**UNIVERSITI PUTRA MALAYSIA**

IMPACT OF WOOD FUEL CONSUMPTION ON FOREST DEGRADATION, HEALTH OUTCOMES AND ECONOMIC GROWTH IN SUB-SAHARAN AFRICA

CHINDO SULAIMAN

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By

CHINDO SULAIMAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy

February 2017

DEDICATION

This work is dedicated to my parents, Malam Aminu Bello and Aisha Aminu.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the Degree of Doctor of Philosophy

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February 2017

Chairman : Associate Professor Abdul Rahim Abdul Samad, PhD
Faculty : Economics and Management

This thesis is motivated based on the increasing production of wood fuel driven by its growing consumption in the Sub-Saharan African region. While other parts of the world are already on the verge of reducing the use of wood fuel and switching to much cleaner and healthier fuel such as electricity, considering the potential environmental, health and economic effects it has, the story is different in Sub-Saharan Africa. The demand for the wood fuel in Sub-Saharan Africa is on the increase and has been even projected to increase further in the coming decades. This calls for concern and research into the area, as some challenges accompany the increase. These likely challenges, which are related to forest degradation, health and economic growth, are the focus of our study. Therefore, this study specifically investigates the impact of wood fuel consumption on forest degradation as objective one. Whereas, the impact of wood fuel consumption on health outcomes (under five and adult mortality rates) and economic growth are investigated as objective two and three, respectively. The organisation of this thesis is based on essay format of thesis layout and not the conventional format.

A panel method of system generalized method of moment (GMM) was used to estimate the impact of wood fuel consumption on forest degradation and the impact of wood fuel consumption on health outcomes in 45 and 46 sub-Saharan African countries, respectively, for the 2005-2013 period. While the impact of wood fuel consumption on economic growth was estimated using panel autoregressive distributed lag (ARDL) method, which included pooled mean group, mean group and dynamic fixed effect estimators in 19 sub-Saharan African countries for the 1979-2013 period. The data on all the variables for all the countries were sourced from the databases of World development indicators (WDI) of World Bank, World Governance Indicators (WGI), and food and agricultural organisation (FAO).

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The estimated results for the impact of wood fuel consumption on forest degradation reveal that wood fuel consumption significantly increases forest degradation in the region. When interacted with control of corruption or government effectiveness, wood fuel consumption has been found to have a negative impact on forest degradation. It suggests that a sound control of corrupt practices and effective governance can help to reduce degradation in the region. On the impact of wood fuel consumption on health outcomes, the results show that wood fuel consumption has significant positive impact on adult and under-five mortality rates in the region. This finding confirms the assertion that the rising deaths recorded in the region from indoor air pollution related illnesses can be linked to wood fuel smoke. Lastly, the results of the impact of wood fuel consumption on economic growth disclose that wood fuel consumption causes a decline in economic growth through a decrease in productivity of labour and increasing medical expenses due to indoor air pollution related infections. The estimated models were validated via diagnostic and robustness tests, which suggest that the estimates were reliable.

The general findings indicate that an increase in wood fuel consumption facilitates forest degradation, adult and under-five mortality rates, as well as slow down economic growth. The policy recommendation from this study is that governments of Sub-Saharan African countries should strengthen the fight against corruption and ensure effective governance, as well as strive to make the modern fuel available and affordable. Thus, it will assist in reducing the too much dependence on wood sources for energy use. Consequently, the region can safeguard its forests, prevent indoor air related smoke diseases, and avert the adverse effect of wood fuel consumption on growth.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

KESAN PENGGUNAAN BAHAN KAYU API TEHADAP KEMUSNAHAN HUTAN, HASIL KESIHATAN DAN PERTUMBUHAN EKONOMI DI SUB-SAHARA AFRIKA

Oleh

CHINDO SULAIMAN

Februari 2017

Pengerusi : **Profesor Madya Abdul Rahim Abdul Samad, PhD**
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Tesis ini adalah didorong berdasarkan pengeluaran bahan kayu api yang semakin meningkat oleh penggunaan yang semakin meningkat di rantau Sub-Sahara Afrika. Manakala kawasan-kawasan lain di dunia sudah mula mengurangkan penggunaan bahan kayu api dan beralih kepada bahan api yang lebih bersih dan sihat seperti elektrik memandangkan kesan yng dimiliki terhadap alam sekitar, kesihatan dan ekonomi yang dimilikinya. Cerita ini adalah berbeza di Sub-Sahara Afrika. Permintaan untuk bahan kayu api di Sub-Sahara Afrika semakin meningkat dan dijangka terus meningkat dalam dekad-dekad akan datang. Hal ini memerlukan perhatian terhadap kawasan dan penyelidikan berkaitan peningkatan disertakan dengan beberapa cabaran. Cabaran-cabaran besar yang berkaitan dengan kemusnahan hutan, kesihatan dan pertumbuhan ekonomi, akan menjadi tumpuan kajian kita. Oleh itu, kajian ini secara khusus mengkaji kesan penggunaan bahan kayu api pada kemusnahan hutan sebagai salah satu objektif. Manakala kesan penggunaan bahan kayu api terhadap kesihatan (di bawah lima dan kadar kematian orang dewasa) dan pertumbuhan ekonomi akan disiasat sebagai objektif kedua dan ketiga. Organisasi tesis ini adalah berdasarkan kepada susun atur format esei dan bukan format konvensional.

Satu kaedah panel kaedah sistem teritlak masa (GMM) telah digunakan untuk menganggarkan kesan penggunaan bahan api kayu pada pelupusan hutan dan kesan hasil penggunaan bahan kayu api pada kesihatan di 45 dan 46 negara-negara di Afrika Sub-Sahara, masing-masing, untuk tahun 2005-2013. Manakala kesan penggunaan bahan kayu api pada pertumbuhan ekonomi dianggarkan menggunakan kaedah panel autoregressive taburan lag (ARDL), termasuk kumpulan min terkumpul, kumpulan min dan dinamik penganggar kesan tetap di 19 negara-negara Afrika Sub-Sahara bagi tempoh 1979-2013. Data mengenai semua pembolehubah untuk semua negara-negara diperoleh dari pangkalan data petunjuk pembangunan Sedunia (WDI) dari Bank

Dunia, World Governance Indicators (WGI), dan organisasi makanan dan pertanian (FAO).

Keputusan anggaran kesan penggunaan bahan kayu api pada kemusnahan hutan mendedahkan bahawa penggunaan bahan kayu api meningkat dengan ketara di rantau ini. Manakala, kawalan keberkesanan rasuah dari pihak kerajaan dapat mengurangkan kemusnahan hutan. Apabila berinteraksi dengan kawalan keberkesanan rasuah / kerajaan, penggunaan bahan kayu api telah didapati mempunyai kesan negatif ke atas kemusnahan hutan. Ini bermakna bahawa kawalan rasuah dan pentadbiran diurus dengan berkesan boleh membantu untuk mengurangkan kemusnahan di rantau ini. Mengenai kesan penggunaan bahan kayu api pada hasil kesihatan, keputusan menunjukkan bahawa penggunaan bahan kayu api mempunyai kesan positif yang signifikan pada orang dewasa dan di bawah lima kadar kematian di rantau ini. Ini mengesahkan dakwaan bahawa kematian yang semakin meningkat dicatatkan di rantau ini adalah daripada penyakit dalaman berkaitan pencemaran udara boleh dikaitkan dengan asap bahan kayu api. Akhir sekali, hasil kesan penggunaan bahan kayu api pada pertumbuhan ekonomi mendedahkan bahawa penggunaan bahan kayu api merupakan punca penurunan pertumbuhan ekonomi melalui penurunan dalam produktiviti tenaga pekerja dan peningkatan perbelanjaan perubatan kerana jangkitan dalaman yang berkaitan pencemaran udara. Semua model yang dianggarkan telah disahkan melalui diagnostik dan keteguhan ujian, yang menunjukkan bahawa anggaran yang diperolehi boleh dipercayai.

Hasil kajian umum menunjukkan bahawa peningkatan dalam penggunaan bahan kayu api memudahkan kemusnahan hutan, dewasa dan di bawah lima kadar kematian, dan juga memperlahankan pertumbuhan ekonomi. Syor dasar daripada kajian ini adalah bahawa kerajaan negara-negara Afrika Sub-Sahara perlu mengukuhkan usaha memerangi rasuah dan memastikan tadbir urus yang berkesan, serta berusaha untuk memoden bahan api adalah sedia ada dan berpatutan. Ini akan membantu dalam mengurangkan pergantungan terlalu banyak sumber kayu untuk kegunaan tenaga. Oleh itu, hutan akan dilindungi, penyakit dalaman berpunca daripada asap yang berkaitan boleh dielakkan dan kesan buruk kepada pertumbuhan juga dapat dielakkan.

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Finally, I will like to thank my friends in my home country for their prayers and well wishing.

I certify that a Thesis Examination Committee has met on 8 February 2017 to conduct the final examination of Chindo Sulaiman on his thesis entitled "Impact of Wood Fuel Consumption on Forest Degradation, Health Outcomes and Economic Growth in Sub-Saharan Africa" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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Date: 22 March 2017

This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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Date:

Declaration by graduate student

I hereby confirm that:
- this thesis is my original work;
- quotations, illustrations and citations have been duly referenced;
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Declaration by Members of Supervisory Committee

This is to confirm that:
- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) were adhered to.

Signature: Name of Chairman of Supervisory Committee:	Associate Professor Dr. Abdul Rahim Abdul Samad

Signature: Name of Member of Supervisory Committee:	Professor Dr. Mohd Shahwahid Haji Othman

Signature: Name of Member of Supervisory Committee:	Associate Professor Dr. Lee Chin

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CEPF	Critical Ecosystem Partnership Fund
EIA	Energy Information Administration
ESD	Ecologically Sustainable Development
ESMAP	Energy Sector Management Assistance Program
FAO	Food and Agricultural Organization
FRA	Forest Resource Assessment
GFRA	Global Forest Resource Assessment
GMM	Generalized Method of Moments
GTZ	German Agency for Technical Cooperation
IEA	International Energy Agency
IISD	International Institute for Sustainable Development
IREA	International Renewable Energy Agency
IUCN	International Union for Conservation of Nature
Kg	Kilogram
LPG	Liquefied Petroleum Gas
NEPAD	New Partnership for Africa's Development
OLS	Ordinary Least Squares
SDGs	Sustainable Development Goals
UN	United Nations
UNDP	United Nations Development Program
UNECA	United Nations Economic Commission for Africa
US EIA	United States Energy Information Administration
WDI	World Development Indicators
WGI	World Governance Indicators

WHO   World Health Organization

WRI   World Resources Institute

CHAPTER 1

INTRODUCTION

1.1   Background of the Study

Human needs, especially heat and motive power, require energy to be satisfied. So also, commercial activities, healthcare, industries, communication, education and general public services are reliant on the energy supply to be operated. IEA (2000) asserts that poor access to the energy supply prompt people to migrate to urban areas to search for a better living standard and hence lead to rapid urbanisation. While other continents of the world such as America, Europe and Asia are mostly relying on a modern form of energy, Africa still relies mainly on traditional biomass (example, fuelwood and charcoal) for its energy source, particularly the Sub-Saharan part of the continent (i.e. Sub-Saharan Africa).

In 2012, wood biomass energy sources constituted about 76% of the total primary energy in sub-Saharan Africa (IREA, 2013), while the remaining percentage was accounted by oil, natural gas, coal and peats, hydro, nuclear and other renewable sources. Equally, the region specifically relies more on wood fuel, which carries more than 90% of the biomass fuel consumption (FAO, 2015).

Before we proceed, it is important to define the term wood fuel for a proper understanding of the topic. According to Food and Agricultural Organization (FAO), wood fuel refers to all kinds of fuels obtained from trees and shrubs in forests and non-forested lands, directly or indirectly. The common wood fuels in Sub-Saharan Africa are fuelwood (firewood) and charcoal.

Charcoal is a solid residue obtained from a process of carbonisation, distillation, pyrolysis and torrefaction of wood, mainly, trunks and branches of trees using continuous/batch systems. While, fuelwood (also known as firewood) refers to the wood in its rough form in pieces, chips and pellets cut from forest trees and non-forest trees, and by-products of wood from the timber industry, as well as the recovered wood products. While rural populace mostly consume firewood, charcoal is mainly consumed by urban dwellers.

The choice of Sub-Saharan Africa region as the focal point of the study is motivated based on the ever increasing consumption of wood fuel in the region for decades, as other regions' consumption of the product decreases or remains the same. The general background of the study area, which is Sub-Saharan Africa, is given in the next subsection.

1.1.1 General Background of the Sub-Saharan African Region

Sub-Saharan Africa is the area of the African continent located in the south of the Sahara desert. It comprises of all African countries located within the geographically demarcated area. Figure 1.1 shows map of sub-Saharan Africa with the countries found in it. The number of countries located within the region is 48 countries with the total population of 973.4 million (WDI, 2014). The division of the region's population between the urban and the rural areas are 37% and 63%, respectively.

