SCHOOL OF GRADUATE STUDIES

ASSESSMENT OF FUELWOOD DEMAND AND SUPPLY WITH ITS FOREST DEGRADATION CHALLENGES IN NAGELLE TOWN, SOUTHEASTERN ETHIOPIA

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DEDICATION

This manuscript is dedicated to the soul of GiriNagari “DIDA NAGARII DHERESSA ", who is nursing me with unconditional affection and sacrificed a lot in my life journey.

AUTHOR DECLARATION

I, TemesgenGiri, hereby declare that this MSc thesis is my original work and that it has not been presented by me to any other university for a similar or any other degree award, and all sources of material used for this thesis have been appropriately acknowledged.

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LIST OF ABBREVIATION ANDACRONYMS

AFREAP	Africa Renewable Energy Access Programme
CSA	Central Statistical Agency
EFAP	Ethiopian Forestry Action Programme
FAO	Food and Agricultural Organization
GEF	Global Environmental Facility
IAP	Indoor Air Pollution
IEA	International Energy Agency
NTRD	Nagelle Town Rural Development
LDSA	Liban District Statistical Agency
LPG	Liquid Petroleum gas
NCAER	National Council of Applied Economic Research
SPSS	Statistical Package for Social Science
UNDP	United Nations Development Programme
WHO	World Health Organization

Assessment of Fuel Wood Supply Demand with Its Forest Degradation Challenges in Nagelle Town, South-eastern Ethiopia

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ABSTRACT

Fuelwood and woody biomass are the most important forest product in Ethiopia. The high demand for wood as a source of household energy has been the cause of serious deforestation which in turn is fuelled by an ever-increasing population. Therefore, the major concern of this study was to quantify fuelwood demand and address the uncertainty surrounding fuelwood consumption. The study was conducted in Nagelle town, Liban district, OromiaRegional State, to assess fuelwood supply demand and its forest degradation challenges mainly following the ever-rising apprehensions about growing stock and any contributions thatfuelwood use may make to regional environmental degradation. Data was collected through structured questionnaires to know the socio-economic characteristics, causes of deforestation, and preferences of tree species for fuelwoodand service sectors survey by structured interview. The analysis of data was done by using Analysis of Variance and multiple linear regressions. Asa result, the average fuelwood demand at household levels in the area was estimated at 199.2 M^3 per year while in service sectors the fuelwood demand was estimated at 145$M^3$and amount of fuelwood supplied to the town was 78212.2M^3per year. At the study site, fuelwood consumption a was significant ($p<0.05$), variable across the income categories. Similarly, energy consumption was also significantly different among household income levels. The major fuel wood supply in Nagelle towns was Retailersandwholesalerswhichcontributed78%and7.8%respectively.Fuelwoodpriceanddistan cefromfuelwoodsourcehad a significantly positive linear relationship with fuel wood consumption at ($p <0.05$). From the result, fuel wood is the second cause of deforestation next to agricultural expansion. The study implied that fuel wood Consumption has an impact on the remaining forest in the country as a whole and in the surrounding areas of Nagelle town. Therefore, improving the end-use efficiency in the use of traditional fuels through improving the efficiency of the existing cooking stoves and introducing new and more efficient stoves is forwarded for energy policy.

Keywords*: deforestation, fuelwood demand, fuelwood supply, income levels, Negelle Town*

CHAPTER ONE

1. INTRODUCTION

1.1 Background of the study

Over three billion people of the world live in rural areas with inadequate supply of energy for cooking, lighting, heating, transportation, and other purposes. Worldwide, 1.4 billion people have limited access to electricity and 2.7 billion people rely on biomass fuel, mostly in rural areas (IEA, 2019). (FAO,2018)revealed that up to two billion people depend on forest goods such as fruits, game meat, fibres, and fuel wood to meet their basic needs. Over three billion people throughout the world rely on traditional fuels, such as wood, charcoal, dung, and agricultural residues, for cooking and heating (Bonjour, 2013). Many researchers claimed that fuel wood harvesting in developing countries is so important that it rivals other sources of industrial energy such as electricity, principally among poor people in rural areas. Throughout the developing world, biomass energy is the primary source of energy for domestic use. The most widely used form of biomass is fuel wood, although in a mass of natural or human imposed scarcity of wood, other biomassforms such as crop residues and dung become more relevant. Biomass as a source of energy is also enjoying renewed interest in the developed world as renewable energy (Berndes*et al.,* 2003). About 2.8 billion people in developing countries rely on biomass fuels (such as fuel wood, charcoal, and animal dung) to meet their energy needs for cooking food (Chirambo, 2018).

In many instances, it has been argued that the widespread use of fuel wood is linked to the number of environmental problems including deforestation, biodiversity loss, climate change and land degradation (Sitaula*et al.,* 2001). Fuel wood accounts for over 54 % of all global harvests per annum which results in a huge amount of forest loss (Williams *et al*., 2002). As Kebede (2002), until nowadays Ethiopia is still heavily dependent on traditional fuels (e.g. fuel wood, charcoal, crop dung etc.) for domestic energy consumption, especially for cooking. Even in urban areas, the cost for electricity and kerosene is unaffordable for many households (Kebede*et al.,* 2002). In rural areas, most households are using fuel wood and charcoal excessively and will turn to more inferior fuels (such as crop residues and dung) when there is a shortage of fuel wood in many areas (Macht*et al.,* 2007).

Fuel wood collection and consumption are highly linked to natural resource management. There is a two-way relationship between fuel wood collection and deforestation. On the one

hand, demand for fuel wood from commons and forests causes' resource degradation to the extent that collection exceeds sustainable yield (Jimento, 2013). Forest degradation, on the other hand, leads to a situation of fuel wood scarcity. In Ethiopia, fuel wood and charcoal are the stable energy forms for most rural as well as many urban and pre-urban communities. Most Ethiopia rural households relies on fuel wood as their basic energy source and has changed little over the last few decades. A study from Ethiopia, which considered regrowth, harvesting of fuel wood and fuel wood consumption, revealed that on a local scale the harvest is three-times the annual allowable cut. Present rate of fuel wood consumption and cutting may soon convert our forests to savannas and grasslands (Gebreegziabher*et al.*, 2007).

