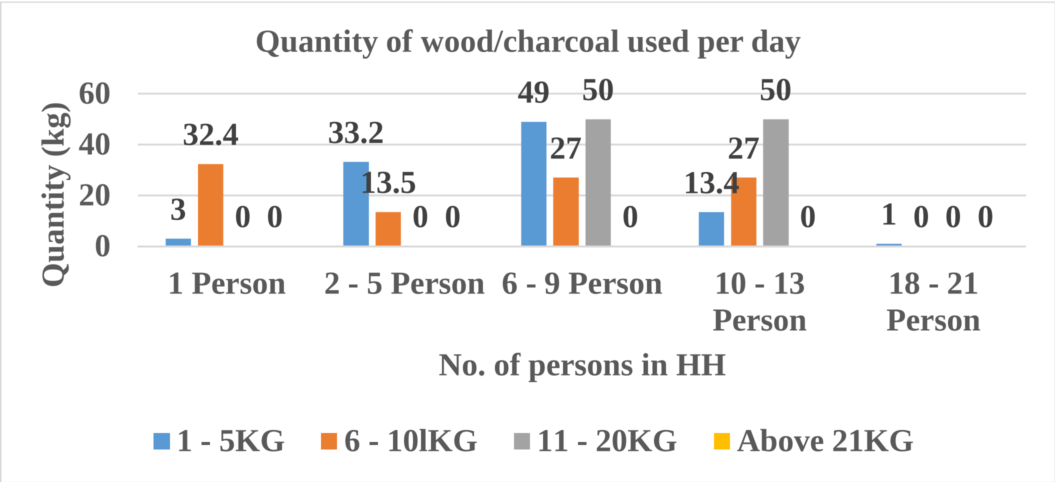

Figure 4.6: Household size and the quantity of biomass used per day
Source: Field survey, 2018.

The next largest households (10-13 persons) and (6-9 persons) also consume half of the largest quantities (16-20kgs and 11-15kgs respectively. Conversely, the least quantity (1-5kg) was consumed by only 1% of the largest household size (28-21 persons). (Figure 4.6). The results further show that the larger the family, the higher the quantity of wood consumed. This is because larger household sizes will need to cook a larger amount of food daily to feed a large number of persons. This also means the huge economic burden of providing food for all family members. Clearly, the results also show that households (6-9 persons) consume the largest quantities of fuelwood/charcoal; with an average score of 45.5%. This is followed by household size (2-5 persons) with an average score of 26.9%. The least average score (2.6%) was recorded among the largest household size (18-21 persons) (Figure 4.6).

The FGDs results further corroborate these results to a larger extent. During FGDs sessions at Bujang, Discussants reported that households with larger family members are abler and likely to consumed fuelwood/charcoal than those with fewer members. They report that the larger numbers of individuals require a larger cooking pot, especially in the cultural setting where communal eating and cooking is highly cherished. According to one discussant, the practice of communal cooking and eating is a value they are cherished because of its potentials to unite the children, and strengthened social ties, which also promotes peace and unity in the family. Discussants further disclosed that larger household sizes are particularly associated with traditional and Islamic homes where polygamy is a common feature of the family. In such homes, there noted that co-wives' cooks in turns for the entire family. For instance, a female discussant reported the following;

> *My husband has two wives. We both live in the same compound. Although we cook separately, we all eat from one pot. My husband has structured it in such*

a way that when I cook today, tomorrow it is the turn of my co-wife (rival) to also cook, except when she is sick or not around. In that case, I automatically assume cooking duties for the family. When one cooks, we share the food for all the family members; including my other co-wife. Cooking for more than 10 people daily requires lots of burning of fuelwood. In such cases, we cannot even use charcoal because it will delay the cooking process… (Female discussant, Bujang., 03.2018).

This report was equally corroborated in the Ping community. A male discussant reported that cooking for the larger family essentially requires that a lot of fuelwood be used. He reported that coming from a large household himself, he has practical experiences with the situation. According to him, his household size is 12 members; comprising two wives, him and nine (9) children. The two wives cook together for the entire family. This means that his household requires a lot of fuelwood daily to cook for the family. He reports that;

I have two wives but one doesn't cook because she's old. The younger one does the cooking for all of us. Daily, she carries a head load of fuelwood (estimated=6- 10kg) from the farm/bush for cooking. This has been a daily routine, and if she fails it a day, she has to resort to the wood bank (reserve wood) for cooking (male discussant, ping, 03.2018).

From the foregoing, it is sufficient to state that the larger the family size the higher the quantity of wood fuel used. Aside, this, it is instructive to note that larger family sizes are more likely to used wood fuel and not charcoal. This is because the larger numbers require bigger cooking pots/bowls which essentially require a large amount of heat that charcoal may not be able to provide. Thus, practically, using charcoal in for cooking in larger households is uncommon in the study area because it will slow down the process.

4.4.4: Average quantities consumed by households per day

On average, majority of households consume 1-5kgs of biomass (crop residue and wood/charcoal fuel) per day, followed by those who consume more than 21kgs per day (19.35%), and 16-20kgs per day (17.9%) and the is represent those who consume 11-15 kgs per day (8.5%) (Figure 4.7). Again, these results suggest the majority of the households interviewed have larger family sizes and thus require that food is cooked in larger quantities for all family members. However, the majority of households (74%) relied on wood fuel/charcoal more than crop residue (36.6%). Furthermore, the majority of households (67.6%) that relied on crop residues for their energy consumes large quantities of crop residues (16-20kg) and above 21kgs). This means that if a household wants to depend on crop residues for their energy needs, a lot of crop residue will be used. This is because crop residues are very light and burn faster than normal wood/charcoal fuel and thus, one needs a lot of them to be able to cook food as compared to fuelwood/charcoal. On the contrary, households that consumed a large amount of wood fuel/charcoal (16-20kgs) and (above 21kgs) constituted only 6.9% of the entire population that relied on fuelwood/charcoal for their households' energy needs (Figure 4.7).

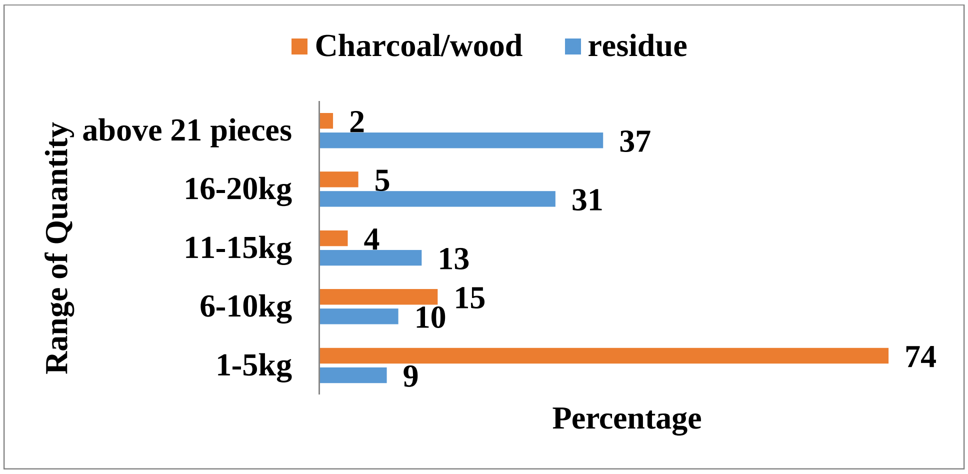

Figure 4.7: Quantities of biomass fuel used by households per day

Source: Field survey, 2018.

Ghana’s energy sector discourse is dominated by hydro and thermal power. However, biomass energy constitutes the most supply of energy for households. From literature, the Ghana energy commissioned estimates that charcoal and fuelwood constitute the best proportion of the energy matrix of Ghana; constituting 44% and 34% severally. Since hydro resources are nearly utterly employed by currently, any future increase in energy demand can have to be compelled to be met by either larger oil imports or wider use of biomass resources. It looks that sensible choices would be to extend property production and/or to scale back the demand by suggests that of upper potency in conversion and finish use of wood fuels. In a study conducted by Ghana's Energy Commission (2010), it had been established that fuelwood consumption has accumulated speedy increase in Ghana (from fifteen.9 million M3 to twenty.6 million M3, i.e. in 10 years (1988-1999) which ends in serious offer and demand imbalance and explanation for depletion of natural vegetation, significantly the savannah woodlands within the Brong Ahafo region. Ghana's forest resources are subject to several pressures together with pressure from indiscriminate wood harvest home, it's thus necessary to contemplate long-run resource management choices.

Throughout Black Africa, deforestation and degradation ensuing from accumulated population pressure, agricultural encroachment, uncontrolled and wasteful fuelwood harvest home, together with inefficient charcoal production are common (FAO, 2011). A 30% increase in fuelwood consumption over the last ten years implies that the per capita wood fuel consumption of Ghana getting ready to one M3 per capita per annum. This figure is predicted to extend as the population in growth and growth is predicted across Africa, together with Ghana.

Research has established a link between fuelwood consumption, poverty, and urban and rural dwelling. A study conducted by Ghana's Energy Commission (2010) shows that urban households are more likely to consume charcoal fuel than firewood. Conversely, rural households tend to consume more firewood than charcoal. Another study conducted by Nyarko (2015) found that wood fuel supply and demand patterns in Ghana are extremely unstable between countryside areas and urban areas. The use of biomass is also intertwined with poverty. For instance, a study conducted by (IEA, 2009) found that as households' income rises in developing countries, households tend to change to LPG and numerous types of specific electric cook stoves. However, expanding their incomes in a country will only decrease the number of people reliant on biomass by only 16% and an indication that biomass use will continue to increase in the future (IEA, 2009) cited in (World Bank, 2011). This supports the earlier findings that cost and affordability is the major factor inhibiting uptake and utilization of improved fuel energy alternatives in most impoverished societies. In another dimension, this is an indication that though the cost is a major factor in households' energy decision-making process, there are other important determinants such as household size. The government has become progressively involved concerning the necessity for combined action to preserve the country's wool fuel resources. It is expressed objectives to manage the wood fuel resources by strategies making certainly improved productivity (potency in transformation and distribution) economical us of those resources through the promotion of improved end-user devices and best practices cannot be achieved without empirically driven evidence, especially, for understanding households decision-making.

4.5 Spatial Analysis of the Nature of Tree Species Destruction by Households Biomass Consumers

This section presents a spatial analysis of the number of different tree species on plots of households. It also highlights the available trees population in the area by plots; taking a plot size to be a hectare. Details are in Figures 4.8 and 4.9). Spatial analysis of two (2) households plots from each of the communities *Bujang*, *Chingchan*, and *Kong* shows the variation in the population of different species of trees present on the plots of households. These are the type of trees that are normally used as households' biomass fuel in the study environment. The plots are populated with standing trees and felled tree stumps.