The aggregated gross domestic product (GDP) of the region is $1.729 trillion (at market price) and with gross national income (GNI) per capita of the region put at $1,638 (current US$) (WDI, 2014). The average life expectancy at birth for a Sub-Saharan African is 58 years (WDI, 2013). The total forest cover in the region, according to FAO (2010), is 595 million hectares of land. That is about 88.3% of the continent's total forest cover of 674 million hectares. Figure 1.2 shows the forested land in Africa. The location of the forests is mostly in the Sub-Saharan African region.
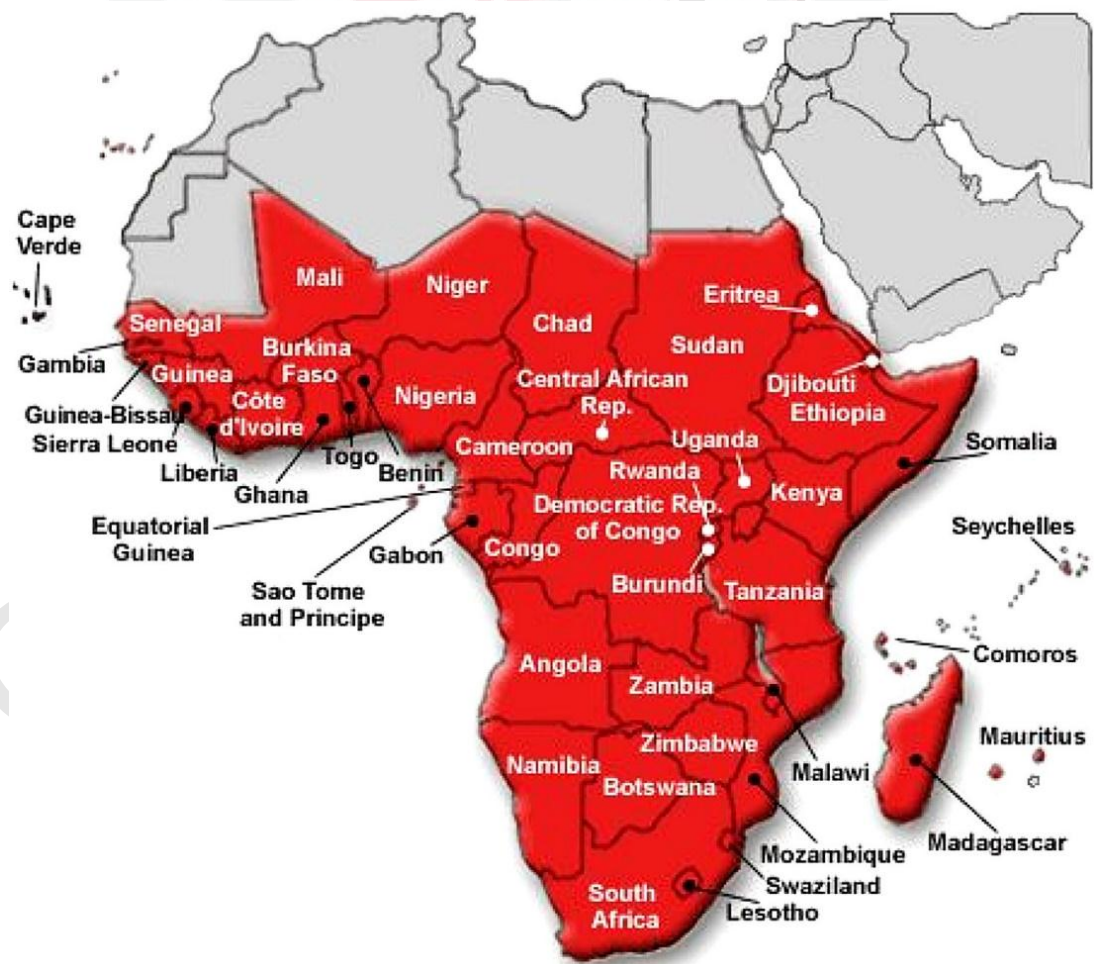
Figure 1.1 : The map of Sub-Saharan Africa
(Source: https://www.pinterest.com/pin/326159197983207674/.)

Figure 1.2 : Forests and woodland cover in Africa
(Source: http://static.newworldencyclopedia.org/2/21/Africasatelliteorthographic.jpg)

1.1.2   Sub-Saharan African Forest Profile

The Sub-Saharan African forests cover about 19% of the total land area in the region (WRI, 2005), with the percentage of an individual country's forests in the region ranging from as high as 85% in Gabon to as low as 0.5% in Lesotho, as reported by FAO (2003). The classification of the Africa's forests and woodlands are about nine, namely, subtropical dry forests, tropical shrubs, subtropical humid forests, subtropical mountain forests, tropical moist forests, tropical dry forests, plantations, tropical mountain forests and tropical rain forests (FAO, 2003). In the whole of Africa, plantation forests cover only 8 million hectares of land, representing only 4.3% of World's total of plantation forests (Kambewa et al., 2007). In Sub-Saharan Africa, the

primary plantation forests are in Sudan and South Africa. Out of the total forested lands in Africa, FAO (2003) reports only 5% as fomally protected. FAO (2002) states that the per person forest cover in Africa is 0.8 hectare, which is above the global average of 0.6 hectares.

The Congo basin located in the central Africa is the major largest forest cover block in the region, covering about 200 million hectares (Bruinsma, 2003), and is ranked the second largest continuous tropical rainforest in the World after Amazon forest. Other important forest areas in the region comprise the eastern arc mountain forests of East Africa, the Guinea forest of West Africa, and the Mopane and Miombo woodlands located in part of southern Africa and the eastern Madagascar.

The role of the forest sector to economic development in Africa is enormous, specifically in Eastern, Western and Central Africa, where there is significant forest cover. All these sub-regions above belong to Sub-Saharan region of Africa. The only sub-regional part of Africa with tiny portion of forest land is Northern Africa due to its desert nature. By geographical location, this sub-region is outside Sub-Saharan Africa. Emerton and Muramira (1999) reveal that forests contribute to the economy of the Sub-Saharan African region through tourism, energy, forestry and agriculture. The contribution of forests to the gross domestic products (GDP) for Africa as a whole, as reported by NEPAD (2003), is 6 percent on the average.

These forests provide some ecosystem services such as regulating services such as flood and climate; supplying timber and non-timber products; cultural services such as aesthetic, recreational and spiritual; provision of shelter; and storage of carbon. Equally and importantly, most of the region's households, especially, in the rural areas, rely on biomass (in the form of fuelwood and charcoal) for their energy needs and income generation. With the increase in human population, agricultural expansion, illegal logging activities, overgrazing, these forests are continuously losing woody vegetation. Lepers et al. (2005) assert that the clear evidence of forest cover loss in Sub-Saharan Africa can be visibly seen and observed in the southern Africa's sub-tropical dry Miombo forests. The description of the sub-regional forests in the region of Sub-Saharan Africa are as follows:

Central African forests

Central Africa's forests cover an estimated area of 240 million hectares of land, and it is mainly a condensed type of tropical rain forest (FAO, 2005). Figure 1.3 shows the forest cover map of the region. Central Africa's forests constitute the second largest rainforest area in the world. The forest cover in the Central Africa also constitutes about 35% and 6% of the Africa's and World's forest cover, respectively. An approximately 60% of the subregion's forest area is in the Democratic Republic of Congo. Burundi and Rwanda have the lowest forest cover in the sub-region.

The major forest block, which dominated the sub-region is Congo basin forest. This forest block is considered the second World's largest forest after Amazon forest. The

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dense forest covers about 200 million hectares of land, which is about 18% of the tropical forests around the globe. Maathai (2005) maintains that Congo Basin forest contains over 10,000 plants species and nearly 400 mammalian species. The sub-region houses six countries, namely, Central African Republic, Sao Tome and Principe, Congo Republic, Gabon, Equatorial Guinea and the Democratic Republic of Congo. Among these countries, Gabon has the highest forest cover with about 84.7% of its total land area covered by forests. FAO (2005) reports that almost all the countries in the sub-region suffer from forest loss.

Congo Basin forests have relatively experienced low rates of deforestation as compared to Africa as a whole. However, the forests of the Congo basin experienced continuous degradation that is hard to estimate. Rwanda and Burundi have the highest rate of forest degradation in the sub-region. While Congo, Gabon and the Central African Republic have less rate of annual forest loss, sometimes even below -0.1%. Cameroon and Democratic Republic of Congo have the largest cleared areas every year in the region.
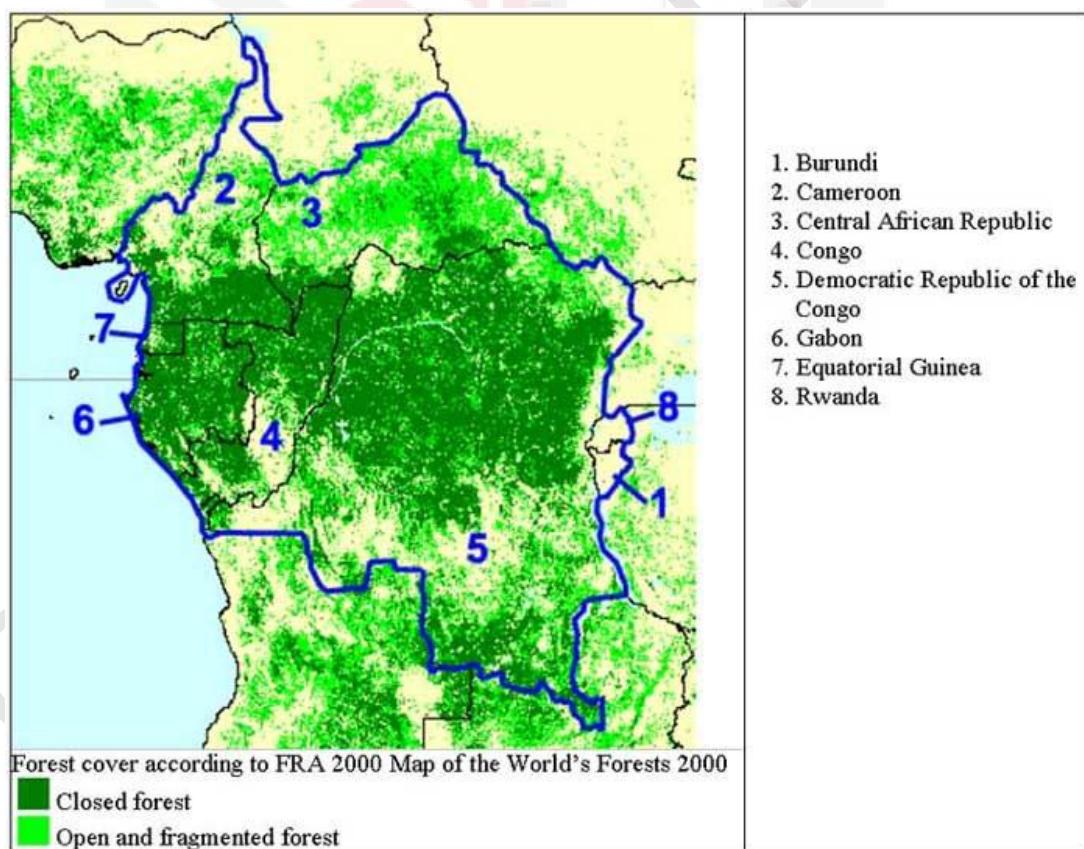
Figure 1.3 : Forest cover map of Central Africa
(Source: http://www.fao.org/docrep/004/Y1997E/y1997e17.jpg)

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Eastern African forests

Eastern Africa has about 13% land area covered by forests. Figure 1.4 illustrates the map of the subregion's forest. The natural forest cover in the sub-region is about 134 million hectares. The sub-region contains countries such as Uganda, Eritrea, Kenya, Seychelles, Comoros, Tanzania, Ethiopia, Mauritius, Rwanda, Somalia, Burundi, Djibouti and Madagascar. The most forested country in the region is Kenya, with about 30% of its land area covered by forests (UNEP, 2002). Uganda is a second forested country in the sub-region with 21% land area covered by forests. On the other hand, Djibouti has only 0.3% forest cover (FAO, 2005), which is the least in the sub-region. The sub-region as a whole suffers from forest loss, which is at a yearly average of 0.51%. However, the scale of the loss varies from country to country. FAO (2005) states that Burundi suffers much in the sub-region with about 9% and the least is 2% in Uganda. Some countries (e.g., Eritrea) in the sub-region are more exposed to degradation than others due to the nearly absence of forests' protection law in the country.