In 1994 the estimated annual wood fuel in Ethiopia was 45 million m^3, while estimated annual incremental yield available for fuel woods is 12.4 million m^3 (EFAP, 1994). In this situation the fuel wood deficit was 32.5 million m^3. To meet the demand, the exploitation of the forest source must be above its regenerating capacity, which results in the decline of the growing stock over the time. Moreover, where there is acute shortage of fuel wood, the household in rural areas is forced to use cow dung and crop residue or move with less fuel. Similarly, the growing demand of fuel wood as a source of energy increases the rate of forest degradation and deforestation in the country (Berhanu*et al.*, 2017). Socio Economics characteristics, environmental characteristics and technology affected the household's fuelwood consumption. Fuel wood availability is a significant variable that directly influence fuelwood consumption (Mekonnen, 1997, Mitiku and Yi, 2020) Household's residence far from fuel source negatively affect the daily fuelwood consumptions, the people who live in sufficient available fuel wood area or nearby forest relatively consumed higher fuel wood as compared to the other. (Ullah and Tani, 2017). However, study relatedtoassessment of fuelwood supply and demand with its forest degradation challenges is limited in the study area. So, this study was undertaken with the aim to examine the extent of fuelwoodutilisation and its implication on the extent of forest degradation in Nagelle town, Ethiopia.

1.2 Statement of the Problem

In Ethiopia, fuelwood is the most important source of energy, where 96 percent of the population is dependent onbiomass energy sources for cooking and other energy demands (Mekonnen, 2012). Such extreme dependence ontraditional fuels has an impact on the natural environment. Especially the heavy dependence on fuelwood hasmultifarious and related problems which have to do with deforestation, land degradation, and another

circle of fuelwood crisis. Despite the measures being taken at the country level to rehabilitate the environment,the consumption of biomass fuels has been increasing by 2.5 percent (Mekonnen, 2012).In Ethiopia, fuelwood is widely used in rural areas as well as in urban centers including big towns(Kebede, 2002), but the factors influencing the pattern and magnitude of use of these fuels by rural and urbanhouseholds are still not similar. According to (Yissehak, 2012), 80 percent of the urban fuel source is fromtraditional fuels, and in recent years fuelwood alone contributes almost 56 percent of the total energy consumptionof the urban city. Also, there is a question over the growing stock or sources that are potentially available for fuel wood supply and any contribution wood fuel use may make to forest degradation. As gap, this research fills the problem the above researchers haven't answered and missed at Nagelle town regarding assessment of fuelwood supply demand with its forest degradation challenges. Hence, it could be anticipated that it was the initial study addressing the uncertainty surrounding fuel wood supply demand and its forest degradation challenges in the study area.

1.3 Objectives of the study

1.3.1 General Objective

To examine the extent of fuelwoodutilisation and its implication on forest degradation in Nagelle town, Ethiopia

1.3.2 Specific Objectives

1. To assess fuel wood supply as a source of energy for household and service sectors in Nagelle town.
2. To assess fuelwood demand of study area
3. To identify factors influencing fuel wood consumption rate in the study area.
4. To assess environmentalimplication of fuel wood consumption on forest degradation in the study area
5. To assess Tree species preference for fuel wood at study area

1.4 Research Question.

1. Where is the source (supply) of fuel wood for Nagelle town?
2. What are the demands of fuel wood as a source of energy?
3. What factors influence fuel wood consumption?
4. What is the implication of fuel wood consumption on forest degradation?

5. What tree species are preferred for fuelwood at study areas?

1.5 Significance of the Study

Commerce, industry and man kind's way of life and standard of living are dependent and directly related to relatively cheap and freely available energy (Garbutt, D.C.F. and Van Breda, P.V., 1979). The progressively increasing gap between consumption and supply of energy, as well as severe economic changes created by large oil prices increases. Hence, it becomes necessary to use Biofuels/ the fuel wood. Consumption of fuel wood has an impact on the remaining forest in the country as a whole and in the surrounding areas of Nagelle town. A study carried out on the wood energy situation in Bangladesh indicated that fuelwood scarcity is because of overuse and unsustainability of fuel wood production (Miah,2010). For this reason, the study will help to minimise re-use and wastage of resources, dissemination of fuel wood statistical data for policy decision makers and there is made to have precise, organised, available information to serve a base for local energy development strategy. It could further inform policy makers and potential environmentalresearchers the impact associated to fuel wood consumption. This study helps as to inform the concerned bodyabout endangered tree species due to household tree preferences for fuel wood collection. It could be informedpolicy makers and researchers, the factors that were associated with the patterns of demand for wood fuelconsumption.

1.6 Scope of the Study

The study was conducted in Nagelle town. The data collection was completed within 30 days in March 2022. The study is restricted only to study significantly particularly Assessment of fuel wood supply and demand and its forest degradation challenges Nagelle town.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Fuel wood

Fuel wood is a source of energy derived by burning wood materials like logs and twigs and is common among the rural dwellers. It is a traditional source of energy, which has remained the major source of fuel for over half of the world's population (FAO, 2018). Fuelwood is the most common source of demotic energy for rural communities in the world. Wood fuels (firewood and charcoal) are the most important energy source and the leading forest product in most developing countries, where they may contribute 50 to 90 percent of all energy used and 60 to 80 percent of total wood consumption. Firewood gathered from forested commons is an important source of domestic energy in rural areas of many poor countries (Heltberg et al., 2000). It has been estimated that more than 2.4 billion people rely directly on traditional biomass fuels for their cooking and heating, and in poor countries biomass use represents over half of residential energy consumption (Unander, 2005). The consumption of fuel wood has a complex interrelationship with deforestation (Rudel et al., 2005).

Around 1.8 billion cubic metres of round wood (roughly half of the global supply) is currently used as fuel each year (FAO, 2015). The significance of fuel wood is likely to increase even further due to high fossil fuel prices, persistent poverty, and climate change considerations. Fuel wood has remained as the principal component of mostly domestic rural and urban energy in Ethiopia and in most developing countries. Most of the fuel wood has been reported to be derived from forest with some from trees growing on homesteads, farmlands, and common lands outside forests. Because of the increasing population, the area under agriculture expanded and forest shrunk. About 35% of total population demand on fuel wood for energy sources /cooking and heating/ in the developing countries (Heltberg et al., 2000). Fuel wood is the most important forest product in Ethiopia. For example, annual demand for fuel wood (45 million m3) is close to twenty times the demand for other forest products combined. In addition, woody biomass is the country's single largest source of energy supply. The current annual incremental yield of woody biomass resources is estimated to be 14.4 million m3. If harvesting were limited to this volume (sustainable supply) and managed according to prudent practice, some 1.2 million m3 would be used for construction wood, about 0.2 million m3 for industrial wood, and 0.6 million m3 for fodder. This would

leave about 12.5 million m3 for fuel wood. The estimated demand for fuel wood of 45 million m3 is almost three and a half times greater than sustainable supply, demonstrating the imbalance between the energy required and the capacity of the forest resources to produce (Keenan, 2015).