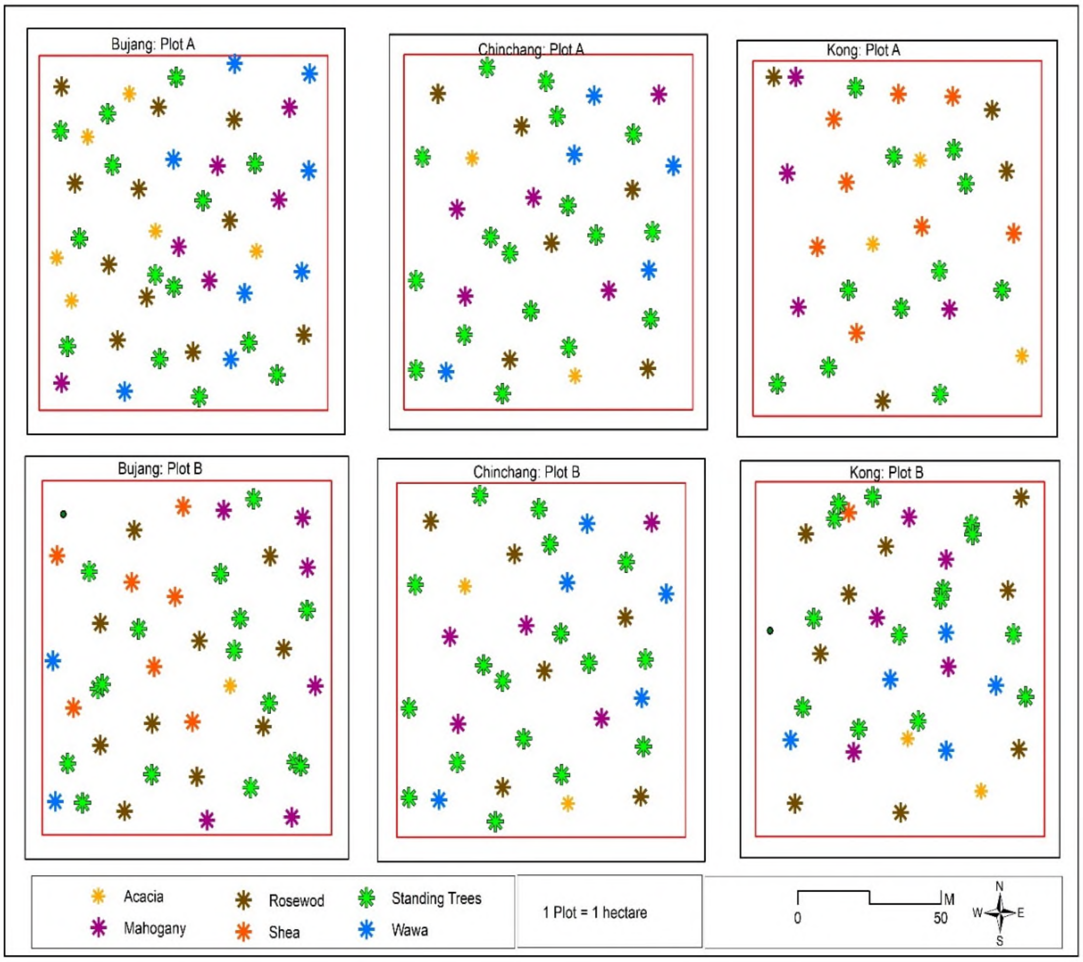

Figure 4.8: Number of trees species on households' plots of rural communities
Source: Field survey, 2019.

Their exact locations were taken with the help of a handheld GPS device. In the first household in the *Bujang* community, thus plot "A' has the following trees species population; Standing trees (14), tree stumps found include Acacia (6), Rosewood (11), Mahogany (6), Shea (0) and Wawa (8). In the second household plot, thus plot "B" the following details; felled tree stumps include Acacia (1), Rosewood (10), Mahogany (6), Shea (7) and that of Wawa (2) with Standing trees (14).

Table 4.5: Number of trees species on households plots in rural communities

Name of community	Type of trees	Number per plot	
		A	**A**
	Standing trees	14	14
	Acacia	6	1
Bujang	Rosewood	11	10
	Mahogany	6	6
	Shea	0	7
	Wawa	8	2
	Standing trees	17	17
	Acacia	2	2
Chingchan	Rosewood	6	6
	Mahogany	4	5
	Shea	0	2
	Wawa	5	5
	Standing trees	11	14
	Acacia	3	2
Kong	Rosewood	4	9
	Mahogany	4	5
	Shea	8	1
	Wawa	0	5

Source: Field survey, 2018

In the case of *Chingchan* community, while the first household – plot "A" has Standing trees (17) felled tree stumps were Acacia (2), Rosewood (6), Mahogany (4), Shea (0) and that of Wawa (5), the second household, thus plot "B" has Standing trees (17). Felled tree stumps include Acacia (2), Rosewood (6), Mahogany (5), Shea (2) and that of Wawa (5). On the other hand, while in Kong community, the first household, thus plot "A" has Acacia (3), Rosewood (4), Standing trees (11), Mahogany (4), Shea (8) and that of Wawa (0), the second household, thus plot "B" has Acacia (2), Rosewood

(9), Standing trees (14), Mahogany (5), Shea (1) and that of Wawa (5) (Figure 4.8 and Table 4.5).

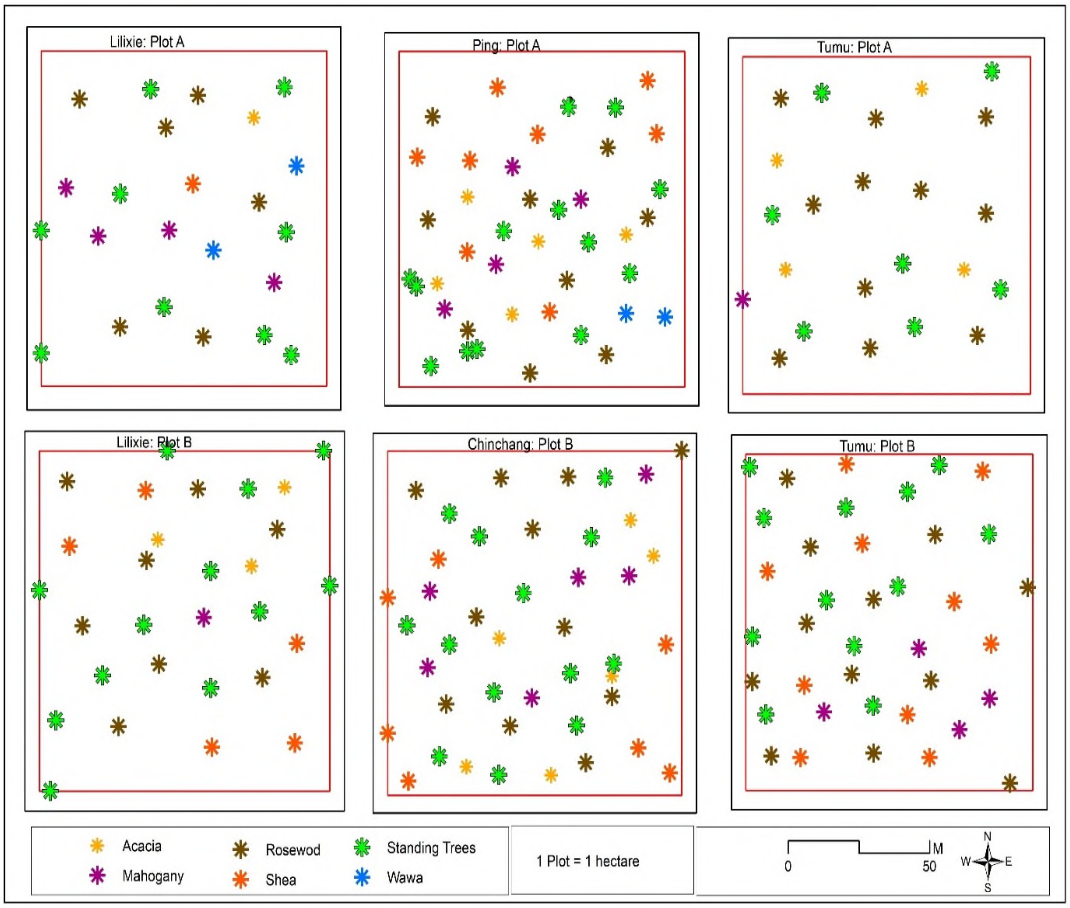

Figure 4.9: Number of trees species on households plots in urban area
Source: Field survey, 2019

In the figure above, the results from *Lilixia*, *Ping* and *Tumu* communities showed that there is a different population of tree species on the various plots. In the first household, thus plot "A" in community has Acacia (1), Rosewood (6), Standing trees (9), Mahogany (4), Shea (1) and Wawa (2) while in the second household, thus plot "B" has Acacia (1), Rosewood (8), Standing trees (12), Mahogany (1), Shea (5) and Wawa (0). The situation in first household, thus, plot "A" of Ping community shows that Acacia (5), Rosewood (9), Standing Trees (13), Mahogany (4), Shea (8) and Wawa (2) while in the second household – plot "B" portrays that Acacia (5), Rosewood (11), Standing trees (13), Mahogany (6), Shea (7) and Wawa (0). In Tumu community, the first household – plot "A" has Acacia (4), Rosewood (11), Standing trees (12), Mahogany (1), Shea (1) and Wawa (0), in the second household – plot "B", Acacia (0), Rosewood (12), Standing trees (9), Mahogany (4), Shea (10) and Wawa (0) (Figure 4 and Table 4.6).

Table 4.6: Number of trees species on Households plots in rural communities

Name of community	Type of trees	Number per plot	
		A	**A**
Lilixia	Standing trees	9	12
	Acacia	2	1
	Rosewood	6	2
	Mahogany	4	4
	Shea	1	1
	Wawa	2	2
Ping	Standing trees	13	13
	Acacia	5	5
	Rosewood	9	11
	Mahogany	4	6
	Shea	8	7
	Wawa	2	0
Tumu	Standing trees	12	9
	Acacia	4	0
	Rosewood	11	12
	Mahogany	1	4
	Shea	1	10
	Wawa	0	0

Source: Field survey, 2018

From the results, it was ascertained that the dependence of households on biomass in the area is a threat to biological diversity. Especially fauna as it lessens the number of trees that are found on a hectare of the plot of smallholding farmers. There is a reduction in the plant population as a result of the continued cutting of these trees to satisfy their home fuel demands. It was clear that at least in every acre of the plot, there is an average of about 22 trees that are cut down to serve as biomass fuel while just about 13 trees can be found on the plot. This population consists of all the different species of trees that are used for this spatial analysis (Acacia, Rosewood, Mahogany, Shea, and Wawa).

4.5.1: Household energy decision making

From the results, adult females in households are the majority decision-makers when it comes to domestic energy issues. In close to 90% of household, females (wife or female heads) constitutes the main decision-makers with regards to which form of domestic energy to use for cooking and heating purposes. The remaining 10% was distributed among male (7.8%) and the children (2.7%) in the households (Figure 4.10)

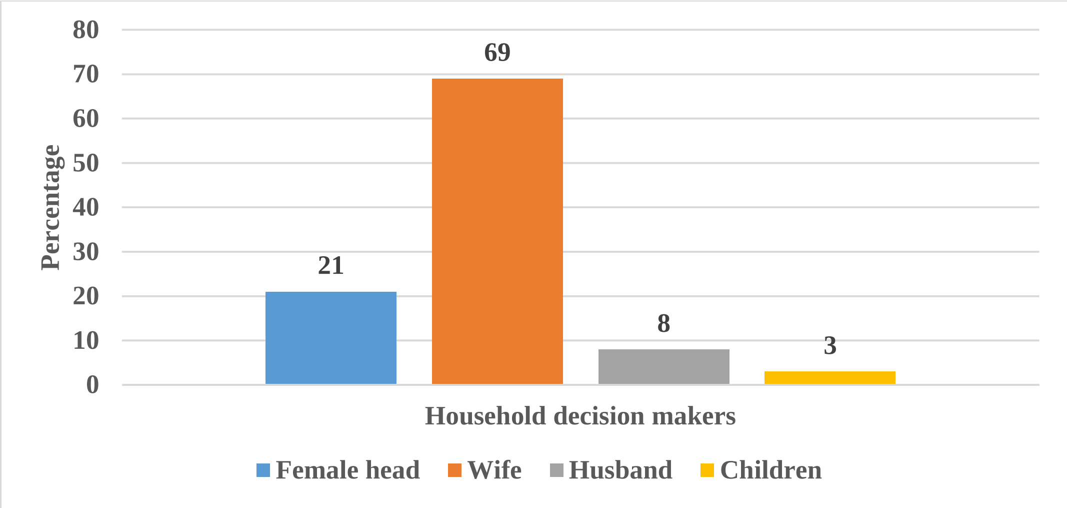

Figure 4.10: Household fuel decision making
Source: Field survey, 2018.