The subregion suffers from heavy deforestation mostly caused wood harvest for fuel. This is because the primary use of wood in the sub-region is for burning as fuel. Statistics show that over 1 million hectares of forests are deforested yearly in the subregion. Because of the civil war that ravaged some countries in the sub-region (e.g. Somalia, Uganda and Sudan), the degradation of forests continued uninterruptedly. The tree planting programs began in the 1990s by most countries in the sub-region, have later stopped due to war and political instability. Equally, even the plantation forests have declined due to excessive dependence on wood fuel.
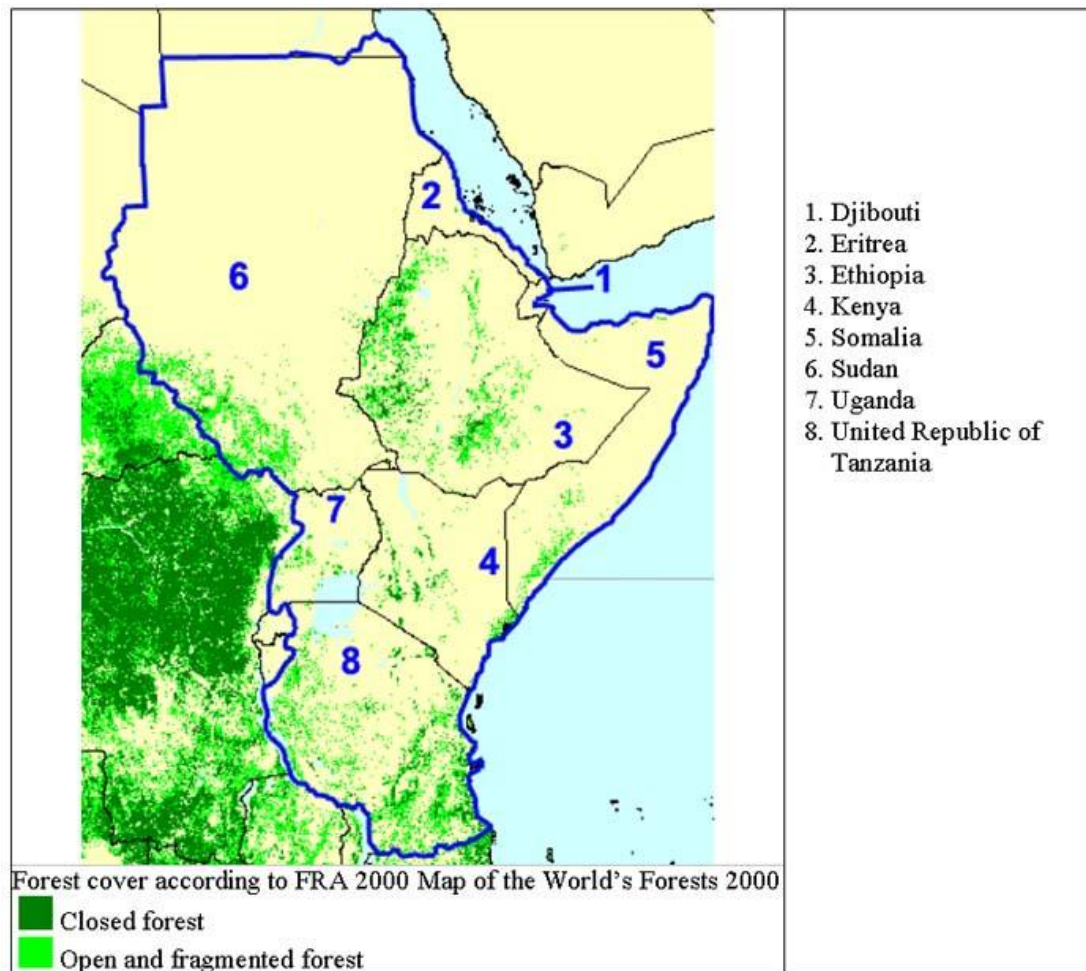
Figure 1.4 : Forest cover map of Eastern Africa
(Source: http://www.fao.org/docrep/004/Y1997E/y1997e19.jpg)

Southern African Forests

Southern African subregion has 32.5% of its land covered by forests, according to FAO (2005). Figure 1.5 illustrates the map of the subregion's forest cover. The subregion consist of Lesotho, Angola, South Africa, Zimbabwe, Namibia, Zambia, Mozambique, Swaziland, Botswana and Malawi. The types of forests found in this sub-region are tropical rain forests, mangrove forests, Miombo woodlands, Zambezi teak forests, Mopane woodlands and Cape Floristic Centre forests (McCullum, 2000).

The forest cover varies considerably across countries in the sub-region. According to UNEP (2002), Angola with about 56% vegetation cover, is the most forested country in the sub-region. While Namibia, South Africa and Lesotho are having only 30% their land area covered by forests, which are considered the least forested countries in the sub-region. Southern Africa is the only Sub-Saharan African sub-region that has many plantation forests. For example, in 2001 the entire forests plantation is estimated to be around 2.5 million hectares of land, which signifies a 9% growth from 2.3 million forest plantations in 1992. However, FAO (2003) maintains that the sub-region has

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experienced forest loss over time at the rate of 2.4 % in Zambia and Malawi, 1.5% in Zimbabwe, 1.2% in Swaziland, 0.9 in Tanzania, Mozambique and Angola, and South Africa with the least, 0.1%. It is worth noting that South Africa is the country that has the least rate of forest loss and at the same time has the largest forest plantations in the sub-region.

Most countries in the sub-region have exhibited forest cover loss over the last few decades. The countries have shown a different level of deforestation due to certain factors such as conservation policies, development projects, ecological conditions, and the size of the rural economy. A significant portion of the subregion's population uses wood as their main source of energy for cooking and heating, which facilitates the cutting down of trees for fuel. The degradation of forests in this sub-region has also been linked to the commercialization of forest products, which generate cash income to many people. The degradation of forests in Zambia constitutes about 49% of the subregion's deforestation. That is, the country degrades about 14 times more forest per person than Malawi. However, countries such as Botswana, Zimbabwe and Namibia are categorised as having moderate deforestation rate.
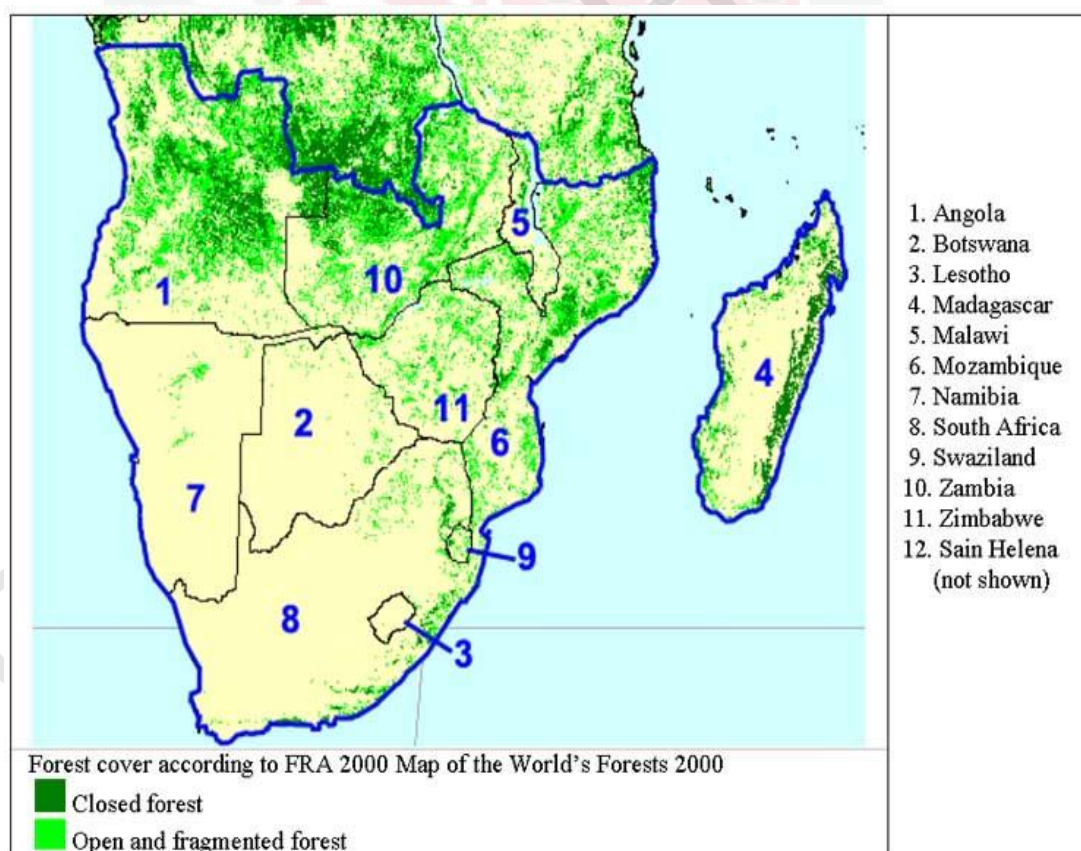

Figure 1.5 : Forest cover map of Southern Africa
(Source: http://www.fao.org/docrep/004/Y1997E/y1997e1b.jpg)

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Western African Forests

About 12% of the total land area, amounting to 115 million hectares is covered by forest in west africa (FAO, 2005). Figure 1.6 shows the map of the subregion's forest cover. There is variation in the forest cover across the countries in the sub-region with Guinea-Bissau having the highest percentage of forest cover. Forest land covers about 60.5% of Guinea-Bissau. The forest cover in the sub-region represents 13% of the continent's total forest cover. While Guinea-Bissau has the highest cover, on one hand, Niger and Mauritania have the least forest cover on the other hand. The less forest cover in the Niger and Mauritania is linked to their dry climatic conditions.

The popular forest in the sub-region is the Guinea forest, which is recognised as one of the World's major biodiversity hotspots by Conservation International (CEPF, 2000). The countries located in this sub-region include Guinea, Benin, Guinea-Bissau, Burkina Faso, Liberia, Cameroon, Togo, Mali, Cape Verde, Mauritania, Chad, Niger, Cote d'Ivoire, Nigeria, Gambia, Senegal, Ghana and Sierra Leone. Due to deforestation and forest degradation triggered by anthropogenic activities, the sub-region suffered severely from forest loss. UNEP (2004) reports that due to human activities, only 15% of the original vegetation of the Guinea forest of West Africa is now available due to forest loss, with Nigeria and Cote d'Ivoire having the highest rate of annual forest loss. Forest plantations are little in this subregion, and the data on them are not available.

The limited forest resources located in the area are attributed to the climatic condition of the area, large population, export of wood products and agricultural land expansion. Countries such as Nigeria, Benin and Togo are highly populated, which causes more forest degradation through residential expansion and clearing of more lands for farming activities. This sub-region has a high negative rate of forest change, which is about -1.5% annually. This rate of degradation is far above the Africa's -0.78% rate of forest change. Cote d'Ivoire and Niger suffer most regarding forest cover loss than any other country in the sub-region. Furthermore, Niger has the highest rate of annual deforestation in the region.
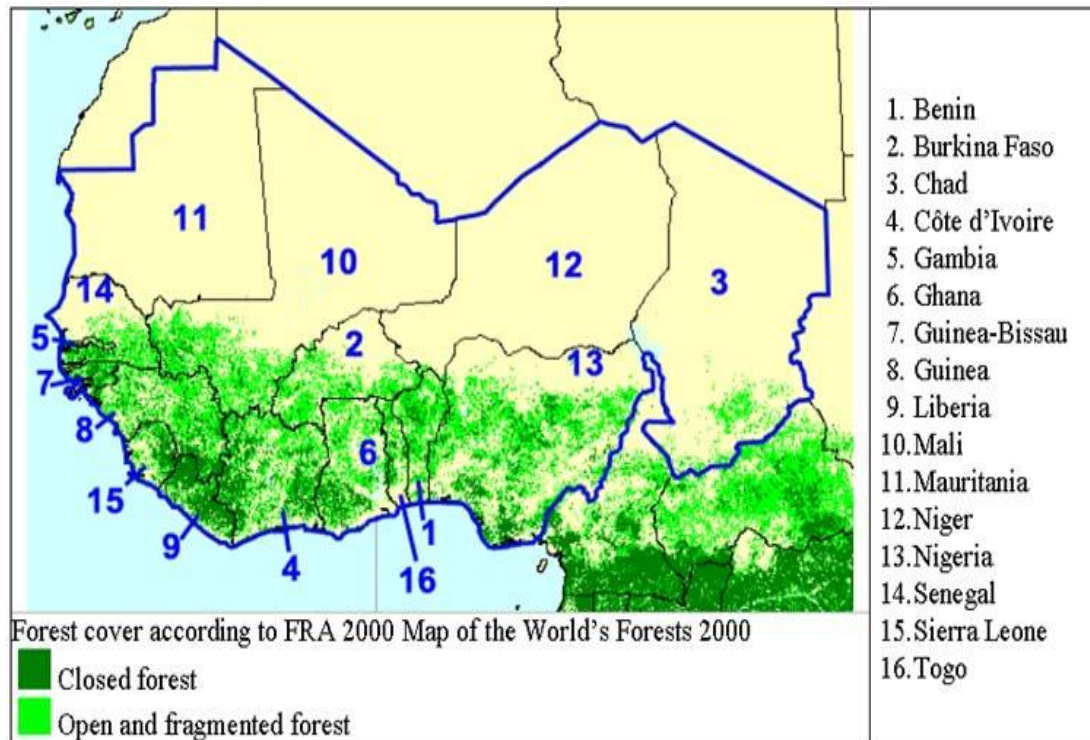
Figure 1.6 : Forest cover map of Western Africa
(Source: http://www.fao.org/docrep/004/Y1997E/y1997e15.jpg)

1.1.3 Wood fuel Consumption in the World

It is worthy to note that, about 50% of the world's population depends on the use of wood biomass as a source of energy for cooking (IEA, 2010). Similarly, nearly 81% of the households residing in Sub-Saharan Africa also rely on wood energy for cooking activities (IEA, 2010). The Sub-Saharan African region accounts for a smaller fraction of 2% of the global modern energy consumption. Even at that figure, the rural energy consumption from non-renewable source is still very low compared to the urban rate of energy consumption. This indicates how important wood fuel is, to the countryside of the region, where about 63% of the population of the region reside (WDI, 2014).