2.2 Environmental Impacts of biomass energy utilization

In Sub-Saharan African (SSA) countries, household energy is largely derived from fuelwood burned in simple stoves with poor combustion characteristics. In these countries, two thirds of the population (nearly 620 million people) lack access to electricity (IEA, 2014.). Reports indicate that more than 70% of the population in SSA countries lack access to clean cooking and depend on biomass energy for cooking and heating purposes (IEA, 2019). Heavy dependence and inefficient utilisation of biomass resources in SSA countries pose a major threat to forest resources (Gebreegziabher*etal*., 2013) And 500, 000 premature deaths annually are attributed to household air pollution, mostly from cooking smoke (IEA, 2019). Fuelwood collection is the major reason for forest degradation in most Sub-Saharan African countries (Dresen*etal*., 2014.). In this region, fuelwood is generally collected by the households for their own supply of biomass from nearby forest. This makes estimation of the rate of forest degradation and the resultant carbon dioxide emission difficult (Specht*etal*., 2015).

The relationship between the household energy source and the resulting greenhouse gas (GHG) emissions and indoor air pollution is becoming an important area of research to know the effect of domestic energy use at the local and global scale (Rob et al., 2003). Reports showed that around 17% of global greenhouse gas emission comes from burning of fuelwood (Van der Werf et al., 2009). (Barnes et al., 2005) reported that biomass fuels emit particulates and harmful gasses that affect the environment and human life. Most people in developing countries depend on wood, cow dung, charcoal and other biomass fuels for cooking and baking. It is reported that solid biomass consumption for cooking and heating alone contributes about 25% of carbon emissions globally (Rehman et al., 2011). The majority of these biomass burns in the open stove which has low fuel use efficiency and high pollutant emissions (Desai, 2004). In Ethiopia, only 7.20% of the population has primary access to clean cooking facilities (IEA,2018). The need for electric power becomes increasing, in which 32% of urban households get access to cooking with electricity in 2018 as compared with only 6% in 2011 (IEA, 2019).

However, electrification suitable for cooking lags significantly behind the electrification of household lighting (Alstone et al., 2015). In the country, fuelwood accounts 77–78% of all the different biomass energy sources used for domestic consumption (Alemayehu and Motuma, 2018). According to Samuel, 2003traditional fuels such as firewood and charcoal take a 54% share of the total household energy need in Ethiopia and are mainly used for baking 'Injera' (pancake-like bread made from flour of tef/Eragrostis tef (Zucc.). The consumption of biomass as a source of household energy in the country is one of the highest in the world and accounts for about 90% of the total energy demand (Gudina, 2015). As a result of dependence on biomass for cooking, CO2 emissions in Ethiopia have increased from 5.10 million tons in 2005 to 6.50 million tons in 2010 (Mdalam et al., 2018). On the other hand, (Gebreegziabher and van Kooten,2013), pointed out that fuelwood harvesting is believed to be the most important cause of forest degradation in Ethiopia. In Ethiopia, fuelwood harvesting at a local scale is reported to be three times the annual allowable cut (Haile et al., 2009). A study in south-eastern Ethiopia showed that 95% of the household in the study area collect fuelwood from natural forests and concluded that the use of fuelwood as energy source contributes to forest degradation (Urge et al., 2018). Land cover change from forest land to the other land use types aggravates soil degradation, resulting in soil fertility decline and loss of biodiversity. The (UNFCCC, 2017) report indicates that the Ethiopian natural and plantation forests, woodlands, and shrubs, sequestered about -27,573 Gg of CO2 in 1994, however, the country's CO2, emission as a result of fuelwood burning was 12,510 Gg in the same year.

2.3 Factors Influencing Households Fuelwood Consumption

Analysing Household consumption of firewood is one of the areas that attracted the interests of researchers. For instance, (Sofi, 2018) found that over the years, households keep on increasing their consumption of firewood because of availability and cheapness. On the other hand, there has been a decrease in the consumption of modern clean fuel. Similarly, (Danlami,2017) analysed the factor that influences household firewood consumption. On the other hand, (Onoja et al., 2012), indicated that distance from the firewood source and household income are the variables that have negative impacts on the consumption of firewood, while price of kerosene and household size are positively related to the consumption of firewood respectively. Logit analysis by (Danlami, 2017) shows that income;

number of rooms and nature of the home building are negatively related to the odds of adopting firewood sources.

Age of household head, gender of household head and home appliances are positively related to the odds of adopting firewood sources. (Oyekale, 2012) Found that the price of firewood and the households' heads' levels of education have a negative relationship with the adoption of firewood use by the households. On the other hand, the level of income of the household has a positive relationship with the use of firewood by the households respectively, this conforms the findings of (Onoja, 2012). Couture et al., 2012 conducted a study to investigate the determinants of fuel wood consumption in France. The result indicates that fuelwood consumption is positively related with homes where there exists an open fireplace, while the fuel wood price is negatively related to the fuel wood consumption. (Oyekale, 2012) used regression to estimate the determinants of household fuel wood expenditure in Kenya. Out of the seven variables estimated, only two were found to be statistically significant in influencing household's consumption of fuel wood. These variables are older household heads with 40 years and above, and household heads with only primary education. The conclusion is that households with a head that has one or both two characteristics tend to consume more firewood than otherwise.

Furthermore, Song et al. 2012 conducted a study to identify factors affecting wood energy consumption by US households. The study found that the size of the householdhas a positive significant influence on household wood consumption. Pundo et al., 2006 concluded that education level of both the husband and wife, as well as nature of dwelling encourages households to adopt more energy sources from charcoal instead of firewood. Danlami et al. (2018b) found that increase in income and living in urban areas reduce the probability of using firewood as the main source of cooking fuel in developing areas. Similarly, (Muller, 2018) used logit model to analyse the determinants of households' adoption of firewood. Factors like; household income, number of adults in the household and the distance from the source of fuel, increases the probability of households to adopt firewood source of energy than otherwise. (Abebaw, 2007) concluded that as household size and level of education of the household's head have an exact negative impact on fuel wood consumption, per capita income and the household's head being male encourage the consumption of fuelwood. The inconsistencies in the findings of these studies indicated that not all factors are equally important in different areas and locations as per influencing household energy consumption.

The findings from one area cannot be generalised to another area due to geographical, environmental, and socio-demographic differences from one area to another. Therefore, analysing household firewood consumption in a new area of study is an additional contribution to the existing literature.

2.4 Biomass energy utilization patterns of Ethiopia

In many rural areas in developing countries, rural and urban households still depend on biomass energy for most of their household and income-generating activities (Kaygusuz, 2021). Biomass is the main source of energy for most African households and is predominantly used for cooking, drying, and heating (Kebede et al.,2020). Over 90% of the population in sub-Saharan African (SSA) countries relies on traditional biomass energy for cooking, heating and lighting (Wolde-Rufael, 2009). However, this heavy and non-sustainable reliance on traditional biomass has caused a range of adverse consequences, including increased deforestation rate, decline in biomass resources, and scarcity of traditional energy sources and will, eventually, deprive rural communities of basic energy services (Adkins et al.,2020).The challenges of long-term energy security and environmental sustainability can only be met through the deployment of efficient and less-expensive technologies that are capable of using more plentiful, cleaner and cheaper sources of energy (Kaygusuz, 2021). As one of its main goals of resolving the declining biomass resources and growing energy insecurity in Ethiopia, therefore, the government launched the National Biogas Program of Ethiopia. Biogas technology has the potential to replace biomass in Africa (Mwirigi et al.,2014).