According to both male and female discussants in the FGDs interviews, the responsibility of decision making with regards to fuelwood use and application is solely the duty of the adult female in the households, and more precisely the principal homemaker. This is because women are traditionally responsible for cooking and feeding the households, and whatever decision taken by them is not a concern for males, provided it does not affect the larger households. Thus, in most cases, men do not worry about domestic issues because that is traditionally and culturally; the role of a female. However, with regards to fuel-related expenses such as procuring charcoal fuel, the men sometimes step in when there need arises. A female discussant aptly reported in the following statement;

In the kitchen, we the women are the decision-makers. It is you that decides what to do to put food on the table for your children and husband to eat. As a woman, you have taken decisions that are practical, and least expensive. We all would have loved to use charcoal or LPG for cooking because it is simple and efficient, but it is expensive too, and so we cannot afford......(Female Discussant, Bujang Community, 03.2018)

4.5.2: Factors influencing decision making at households

From this study results, it was reported that, in addition to these factors, households are also influenced by energy source efficiency, availability, and affordability. Thus, the household will consider many factors such, cost, efficiency, availability, and affordability of the particular source before opting to use it. For instance, during the FGDs session, a discussant reported that the household size plays an important role in the selection of the energy type. This is because; the size of the household determines the quantity of food to be cooked, and the size of cooking pots to be used. Therefore, in larger households, where large quantities of food are cooked daily, it is more useful to use firewood as compared to charcoal. Conversely, if the household size is small, it is suitable to use a small pot and charcoal will be appropriate. The other important factor discussant reported is the cost, especially for modern energy sources such as LPG and electric stoves. According to a discussant, the cost of these types of energy products is far above the reach of the poor and therefore, the majority of the households are unable to afford and use them.

Globally, 2 billion folks us US$1/day in the consumption of varieties of fuel woods as those deficient of accessing business energy (Kneeland & Vahanen, 2005). The matter is that spreading an electrical grid to merely many households in rural settings will price up to seven times the quantity as in urban areas. Thus, wood-based biomass incontinent, Asia and geographic area account for 89%, 81%, and 66%, severally, of total wood use. In an Asian country, Cambodia, Asian country and Asian nation, the share increases to 98% (IEA 2006 and 2010).

Energy decision making in households is the primary responsibility of the principal homemakers, especially for rural households in northern Ghana. A review of the literature shows several factors influence households' decisions making process, particularly with regards to domestic energy choices. In general, household size, level of education, income and external factors such as the prices of the product affects households' decision-making process. According to Kuunibe et al (2013), factor influencing households' decision to use fuelwood for their domestic cooking activities varies from one household to the other. In their study, they found that factors such as level of completed education, household size, income and price of fuel have often influenced household decision to use fuelwood. In particular, the price of energy production has been found to have a stronger correlation with tits adoptions.

The primary source of energy to the common of households in Ghana, particularly rural areas is fuelwood. From the survey, 94% of families in the study area used firewood as their main source of energy cooking, heating and lighting purpose. The remaining 6% is equally distributed among households who used charcoal and LPG as their main energy source. Thus, charcoal and LPG each recorded 3% (Figure 2). This means that in every 10 households, at least 9 of them will be dependent on fuelwood for their cooking heating and lighting happenings at the household level. However, charcoal fuel is a second alternative energy source to more than one third (1/3) of all households involved in the study. Also, in 16% of households, LPG gas s constitutes their secondary energy source for domestic activities. Furthermore, fuelwood and crop residues each constitute 5% and 1% respectively; for the household's secondary source of energy (figure 3). This means that the majority of households depend on firewood and charcoal fuel for their household's energy requirements because both their primary and secondary sources of energy depend on biomass such as wood.

Charcoal is the primary cooking fuel for several households living in growing urban centres. Charcoal is typically created by a method named slow transmutation, the heating of wood or completely different substances among the absence of element. Besides employed by households, charcoal is additionally usually the first cooking fuel for several little road-side restaurants and in kitchens of larger public institutions, like faculties and universities, hospitals, and prisons. Charcoal is additionally wide used for house industries, as degree example, bread baking, house metal smelting operations, and brick kilns. Further, households in urban areas are usually smaller than in rural areas that interprets into less economical use of fuels for cooking per capita. These multiplier effects triggered by urbanization cannot be underestimated: One study for Dar Salaam suggests that the tenth increase in urbanization winds up in an exceedingly 14% increase in charcoal consumption (Hosier et al., 1993). Because of the triple impact of increment, exaggerated urbanization, and relative price changes of alternate energy sources for cooking, it's expected that the consumption of charcoal will live high levels or even increase in absolute terms over succeeding decades (Zulu & Richardson, 2013). A regional study for the Southeast continent estimable that charcoal consumption from 1990-2000 grew by regarding 80% in every Lusaka and Dar Salaam (SEI, 2002). From 2001-2007, the amount of Dar Salaam households' cooking with charcoal exaggerated from 47% to 71%, whereas the utilization of LPG born from 43% to 12% (World Bank, 2009). In Senegal, shoppers jointly massively switched back to wood-based biomass for cooking once subsidies were eliminated, caused LPG prices to extend significantly (World Bank, 2009). The irresponsibility of giving is another issue that keeps shoppers with wood-based biomass: Not only can the purchased quantity be adjusted to the households' amount of gettable cash, but wood-based biomass is additionally out there through an honest network of shops and there is ne'er a shortage.

In distinction, shoppers report that the availability of varied fuels notably LPG is unreliable and, thus, unattractive for traditional use (World Bank, 2009). From literature, similar results are found in earlier studies, that typically corroborates the study results. in an exceedingly similar study by Ghana´s Energy Commission and biology Commission (ECG, 2010), established that wood fuels account for 78% of all primary energy consumption within the country (Energy Commission, 2010). Mohamed et al (2013) as cited by Boampong, et al. (2015) contends that biomass stays the foremost used fuel for preparation and heating in the state, with wood been the foremost most popular in rural areas while charcoal and gas are preponderantly utilized within the urban areas.

Furthermore, Kuunibe, et al (2013) established that only 30% of households in the Wa Municipality use modern fuel such as LPG and electricity, whiles the remaining 70% rely heavily on traditional biomass such as firewood/charcoal (60%) and charcoal (10%). These studies also correspond to similar studies conducted by Amissah-Arthur et al (2004) and Bailis et al (2007). Primarily, wood fuel, charcoal, and crop residues are obtained from the forest, farms, and savannah bushes. However, the mode of acquisition and collection of each type varied slightly across the study area. A greater proportion of wood and charcoal products used in households are harvested or collected personally from the farm or bush by household members, especially women and female children. These materials are collected and transported on the head or with support of donkey cart or bicycles to homes for use. In 95.6% and 94.8% of households surveyed, charcoal and fuelwood respectively are collected from the bush/farm by households themselves (Table 4.7). Only 2.7% and 3.3% of households indicated they purchased charcoal and fuelwood respectively. For charcoal, only (1.4%) reported that they sometimes collect charcoal fuel from friends and neighbours without paying for it.

Table 4.7: Mode of collection of fuelwood/charcoal

Mode of acquisition	**Type of biomass used in households**	
	Charcoal (%)	Fuelwood (%)
Harvested from bush/farm	95.6	94.8
Purchased from vendors/suppliers	2.7	3.3
Collected from neighbours/friends	1.4	0.5
From other cooking activities	0.3	1.4
Total	**100**	**100.0**

Source: Field survey, 2018

With regards to fuelwood, however, less than 1% (0.5%) of households reported that they collected fuelwood from neighbours/friends. This means that it is more common for households to borrow or beg for charcoal than for wood fuel. Perhaps, the fact that fuelwood is more readily available than charcoal is the possible reason. The least mode through which households obtain charcoal and wood fuel is "collection from other cooking activities" (reusing left-over charcoal or fuelwood), which recorded 0.3% and 1.4% respectively. This also means that reusing fuelwood (used wood fuel) is more likely in households than reusing charcoal (Table 4.7).

Again, in-depth interviews confirmed that firewood, in particular, is often collected daily, and transported on the head from the farm to home for use. Discussant revealed that fuelwood often made available during farm clearing; cutting of branches, trees, and clearing of the bushes, especially for plouging. After that, adult women and children then carry the logs home for safekeeping till they are dry and ready for use as fuelwood. Another female discussant reported that they also collect firewood mostly from the bushes, especially in the dry season. She reports in the following statement;

firewood is often obtained from the bush or farm, especially during the dry season, when bush fires had cleared the bushes. During this period, we go to bushes to harvest dry wood for storage. If you fail to store sufficient firewood in the dry season, you will face difficulties in the rainy seasons because at that time it becomes bushy and difficult to get dry wood in the bush (Female discussant, Kong community, 03.2018).

In terms of frequency of collection of wood/charcoal fuel, the survey results show five different collection intervals exist. From figure 4.11, the results revealed that fuelwood/charcoal is collected/harvested on a daily, weekly, monthly, half weekly (twice weekly), and "as and when needed" basis. From the results, the majority of households (52%) collect/harvest wood/charcoal products every week. This is followed by households that collect/harvest wood fuel on as and when need basis (21%), followed by a twice-weekly basis (15%) and daily (10%).

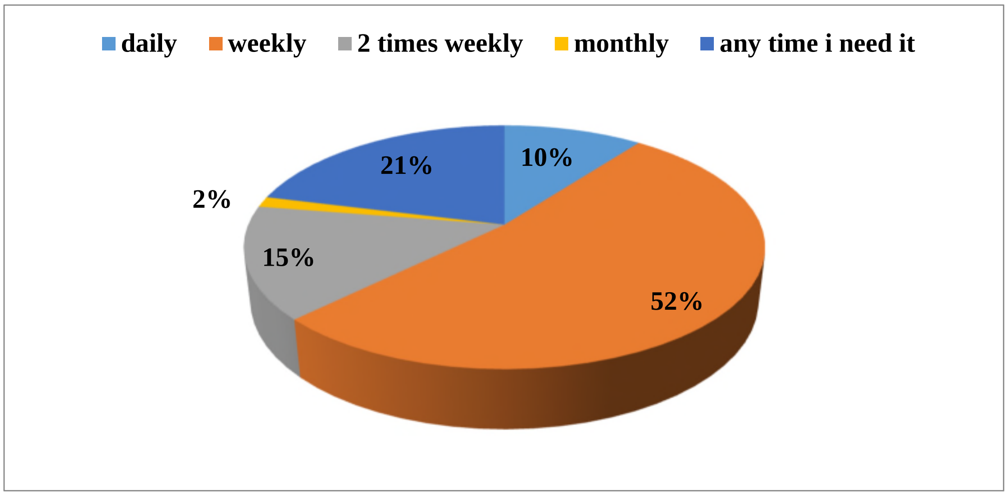

Figure 4.11: Frequencies of biomass collection by households

Source: Field survey, 2018.

The least recorded only 2% for a monthly basis (Figure 4.11). Thus, overall, 67% of households in the study area collect wood fuel every week (weekly and twice-weekly).