Figure 1.7 shows the trend of wood fuel consumption across different continents of the World. We can observe that while the use of wood fuel by other continents is declining or remains stable, that of Africa is steadily increasing. It suggests that the use of wood fuel in the continent is still on the increase, which signifies more pressure on the forest resources.

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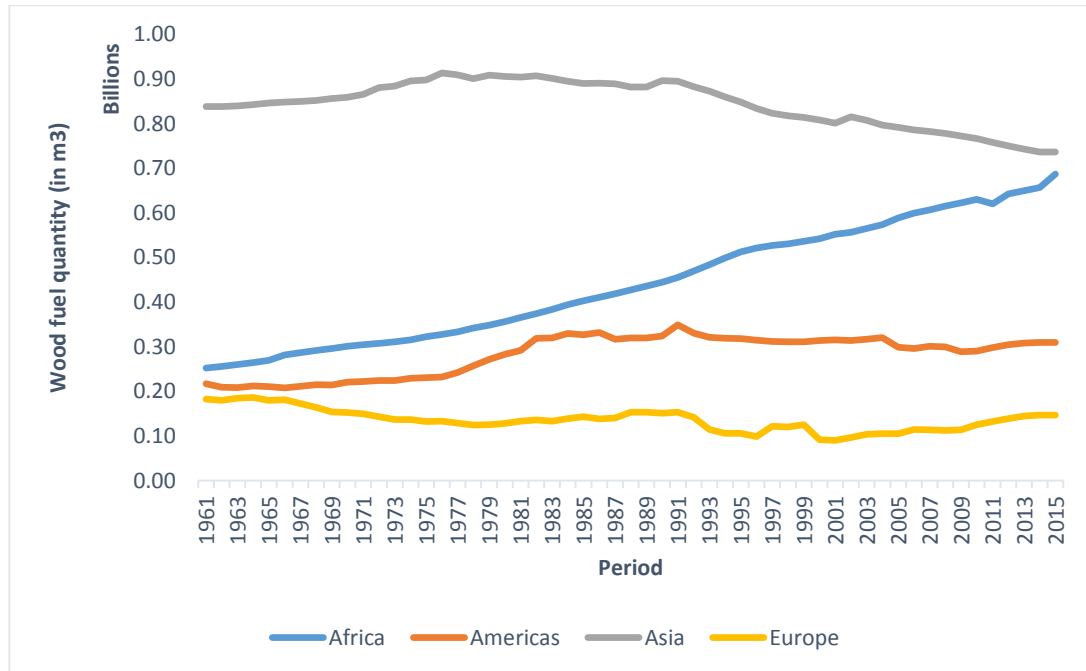
Figure 1.7 : Wood fuel consumption in different continents of the World
(Source: Computed based on data from FAO (2016).)

1.1.4 Wood fuel Consumption in Sub-Saharan Africa

In Africa, wood consumption has two major components- fuelwood and industrial round wood. The total wood consumption is about 700 million cubic meters yearly (Sander et al., 2011), of which only 75 million of it go for industrial processing. While the remaining major portion, 625 million, is used as fuel. In other words, the region consumes about 90% of the round wood produced as wood fuel. The larger portion of wood consumed as fuel is due to the high demand for wood fuel brought about by inaccessibility and unaffordability of the modern fuel. Another reason is that most of the tree species in African forests have low commercial value, as such, only a few can serve as industrial round wood. There are over 400 different species of trees in Sub-Saharan African forests, out of which only about 100 species have commercial value and can serve as industrial round wood. The detail discussion of the reasons why the region heavily relies on wood for fuel will be presented later in this chapter.

Sub-Saharan Africans mostly use wood fuel for cooking. On the average, a family consumes three bundles of fuelwood weekly by cooking 2 to 3 times a day. However, the consumption depends on the size of the household as a larger family consumes more fuelwood than smaller families. Larger families require cooking to a great quantity, which in turn requires more wood fuels.

Sub-Saharan African countries such as Tanzania, Kenya, Rwanda, Burundi and Uganda are good examples where wood fuel plays a major role in providing energy, creating jobs, reducing poverty and enhancing economic development. Figure 1.8

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shows the increasing trend of production and consumption of wood fuel in Sub-Saharan Africa from 1990 to 2014. The trends indicate that both production and consumption increase simultaneously. It shows that most of the wood fuel produced are consumed locally.
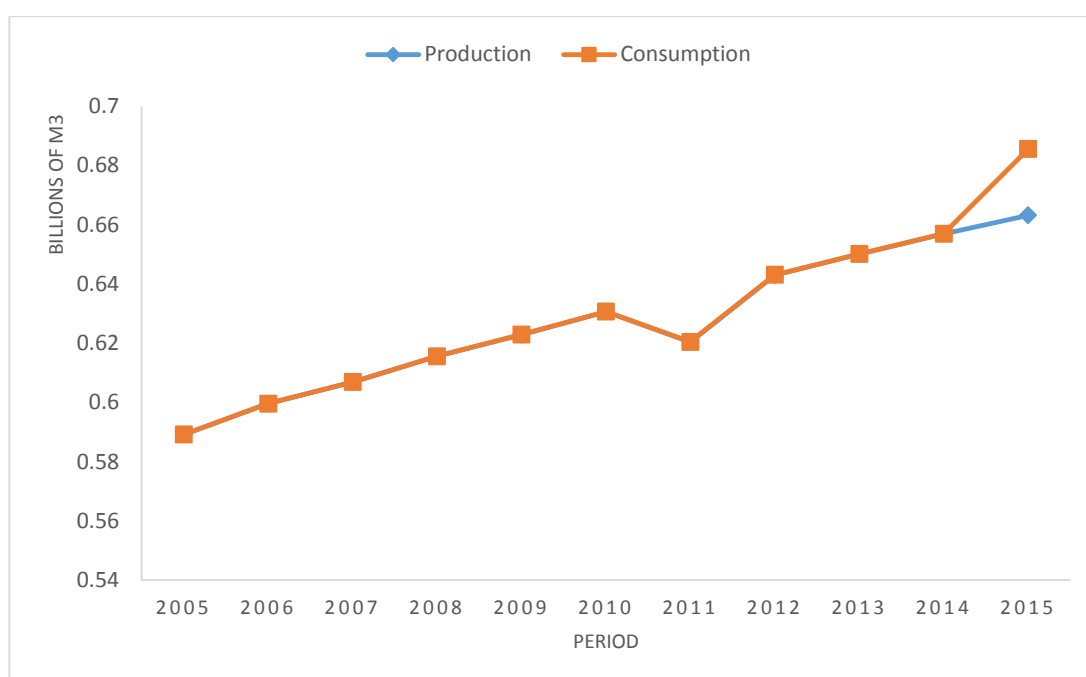
Figure 1.8 : The production and consumption of wood fuel in Sub-Saharan Africa
(Source: Computed based on data from FAO (2016).)

The percentage of the dependence on wood-based energy in Sub-Saharan Africa is by far more than what is obtainable in any other regions of the world. IEA (2010) reports that while the usage of wood fuels for energy generation in developing countries such as India and China has reached its peak or almost, the use of wood fuels either remains high or grows in Sub-Saharan Africa. For instance, wood energy, particularly fuelwood contributes more than two-thirds of total primary energy supply in Ethiopia, United Republic of Tanzania, Congo, Mozambique and Eritrea (IEA, 2003). The growing demand for wood-based fuels is due to certain factors such as the population growth, urbanisation and relatively high prices of alternative fuels such as fossil fuels.

From Table 1.1, the composition of energy consumption in Sub-Saharan Africa shows that wood fuel contributes about 75% of the overall energy consumption in the region in 2014. Then, petroleum follows with 19%, and lastly electricity accounts for only 6% of the total. When combined, the total commercial energy consumption, comprising petroleum and electricity is 25%, which is far less than the contribution of wood fuel alone.

Table 1.1 : Sources of energy consumption in sub-Saharan Africa (in percentages)

Year	Wood fuel (%)	Petroleum (%)	Electricity (%)
1980	71	23	6
1985	73	23	4
1990	71	24	5
1995	77	19	4
2000	74	22	4
2005	72	23	5
2010	73	21	6
2014	75	19	6

Source: EIA (2015)

With the current quest for economic growth by many countries across the globe including sub-Saharan African countries, the demand for energy increases for these countries to satisfy their growing needs. Although, electricity is required to meet some energy demands for industrial purposes, yet the majority of the households and some small/medium scale businesses in Sub-Saharan African countries still rely on wood fuels for energy use. The usage of wood fuel in Sub-Saharan Africa is not limited only to households but also small and medium enterprises. Katerere et al. (2010) revealed that about 84% of the region's small and medium enterprises depend largely on solid fuels, especially, fuelwood and charcoal for energy. The World Energy Outlook (IEA, 2010) forecast that the number of consumers of wood-based energy in Sub-Saharan Africa will rise to almost one billion by the year 2030. The reasons why Sub-Saharan Africans heavily rely on wood-based fuels are discussed in the following sub-section.

1.1.5 The reasons for heavy reliance on wood fuel by Sub-Saharan Africa

The high consumption of wood fuel in Sub-Saharan Africa is due to population growth, low electrification rate, rapid urbanisation, economic development, the relative high price of other alternative energy and poverty. Kebede et al. (2010) indicate that the high energy demand, including wood fuel consumption, is positively related to population growth in Sub-Saharan Africa. The continuous increase in the use of wood fuel is linked to the rising population of the region. Predictions by IEA (2009) show that Sub-Saharan Africa's wood fuel consumption will continue to increase in the next coming decades as the population growth has outshined access to modern fuel.

Lack of access to electricity is an important determinant of wood fuel consumption in the region. IEA and WHO (2010) reported that about 69% of the population in Sub-Saharan Africa have no access to electricity. This implies that only 31% of the total population have access to electricity in 2009, and only 8% of rural population have access to electricity. South Africa excluded, the total percentage reduces further to 28%. This pushes people to rely on wood for an energy source.

Rapid urbanisation in the region has also increased the demand for wood fuel, particularly, charcoal, which is the most common fuel consumed by urban residents. The correlation between urbanisation and wood fuel consumption has been reported by UN Habitat (2010). For example, a 1% increase in urbanisation is found to cause about 14% increase in charcoal consumption in Tanzania (Hosier et al., 1993). An increase in urbanisation results in an increase in demand for wood fuels by households, businesses such as restaurants, public facilities such as prisons, and boarding schools. Similarly, increasing urbanisation comes with an increase in a number of houses, which require more wood fuels for brick burning to construct houses (GTZ, 2010).

Though the price of commercial wood fuel has increased over the past years, the prices of other alternative modern fuel sources have also increased and are much higher. It implies that there is less incentive for wood fuel consumers to shift to other modern energy sources. For instance, in Tanzania, from 2001 to 2007, the percentage of households consuming charcoal as a cooking fuel raised from 47% to 71%. At the same time, the usage of liquefied petroleum gas (LPG) decreased from 43% to 12% (World Bank, 2009). Additionally, the consumption of electricity for cooking was reported to be below 1%. In most Sub-Saharan African countries, subsidies for LPG have been removed in the recent times, which cause its price to go up. This, has in some way contributed to the growing demand for wood fuel in the past few years. In countries like Nigeria and Senegal, subsidies removal for LPG has significantly caused an increase in demand for wood fuel (IISD, 2010), as many people are shifting from the usage of LPG for cooking to wood fuel.