In Ethiopia, the total available woody biomass resources are estimated to be around 1,389 million tons in terms of standing stock and about 26 million tons in terms of annual sustainable yield (Eshete etal., 2019). The consumption pattern of annual biomass energy in rural Ethiopia is largely dominated by combustible and renewable biomass resources of firewood, crop residues, animal waste, and charcoal. The most important biomass energy source is firewood (77%), followed by cow dung cake (13%), crop residue (9%), and charcoal (1%), which together constitute the annual energy requirement in rural Ethiopia. These energy sources are mostly used as cooking fuels. Firewood is the predominant cooking energy source, accounting for 77% of all cooking energy sources. It is used secondarily for lighting and space heating. Thus, to meet domestic energy requirements, rural populations use various forms of biomass, almost exclusively firewood, agricultural residue, cow dung

and charcoal. This shows that the pattern of biomass energy consumption in Ethiopia is similar to other countries in SSA: The biomass energy supply, including charcoal, wood, and animal waste accounts for more than 80% for many SSA countries' domestic energy supply (Kebede etal., 2010).In Ethiopia, biomass energy sources are commonly collected from nearby forests or plantations or sometimes purchased at local markets, and obtained from various kinds of crop residues and animal wastes. Charcoal is hardly used in rural settings but is a potentially important cooking fuel that is available at local markets. Relatively, charcoal is widely used in urban areas.

2.5 Fuel wood, deforestation, and land degradation

Fuel wood gathering is one of the major contributory factors to deforestation, which is already claiming about 10 million hectares of forest each year in the developing world (World Bank, 2006). This excessive deforestation has resulted in fuel wood crisis in many countries and hence agricultural residue and animal dung are being substituted for fuel wood. But this reduces the availability of valuable soil nutrients and hence reduces soil fertility, contributing to slowdown in agricultural production (smil, 2020). Forest and generally biomass degradation, as well as consequent land degradation, leads to the destruction and erosion of biodiversity of both plants and animals. More specifically, the destruction of habitats, the introduction of a narrow spectrum of crop varieties, recurring droughts, as well as wars and conflicts could be mentioned as the most common causes for the erosion of biodiversity in Ethiopia. In view of the presently growing conflicts between biodiversity conservation and agricultural needs, there is a potential danger that conservation of biodiversity may lose (Gebreegziabher et al., 2007).

Land degradation is broadly defined as "any form of deterioration of the natural potential of land that affects ecosystem integrity either in terms of reducing its, sustainable ecological productivity or in terms of reducing its sustainable ecological productivity or in terms of reducing its sustainable ecological or biological richness and maintenance of resilience" (Clemencon, 2020). Land degradation is a result of unsustainable agricultural practice, overgrazing and deforestation. Deforestation, a major cause of forest cover loss leads to their degradation. A growing urban population and an increasing demand for charcoal and fuel wood have further stressed the environment (Soussan, 1992).

The rural fuel wood use is often cited as a factor in large scale deforestation, but these as certain are rarely substantiated (Mcclintock, 2006). Indeed, according to the authors, the evidence points the other way around where the forests are opened, land clearance leads to massive fuel wood surplus, and substantial quantities of wood resources are either burnt or left to rot. Deforestation represents one of the most pressing environmental problems faced by almost all Sub-Saharan African nations, and one of the primary causes of deforestation is wood utilisation for fuel. Many sub-Saharan countries have had over three quarters of their forest cover depleted. It is estimated that if current trends continue, many areas, especially that of the Sudano-Sahelian belt, will experience a severe shortage of fuel wood by 2025 (Mulgeta and Zenebe, 2011). According to these Authors, Land clearing by farmers may contribute as much as fuel wood gathering in the depletion of tree stocks. An estimated 20 to 25 percent of annual deforestation is thought to be due to commercial logging. The remaining 15 to 20 percent is attributed to other activities such as cattle ranching, cash crop plantations, and the construction of dams, roads, and mines.

2.6 Tree planting Approaches

The most common approach by government and donor agencies to ameliorate perceived fuel wood problems has been to plant trees (Mercer and Sausan, 2016). This was done to solve energy needs of the rural communities while at the same time contributing to the economic development and maintenance of biodiversity and environmental quality. For this purpose, programmers ranging from establishment of village wood lots to large scale fuelwood plantations were implemented. Tree planting initiatives for fuel wood can also be viewed as another way of reclaiming degraded forest lands. Planting of trees not only assists in the mitigation of fuel wood shortages, but also fulfils the rural need for the economic and non-economic benefits from trees to sustain their rural livelihood.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1 Description of the study area

3.1.1 Location and Topography

The study was conducted in Nagelle town of Liban District Guji Zone Oromia regional state. Nagelle town is located at distance of 595 km from Addis Ababa to southern direction. Nagelle town is located between 4º30'58" - 5º42'8" northing latitudes and 41º34'57" - 39º9'34" easting longitudes. It is in the low land of Oromia national regional state (LARDO, 2018).