This result supports the earlier findings that the majority of households relied on wood fuel for their daily domestic cooking and heating activities. This suggests wood fuel is used daily in the household, which also means that unsustainable consumption of wood fuel could pose significant threat household domestic activities, especially considering that population growth is projected to increase in the future.

Primarily, FGDs interviews suggest that fuelwood collection is done daily, especially after the close from farm work, although some others disclosed other means of collections, including; weekly and monthly basis. More so, from the FGDs results, it thus appears that firewood collection is not a major activity that requires designated days to carry out. However, it is an activity that every adult woman, especially principal homemakers often endeavours to carry out daily or regularly to ensure fuelwood sufficiency in the household.

4.5.3: Benefits derived from the sale of wood/charcoal products

The study revealed a wide range of benefits derived from charcoal production and the sale of firewood in the study area. From the survey, almost all respondents (99%) agreed that charcoal and firewood trade has benefits to the households. Additionally, almost all FGD and key informants acknowledged these benefits.

In particular, FGD discussants reported that the most important benefits of firewood/charcoal production are its potential for generating income for households. Furthermore, key informant interviews disclosed that income generated from the sale of firewood/charcoal is mostly applied for supporting their household's social and food needs such as procuring food staff, payment of children's school fees, health care expenses, purchasing farm inputs and clothing for the children. FGD discussants further stressed on the important roles charcoal and wood trade plays in their socio-economic lives. They further revealed that selling wood/charcoal is a major livelihood for a considerable proportion of households in the study area, thus employing a significant number of people in the area. Both males and females are involved in the charcoal trade; however, female play a more dominant role than males, especially in the selling of charcoal fuel. In some households, charcoal production and sale forms a major part of the household income and thus attract considerable attention from both parents and children. A female key informant reported this in an interview;

> *Selling fuelwood, particularly charcoal is a major source of income for some of us in this community. After the farming season, most of us also engage in charcoal production and sale, which gives us extra income for supporting the household. I have been in this business for the past 10 years, and it has supported me to cater to my children's education, clothes and occasionally procure food for the family. I know a lot of people in this community who are equally dependent on charcoal. We don't have any alternative job here except farming, so during the offseason, we have to do this to make extra incomes to support the family (Key Informant Interview Chingchang community, 03.2018)*

Ghana Energy Commission (GEC, 2010) estimates that there are over 600, 000 people who use firewood and charcoal for other none-domestic activities in the small scale sector; smoking, commercial chop bar operators, pito brewing and many other activities that are contributing to the economic growth of the country. Apart from this, there are a vast number of merchants; suppliers, retailers, and wholesalers, along the value and supply chain of firewood and charcoal products in Ghana. These activities not only provide a direct source of income, government revenue and employment to many households, they are also important sources of livelihoods for a chunk of the rural population in Ghana. Additionally, and more importantly, these activities are very critical for the nutritional needs of over 2.2 million o Ghanaians (GEC, 2010).

According to Effah and Boampong (2015), if Ghana's bioenergy sector is well developed, it has the potentials to help Ghana attain energy safety, lessen oil import bills, and save foreign exchange. It might also be an avenue for reducing poverty and wealth formation, increase export earnings and contribute to reducing climate change. Aside from that, there are notable health benefits for using improved household energy such as LPG and improved cook stoves. For example, modern biomass usage reduces indoor air population and thus provides significant health benefits to the users as a result of better and improves wood stove design (Remedio & Domac, 2003)

4.6 Implications of Households Fuelwood Consumption on Environment and Health

This section seeks to meet the requirements in objective three of the study which is cantered on exploring environmentally sustainable alternative energy sources for households in the study area. Issues include the mode of harvesting fuel, alternative sources of these fuels.

4.6.1: Indiscriminate harvesting of wood fuel and deforestation

Form the study; it was revealed that unsustainable collections of firewood, in particular, have the potential to affect forest sustainability deforestation. If deforestation is not unchecked, it could potentially affect the climate, and lead to further damages to the environment. From the survey, 28% of respondents reported that uncontrolled harvesting of wood fuel could lead to deforestation. Another 24% also noted that this has the potentials to affect the climate and exacerbate change.

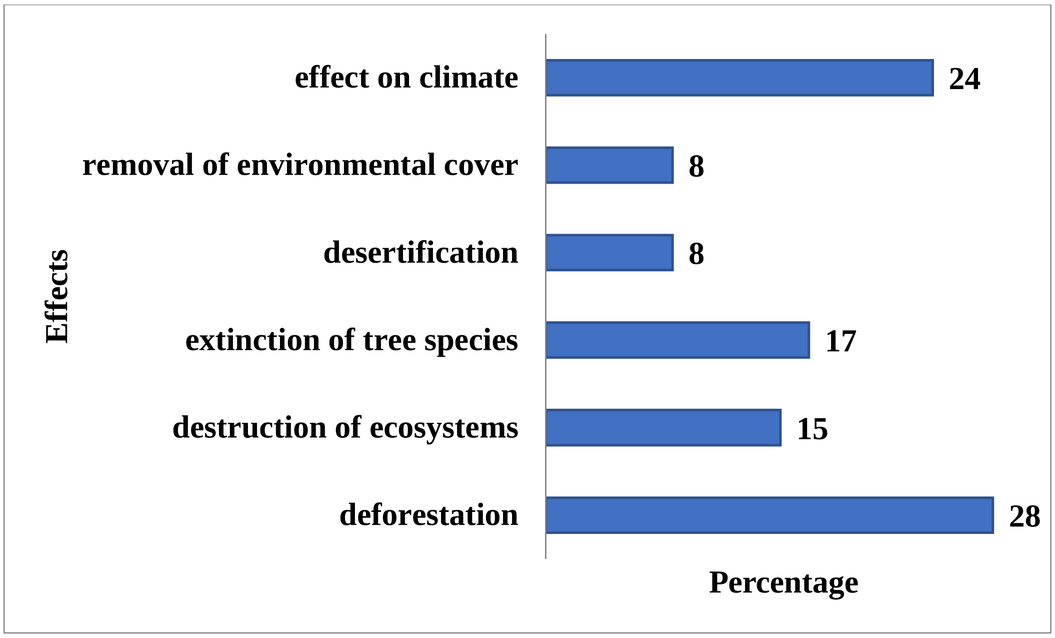

Figure 4.12: Effect of biomass collection on vegetation resources
Source: Field survey, 2018

Furthermore, 17% reports that it would lead to the extinction of plant/tree species, whiles 15% reported that it could lead to the destruction of the ecosystem. The remaining 16% was reported equally for the removal of environmental cover (8%) and desertification (8%) (Figure 4.12).

Also, results from in-depth interviews largely support the survey results. Throughout the study communities, it has been reported that the effect of indiscriminate cutting of wood for charcoal production and wood fuel has negative implications for the environment and the forest in particular. Prominently, discussants reported that indiscriminate harvesting will ultimately cause deforestation and depletion of the forest resources. If unchecked, discussants noted that the practice could eventually lead to climate change and affect the rainfall pattern. This is because it has been stated that tress and rainfall patterns have long-standing correlations. In some communities, discussants reported widespread rainfall variability and attributed that to indiscriminate cutting of trees. For instance, during a focus group discussion at Bujang, a male discussant stated that;

> *.... because of these practices (indiscriminate cutting of trees), the rainfall patterns these days are not favourable. We don't get rains at the right time. I think it is a result of the cutting of trees......." (A male discussant, Bujang, 03.2018).*

Undoubtedly, biomass making in the arrangement of removal of wood and trees from the forest for fuelwood and charcoal production has serious negative repercussions for environmental sustainability, particularly forest resources (World Bank 2006) as cited in (Kuunibe et al 2013). Inefficient and unsustainable preparation practices can have serious implications for the atmosphere, like land degradation and native and regional pollution. as an associate example, Unsustainable production of charcoal in response to urban demand, considerably in a geographic area, places a strain on biomass resources. Charcoal production is usually inefficient and might end in localised deforestation and land degradation around urban centres. deficiency of wood sometimes ends up in larger use of agricultural residues and animal dung for preparation. Once dung and residues are used for fuel instead of left inside the fields or ploughed into fields, soil fertility is reduced and propensity to sporting is hyperbolic.

Thus, the notable negative effect includes; erosion, leaching, denudation, and deforestation. These factors act as further drivers for environmental and climate change. In particular, deforestation has been widely acknowledged as a key source of greenhouse gas (GHGs) emission, which drives global climate change. Although factors exist, deforestation is the main cause of forest depletion in most parts of Africa including Ghana. It has been projected that population expansion and industrialisation drive will propel deforestation in Africa, and if care is not taken, this could exacerbate the effect of deforestation and global warming more than projected. According to the Energy Commission of Ghana (2010), over-reliance on wood is depleting Ghana's woody forest. Thus, the continuous dependence on wood fuel in Ghana has the potentials to affect the country's progress towards achieving the SDG7 which seeks to attain environmental sustainability.

4.6.2: Impact fuelwood consumption on forest resources

The survey results show that the majority of the respondents (60%) reported that indiscriminate harvesting of wood fuel has a high risk of impact on the environment, whiles 35% and 3% reported extreme and moderate impacts respectively. Only 1% does not think it will have any effect on the environment (Figure 4.13).

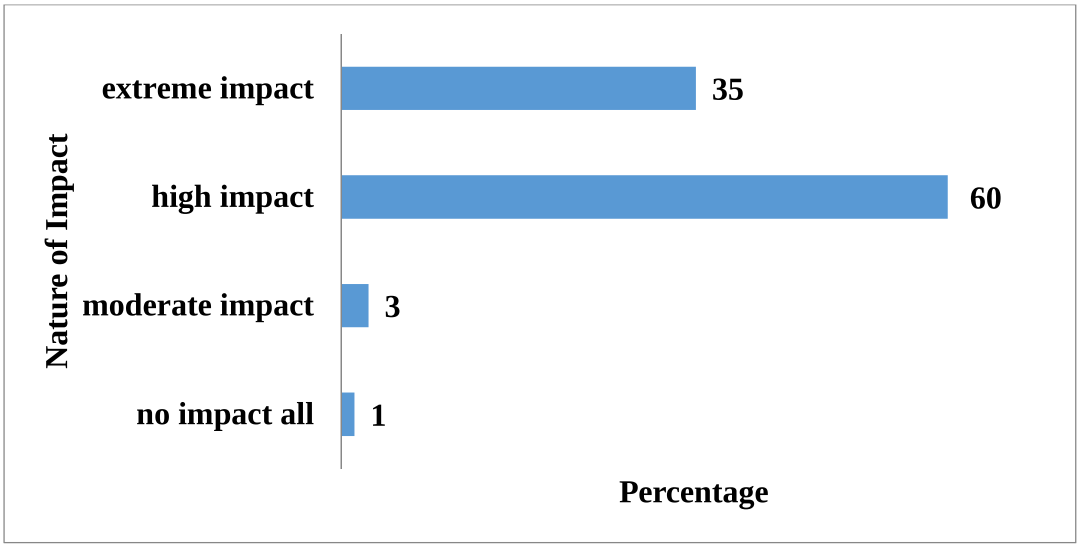

Figure 4.13: Respondents' perceptions of the impact of biomass collection on vegetation
Source: Field survey, 2018.