Figure 1.9 shows the trend of the average prices of diesel, gasoline and wood fuel in Sub-Saharan Africa.We can see that the pump prices of diesel and gasoline have been steadily increasing from 2005 to 2014. While the average price of wood fuel per cubic meter, though it has been increasing but remains far less than diesel and gasoline prices, over the same period. The continuous increase in the price of diesel and gasoline could be as a result of the removal of subsidies by various countries in the region. Studies and reports have shown that the comparatively low price of wood fuel in the region is one of the major reason for the rise in the demand for wood fuel.
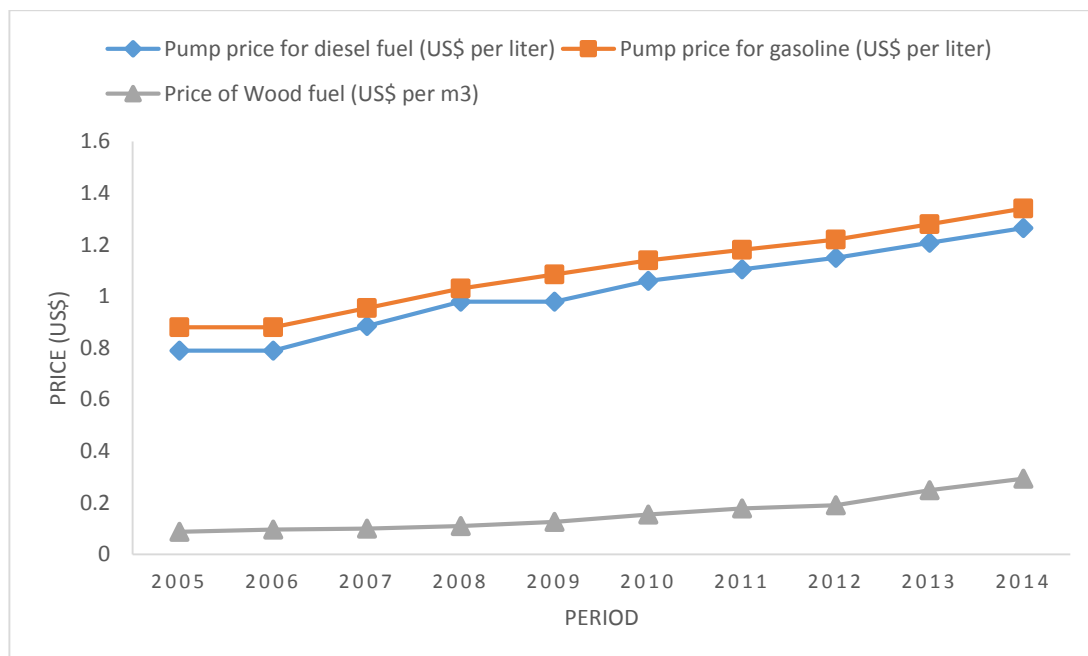
Figure 1.9 : The prices of wood fuel and fossil fuel products in Sub-Saharan Africa
(Source: Computed based on data from FAO (2016) and WDI (2016))

Table 1.2 compares the alternative sources of fuel consumed and their calorific value (i.e. heat units). We can see that the calorific value of wood fuel per kilogramme (kg) is lowest of all. However, it is worthy to note that the price of wood fuel per cubic meter (from Figure 1.6) is far less than the price of other alternative fuels per litre. Also, one cubic meter of wood fuel contains several kilogrammes, which in turn produce more calorific values than a litre of any other alternative fuel. This makes it be the cheapest source of energy for cooking and heating.

Table 1.2 : Fuel comparison based on sources and gross calorific value

Fuel sources and units of purchase	Calorific value in mega joules	Calorific value in Kilowatt per hour
1 litre of diesel	40MJ	11.1KWh
1 litre of gasoline	34MJ	9.4KWh
1 litre of gas oil	41MJ	11.4KWh
1 litre of fuel oil	44MJ	12.2KWh
1 kg of wood fuel	19MJ	5.3KWh

Source: Smil (2012) and FAO (2015)

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Another important factor that makes people rely heavily on wood-based fuels is unreliability of modern fuel supply. In Sub-Saharan Africa, World Bank (2009) reports the supply of LPG is unreliable, and as such, it is unsuitable for daily use.

Poverty is one of the key factors driving wood fuel consumption in the region. The percentage of the population living on less than $1.25 and $2.00 per day in Sub-Saharan Africa are 48.5% and 69.9% respectively. Many people cannot afford modern fuel, such as LPG. Similarly, since the majority of the population in the region reside in the rural areas, access to the modern fuel is little or non-existent.

1.1.6 Contribution of wood fuel sector to the economy of Sub-Saharan Africa

Although fuelwood and charcoal constitute about 90% of the total timber harvests in Sub-Saharan Africa (Bromhead, 2012), the economic contribution of this sub-sector does not comprehensively show in GDP. However, country-specific reports and studies show that it has some importance. For instance, in Kenya, Sepp (2008) reports that about 700,000 people work in the charcoal sector. For the same country, an approximated US$450 million income comes from the charcoal sector (ESD, 2007). In Tanzania, the sector provides many hundreds of thousands of people with jobs, particularly the poorest class of the society who have no other livelihood means. The sector contributes about US$350 million to Tanzania's economy, which surpass the annually gained revenue from tea (US$45 million) and coffee (US$60 million).

In the case of Malawi, an approximation of 100,000 people earn their livelihoods from the production, transporting and final sales of charcoal (Kambewa et al., 2007). Moreover, Openshaw (2010) states that market value of the traded wood fuel constitutes about 3.5% of the Malawi's GDP. In addition, an estimate of 93,500 and 133,000 people were full-time workers in wood-based biomass in 1996 and 2008 respectively (Openshaw, 2010). For Ghana, Mombu and Ohemeng (2008) assert that the country's charcoal sector engaged about 3 million people in gainful employment. For Uganda, a total of 200,000 people relies on the charcoal sector as their means of livelihood (ESD, 2007). Another Ugandan study by Khundi et al. (2010), reveal that involvement of households in charcoal production helps them to stay off the poverty line. In Rwanda, Van Der Plas (2008) indicates that charcoal sector accounts for an annual volume of US$77 million.

In general, wood fuel sector in Sub-Saharan African countries provides a significant portion of the workforce with jobs. Hence serving as a source of regular income to hundreds of thousands of people (World Bank, 2009). Sadly, despite its importance in supporting the livelihoods of Sub-Saharan Africans, wood fuel attracts low priority in the national policies of most of the countries in the region (Owen et al., 2013), as the policy makers and governments fail to recognise it as a dominant energy source for the region. As such, less attention paid to it by the Sub-Saharan African countries makes it be harvested and consumed in an inefficient and unsustainable manner that pose a health risk, which in turn harm the economy.

1.1.7 Sustainable development goals (SDGs) and energy in Sub-Saharan Africa

At the United Nations Sustainable development Summit in September 2015, World leaders adopted a 2030 agenda for sustainable development. This agenda comprises a set of 17 sustainable development goals (SDGs). These goals include: (1) no poverty (2) zero hunger (3) good health and well-being (4) quality education (5) gender equality (6) clean water and sanitation (7) affordable and clean energy (8) decent work and economic growth (9) industry, innovation and infrastructure (10) reduced inequalities (11) sustainable cities and communities (12) responsible consumption and production (13) climate action (14) life below water (15) life on land (16) peace, justice and strong institutions (17) partnerships for the goals.

SDGs centre on the inter-linkages of three dimensions, comprising of economic, social development and environmental sustainability. The environment is regarded as the source of life, which support economic activities and by extension sustain social development. Since the target of every country is to achieve sustained economic growth. SDGs state that for growth to be sustainable, environment has to be taken care of. Efforts need to be made to ensure efficient and sustainable use of natural resources (forest resources inclusive). Other recommendations by SDGs are environmental friendly agricultural practices, less intensive production and consumption of goods and services, renewable energy development, less carbon intensive production of goods and services, among others.

The achievement of the three dimension of SDGs rests on the role of governance and institutions, which serve is considered fundamental to sustainable development. In other words, they act as the foundation for economic growth, social and environment-friendly development. Therefore, having better institutions and effective governance can assist to achieve SDGs.

SDGs have identified and outlined key sustainable development priorities in Sub-Saharan Africa. These include improved access to affordable and quality health care, natural resource management, clean and affordable energy, tackling the environmental challenge, gender equality, inclusive growth, good and quality education, food and agriculture, good sanitation, unemployment and underemployment, infrastructural development and fight poverty.

One of the major priority areas of SDGs in Sub-Saharan Africa is energy. At least 75% of the Sub-Saharan Africans as reported by IREA (2013), is without electricity, even though the region has abundant fossil and renewable energies. This situation makes significant portion of the population in the region to rely heavily on wood biomass fuel for cooking. The report further predicts that the population without access to electricity may increase to 655 million by 2030. Equally, the population without clean cooking energy is projected to increase to 883 million by 2030.

At the moment, Sub-Saharan Africans continue to rely largely on unsustainably harvested traditional wood fuel in the form of firewood and charcoal as cooking fuels. Moreover, using wood fuel for cooking is considered as the leading cause of indoor air pollution in the region, which has a link to several deaths. Therefore, the outcome of this study will provide useful information that will assist in achieving some of the targeted goals, especially, affordable, clean energy and good health.

1.2 Forest degradation

FAO (2001) defined forest degradation as "changes within the forest which negatively affect the structure or function of the stand or site, and thereby lower the capacity to supply products and services". Forest degradation also refers to the destruction or reduction in quality of the forests. Persistent degradation in most cases results in a reduction in tree cover or forest cover in general. In some cases, long-time degradation can result in wiping out of the entire forest. Sub-Saharan African has experienced continuous degradation of forest over time. We can observe from Figure 1.10 that the forest cover shows a continuously decreasing trend from 1991 to 2014.

Several factors are likely causes of forest degradation, namely; wood fuel harvests, timber harvests, forest fires, population growth, institutional quality and so on. It is worth noting that when degradation occurs, severe environmental problems are caused, such as; soil erosion, loss of biodiversity, poor water quality and climate change. Forest degradation could also result in a shortage of timber and wood fuel supply.
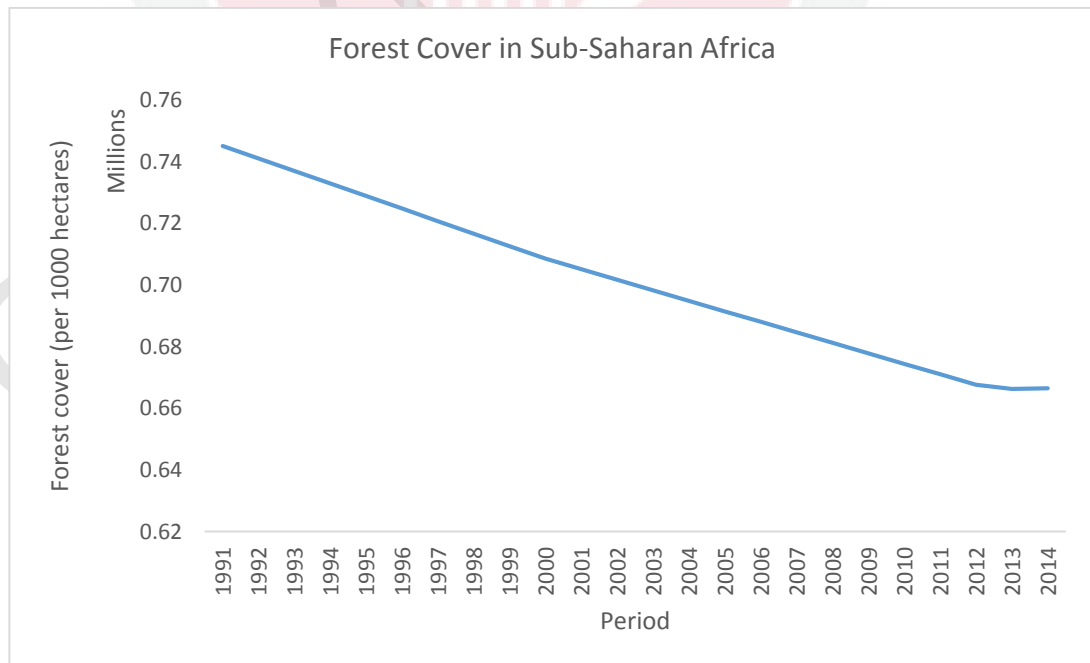
Figure 1.10 : Decline in forest cover/forest degradation in Sub-Saharan Africa
(Source: Author's computation based on data from FAO (2015))

1.2.1   Why are Sub-Saharan African forests important?

African forests constitute 674 million hectares of world's forested lands. The Sub-Saharan African forests significantly contribute to the social, cultural and economic development of the region. They provide timber and non-timber forest products, and most importantly they provide ecosystems services. They also serve as habitats for organisms and have aesthetic and spiritual values. The contribution of forests to the GDP is more than 10% for 29 sub-Saharan African countries in the region (IUCN, 2011).

About 63% of the sub-Saharan African population live in the rural areas and rely on forests directly or indirectly for fuelwood, medicines, foods, building materials, and gums. Rigg et al. (2009) disclose that in Sub-Saharan Africa, forests provide no less than 20% of the disposable income of poor households in the region. Forests also store large amounts of carbon, serve as water sources and support biodiversity. For instance, the Mediterranean basin forests, the Eastern Arc mountain forests and the Guinean forests are biodiversity hotspots. The Congo Basin, located in sub-Saharan African region houses about 60% of the Africa's biodiversity. Similarly, about 25 to 30 billion tonnes of carbon are stored in the Central African forests, which equals four years of carbon emissions from anthropogenic activities globally (FAO, 2010). About 630 kilogrammes of carbon are sequestered per hectare annually by the Mature Humid Africa's forests, which help to reduce the problem of climate change.

Unfortunately, despite the importance of the region's forests, the forests still continue to decline briskly due to some factors. The increasing demand for fuel wood and charcoal is one of the likely factors that can facilitate forest degradation in most of the sub-Saharan African region.

The region is the most susceptible to the climate change due to some challenges faced. These include weak institutions, lack of adequate finance, poor planning, armed conflicts, less technological advancement, poor infrastructure, low level of education and so on. Though Africa's forests serve as a source of livelihoods to the Africans, it also caters for the well-being other people residing in the rest of the World's regions through climate change mitigation. However, Africa's response to these issues is still not encouraging and insufficient.

1.3   Institutional Quality

Institutional quality is a broad concept that covers law, individual rights, and quality of government regulation and services. In recent times, the quality of institutions plays an important role in promoting economic growth and development. The relationship between quality of institutions and growth or environment is receiving growing attention by development practitioners, policy makers and researchers. Jutting (2003) opined that institutions provide the missing link which can explain the differences between the growth rates across developed and developing countries. By definition, "institutions are constraints that human beings impose on themselves" according to

North (1990). Institutions prohibit or permit certain actions, whether it is political, social or economic. They comprise of both formal, i.e., constitutions, law, regulations and property rights, and informal, i.e., taboos, customs, sanctions and traditions. Establishing appropriate institutions will reduce uncertainty in exchange, transaction cost, production cost and improve efficiency in economic activities.