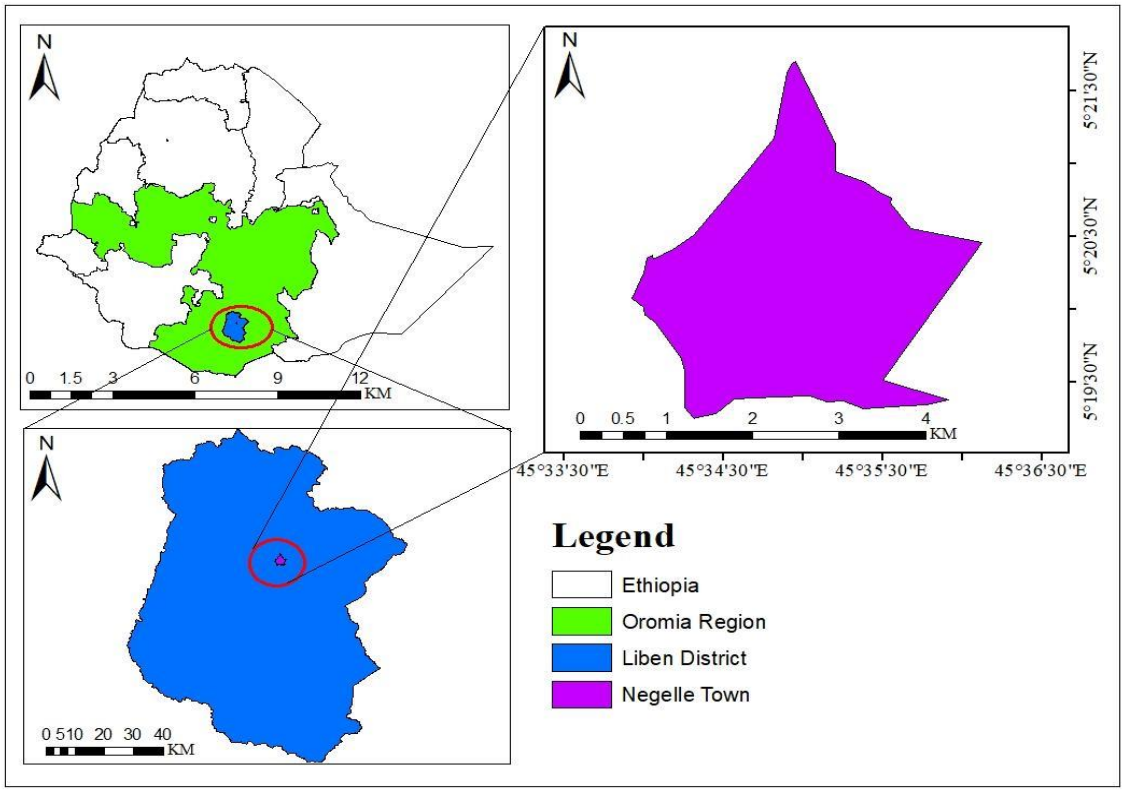

Figure 1: Location Map of study area *(Source: Ethio GIS Data)*

Most of the earth surface of the town is Plains and dissected hills characterise the relief of the town. Therefore, the relief of the town shows that the highest above mean sea level is 1490ms and the lowest below mean the sea level is 1440 ms respectively (LARDO, 2018).

3.1.1 Climate

Theclimate of Nagelle town is 2/3 hot tropical and 1/3 warm temperate. About 67% of the total area of the town is characterised by tropical/desert climatic condition, while about 33% has warm temperate climatic condition. Desert evaporation exceeds precipitation its agroclimate is deserts, and its mean annual temperature is between 24^0c-34^0c. The town is also characterised by two rainy seasons, namely spring or Belg (locally known as 'Gannaa') which starts in early March up to May and autumn (locally known as 'Hagayya') which starts late September up to the beginning of November). Spring season lasts for about three months (March to May), while autumn season similarly lasts for three months (September to November). The annual average rainfall of the town is 410mm-600mm. (LARDO, 2018).

3.1.2 Farming system and livelihood

Most agricultural production taken place in most agrarian places of Ethiopia is a mixed type of farming system, which allow farmers to diversify risks from single cropping, use labour efficiently, access cash and add value to products, and there is high potential for increasing system productivity, diversification, and sustainability. Crop farming, animal husbandry and commercial activity prevail as dominant economic activity in the NegelleTown. High forests (Ganale forest), grassland, exposed sand soil, Riparian woodland or bush land and cultivated land are available in the district (LARDO, 2018).

3.1.3 Vegetation

The natural vegetation of the district has 8111 and 7705 hectares of forest area has natural forest under preservation and management and decreasing at an alarming rate for urbanisation, fuel wood, and charcoal and for expansion of farming area (LARDO, 2018). The current combination of natural vegetation of the district includes all types ranging from high dense forests to shrubs and bushes. The species diversity include-Aningeriaspp, Cordiaafricana, Croton macrosstachyus, Combretummolle, Podocarpusfalcatus, Bushy trees, Acacia spp and Savannah grasses e.t.c.

3.2 Research Design

Cross-sectional survey design was employed to conduct this research.

3.2.1 Sampling method and sample size

The sampling technique for service giving sectors was done by whole census (Table1). Both primary and secondary data sources were collected. Primary data was collected through a household survey, focus group discussion, and key informant interview in the form of open and close-ended questionnaires provided by the local language Amharic. Secondary data was collected from administration offices and agriculture offices and reviewing literatures from published and unpublished materials that supported the finding of this study. The total numbers of households in Nagelle town are 37682 (CSA, 2022). The sample size of household was determined based on Kothari's sample size formula which states as follows (Kothari, 2004).

$$n = \frac{z^2 pqN}{(E)^2(N-1)+z^2 pq} \quad \frac{(1.96)^2*(0.05)(0.95)*37682}{0.05^2*(37682-1)+1.96)^2*0.05*0.95}$$

= 5313/72.9=73

n = sample size of household

p= maximum possible proportion of population to be included in the sample which is 5% (0.05).

q= 1-p (1-0.05) =0.95

E- Allowed error which is now 5%

Z- Confidence interval which is now 95%, 1.96 from z- table.

N- Total number of households.

Table 1: Sample size of Household in the study area

Name of kebele	Total number of households	Household headed
01 kebele	11,931	30
02 kebele	11,605	20
03 kebele	14,145	23
Total	29,118	73

Source: Nagelle Administration and Municipal office, 2022

All the above kebeleswere selected purposely and individuals are selected with snowballing method. Moreover, eight key informants composed of local elders with indigenous knowledge on fuel wood supply demand and its forest degradation challenges kebele leaders,

development agent (DA) and women were selected. Similarly, twenty-three FGD participants were also purposely selected from different sections of the community which include elders and kebele administrators, household heads and development agents who had experience on the past and present trend of fuel wood use of the study area.

Table 2: Sample Size for Key Informant Interview respondents and FGD

Position/profession	Sample respondents		Sampling technique
	Key informants	FGD participants	
Local elders	3	8	Purposive
Household heads	-	6	Purposive
Kebele administrators	3	3	Purposive
Development agents	1	-	Purposive
Women household	-	6	Purposive
Town energy expert	1	-	Purposive
Total	8	23	

Source: Field survey, 2022

All service providing sectors namely Restaurant and hotels, Tej bet, and bakeries and Black smith were considered for this study. The Total numbers of non-household or service sectors in Nagelle Town are 79.

Table 3: Sample size allocation of non-household sectors

Service sectors	Total No	Sample size	Method of sampling
Restaurant and hotels	37	37	Census
Ifaboru special boarding school	1	1	Census
Tej bet and bakeries	29	29	Census
Black smith	10	10	Census
Total	76	76	
Prison	1	1	Census
Hospital	1	1	Census
Total	2	2	

Source: Nagelle administration and municipal office, 2022

Therefore, a total of 152 (households + service sectors = 73+79) sample size was undertaken for this study.