Overall, the impact of indiscriminate wood cutting/collection has been noticed and reported across all communities and stakeholders. Both Key informants and FGDs reported that indiscriminate cutting of fresh trees and economic trees such as Shea trees, especially for commercial charcoal production is a major challenge to the sustainability of woodlands and forest resources. From FGDs, discussants reported that indiscriminate logging of wood, in particular cutting of fresh trees for firewood and charcoal production is a practice that is affecting the natural vegetation and thus, poses a threat to the livelihood of women and children in particular. To curb this menace, some communities reported that they have instituted by-laws and mechanisms to protect the forest and the environment. However, it was reported though the practice has been outlawed, some other people are still engaged in it. A key informant reported that;

> *...some 4 years ago, the chief and elders instituted some bylaws to prevent cutting of fresh trees for charcoal burning. The paramount chief of the sissala traditional area (Kuoro Kanton) insisted that all chief should endeavour to protect the environment, especially preventing fresh logging of trees for charcoal production. The assembly has also supported this initiative and most communities do not allow this practice now… (Key Informant, Kong Community, 03.2018).*

Clearly, from the foregoing, communities are not unaware of the impact of indiscriminate logging on the environment and forest resources. Although communities have made attempts to curb the practice, it is still prevalent in some communities. For instance, it was reported in Chingchang that some charcoal producers are still engaged in the act by cutting fresh trees for charcoal production. This was also reported in Kong, and Lilixia though not on a large scale as compared to the previous years.

4.6.3 Impact of fuelwood consumption on human health

Several past studies have established linked with household fire/charcoal consumptions with several health problems, especially for women and children in Africa. This is so because in most parts of Africa women and children are answerable for cooking and preparation of food and thus inhale or spend more time in polluted kitchens. Worldwide, interior air pollution is accountable for the death of nearly 2 billion people annually (WHO, 2005) cited in Smith (2010), and 99% of them are from the developing countries (WHO UNDP, 2009). Smoke from emanating from household's firewood consumption is highly related to a wide variety of respiratory diseases and conditions such as acute respiratory infection (ARI) severe lesser respiratory infection (ALRI) among infants, and pneumonia among children. Women and children are more exposed to the health risk from firewood smoke 20 times higher than WHO recommended standards – and thus face a higher risk of health complications from smoke pollution resulting from cooking activities (WHO, 2005).

According to (Smith 2000) as cited in (World Bank 2011), smoke from biomass combustion cause acute respiratory infection among children, and ALRI for children under 5 years is predominant, especially in Africa. Furthermore, Ezzati & Kammen (2001) conducted an exposure study in Kenya and found that the highest exposure to smoke is from a three-stone fire, which generates between 2000-7000 mg per m3 of smoke, followed by ceramic and wood stove, generating 1000 to 1500 mg per m3; and charcoal stove emitting less than 1000 per mg m3. A follow-up study by the same authors in 2002 found that switching from three tones of fire to ceramic and the wood stove will reduce ARI by ¼ and ALRI by 1/5 among infants under 5 years. Smith, Mehta, & Maeusezahl-Fuez (2004) also link indoor smoke to childhood pneumonia after extensive review. More so, a study conducted by Dharani, et. al, 2008) found that children who have exposure to smoke are 1.8-time risk of contracting pneumonia as compared to those without exposure. A new global assessment of the disease burden of smoke on humans found that indoor some from cooking increase the risk of contracting the following disease; ARI (45-118%), COPD (Chronic obstructive pulmonary disease)-95-275%; cataracts (16-276%), lung cancer (7-206), and cardiovascular diseases (Smith, et al., 2014). Overall, these studies have sufficiently established a close link between using firewood and some health complications among users. In particular, these studies found that acute respiratory infection and childhood pneumonia are common among the people who inhale excessive smoke from cooking.

4.6.4: Alternatives Energy Source for Household

People's knowledge of available alternative energy sources has the potentials to influence their domestic energy choices. In the study area, respondents expressed a wide range of preferences for different alternative energy sources, if given the opportunity. From the survey results (figure 7), 93% of the households who participated in the study showed their preference for LPG energy, 13% would also prefer electric cook stoves, while 4% and 3% would have preferred charcoal and fuelwood if given the opportunity (Figure 4.14).

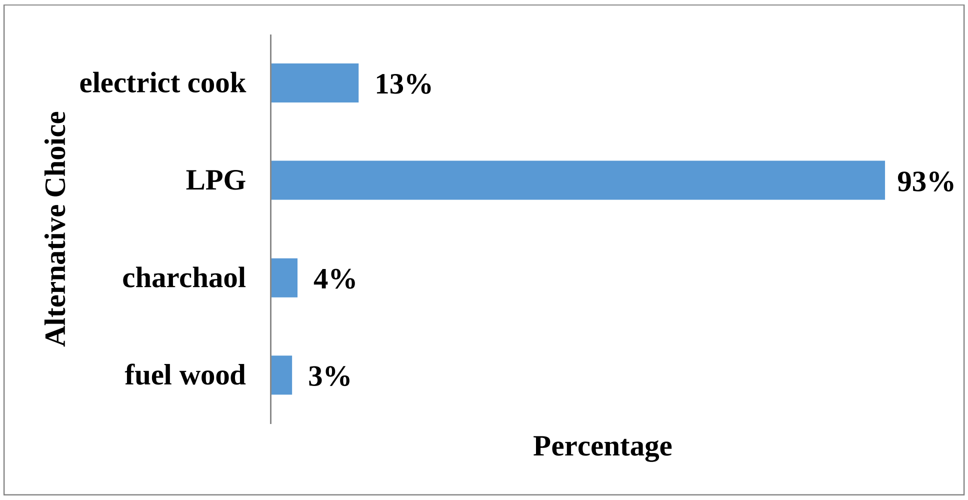

Figure 4.14: Preferred alternatives of households' fuel
Source: Field survey, 2018

Given these results, the majority of the household have modest knowledge about the existing alternative households' energy sources. The conservative viewpoint on energy use is that the monetary process can activate a summary request for wood and alternative biomass energy, with customers and states shifting towards the employment of business fuels, like LPG, fossil fuel, and alternative fossil fuels. A wide range of reasons was proffered for selecting these alternatives. For the majority of who chose LPG for instance, the common reason was efficiency; easy to use, and the fact that LPG widely used in many other homes. Those who opted for other types cited reasons such as cost, availability, and easy to use, especially for none literates. However, the main reason most households are unable to use their preferred energy source is the cost. In almost all households surveyed, respondents reported that they are unable to use their preferred alternative energy because the households cannot afford to procure and maintain it. For instance, during FGDs, discussants expressed that but for the cost implications, they would have all wished to use LPG for cooking because it is easy, faster and efficient as compared to using traditional methods such as firewood. According to the majority of discussants, alternatives energies such as LPG and electric cook stoves are expensive to use but very easy and efficient methods as compared to wood fuel or charcoal. According to a discussant, "*everyone necks loves necklaces but not all necks get to lace a necklace"*. This is interpreted to mean "*everyone loves to have good things but not all can afford good things*". For most discussants, their wish to use LPG will only remain a wish until there are interventions to reduce the price of the product to a level that they can also afford. One discussant reported that;

> *...as for good things, we all love to have a good thing. However, not all of us can get good things because we cannot afford it. There is a popular saying that everyone necks love necklaces but not all necks get to lace a necklace. This simply means that we all would have wished to use LPG but not all of us can afford it. The cost is too much for us.... (A Male FGD discussant, Tumu, 03.2018).*

This behaviour is mostly cited because of energy ranking. Though proof happens that doesn't provision of this model, but that, in distinction, the fuel changeover for homes in emerging states keep an eye on a lot of complicated courses, wherever they change and use fuels from totally dissimilar classes on the energy tree at identical time (Pachauri and Spreng, 2003). The dynamism stack theory was announced, that higher replicates this quality (Schlag and Zuzarte, 2008).

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This closing chapter gives the summary emanating from the research key finding, discussed major conclusions drawn, and makes the recommendation for policy formulation and further research. Thus, the chapter is structured into three subheadings; summary of key findings, conclusions, and recommendations. In each of these subheadings, the issues are cantered on the main research questions. However, for the recommendations sections, recommendations are organized around two main themes; policy formulation and for study.

5.2. Summary of Key Findings

The key discoveries of the study have been presented around the specific research questions, aimed at providing insight for understanding consumption of fuelwood/charcoal in households, especially for native actions in the form of cooking, heating, and lighting. The key research findings are;

1. *Which tree species are usually used for biomass fuel in the study area?*

   First, it was discovered that biomass materials like firewood, charcoal and crop remains are the main materials used as biomass fuel in the study area. However, the study established that charcoal fuel and crop residues are rarely used in larger households because it will delay the cooking process. Furthermore, large quantities need to be used to be able to meet food requirements in large households. Thus, in large households, firewood is often the preferred fuel choice for cooking.

Secondly, from the study, households used several plants/trees for meeting their fuel needs and charcoal production in the study area. The commonest among them are rosewood; mahogany; Shea and dawadawa trees. These species altogether form 96% of all fuelwood used in households in the study area. The dominant reasons respondents cited for using these plants/tree species include; availability and efficient out for burning. Therefore, using these species has proven to be efficient for households' use.

2. *The factors determine households' decision to use biomass energy in the study area*

Furthermore, the study established that several factors determine households' choice for using a particular biomass energy source. The primary source of energy in 94% of households in the study area is firewood; and the main reason cited for using firewood includes; household size (number of persons that are lining in in a household); efficiency of the particular energy material sources, availability and the cost of the product. The investigation further established that adult females in the households primarily make decisions with regards to the type of biomass materials to use in most household levels; especially for cooking, boiler and lighting activities. In most Ghanaian societies, where gender roles are primarily defined and shaped by culture, women are and men grow up knowing their roles and responsibilities in the households. In this cultural context, women in the study areas are bestowed with all domestic responsibilities, including decisions making on domestic energy. Perhaps, this is the only responsibility that women are solely responsible for, considering that females are often ignored in major households' decision makings process.

3. *Alternative sustainable fuel sources are available for households in the study*

Most households' respondents are not unaware of the existence of improved energy sources and wished to have them. However, the major hindrance is the cost. For instance, the majority of households acknowledged the existence of improved energy sources such as LPG, electric cook stove, and kerosene stoves, and expressed their desire for them, but almost all of them reported that they are unable to use it because of the cost is far beyond affordability. The study also established that the most preferred improved alternatives energy source for most households is LPG, although charcoal and electric stoves were also mentioned. The reason being that LGP enhances efficiency and makes cooking easy. However, the cost of acquiring these alternatives sources of energy has made it impossible for the majority of households to use it. More so, the level of educational attainment of the household head has some sort of positive correlation with the use of LPG for domestic activities. Stated differently, as households head educational attainment increases, they tend to opt for using LPG. Thus, the higher the level of education, the higher the chances for the household using an improved source of energy. Similarly, the level of the educational level of the household heads has a negative correlation with the use of firewood as primary domestic energy.

5.3 Conclusions

Base on the foregoing findings, the following key conclusions have been made. These have been organised around the three main research questions. Thus, key conclusions have been organised under three main themes. These include;

1. *Tree species are usually used for biomass fuel in the study area*

Based on the results, it can be concluded that the main biomass energy sources in the study area are firewood, followed by charcoal and crop residue. Firewood fuel is preferred to others because of its efficiency especially for preparing large quantities of food for large family sizes. The most vulnerable trees/plant classes used for firewood and charcoal burning in the study zone include; rosewood, mahogany, Shea and dawadawa trees. These trees are preferred because they are readily available and efficient for charcoal fuel production.

2. *The factors determine households' decision to use biomass energy in the study area*

The multiplicity of factors, including; economic, social and cultural orientation, influences households' choices for particular fuel energy sources. The commonest ones include; readily availability of the energy source, its efficiency for cooking, cost of the product, and the household or family size. Adult females in households are primarily responsible for taking decisions related to household energy, especially for domestic cooking activities. This is driven and shaped by culture and social norms.