More importantly, the quality of these institutions determines our choice and use of natural resources. Therefore they play an important role in sustainable use of natural resources and ensuring environmental quality. North (1981) divided institutions into three, namely; constitutional rules, operating rules and moral behavioural codes.

This study will focus on the first two division, that is, constitutional rules and operating these rules. Hence, this study considers the following institutional quality indicators: government effectiveness and control of corruption. These two institutional quality indicators are chosen owing to their relevance to forest degradation in the region. Other indicators are believed to be less relevant to forest degradation. The discussions on each of the chosen indicators are in the following sections.

1.3.1 Control of corruption

Control of corruption according to WGI (2015) measures the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as the capture of the state by private interests and elites. It also evaluates the effectiveness and strength of the country's fight against corruption. The problem of corruption is considered a universal but with different forms and degrees (Alatas, 1990). However, Hope (2000) maintains that in sub-Saharan Africa, corruption has reached a cancerous state and become a matter of grave concern. The problem has infiltrated nearly all public and private institutions in the region. It has equally become a way and method of acquiring and accumulating private property(s).

Sub-Saharan African countries are among the most corrupt countries in the World. For instance, in 2008, according to Transparency International, six out of the ten World's most corrupt countries are in Sub-Saharan Africa (Hanson, 2009). Recent statistics from 1999 to 2014, show that Sub-Saharan Africa is the region with the least control of corruption (see Figure 1.11). The practice of corruption is considered one of the factors that slows down economic growth of many countries in Sub-Saharan Africa. The increasing degradation of forest in the region can also be linked to the prevalence of corruption in the region, as the practice has no boundary in virtually all the sectors of the region's economy.
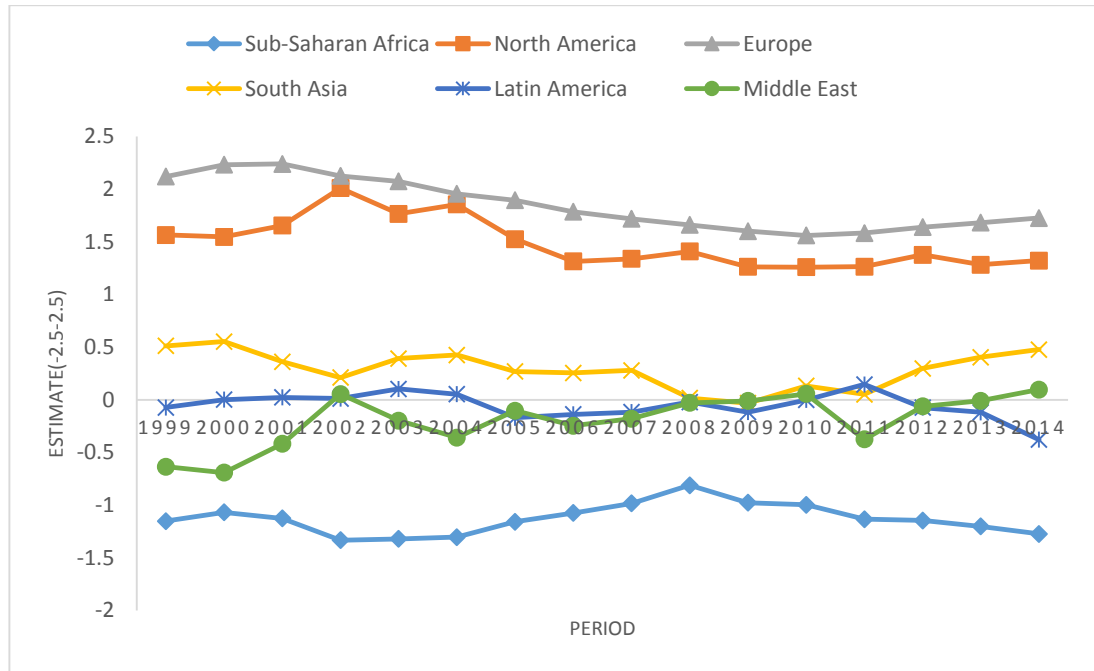
Figure 1.11 : Control of corruption across different regions of the World
(Source: author's computation based on data from WGI (2015))

1.3.2 Government effectiveness

The institutional quality, government effectiveness evaluates the competence of civil servants and the independent of civil service from political pressure, the quality of bureaucracy, the quality of public service and the overall commitment of the government to credible policies. It also measures the quality and the process of policy formulation and its implementation. Effective governance has a direct link with the social welfare as it has some consequences on well-being of individuals. Sacks and Levi (2010) argue that an effective government will provide the necessary goods and services that will improve the well-being of citizens.

An effective government will also be able to make policies, including environmental protection policies that will safeguard the environment and ensure its sustainability. Whereas, the ineffective government may be ineffective in formulation and implementation of environmentally friendly policies. This is evident in most Sub-Saharan Africa, as some the governments in the region pay little attention to environmental protection measures due to poor governance. This act may likely have some link with the increasing forest degradation in the region. Figure 1.12 shows the level of government effectiveness across different parts of the world from 1999 to 2014, where Sub-Saharan Africa is ranked the lowest among all the regions.

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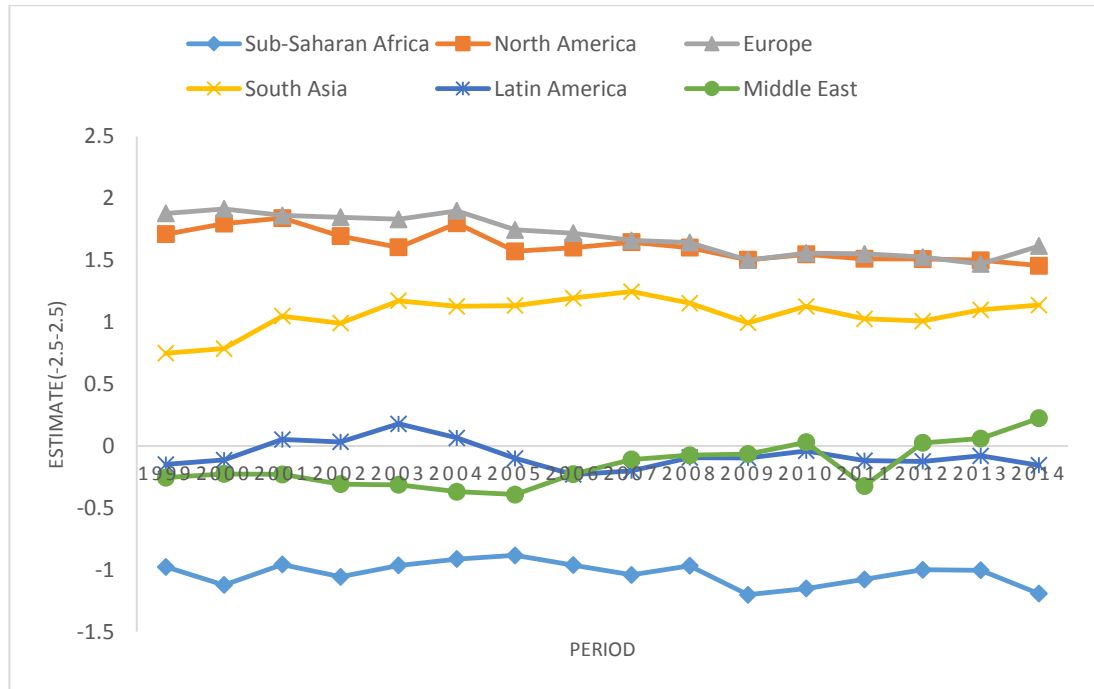
Figure 1.12 : Government effectiveness across different regions of the World
(Source: WGI (2015))

1.3.3 Institutions and forests protection policies in Africa

The legislations on forest and other lands use in Africa are usually part of legislations and policies at national levels. The role of these legislations and policies to stop forest degradation is a good indication of the quality of institutions. Natural resource policy in Africa began in the pre-colonial era when resources were managed based on the traditional practices. Though the traditional practices vary from one location to another based on the social organisation. The traditional leaders were charged with the responsibility of allotting forests and lands. The system was successful then due to the low population and fewer demands.

The colonial era gave birth to centralised laws and policies that were meant to regulate activities that were considered destructive on the forest resources. The colonial governments also set policies targeted at sourcing raw materials for their timber industries. However, the central government policies ignored the social and economic importance of the forests to the local community.

Post-independence authorities continued with the colonial approach of centralised policies for achieving total control over all forest and land resources. Later, new policies emerged, based on the economic production of forests. Nonetheless, these policies perceived as a failure as they could not stop forest degradation and deforestation. The failure was attributed to poor coordination and implementation of the forest laws and regulations.

Several changes in policies and legislations have taken place in the past decades due to the recognition of the failure of the previous policies of the central government, which could not address the problem of forest degradation. Similarly, the previous policies gave rise to many lessons, which necessitate the formulation of new ones. There were also support from international bodies such as Convention on Biological Diversity (CBD) and United Nation Framework Convention on Climate Change (UNFCCC), a convention to combat environment degradation.

1.3.4 Forest planting programmes in Sub-Saharan Africa

Since about 90% of the wood fuel in sub-Saharan Africa emanates from natural forests (Chamshama and Nwonwu, 2004), several forest management policies were introduced in different countries of the region to prevent further degradation linked to wood fuel harvests. The policies range from conservation to afforestation and reforestation. So many countries in the region set aside some forests as conserved forests and at the same time encourages plantation forests. For instance, in the 1970s, most of the countries in the region implemented a policy/programmes called 'plantings for fuelwood' to deal with perceived forest degradation potentially linked to fuelwood harvests. Most of these policies were donor supported and driven/funded by the donations received from foreign donors (Arnold et al., 2003). For instance, peri-urban fuelwood plantations in Ethiopia and Tanzania were funded by donors between 1975 and 1994, in which, over 40,000 hectares of *Eucalyptus globulus* were planted. However, later the plantation programme stopped due to cease of the donations. Hence the plantations could not be expanded.

The stoppage of the external donations, which was the main back born of the programs was attributed to the poor performance of local governments in the handling of the support and shifts in donors' interests. Since then the donations received from external sources have declined significantly. Only in Southern part of Africa that the plantation forests seem to achieve significant results. However, in other parts of the region, the plantation forests remain very low. Tree plantations in Sub-Saharan Africa remain very low when compare to the natural forest cover. The percentage of the plantation forests of the total forest area in Central, Southern, East and West Africa are 0.3%, 3.2%, 1.2% and 2.3% respectively (World Bank, 2009).

In general, the several policies adopted to conserve forests and manage wood fuel resources yielded fruitless results (Keterere et al., 2010), due to the poor regulations and ineffective governance. As most of the regulations target only managed forests, while wood fuel harvest takes place illegally in the unmanaged forest areas. Inadequate workforce has equally contributed to the failure of the policies in the region, as in most cases one forest officer is in charge of controlling the illegal harvest of trees in 10,600 hectares of forests (Keterere et al., 2010).

However, despite all these policies and supports, the result is still not encouraging in most sub-Saharan African countries due to some institutional defects such as corruption and ineffective governance in the region. For instance, most governments

of sub-Saharan African countries have failed to provide and make available affordable modern fuels to the populace. This makes people continue to rely on wood fuel for energy use. Also, in most cases when charcoal operators are caught cutting forest trees in a protected forests, they usually get freed by giving bribe to escape punishment.

In general, the failure of these policies and programmes to address forest degradation can be attributed to the poor role played by institutions. Thus, this study seeks to examine the impact of wood fuel consumption and institutional quality on forest degradation in sub-Saharan Africa.

The remainder of the chapter is organised in the following sequence: objective of the study, methodology, results and discussions, and conclusions.

1.4 Mortality

Globally, about 4.3 million deaths occurred due to diseases related to indoor air smoke globally (WHO, 2014). At least 1.6 million infants' premature deaths and 2.8 million adults' deaths are reported annually from indoor air related complications. Indoor air pollution largely comes from solid biomass fuel use, mainly wood fuel burning. For instance, about 3 billion people still depend on biomass fuels for cooking and heating (WHO, 2014).

The relationship between mortality and indoor air pollution from of biomass fuels burning through some infections have been widely reported by World health organisations and other bodies. Indoor air pollution is responsible for about four to five millions new cases of bronchitis (chronic) and its economic burden, put between 0.5% to 2.5% portion of World's gross domestic products (GDP). EIA (2015) reports the monetary loss to indoor air pollution to be between $150 to $750 billion annually. This figure makes it be one of the major potential environmental causes of the ill health. This public health threat varies according to the level of development. For instance, in low and middle-income countries, 10% of the total mortality is linked to indoor air pollution, whereas only 0.2% in high-income countries.

Indoor air pollution is a very troubling issue that needs attention from researchers, organisations and governments. Statistics show that about one billion people are exposed to indoor air pollution more than 100 times of the standard level worldwide. Similarly, 50% of the under five deaths, mostly in developing countries, occur as a result of diseases associated with woody biomass fuel consumption. Wood fuels burning is linked to so many respiratory and pulmonary diseases in the developing World. For instance, about 10% of illness related deaths in Africa has link with indoor air pollution from burning biomass fuels. However, the main component of the biomass in the sub-Saharan Africa consumed by households is wood fuel, which provides at least 90% of households' energy demand.