3.2.2 Data collection for fuel wood consumption

To study fuel wood demand, household and service sectors are the target population in the study area. From the target population different kinds of interviews and questionnaires were conducted (Appendix 1). To accomplish the measurement of fuel wood consumption on household level, information related to household characteristics such as household family size, income level, fuel preference, availability of alternative fuels, cooking stove used, quantity used per day, price of fuel wood, kind of fuel wood species preferred was collected from selected household using interview and questionnaire. Beside households, service sectors were significant users of fuel wood and charcoal. To start with the survey of fuel wood demand in service sectors, a decision was made to focus on those businesses that are known to utilise fuel wood. From the identified target population (Table1), information related to fuel demand was conducted through questionnaire, interview, and direct observation (appendix 2).

3.2.3 Method of data collection for fuel wood supply

The potential suppliers of fuel wood that is ready for use are local farmers, whole sellers, Retailers and saw millers.

Local farmers: - local farmers found in pre-urban areas are the dominant suppliers of fuel wood to the consumers in the town of the study area. These local farmers collect fuel wood from local forest or non-forest areas, split the wood or as it is round wood, and bring to the town usually using animals back (donkey). They are also the major suppliers of charcoal. Method collecting data on wood fuel supply by local farmers (pre urban farmers) is given as follows; Collecting information on fuel wood (firewood and charcoal) supply by pre-urban suppliers (Local farmers) was made at four checkpoints (directions) established through which wood fuel flows into the town. At each check point's data was collected for seven days in one month since there is variation in supply on different days of the week. The information that was collected during surveying, type of fuel wood (species), number of bundles, price per bundle, source of fuel wood and charcoal, distance travelled (appendix 3).

Whole sellers: - Whole sellers also supply fuel wood to the town. Whole sellers are those business individuals/entities that buy fuel wood from individual producers or farmers,

government organisation, institution, community woodlots and provide either directly to consumers or through retailers. Questionnaires were prepared to collect information on the amount of fuel wood sold per day, price of fuel wood, source of fuel wood, distance of fuel wood, species preferred from respective wholesalers.

Retailers: - Retailers are those businessmen that supply fuel wood to consumers through buy from the wholesaler, or from pre urban farmers. To collect information from retailers was cross checks for sources of fuel wood.

Sawmill industry: -saw millers also provide or sell fuel wood to local customers/consumers as saw dust and slabs. To assess fuel wood supply by sawmills information's been collected directly from the sawmills (Urgessa et al.,2009). Furthermore, for fuel wood consumption estimate in urban area initial population was divided into strata based on income level (category) since there is difference in wood fuel consumption between households due to income level. The income category made by the central statistical authority in 2007 divided the urban household into three categories: low, medium, and higher income. It has been described as income with greater than 12,600 as rich, 2000-12599 as medium and below 2000 as poor (CSA, 2007).

3.2.4 Data Collection method for consumption of fuel wood on forest degradation

Assessing challenges of fuel wood consumption on forest degradation was done by interviewing households based on a prepared structured questionnaire (Appendix 4).

3.3 Data analysis

After collection of all the necessary information regarding fuel wood demand and supply with its forest degradation challenges, the analysis was made. Analysis of variance (ANOVA) and descriptive statistics employed to analyse the quantitative data and multiple linear regressions were used to see the relationship between variables of supply demand of fuel wood. Data was presented in the form of tables, charts, and figures. The multiple linear regressions model applied was based on the (Mendenhall, 1989) formula as follows: The model was preferred because it offers full explanation to the dependent variables since few phenomena are the product of a single cause and the effect of the independent variable (Mendenhall, 1989).

$Y = \alpha + \beta 1x1 + \beta\ 2x2 + \beta\ 3x3 + \beta\ 4x4 + \beta 5x5 + \beta 6x6 \ldots + \beta nxn + \varepsilon$

Where: α = constant

ε = error term

Y = wood fuel consumption as dependent variable (m3)

$\beta 1$ to βn= regression coefficients,

X1 = fuel wood availability,

X2 = fuel wood price,

X3= distance walked to sources of fuel wood

X4 = security problem

X5=household family size

X6=level of education

Regression was tested at 5% level of probability. The model was preferred because it offers full explanation to the dependent variables since few phenomena are the product of a single cause and the effect of the independent variable (Mendenhall, 1989). Regression analysis helps one understand how the typical value of the dependent variable changes when any one of the independent variables is varies, while the other independent variables are held fixed. The estimators, however, end up with almost the same standardised (marginal) impacts of independent variables. For this reason, the study has used multiple regression models to identify the determinants of fuel wood consumption.

Table 4: Independent variables, their description, type and expected effects on linear model.

Variable code	Variable Type	Definition and measurement	Expected sign
FWC	Continuous	Fuel wood consumption (1 if high consumption, otherwise 0)	Dependent variable
FWA	Dummy	Fuel wood availability (1 if access to open forest, otherwise 0	-
FWP	Continuous	Fuel wood price (1, if price increased, otherwise, 0)	+
DFS	Continuous	Distance of fuel wood source (1, if 1. distance is short, otherwise)	+
SCP	Dummy	Security problem (1 if secure, otherwise 0	-
HHFS	Continuous	Household family size	+ve
HHLED	Continuous	Household Level of Education	-ve

CHAPTER FOUR

4. RESULTS AND DISCUSSIONS

4.1 Results

4.1.1 Socio Economic Characteristics of the Respondents

The result of the study showed that 38.3% of the respondents were male while 61.7% were female. About 50.6 percent of the heads of households were within the age ranges of 25 and 35 years. Nearly 8 percent of the respondents were under the age of 30 years and heads of the households over the age of 45 constituted 3.3 percent of total (Figure 1). 49 % of the respondents are within the age group of 25-35 years; whereas; about 38.1 % belong to the age group of 35-45. So, the results of this study revealed that most of the respondents are in a condition of ability to participate in any economic activity. Relatively like this study finding, the research result conducted at Gechi District southwestern Ethiopia described as more of the respondents in this age are in economically active age group (Berhanu*et al.*, 2017).