3. *Alternative sustainable energy sources are available for households in the study*

Households in the study area have a wide range of alternative improved energy sources. The most common and preferred one being LPG, electric cook stove, and kerosene stoves because of their efficiency. However, the cost implication of these alternatives is a major hinder to household access.

5.4 Recommendations

Recommendations for the study have been organized around two main themes; for improving access and sustainability. The last theme provides a suggestion for further research.

1. *Improving access to clean and affordable household energy*

   Subsidy approach to improving access to improved cooking stoves – although household has a wide range of options of improved energy sources available, the cost of these alternatives is a major hindrance. Therefore, to address this, the government of Ghana in collaboration with the ministry of food and agriculture should initiate a process of providing "low cost" improved cooking stoves for rural households, through subsidy programmes. Apart from reducing household' dependence on firewood, this will enhance efficiency and good health, especially that unimproved cooking methods have a close connection with respiratory diseases.
2. *The government should pursue a clean energy agenda* besides; the government should pursue clean energy agenda by promoting clean energy sources through extended subsidy programme to make clean energy alternatives affordable in the country. Access to improved energy will not only reduce deforestation but also reduce the health risk and hazards associated with using firewood for cooking and other domestic activities.
3. *Sensitization and mass education on sustainable ways of harvesting wood fuel* – the Forestry Commission should also initiate steps to educate communities and households, on sustainable ways of harvesting wood fuel without causing harm to the natural environment. This should include radio and mass media programming on local languages across the country. This way, the household

will be able to reduce their consumption of fuelwood and thus reduce the impact on the environment.

4. *Enactment and enforcement of existing rules on wood harvesting* – as it stands now, there are rules or existing rules that are not well enforced. This situation makes it difficult to regulate the harvesting of fuelwood in the country. As a recommendation, the forestry commission should revise the legislation to include sustainable wood harvesting, or if there are already regulations, these should be enforced strictly. If well enforced, this has the potentials to reduce uncontrolled usage of fuelwood and enhance sustainability.

Recommendation for further research

For further research, and further understanding of households' energy consumptions, the following have been recommended;

Although this study was comprehensive by design, the findings were limited in scope because empirical data was gathered from only one out of the 11 districts in the Upper West Region. This makes generalization of the results very difficult. Hence, it is recommended that subsequent studies should expand the geographic scope to include two or more districts for comparative analysis and generalization of the research findings.

Secondly, the study was employed survey design, which does not allow spending more time with respondents. To gain a deeper understanding, future studies should explore possibilities of using case study approaches, which allows the researcher more time to fully understand the issues, dynamics, and trends for a deeper insight.

REFERENCES

Amigun B, Sigamoney R, von Blottnitz H. Commercialisation of biofuel industry in Africa: a review. Renew Sust Energ Rev 2008;12(3):690e711.

Amigun, B., Sigamoney, R., & von Blottnitz, H. (2008). Commercialisation of biofuel industry in Africa: a review. *Renewable and sustainable energy reviews*, *12*(3), 690-711.

Amissah-Arthur, J., &Amonoo, J. A. (2004). Study of the social and poverty impacts of energy interventions on rural communities in Ghana. *Final Report. Study performed under the auspices of the Climate Technology Initiative (CTI) and sponsored by Natural Resources Canada (NRCan).*

Bailis, R., M. Ezzati, and D. M. Kammen. 2003. “Greenhouse Gas Emissions from Cooking

Batidzirai, B., Faaij, A. P., & Smeets, E. (2006). Biomass and bioenergy supply from Mozambique. *Energy for Sustainable Development*, *10*(1), 54-81.

Bazilian, M., Nussbaumer, P., Eibs-Singer, C., Brew-Hammond, A., Modi, V., Sovacool, B. & Aqrawi, P. K. (2012). Improving access to modern energy services: insights from case studies. *The Electricity Journal*, *25*(1), 93-114.

Bekunda M, Palm CA, De Fraiture C, Leadley P, Maene L, Martinelli. (2008). Biofuels in developing countries. In: Howarth RW, Bringzu S, editors. Biofuels: environmental consequences and interactions with changing land use proceedings of the Scientific Committee on Problems of the Environment (SCOPE) international biofuels project rapid assessment, 22-25 September 2008 in Gummersbach, Germany. Ithaca, NY: Cornell University; 2009.

Berndes, G., Hoogwijk, M., & Van den Broek, R. (2003). The contribution of biomass in the future global energy supply: a review of 17 studies. *Biomass and bioenergy*, *25*(1), 1-28.

Bildirici, M., & Özaksoy, F. (2018). An analysis of biomass consumption and economic growth in transition countries. *Economic research-Ekonomska istraživanja*, *31*(1), 386-405.

Boampong, E., Effah, B., Antwi, K., Asamoah, J. N., & Asante, A. B. (2015). Factors influencing the choice of timber for furniture and joinery production in Ghana. *European Journal of Engineering and Technology Vol*, *3*(5).

Bonjour, S., Adair-Rohani, H., Wolf, J., Bruce, N. G., Mehta, S., Prüss-Ustün, A., & Smith, K. R. (2013). Solid fuel use for household cooking: country and regional estimates for 1980–2010. *Environmental health perspectives*, *121*(7), 784.

Bouwman, A. F., & Leemans, R. (1995). The role of forest soils in the global carbon cycle. *Carbon forms and functions in forest soils*, 503-525.

Brian Van Wyk. (2012). Research Design Methods Part 1. Post-graduate Enrolment

Bridgwater, A. V., Meier, D., & Radlein, D. (1999). An overview of fast pyrolysis of biomass. *Organic geochemistry*, *30*(12), 1479-1493.

Bryman, A. (2015). *Social Research Methods*. Oxford University Press.

Bulsink, P., de Miguel Mercader, F., Sandström, L., Van De Beld, B., Preto, F., Zacher, A., & Bronson, B. (2020). Results of the International Energy Agency Bioenergy Round Robin on the Analysis of Heteroatoms in Biomass Liquefaction Oils. *Energy & Fuels*, *34*(9), 11123-11133.

Butler, R. (2006). Deforestation threat in Sub Saharan Africa. *Journal of Environmental Research and Management* **3** (9): 146–152

Chambwera, M. (2004). *Economic Analysis of Urban Fuelwood Demand-The case of Harare in Zimbabwe*. Wageningen Universiteit.

Cookstoves, H. (2011). Environment, Health, and Climate Change: A New Look at an Old Problem. *Washington: The World Bank.*

CRES, D. (2012). Sustainable Energy Action Plan 2020 for Cyclade.

Creswell, J. (2009). *Research design: Qualitative, quantitative, and mixed methods approach*. SAGE Publications, Incorporated.

Creswell, J. W. (2009). Mapping the field of mixed methods research.

Dasappa, S. (2011). Potential of biomass energy for electricity generation in sub-Saharan Africa. *Energy for Sustainable Development*, *15*(3), 203-213.

Davidson, O., & Mwakasonda, S. A. (2004). Electricity access for the poor: a study of South Africa and Zimbabwe. *Energy for Sustainable Development*, *8*(4), 26-40.

Demirbas, K., & Sahin-Demirbas, A. (2009). Compacting of biomass for energy densification. *Energy Sources, Part A*, *31*(12), 1063-1068.

Dharni, S., Srivastava, A. K., Samad, A., & Patra, D. D. (2014). Impact of plant growth promoting Pseudomonas monteilii PsF84 and Pseudomonas plecoglossicida PsF610 on metal uptake and production of secondary metabolite (monoterpenes) by rose-scented geranium (Pelargonium graveolens cv. bourbon) grown on tannery sludge amended soil. *Chemosphere*, *117*, 433-439.

Domson, O., & Vlosky, R. P. (2007). *A strategic overview of the forest sector in Ghana* (Vol. 81). Louisiana Forest Products Development Center.

Duku, M. H., Gu, S., & Hagan, E. B. (2011). A comprehensive review of biomass resources and biofuels potential in Ghana. *Renewable and sustainable energy reviews*, *15*(1), 404-415.

Duncan, B. N., Martin, R. V., Staudt, A. C., Yevich, R., & Logan, J. A. (2003). Internal and seasonal variability of biomass burning emissions constrained by satellite observations. *Journal of Geophysical Research: Atmospheres*, *108*(D2).

Energy Commission, Ghana. (2010). 2010 energy (supply and demand) outlook for Ghana. Accra-Ghana. Access on 20th October, 2020. From: file:///C:/Users/USER/Downloads/Energy%20Commission%202010%20 Energy%2 0outlook%20%20for%20Ghana_2010_Final.pdf

Ezzati, M., & Kammen, D. M. (2001). Indoor air pollution from biomass combustion and acute respiratory infections in Kenya: an exposure-response study. *The Lancet*, *358*(9282), 619-624.

Ezzati, M., Bailis, R., Kammen, D. M., Holloway, T., Price, L., Cifuentes, L. A., & Dhanapala, K. N. (2004). Energy Systems and Population Health.

FAO: Global Forest Resources Assessment. (2010). Rome: Food and Agriculture Organization of the United Nations.

Farrell, A. E., Sperling, D., Brandt, A. R., Eggert, A., Farrell, A. E., Haya, B. K., ... & Knittel, C. R. (2007). A low-carbon fuel standard for California. *Part I*.

Food and Agriculture Organization of the United Nations. (2005). Woodfuel Integrated Supply/ Demand Overview Mapping (WISDOM) Methodology. Spatial Woodfuel Production and Consumption Analysis of Selected African Countries. Rome, Italy:

Gatama, M. N. (2014). *Factors influencing household energy consumption: the case of biomass fuels in Kikuyu district of Kiambu county, Kenya* (Doctoral dissertation, University of Nairobi).

Ghana Statistical Service (2010). National population and housing census report. Ghana statistical service, Accra)

Ghana Statistical Service. (2014). Population and Housing Census 2010 Analytical Report. Acrra, Ghana.

Gordon, S. B., Bruce, N. G., Grigg, J., Hibberd, P. L., Kurmi, O. P., Lam, K. B. H., & Bar-Zeev, N. (2014). Respiratory risks from household air pollution in low- and middle-income countries. *The Lancet Respiratory Medicine*, *2*(10), 823-860.

Gordon, Stephen B., Nigel G. Bruce, Jonathan Grigg, Patricia L. Hibberd, Om P. Kurmi, Kin-bong Hubert Lam, Kevin Mortimer et al. "Respiratory risks from household air pollution in low and middle income countries." *The Lancet Respiratory Medicine* 2, no. 10 (2014): 823-860.

Hardin, B. O., & Black, W. L. (1968). Vibration modulus of normally consolidated clay. *Journal of Soil Mechanics & Foundations Div*.

Hardin, G. (1968). Science. *The tragedy of the commons*, *13*(162), 1243-1248.

Hoogwijk, M. M. (2004). *On the global and regional potential of renewable energy sources* (Doctoral dissertation).

Hosier, R. H., & Kipondya, W. (1993). Urban household energy uses in Tanzania: prices, substitutes and poverty. *Energy Policy*, *21*(5), 454-473.

Hosier, R. H., & Kipondya, W. (1993). Urban household energy uses in Tanzania: prices, substitutes and poverty. *Energy Policy*, *21*(5), 454-473.

Hosonuma, N., Herold, M., De Sy, V., De Fries, R. S., Brockhaus, M., Verchot, L., & Romijn, E. (2012). An assessment of deforestation and forest degradation drivers in developing countries. *Environmental Research Letters*, *7*(4), 044009. IEA, W. (2007). p. 593; IEA, World Energy Outlook, 2006.

Iiyama, M., Neufeldt, H., Dobie, P., Njenga, M., Ndegwa, G., & Jamnadass, R. (2014). The potential of agroforestry in the provision of sustainable woodfuel in sub-Saharan Africa. *Current Opinion in Environmental Sustainability*, *6*, 138-147.