Figure 1.13 illustrates the number of deaths resulting from indoor air pollution health related complications in 2008 and projection for 2030 in Africa. We can see that deaths from the smoke of indoor air pollution in 2008 is ranked as the second potential killer after HIV/AIDS in the region. However, the projection for the year 2030 shows that smoke from indoor air pollution will be the leading killer in the region. Because of the likely devastating health impact of the smoke from indoor air pollution, indoor air pollution is now one of the major global health concern and contributors to the global disease burden. Though there is an improvement regarding marginal reduction in the general mortality rates in Sub-Saharan Africa, it remains an issue in the region (see, Figure 1.14).
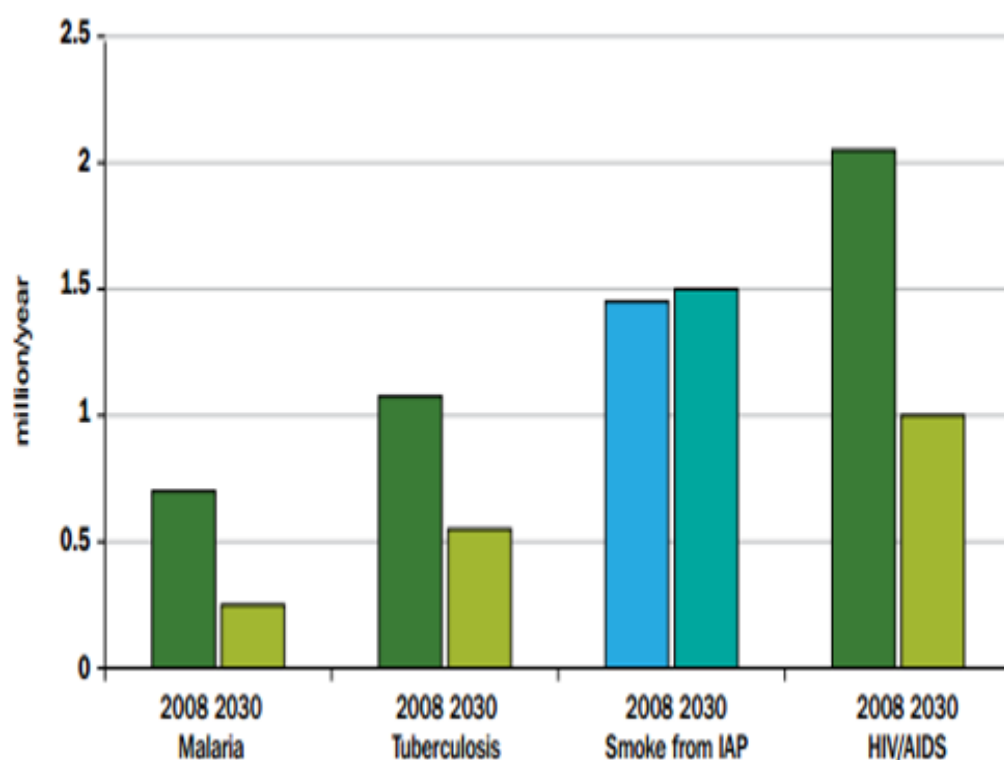
Figure 1.13 : The number of deaths from household air pollution health related complications in Sub-Saharan Africa
(Source: WHO (2014))
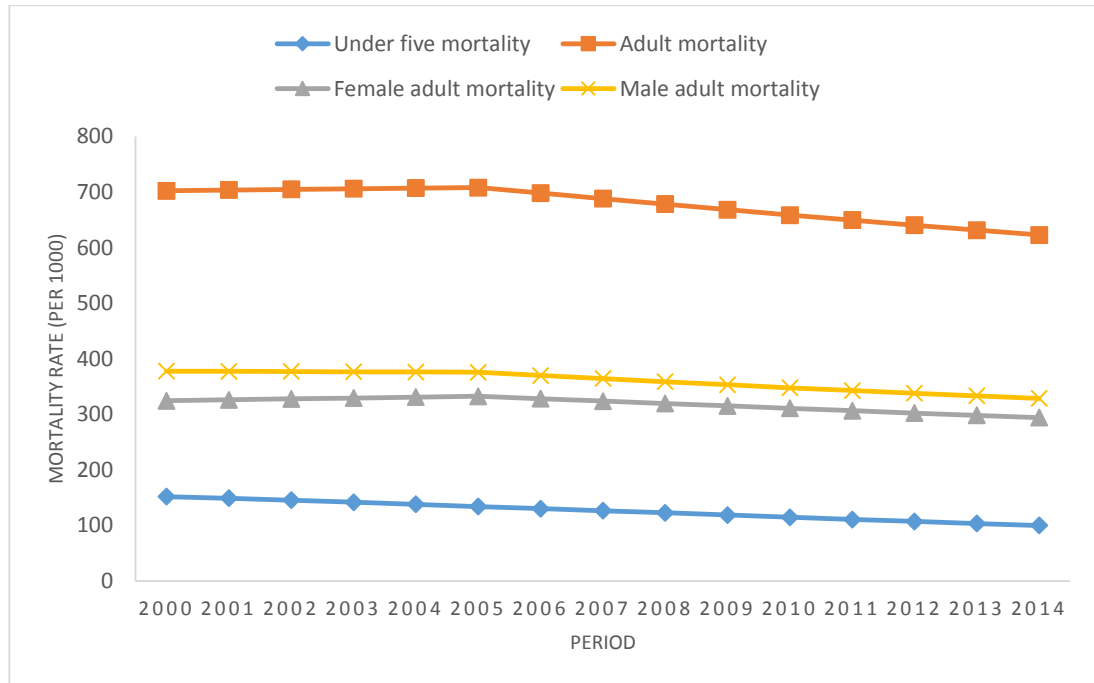
Figure 1.14 : The under five and adult mortality rates in Sub-Saharan Africa
(Source: author's computation based on data obtained from World development indicators (2015))

1.5   Economic growth

UNECA (2007) maintains that economic growth is weakened for countries where households or the society as a whole, have limited access to modern energy or where modern energy is not affordable by households. Despite its role in providing energy to Sub-Saharan Africans, wood fuel can potentially pose some harm on the economic growth of the region through health implications and unproductive time spent in the gathering of wood fuel by the able-bodied persons. The able-bodied individuals in the region travel a longer distance and spend an average of 8 hours gathering wood fuel (FAO, 2007). In most countries in the region, children, who are ought to be in school, are also involved in the collection of wood fuel for their families. This act denies many of them education, which subsequently affect the human capital development.

Despite too much dependence on wood fuel consumption by Sub-Saharan African region, the trend of economic growth of the region has been showing a steady increase over time, as demonstrated in Figure 1.15. This achievement may not be unconnected with the other factors influencing growth in the region. Other factors promoting growth in the region such as modern energy consumption, labour, capital and trade openness may have influenced the steady growth experienced in the region over the sampled period.

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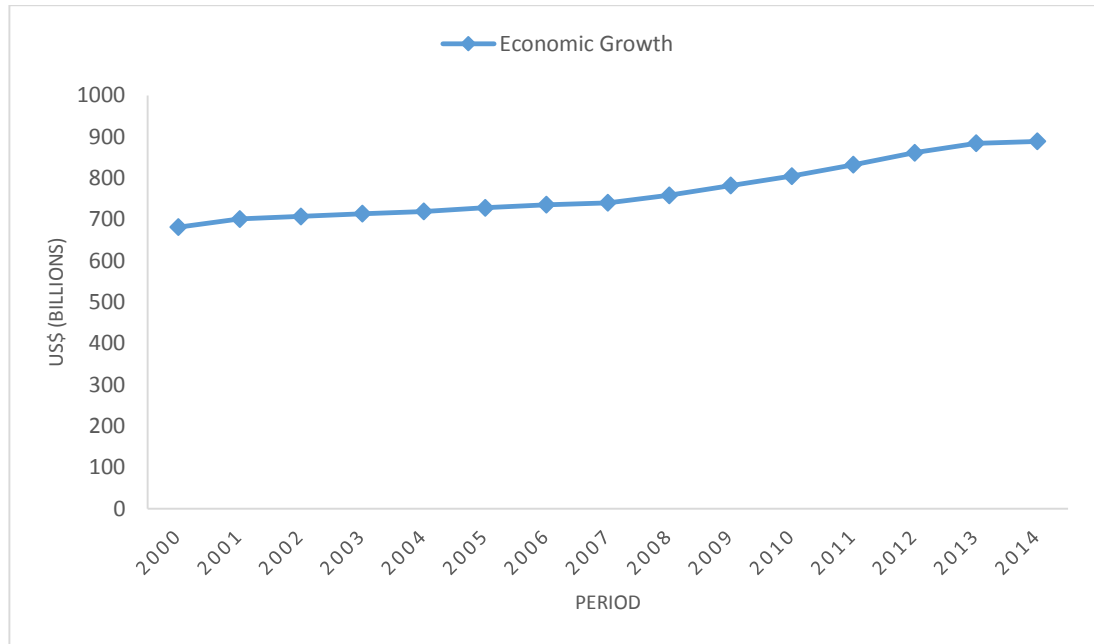
Figure 1.15 : The trend of economic growth in Sub-Saharan Africa from 2000 to 2015

(Source: Author's computation based on data from WDI (2015))

1.6 The relationship between wood fuel consumption, forest degradation, health and the economy in sub-Saharan Africa

Despite the importance of wood fuel in supplying energy to the Sub-Saharan African region, its consumption is likely to be accompanied by some environmental, societal and economic problems. Specifically, the use of wood fuel can potentially drive forest degradation, adversely affect the health of the population and also, adversely affect the general economy. In a simpler term, if the consumption of wood fuel increases, more wood need to be cut to meet up with the demand of the population, as over 90% of the demand are met up from a domestic supply (Sander, Hyseni and Haider, 2011). Similarly, if the consumption of wood fuel rises, particularly by households, it may likely result in more health complications through the smoke released from burning of wood fuels. WHO (2010) reports that smoke from indoor air pollution resulting from primitive stoves powered by wood biomass kills over 1.5 million people globally per annum.

Lastly, though trading in wood fuel may seem beneficial by providing income to people, wood fuel consumption may incur costs on its consumers through increasing the risk of being infected by wood fuel smoke related diseases, which may lower their productivity and increase their medical expenses. This will ultimately harm the economy. We shall expatiate each of the relationships in the subsequent paragraphs to establish their links.

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Beginning with the likely relationship between wood fuel consumption and forest degradation, FAO/UN (2012) and Kebede et al. (2010) state that wood fuel constitutes at least 90% of the total wood removal from forest areas and wooded lands in Sub-Saharan Africa. Since domestic supply mainly meets the demand for wood fuel, the harvest of wood for fuels can potentially result in loss of native forests and thereby leading to forest degradation.

On the relationship between wood fuel consumption and potential resultant health effect, it is paramount to acknowledge that about 94% and 73% of the rural and urban population in Sub-Saharan Africa rely on biomass as a source of energy for heating and cooking activities (Torres-Duque et al., 2008). The consumption of these wood fuels can cause serious health complications that often result in deaths. For example, Bailis, Kammen and Ezzati (2005) estimated that in 2000 alone, about 350,000 children and 34,000 adult women died as a result of respiratory infections and chronic obstructive pulmonary disease from indoor air pollution in Sub-Saharan Africa.

Figure 1.16 shows the proportion of different fuels to cooking in Sub-Saharan Africa as reported by United Nations Development Programme (UNDP). The pie chart indicates that wood fuel (fuelwood and charcoal) carries significant portion (80%) of cooking fuels in the region.
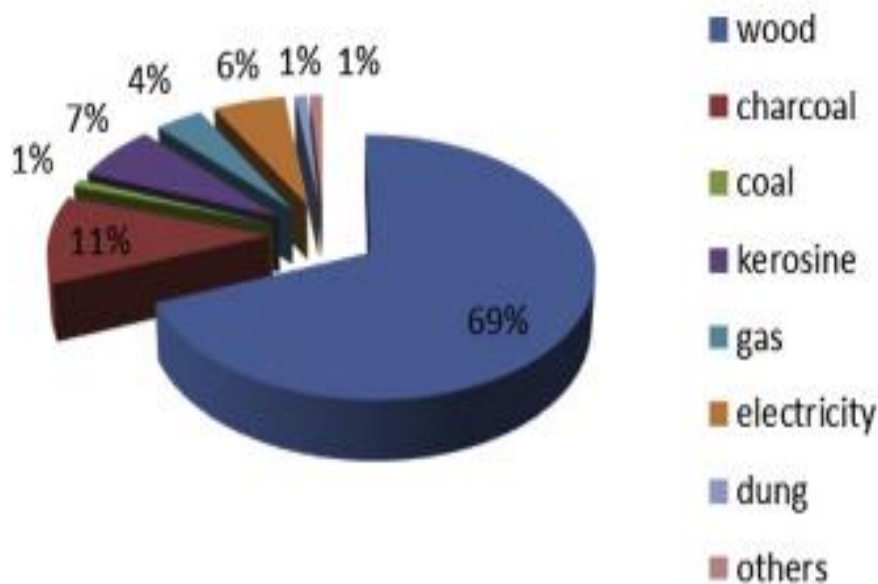
Figure 1.16 : Percentage of different types of fuels used for cooking in Sub-Saharan Africa in 2007 (UNDP, 2009).
(Source: UNDP (2009))

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However, using wood fuels for cooking generates smoke, which is harmful to human health. The smoke released from cooking with wood fuel can potentially cause serious illness such as acute respiratory infections, chronic pulmonary diseases, chronic bronchitis, lung cancer, and eye infections. Balakrishnan et al. (2002) assert that indoor air pollution is now a major global health concern and contributor to the global disease burden.