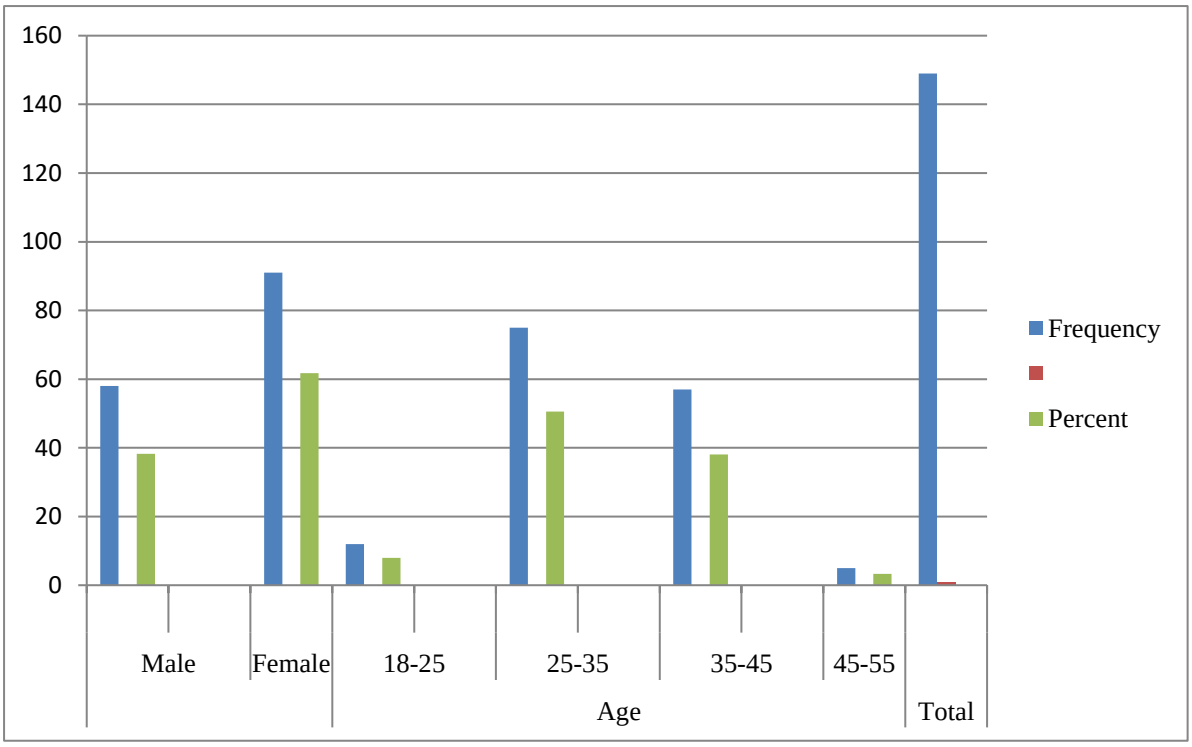

Figure 2: Socioeconomic characteristic of respondents *(Source: field survey, 2022)*

From the total respondents, 30.1 percent of them have no formal education while 20.4 percent of the heads of the households followed adult literacy (Figure. 3). The remaining 49.5 percent of the heads of households have attended different levels of educational qualification ranging from Elementary school to university.

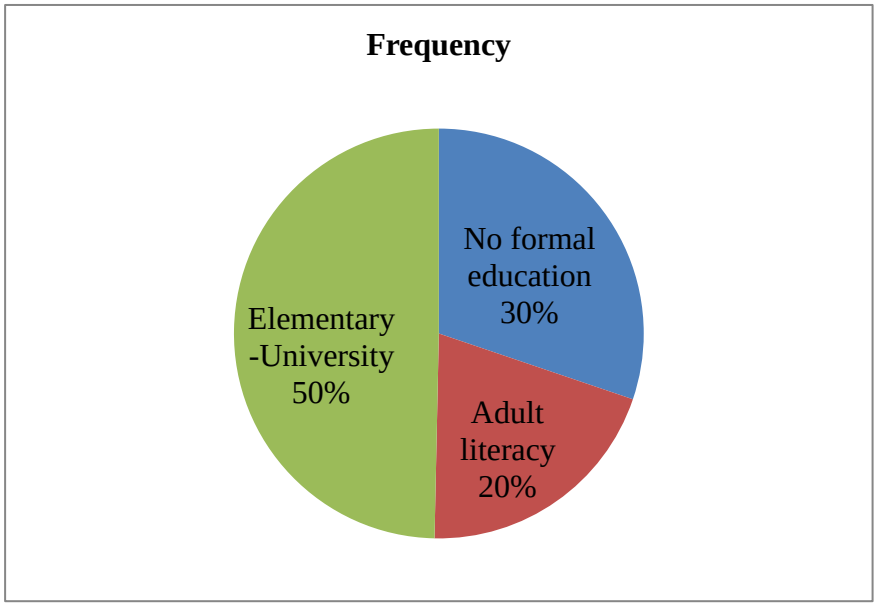

Figure 3: Educational status of respondents (Source: field survey, 2022).

4.1.2 Frequency Distribution of Fuel Consumption

The fuel wood consumption (firewood and charcoal) dominates energy uses in town and accounts for 70% of the total (Table 5). The use of fuels varies from the economic level of the households. The key factors influencing the consumption of fuel wood such as urbanisation, nearness to accessible forest/ trees resource/ income level and climate change.

Table 5: The frequency distribution of the users and non-users of fuel consumption across income categories in Nagelle town

		Income categories			
Energy sources		Rich	Medium	Poor	100%
Firewood	User Non-User	32.5% 63.6%	42.2% 0	25.3% 36.4%	100 100
Charcoal	user Non-User	32.4% 70.0%	42% 0	25.6% 30.0%	100 100
Cow dung	User Non-User	22.2% 47.7%	40.1% 40.5%	37.2% 11.7%	100 100
Crop residue	user Non-User	39.6% 8.7%	43.1% 28.3%	17.3% 63.3%	100 100
Kerosene	User Non -User	100% 33.3%	0 40.7%	0 26.0%	100 100
Electricity	user Non –user	*75.0 %* 31.0	0% 43.1	25.0% 25.9	100 100

4.1.3 Household fuel wood demand

Fuel wood consumption households based on income categories indicated in table 6.

The fuel wood consumption is significantly ($p < 0.05$) different across income levels of the households.

Table 6:Quantity of fuelwood consumed by Household at study area.

Type of fuelwood	Amount of kg/month	Amount of kg/year
Firewood	5110.4	61325.42
Charcoal	4852.8	58234.2

Accordingly, annual quantity of fuel wood (Firewood and charcoal) consumed by households in the study area was estimated that 102.2 and 97m3 (61325.4 and 58234 kg/years) respectively. The average weight of fuel wood (firewood and charcoal) per household head was estimated at (1.4m3 and 1.32m3) per months. This sows that Fuel wood collection and use was substantially responsible for deforestation and the increase in atmospheric carbon dioxide concentration (kasim*et al*., 2020). Wood fuel consumption in both rural and urban areas can be affected by several factors. These factors are broadly divided at national level (macro factors) and at local level or household level (micro factors) (WHO, 2006). The macro factors include economic performance, population growth, and rate of urbanisation, technological advancement, and gender issues. Meanwhile, the micro factors comprise household characteristics such as income, availability of alternative fuels, price, family size, efficiency of cooking stove, and nature of wood and species etc.

The income of household's influences fuel consumption in two ways: with the rise of income levels and supplementary items. All fuel studies have considered income as an important factor influencing per capita consumption. NCAER (1985) found that household energy consumption is positively correlated with annual income. On the other hand, in other studies, it has been found that per capita fuel wood consumption decreases with an annual income of the households. The decrease may be due to the substitution of fuel wood with other fuels like kerosene and electricity.