International Energy Agency (IEA), 2000. World Energy Outlook 2000, Paris. International Energy Agency (IEA), 2010. World Energy Outlook 2010, Paris. Jiang, Y., 2009. China's water scarcity. Journal of Environmental Management 90 (11), 3185–3196

IPCC, 2007: climate change 2007: impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change.

Johannes, T. A., Njong, A. M., & Cletus, N. (2011). Financial development and economic growth in Cameroon, 1970-2005. *Journal of Economics and International Finance*, *3*(6), 367-375.

John Wiley & Sons. Smith, K. R., Bruce, N., Balakrishnan, K., Adair-Rohani, H., Balmes, J., Chafe, Z., & Rehfuess, E. (2014). Millions dead: how do we know and what does it mean? Methods used in the comparative risk assessment of household air pollution. *Annual review of public health*, *35*, 185-206.*Sustainable Development* 14(2): 63–72.

Karekezi, S., & Kithyoma, W. (2002). Renewable energy strategies for rural Africa: is a PV-led renewable energy strategy the right approach for providing modern energy to the rural poor of sub-Saharan Africa, Energy *policy*, *30*(11-12), 1071-1086.

Karekezi, S., & Majoro, L. (2002). Improving modern energy services for Africa's urban poor. *Energy policy*, *30*(11-12), 1015-1028.

Karekezi, S., Kithyoma, W., & Initiative, E. (2003, June). Renewable energy development. In *workshop on African Energy Experts on Operationalizing the NEPAD Energy Initiative, June* (pp. 2-4).

Karekezi, S., Lata, K., & Coelho, S. T. (2006). Traditional biomass energy: improving its use and moving to modern energy use. *Renewable Energy. A Global Review of Technologies, Policies and Markets*, *1*, 231-261.

Kebede, E., Kagochi, J., & Jolly, C. M. (2010). Energy consumption and economic development in Sub-Sahara Africa. *Energy economics*, *32*(3), 532-537.

Keenan, R. J., Reams, G. A., Achard, F., de Freitas, J. V., Grainger, A., & Lindquist, E. (2015). Dynamics of global forest area: Results from the FAO Global Forest Resources Assessment 2015. *Forest Ecology and Management*, *352*, 9-20.

Kersten, S. R., Wang, X., Prins, W., & van Swaaij, W. P. (2005). Biomass pyrolysis in a fluidized bed reactor. Part 1: Literature review and model simulations. *Industrial & engineering chemistry research*, *44*(23), 8773-8785.

Klunne, W.& Mugisha, C. (2001). Responses of rural households to the decline of woodfuel collecting areas: Case study in an expanding sugarcane area of Misinda district of Uganda. *Energia News*, *4*(2), 7-9.

Kneeland, D., & Vahanen, T. (2005). COFO 2005 and the Ministerial Meeting on Forests: fostering commitment to sustainable forest management. “. *Unasylva*, *56*, 3-9.

Kuunibe, N., Issahaku, H., &Nkegbe, P. K. (2013). Wood based biomass fuel consumption in the Upper West Region of Ghana: Implications for environmental sustainability. *Journal of Sustainable Development Studies*, *3*(2).

Luo, Y. W., Doney, S. C., Anderson, L. A., Benavides, M., Berman-Frank, I., Bode, A., ...& Carpenter, E. J. (2012). Database of diazotrophs in global ocean: abundance, biomass and nitrogen fixation rates. *Earth System Science Data*, *4*(1), 47-73.

MacDicken, K. G. (2015). Global forest resources assessment 2015: what, why and how. *Forest Ecology and Management*, *352*, 3-8.

Malimbwi, R., Chidumayo, E., Zahabu, E., Kingazi, S., Misana, S., Luoga, E., & Nduwamungu, J. (2010). Woodfuel. In *The dry forests and woodlands of Africa* (pp. 162-184). Routledge.

Moe, E. (2012). Vested interests, energy efficiency and renewable in Japan. *Energy Policy*, *40*, 260-273.

Moriarty, P., & Honnery, D. (2016). Can renewable energy power the future. *Energy policy*, *93*, 3-7.

Najman, B., Gachassin, M., & Raballand, G. (2010). *The Impact of Roads on Poverty Reduction: A Case Study of Cameroon*. The World Bank.

Njong, A. M., & Johannes, T. A. (2011). An analysis of domestic cooking energy choices in Cameroon. *European Journal of Social Sciences*, *20*(2),336-347.

Nyarko, S. H. (2015). Prevalence and correlates of contraceptive use among female adolescents in Ghana. *BMC women's health*, *15*(1), 60.

Nzeadibe, T. C., & Anyadike, R. N. (2012). Social participation in city governance and urban livelihoods: Constraints to the informal recycling economy in Aba, Nigeria. *City, Culture and Society*, *3*(4), 313-325.

Ondraczek, J. (2013). The sun rises in the east (of Africa): A comparison of the development and status of solar energy markets in Kenya and Tanzania. *Energy Policy*, *56*, 407-417.

Owen, M., van der Plas, R., & Sepp, S. (2013). Can there be energy policy in Sub-Saharan Africa without biomass. *Energy for sustainable development*, *17*(2), 146-152.

Pachauri, S., & Spreng, D. (2003). *Energy use and energy access in relation to poverty. Centre for Energy Policy and Economics—Swiss Federal Institutes of Technology* (No. 25). Working Paper.

Pachauri, S., van Ruijven, B. J., Nagai, Y., Riahi, K., van Vuuren, D. P., Brew-Hammond, A., & Nakicenovic, N. (2013). Pathways to achieve universal household access to modern energy by 2030. *Environmental Research Letters*, *8*(2), 024015.

Peerzado, M. B., Magsi, H., & Sheikh, M. J. (2019). Land use conflicts and urban sprawl:Conversion of agriculture lands into urbanization in Hyderabad, Pakistan. *Journal of the Saudi Society of Agricultural Sciences*, *18*(4), 423-428.

Piedrahita, R., Dickinson, K. L., Kanyomse, E., Coffey, E., Alirigia, R., Hagar, Y. & Hannigan, M. (2016). Assessment of cookstove stacking in Northern Ghana using surveys and stove use monitors. *Energy for Sustainable Development*, *34*, 67-76.

Ponce, V. M. (2006). Groundwater utilization and sustainability. *San Diego State University, College of Engineering. San Diego, Calif. [http://groundwater. sdsu.edu/]*.

Pope, D. P., Mishra, V., Thompson, L., Siddiqui, A. R., Rehfuess, E. A., Weber, M., & Bruce, N. G. (2010). Risk of low birth weight and stillbirth associated with indoor air pollution from solid fuel use in developing countries. *Epidemiologic reviews*, *32*(1), 70-81.

Puzzolo, E. (2013). Factors influencing the largescale uptake by households of cleaner and more efficient household energy technologies.

Quaschning, V. V. (2009). *Renewable energy and climate change*.

Reddy, G. S., & Reddy, S. J. (1997). Estimation of cephalosporin antibiotics by differential pulse polarography. *Talanta*, *44*(4), 627-631.

Remedio, E. M., & Domac, J. U. (2003). Socio-economic analysis of bioenergy systems:A focus on employment. *Rome: FAO*.

Schiffer, H. W., Kober, T., & Panos, E. (2018). World energy council's global energy scenarios to 2060. *Zeitschrift für Energiewirtschaft*, *42*(2), 91-102.

Schlag, N., & Zuzarte, F. (2008). Market barriers to clean cooking fuels in sub-Saharan Africa: a review of literature.

Sikei, G., Mburu, J., & Lagat, J. (2009). *Rural households' response to Fuelwood scarcity around Kakamega Forest, Western Kenya*.

Smeets E, Dornburg V, Faaij A. (2009). Traditional, improved and modern bioenergy systems for semi-arid and arid Africa - experiences from the complete network.Retrieved 3.11.2009, from, http://www.compete-bioafrica.net; 2009.Throughput.

Smith, K. R., Bruce, N., Balakrishnan, K., Adair-Rohani, H., Balmes, J., Chafe, Z., & Rehfuess, E. (2014). Millions dead: how do we know and what does it mean? Methods used in the comparative risk assessment of household air pollution. *Annual review of public health*, *35*, 185-206.

Soneye, A., Balogun, I., & Daramola, A. (2017). Impacts of Agriculture and Biomass Energy Production on Forest conversion: The Case of Igangan Forest Reserve of Ibarapa Region, South-West Nigeria. *Unilag Journal of Humanities*, *4*(2), 110-122.

Sposito, V. A., Romeijn, H., & Faggian, R. (2016). Development of Regional Production Areas in a Changing Climate: A Case Study of Gippsland, Australia. *Applied spatial analysis and policy*, *9*(3), 365-387.

Tahir, S. N. A., Rafique, M., & Alaamer, A. S. (2010). Biomass fuel burning and its implications: Deforestation and greenhouse gases emissions in Pakistan. *Environmental pollution*, *158*(7), 2490-2495.

Trossero, M. A. (2002). Dendroenergía: perspectivas de futuro. *Unasylva*, *53*(211), 3-12.

UNDP. (2008). Human Development Report 2007/2008. Fighting Climate Change: Human Solidarity in a Divided World.

Venkataraman, C., Sagar, A. D., Habib, G., Lam, N., & Smith, K. R. (2010). The Indian national initiative for advanced biomass cookstoves: the benefits of clean combustion. *Energy for sustainable development*, *14*(2), 63-72.

Venkataraman, C., Sagar, A. D., Habib, G., Lam, N., & Smith, K. R. (2010). The Indian national initiative for advanced biomass cookstoves: the benefits of clean combustion. *Energy for sustainable development*, *14*(2), 63-72.

Vermeulen, F., & Barkema, H. (2001). Learning through acquisitions. *Academy of Management journal*, *44*(3), 457-476.

Ward Thompson, D., André, P., & Kirk, J. M. (2002). The initial conditions of isolated star formation–V. ISOPHOT imaging and the temperature and energy balance of pre stellar cores. *Monthly Notices of the Royal Astronomical Society*, *329*(2), 257- 276.

Werner, C., Panesar, A., Rüd, S. B., & Olt, C. U. (2009). Ecological sanitation: Principles, technologies and project examples for sustainable wastewater and excreta management. *Desalination*, *248*(1-3), 392-401.

Wicke, B., Smeets, E., Watson, H., & Faaij, A. (2011). The current bioenergy production potential of semi-arid and arid regions in sub-Saharan Africa. *Biomass and bioenergy*, *35*(7), 2773-2786.

World Bank. (2011). Wood-Based Biomass Energy Development for Sub- Saharan Africa: Issues and Approaches. Washington, DC 20433, USA: The International Bank for Reconstruction and Development; 2011

World Health Organization. UN-HABITAT. (2010). *Hidden cities: Unmasking and overcoming health inequities in urban settings*.

Wright, S. A., Pickard, P. S., Fuller, R., Radel, R. F., & Vernon, M. E. (2009, January). Supercritical CO2 Brayton cycle power generation development program and initial test results. In *ASME power conference* (Vol. 43505, pp. 573-583).

Yamine, A. S. (1978). *U.S. Patent No. 4,071,336*. Washington, DC: U.S. Patent and Trademark Office.

Zhou, G., Myers, R., Li, Y., Chen, Y., Shen, X., Fenyk-Melody, J., ... & Musi, N. (2001). Role of AMP-activated protein kinase in mechanism of metformin action. *The Journal of clinical investigation*, *108*(8), 1167-1174.