On the relationship between wood fuel consumption and economic growth, it is worth noting that Sub-Saharan Africa has the highest per capita wood energy consumption in the World, with 0.69 m^3/year average consumption in 2011 as compared to the World's average of 0.27 m^3/year (Liyama et al., 2014). This is owing to the importance attached it for meeting energy demand in the region. There are certain benefits attached to wood fuel business, for instance, fuelwood and charcoal supply 80% to 90% of the low-income households' energy needs. Similarly, wood-based biomass sector in Sub-Saharan African countries provides a significant portion of the workforce with jobs, from production, transporting, wholesaling, retailing, to hawking. However, the consumption may incur significant costs on the households through illnesses and productive time lost, which affects the productivity of the households and also increases their medical expenses. In some cases, the wood smoke related infections can result in morbidity or mortality. It can also push people to poverty as a result of having much of their income taken away by wood smoke related illnesses. These altogether can harm the economy.

Having discussed wood fuel consumption and its likely relationship with forest degradation, health and the economy, this study intends to empirically investigate the impact of wood fuel consumption on forest degradation, health outcomes and economic growth in Sub-Saharan Africa.

1.7   Statement of the research problems

Inspired by the discussions in the previous sections, three potential implications of wood fuel consumption are of interest. First, one of the most critical environmental hitches nowadays that is faced by all the Sub-Saharan African countries is cutting down of wood for fuel usage. Owing to this action, many countries in the region have a significant portion of their forests eaten up, and if the trend is allowed to continue (see Figure 1.10), there may be severe inadequacy of forests in the future. The rate of dependence on energy from fuelwood and charcoal in the Sub-Saharan African region is the highest among all regions of the world (see Figure 1.7), which eventually results in huge pressure on the forests to cater for the supply.

FAO (2013) reports that the consumption of fuelwood in countries within the Sub-Saharan African region is 200% greater than the annual growth rate of trees in the forests. This undoubtedly can make it be a potential driver of forest degradation in the region. The present extraction rate and usage of these fuels are characterised by inefficient technologies and practices. This, coupled with the lack of alternative affordable modern fuels, continue to put pressure on the already decreasing stock of

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forests. Furthermore, lack of effective national and local resource policies in the rural areas has led to the continued unsustainable wood fuel extraction by the immediate communities to earn income and meet their energy needs. This problem can be attributed to the weak state of the institutions, i.e., ineffective governance in the region, which is further worsened by bribery and corruption.

Corruption and ineffective governance are believed to be the major institutional lapses that can influence degradation of forests in the region. For instance, corruption is widely reported phenomenon in most Sub-Saharan African countries. World Bank (2014) maintained that weak institutions and poor administration constitute the characteristics of most Sub-Saharan economies due to corruption. Two-thirds of the African countries have rampant corruption in 2014, as published by Transparency International. Government effectiveness and control of corruption are considered key determinants of environmental quality (Esty and Porter, 2005; Djankov and Hoekman, 2002). Countries with less corruption and effective governance are considered more efficient in enforcing environmental rules and regulations. For the purpose of this study, two key institutional quality indicators are considered, i.e., control of corruption and government effectiveness, to ascertain their impact on the relationship between wood fuel and forest degradation in Sub-Saharan Africa. In general, the study will investigate empirically whether wood fuel consumption affects forest degradation in the region.

Second, wood fuels are mostly used with traditional stoves by households, which are inefficient and polluting. These fuels are the main source of concentrated air pollutants, which comprises nitrogen oxides, carbon monoxide and particulate matter. These gases and particulate matter are potential causes of some pulmonary and respiratory diseases that are life threatening, which can sometimes lead to death (see Figure 1.13).

In 2010 for instance, indoor air pollution in Sub-Saharan Africa is ranked as the second cause of premature deaths after HIV/AIDS overtaking tuberculosis and malaria (Figure 1.13). It is further projects that if the current pace continues, it will be the number one killer by 2030 (WHO, 2014). Owing to the potential adverse health effect of the smoke from indoor air pollution, UNDP (2009) reports that about 44% of the indoor air pollution disease burden recorded globally, based on disability-adjusted life year (DALY) measure, occurs in Sub-Saharan Africa. Therefore, the effect of indoor air pollution from wood-based fuels based on years lost as a result of ill-health, early death and disability, is likely to be worst in Sub-Saharan Africa compared to other regions. However, only empirical investigation will validate or invalidate this assertion. As such, this study will estimate the impact of wood fuel consumption on health outcomes in the region.

The health outcomes to be considered in this study are an adult and under five-aged mortality rates. The adults, particularly women, are worst affected because they mostly remain indoor and are the ones in charge of cooking. Similarly, the under five-aged children also usually stay indoor with their mothers and sometimes play beside their

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mothers during cooking. Those children below the age of one, are most at times carried on the back by their mothers while cooking. This exposes both the mothers and the children to the apparent health hazard as a result of inhalation of smoke from wood fuels burning.

Third, it is vital to note that the potential adverse effect of indoor air pollution from the wood fuel can lower the income level of the households as a result of a decrease in the individual's productivity through illness. The likely adverse health effect of wood fuel usage can cause an increase in the morbidity and mortality rates (see Figure 1.14) among the population. An increase in traditional biomass usage can potentially increase infant and child mortality rate in developing countries. This may, in turn, reduce the future availability of workforce and also increase the social health cost of pollution. WHO (2010) reports that most of the developing countries have their increased income wiped away by social health cost of pollution from traditional biomass consumption.

Furthermore, the pollution from wood fuels can lead to a loss of workdays by the able-bodied persons due to illness or taking care of sick ones suffering from wood fuel smoke related illness. Similarly, falling sick from indoor air smoke or caring for the sick children, lessens earnings and can result in increased private health care expenditure and medication expenses.

The economic burden of indoor air pollution from wood fuel burning is estimated at 0.5% to 2.5% portions of the world's GDP, which is equivalent to \$150 to \$750 billion per annum (EIA, 2000). While the estimated cost of too much dependence on biomass fuel, mostly wood, in the region is US\$36.9 billion annually, which is quite substantial. Also, the productive time lost from gathering wood fuel is worth US\$29.6billion. However, knowing whether it affects the growth of the region is subject to empirical investigation. To this end, this study will empirically estimate the likely impact of wood fuel consumption on economic growth in the region.

1.8   Research Questions

The study seeks to answer the following research questions:

(i)   What is the impact of wood fuel consumption on forest degradation in Sub-Saharan Africa?

(ii)   What is the impact of wood fuel consumption on health outcomes in Sub-Saharan Africa?

(iii)   Does wood fuel consumption affect economic growth in Sub-Saharan Africa?

1.9   Objective of the Study

The general objective of the study is to examine the relationship between wood fuel consumption, forest degradation, health outcomes and economic growth in Sub-Saharan Africa.

1.9.1   Specific objectives

The specific objectives of the study are as follows:

1. To estimate the impact of wood fuel consumption on forest degradation in Sub-Saharan Africa.
2. To estimate the impact of wood fuel consumption on health outcomes in Sub-Saharan Africa.
3. To assess the effect of wood fuel consumption on economic growth in Sub-Saharan Africa.

1.10   Significance of the study

This study has some significance. First, taking into consideration the role of forests in sustainable development and human well-being, the forests are considered vital to everyone. While wood fuel trading provides many rural families with income and major energy source for cooking, it is essential to assess its real impact on the environmental degradation. This can assist the policy makers to work on finding an optimum level for both the environment and welfare of those rural households. Forest degradation is an important concern to the society as it can cause enormous economic, environmental and social problems. This is because millions of people rely on the goods and services provided by the forests in the Sub-Saharan Africa.

It is worthy to note that degrading the forests may hinder the capacity of the forests to provide fruits, medicines, timber and paper. It may also temper with the flow of services such as carbon sequestration, watershed services and so on. All these goods and services contribute to the well-being of the society. Therefore studying forest degradation in relation to the likely impact of wood fuel consumption and institutional quality will assist to a large extent in ensuring continuous of flow of these goods and services without obstruction.

Second, having information about the specific impact of wood fuel consumption on health outcomes such as adult and under five-aged mortality rates will assist governments that focus on achieving sustainable development goals, especially goal number three and seven. Goal number three targets to achieve good health and well-being. Whereas goal number seven targets at achieving affordable and clean energy. The study will contribute in that regard by providing useful information that will assist in achieving these targets from the source. At the same time, the study will serve as a basis for policy makers to act appropriately to prevent the possibility of exposure to

diseases linked to indoor air smoke. This can otherwise harm the welfare status of the poor by increasing their medical expenses.

Third, considering the increasing demand for wood fuel in the region, it is paramount to ascertain how the continuous reliance on wood fuel by countries within the region affect their economies. Though there some benefits in terms of income generation for the wood fuel operators and rural poor, who rely on the wood fuel extraction as the means of livelihood. However, there are likely costs associated with its consumption through the health impact, which may potentially affect the economy. Consequently, empirical investigation of its real impact on the economy can assist greatly in providing details to the policy makers about the level and magnitude of the impact.

Last, the study will contribute to the body of knowledge and literature in forest economics and biomass related literature. Having discovered that most of the existing literature studied the aggregate impact of clean biomass energy consumption on economic growth, this study distinguishes itself by focusing on one major component of biomass, which is wood fuel and its likely impact on forest degradation, health outcomes and economic growth. The study will also apply a dynamic panel framework that gives more information as against the time series techniques used by most existing literature. Thus, this constitutes one of the contributions of the study to the body of literature.

1.11   Motivation of the Study

This study is motivated based on the increasing production of wood fuel driven by its growing consumption in the Sub-Saharan African region. As shown earlier, other regions of the world are already on the verge of reducing the consumption of wood fuel and switching to much cleaner and healthier fuel such as electricity, considering the environmental, health and economic impact it has. However, the story is different in Sub-Saharan Africa, where the demand for the fuel is on the increase and has been even projected to increase further in the coming decades. This calls for concern and research into the area, as the increase is accompanied by some challenges. These challenges, which are related to forest degradation, health and economic growth, will be the focus of our study.

Secondly, the study is motivated based on the fact that the wood fuel sub-sector receives less attention from most governments of Sub-Saharan Africa countries. Despite its economic and environmental relevance, wood fuel sub-sector has been neglected and left in the hands of the informal sector in Sub-Saharan Africa (Word Bank, 2009). Clear policies governing wood fuel production, usage and trade are inadequate. Moreover, reliable statistics on the activities of the sub-sector are scanty, which makes it remain highly informal. These factors, coupled with unclear regulations, often due to corruption, makes the unsustainable harvest of wood for fuel to increase. This study will analyse and bring to light the impact of the activities in the sub-sector on the environment, society and the economy, with the hope that policy makers in the region will consider these issues in subsequent policy formulations.

Lastly, from the literature angle, the study is motivated from the absence of much literature in the area of the study. Despite the importance of the wood fuel in Sub-Saharan Africa, there are few literature in the area. Intrinsically, this study will contribute to the body of literature.

1.12   Scope of the Study

This study covers the impact of wood fuel consumption on forest degradation, health outcomes and economic growth in Sub-Saharan Africa. Specifically, objective one tries to investigate how wood fuel consumption affects forest degradation in the region. Further to that, the role of institutional quality is also considered in objective one to see how it may affect the wood fuel consumption-forest degradation relationship in the region.

To understand how wood fuel consumption may affect the health outcomes of the population of Sub-Saharan Africa, objective two specifically estimates the impact of wood fuel consumption on under-five and adult mortality rates. This objective further examines the impact of wood fuel consumption across female and male adult mortality to verify the assertion that female adults are more affected by wood fuel consumption than male adults.

Objective three covers the impact of wood fuel consumption on economic growth. This objective tries to estimate whether wood fuel consumption has some effects on the economic growth of Sub-Saharan Africa.

All the Sub-Saharan African countries included in the sample are selected based on data availability. While those countries without required data are excluded from the sample.

1.13   Organisation of the study

The study is an essay based thesis, made up of three essays. It is organised as follows. Chapter one presents the introduction, background of the study, problem statement, research questions, objectives of the study, significance of the study, motivation of the study, the scope of the study and organisation of the study. Chapter two comprises of empirical and theoretical literature. Chapter three presents and investigate the relationship between wood fuel consumption and forest degradation, including the methodology, findings and conclusion. The fourth chapter presents and examines the impact of wood fuel consumption on health outcomes, including the methodology, findings and conclusion. Chapter five investigates the likely impact of wood fuel consumption on economic growth and the chapter also presents the methodology, findings and conclusion. Lastly, Chapter six contains the summary, general conclusion and policy recommendation.

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