Zulu, L. C., & Richardson, R. B. (2013). Charcoal, livelihoods, and poverty reduction: Evidence from sub-Saharan Africa. *Energy for Sustainable Development*, *17*(2), 127-137.

Appendixes

HOUSEHOLDS' BIOMASS CONSUMPTION STUDY

Appendix 1: Household Survey Questionnaire

<u>Introduction</u>

Good day, my name is ……………………………………………… a masters' student of UDS, conducting my thesis research on households' biomass consumption and its impact on forest resources in Ghana. I would appreciate so much if you could spare me some few minutes to talk to me on this subject. Your views and opinions will be extremely valuable as they will contribute not only to the successful completion of my studies, but also to the larger society for enhancing environmental sustainability.

I promise that any information that you will give to me will be kept in absolute confidentiality and use solely for the purpose of this study. There will not be other third party access to this data and I can state that there is absolutely no risk if you participate in this survey. However, your participation is survey is completely voluntary and you have the right to discontinue any time you feel so. Thank you for participation.

<u>SECTION A: BACKGROUND OF RESPONDENT</u>

1. Name of community: ………………………………………………….…..

2. Name of respondent ………………………………………………………….
3. Sex of respondent:
   a) Male
   b) Female

4. Age of respondent:
   a) Less than 20
   b) 21-30
   c) 31- 40
   d) 41- 50
   e) 51- 60
   f) Above 61

5. Marital status of respondent:
   a) Married
   b) Single
   c) Divorced
   d) Widowed

6. Level of education of respondents:
   a) None
   b) Non-formal education
   c) Basic education
   d) Secondary education
   e) Tertiary
   f) Others specify

7. Number of persons in household (Household size);
   a) 1 person
   b) 2-5 persons
   c) 6-9 persons
   d) 10-13 persons
   e) 14-17 persons
   f) 18-21 persons
   g) Above 21 persons

8. Position of respondent in Household:
   a) Female head of household
   b) Male head of household but not husband
   c) Wife to head of household
   d) Husband and head of household
   e) Son to the head of household
   f) Daughter to the head of household
   g) In-law to the head of household

9. Main occupation of respondent:
   a) Farming/agriculture activities
   b) Trade/entrepreneurship
   c) Public/Civil Servant;
   d) Artisans
   e) Unemployed
   f) Student
   g) Others

SECTION B: SOURCES OF ENERGY IN HOUSEHOLDS

1. What is your household's primary source of energy for cooking, and other domestic uses?
   a. Fuel wood
   b. Charcoal
   c. Crop residue
   d. Saw dust
   e. Petrol/kerosene stove
   f. Electric stove
   g. Gas cylinder
   h. Electric burner/cooker
   i. Others specify

2. What is the households' secondary source of energy in household?
   a) Fuel wood
   b) Charcoal
   c) Crop residue
   d) Saw dust
   e) Petrol/kerosene stove
   f) Electric stove
   g) Gas cylinder
   h) Electric burner/cooker
   i) Others specify

3. Apart from domestic uses do you use biomass energy for any of the following commercial activities?
   a) Commercial eatery
   b) Local brewery (*pito*)
   c) Baking of bread
   d) Blast smith work
   e) Other commercial works specify

4. If your source of energy is wood/charcoal/crop residues/saw dust, can you estimate (in kilograms), the quantity of used in your household per day for cooking, heating and lighting activities?

   i. For charcoal/saw dust:

   a) 1-5kg
   b) 6-10 kg
   c) 11-15 kg
   d) 16-20 kg
   e) Above 21 kgs

   ii. For wood/crop residues:

   a) 1-5 pieces
   b) 6- 10 pieces
   c) 11- 15 pieces
   d) 16-20 pieces
   e) Above 21 pieces

   iii. Not applicable

5. Where do your household normally obtain charcoal from? (for households using charcoal)
   a. Produce it personally from the bush/forest
   b. Purchase from vendors and processors
   c. Collect them from neighbours/relations
   d. Obtain it from other cooking activities
   e. Other sources specify.......................

6. Where do your household normally obtain fuel wood/crop residue from? (for only households using fuel wood)
   a. harvest it personally from the bush/forest/farm
   b. Purchase from vendors and processors in the village
   c. Collect them from neighbours/relations in the village
   d. Other sources specify.......................

7. On average, how many times do you go to the bush to harvest fuel wood per month
   a) Daily
   b) Weekly
   c) 2-time weekly
   d) Monthly
   e) Any time I need it

8. What type of trees do you often use for charcoal production?
   a. Dry trees
   b. Fresh trees
   c. Any tree at all

9. What type of trees do you often harvest for use as fuel wood?
   a. Dry trees
   b. Fresh trees
   c. Any tree at all

10. Why do you use this type of tree as your energy source?
    a. It is readily available
    b. It is fuel efficient
    c. It is very cheap to use
    d. Others specify

11. Which plant/tree species do you mostly use for fuel wood/charcoal production for your household?
    a. Crop residues
    b. Shea trees
    c. Acacia trees
    d. Wawa trees
    e. Dawadawa trees
    f. Mahogany
    g. Rosewood
    h. Others specify ....
    i. Don't know

12. Why do you prefer this particular species to others?
    a. It is readily available
    b. It is cheaper to use
    c. It is fuel efficient /It burn efficiently
    d. It produces good charcoal
    e. Others specify

13. Do you get any benefit from harvesting wood/producing charcoal?
    a. Yes
    b. No
    c. Don't know

14. If yes, name some of these benefits you or your household gets from the activity;
    a. ....
    b. ....
    c. ....
    d. ....
    e. ....

SECTION C: EFFECT OFWOOD/BIOMASS CONSUMPTION ON FOREST RESERVE

15. What are the effects of harvesting wood or charcoal production on the forest and environment?
    a. Deforestation/ Destruction of forest cover
    b. Destruction of ecosystem
    c. Disappearance of tree species
    d. Desertification
    e. Removal of environmental cover
    f. Cascading effect on climate
    g. Others specify......................................

16. could you please rate the impact of households' biomass consumption on the forest/woodlots?
    a. No impact at all
    b. Very little impact
    c. Moderate impact
    d. High impact
    e. Extreme impact

SECTION D: FACTORS INFLUENCING HOUSEHOLDS' BIOMASS CONSUMPTION

17. In your household, who determine the type of energy to use in the cooking, heating and lighting?
    a) Female head of household
    b) Male head of household but not husband
    c) Wife to head of household
    d) Husband and head of household
    e) Son to the head of household
    f) Daughter to the head of household
    g) In-law to the head of household

18. What normally influence your decision to use biomass/wood instead of any other energy source?
    a. Cost efficiency
    b. Burning/energy efficiency
    c. Accessibility /availability
    d. Environmental Impact efficiency
    e. Others benefits specify.............................

SECTION E: ALTERNATIVE SUSTAINABLE ENERGY SOURCES FOR HOUSEHOLDS

19. Do you know others sustainable ways to harvest wood and other forest resources without destruction to the forest /ecosystems?
    a. Yes
    b. No
    c. Don't know

20. If yes, can you name some of these ways?
    a. ....
    b. ....
    c. ....
    d. ....
    e. ....

21. If you get the opportunity, which of the following alternative energy sources will you prefer differently?
    a) Fuel wood
    b) Charcoal
    c) Crop residue
    d) Saw dust
    e) Petrol/kerosene stove
    f) Electric stove
    g) Gas cylinder
    h) Electric burner/cooker
    i) Others specify

22. Why will you prefer this source to others?
    a. Cost efficiency
    b. Burning/energy efficiency
    c. Accessibility /availability
    d. Environmental Impact efficiency
    e. Others benefits specify.............................

23. Why is your household not currently using this alternative energy source?
    a. Household cannot afford the cost
    b. Not available/Not accessible to
    c. Don't know how to use it
    d. Specify other reasons ……………………………...

24. What are the advantages of this alternative source over your current energy source?
    a. ....
    b. ....
    c. ....
    d. ....
    e. ....

SECTION F: RECOMMENDATION FOR SUSTIANABLE HOUSEHOLD ENERGY EFFICIENCY

25. What environmentally sustainable energy sources will you recommend for your households' use to enhance biomass sustainability?
    a. ....
    b. ....
    c. ....
    d. ....
    e. ....

26. Give your general recommendations for households using biomass energy as their main source
    a. ....
    b. ....
    c. ....
    d. ....
    e. ....

Appendix 2: Focus Group Discussion Guide (For only seller and producers of wood and wood products)

Introduction

Good day, my name is ……………………………………………… a masters' student of UDS, conducting my thesis research on households' biomass consumption and its impact on forest resources in Ghana. I would appreciate so much if you could spare me some few minutes to talk to me on this subject. Your views and opinions will be extremely valuable as they will contribute not only to the successful completion of my studies, but also to the larger society for enhancing environmental sustainability.

I promise that any information that you will give to me will be kept in absolute confidentiality and use solely for the purpose of this study. There will not be other third party access to this data and I can state that there is absolutely no risk if you participate in this survey. However, your participation is survey is completely voluntary and you have the right to discontinue any time you feel so. Thank you for participation.

SECTION A: BACKGROUND OF RESPONDENTS/DISCUSSANTS

1. Name of community …………………………………….
2. Category of discussant ……………………………………
3. No. of discussants ……………………………………......
4. Sex composition of groups…………………………………
5. Age range………………………………………………….
6. Start time…………………………………………………
7. End time; …………………………………………………
8. Date ……………………………………………………

SECTION B: SOURCES OF WOOD RESOURCES

27. Where do you normally get your wood/wood resources?
   - Probe for main and secondary sources
   - Estimated quantity of wood/ biomass sold/processed daily, weekly or monthly
   - Main customers/consumers of products
   - Reasons why you chose this business

28. Which type of wood/wood products do you often sell/process?
   - Probe for: Charcoal, Firewood, Other uses
   - Why do you choose this type of products over the others?

SECTION B: IMPACT AND BENEFIT OF BIOMASS TRADE/BUSINESS

29. What are the benefits of trading in wood and wood resources? PROBE for
   - Economic benefits
   - Cultural benefits
   - Social benefits
   - Other benefits

30. What are the environmental effects of your trade/business especially on the forest? Probe for

- Effect on climate
- Effect on forest reserves
- Effect on agriculture
- Effect on health
- Other effects

31. Are there disadvantages that you can share with me? Probe for
    - Natural, economic, social and cultural contexts

32. Comparing the benefits and disadvantages, will you say this trade is worthy and why?
    - Economic benefits
    - Cultural benefits
    - Social benefits
    - Other benefits

SECTION C: TREES SPECIES USE IN CHARCOAL PRODUCTIONS

33. Which type of trees do you normally sell or use in the production of charcoal? Probe for
    - Type of trees (dry or wet or both)
    - Species of trees
    - Reasons for the choice of species/tree
    - What are the effect of choosing the option?

34. Where do you normally obtain fuel wood from? (probe for)
    - Source, how many times a week
    - How they convey the wood to sales point
    - How many times you burn/produce charcoal per week/month

35. Can you give me vivid description of how to produce or process charcoal or wood for sale?
    - (probe for detail and step by step description of how to produce charcoal or wood for sale)

SECTION D: FACTORS INFLUENCING HOUSEHOLDS' BIOMASS CONSUMPTION

36. What factors influence your decision to do this business?
    - Probe for factors and drivers

37. What factors influence your decision to choose a particular tree species for charcoal production?

    - Probe for factors and drivers

38. Do you know others sustainable ways of harvesting wood and other forest resources without destruction to the forest /ecosystems?

   - Probe for specify ways

39. What environmentally sustainable energy sources will you recommend for households' use to enhance biomass sustainability?

   - Probe for specific sources and reasons