4.1.4 Fuel wood and other energy sources demand

The mean fuel wood consumption by a non-household sector is shown in Table 7. The higher firewood consumption is found in hospitals and special boarding schools. Charcoal consumption is higher in the hospitals and blacksmith than the other non-household sectors (Table 7).

Table 7:non-household fuel wood (firewood and charcoal) consumption (M3)/year

Name of sectors	Firewood	Charcoal
If aBoru special boarding school	126.88	0
Prison	97.504	131.2
Blacksmith	55.3	122.68
Hotels and restaurants	75.76	0
Hospitals	143.256	65.8
Tejbet and bakery	85.40	2.88
Total	553.1	322.56

The study indicated that household size income level is a significant ($P<0.05$) affecting fuel consumption in all cases, as except cow dung and kerosene (Table 8).

Table 8: Mean household energy consumption by income category

Energy use in tone of oil equivalent (toe) (means ±std) /day						
Income Category	Firewood	Wood charcoal	Cow dung	Crop residue	Electricity	kerosene
Rich	5.03±0.4[a]	35.11±2.[a]	2.303±1.[a]	0.099±0[a]	0.83±0.26[a]	0.024+0.17[a]
Medium	3.58±0.1[b]	20.38±1.43[b]	5.026±0[a]	1.2±0.42[b]	0.02±0.015[b]	0.001±0.01[a]
Poor	1.79±0.1[c]	6.30±0.75[c]	3.51±0.6[a]	2.31±0.4[c]	0.241±0.12[cb]	0.0002±0.003[a]
Overall means	**3.61±0.5**	**21.74±1.34**	**10.06±0.59**	**1.11±0.1**	**0.34±0.098**	**0.008±0.005**

The energy sources in the household and service sectors are presented in table 9.

79.91% of firewood and charcoal was consumed by the households and non-household sectors.

Table 9: Mean Energy consumption by sector and source of fuel type

Source of fuel type	Energy consumption by sector in tone of oil equivalent (toe)			
	Household	Non household	Total	Percentage share %
Firewood	33.61	21.57	55.18	4.11
Charcoal	21.73	993.6	1015.33	75.80
Cow dung	5.06	0	5.06	0.37
Crop residue	1.11	0	1.11	0.082
Electricity	8.56	254.16	262.72	19.61
Kerosene	0.0082	0	0.0082	0.0006
Total	**70.0782**	**1269.33**	**1339.4082**	**100**

Past studies indicate that the household sector utilised the bulk of the country's energy of which biomass was the principal. Biomass fuels dominated the profile of primary energy use owing to the low level of economic development of Ethiopia. Almost 90 percent of the country's energy use is for household purposes mainly for cooking and lighting (Bereket *et al*., 1996). The outcome from this local case study also indicates as the household sector is the dominant energy consumer of which biomass for fuel is the principal, 98.87% of the energy comes from biomass (fuel wood, charcoal, and cow dung and crop residue). Such dependency on wood for fuel (firewood and charcoal) would put pressure on the forest resource potential and tree stock outside forest in the area. The present study indicated that the mean quantity of charcoal consumed in annually was 55.18 ton of which about 75.8% was consumed by households and service sectors.

4.1.5 Fuel wood supply to the Town

Most of the fuel wood supply to the town has been by retailers; whereas nearly 14.5% of the total supply to the town was supplied by whole sellers, sawmills and consumers own supply from community wood-lots, natural high forest, industrial plantation forest and private woodlots and farmlands. The potential fuel wood supply in the town was retailer and wholesalers which contributed 85.5% and 7.8% respectively (Table 10).

Table 10: Total quantity of wood fuel supply to the town

Supplier	Firewood Quantity/ month M^3	Charcoal Quantity/month M^3	Total wood fuel consumption / year M^3	Percentage
Retailers	1711	3861.23	66871.5	85.5
Whole sellers	506.68	0	6080.2	7.8
Sawmills	54.92	0	659.04	0.84
Consumers own farm	383.37	0	4600.4	5.86
Total	2656	3861.63	78212.2	100

Fuel wood comes from a variety of sources such as forest and non-forestland e.g., from trees on farmland, roadside, coffee forest, riverside forest, shrub forest, grazing land, community woodlots, industrial plantation, and from trees planted on settlement land. These standing and potentially available volumes are potential sources for fuel wood. Studying the potentially available growing forest stock and its growth (mean annual increment) is important since the future supply (sustainability) of fuel wood depends on the level of the incremental yield from all woody biomass resources and how these resource managers including farmers, communities, and the state, need to use the assets over which they have control or which they have access (Asfaw cited EFAP, 1994).

4.1.6 Fuelwood Supply Demand Balance

At the study area there is negative balance of fuelwood which indicates lower supply quantities than demand. Total Fuelwood demand was 120435.28kg /per year or 200.7m3 and total fuelwood supply to the town was 78212.2kg/year or 130m3 which shows the deficit of 70m3.The study results indicate that current Fuelwood supply quantities cannot meet the current demandquantities and needs to be improved.

4.1.7Multiple linear regressions

Models are examining the relationship between a dependent variable and independent.

Variables as stated in Tables 11 to 13.

Table 11: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.357[a]	.127	.090	.260

b. Dependent Variable: Fuel wood consumption

The multiple regression determinations also show that R squared is .127, meaning that approximately 12.7% of variability of fuel wood consumption is accounted for by variables in the model. The adjusted R-squared indicates that about 9 % of the variability of fuel wood consumption accounted for by the model; even after considering the number of predictor variables in the model.

Table 12: ANOVA***a***

ANOVA[a]					
Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	1.403	6	.234	3.471	.003[b]
Residual	9.637	143	.067		
Total	11.040	149			

Table 13: Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	.199	.094		2.106	.037	.012	.385
	fuel wood availability	.074	.066	.094	1.118	.266	-.057	.204
	Fuel wood price	.096	.068	.112	1.414	.160	-.038	.230
	Distance travel to fuelwood source	.011	.033	.026	.317	.752	-.055	.076
	security problem	-.277	.073	-.315	-3.791	.000	-.421	-.133
	Household family size	-.006	.030	-.016	-.198	.843	-.065	.053
	Level of Education	.056	.031	.143	1.800	.074	-.006	.118

A. Dependent Variable: Fuel wood consumption

Beta coefficients, also known as standardised regression coefficients, are used to compare the strength of a given coefficient to the coefficient for another variable. For example, here, household level of educationhas the largest β coefficient, around 0.143, and security problemhas the smallest β coefficient, which is around -0.315. Thus, a one standard deviation increases in household level of education leads to a 0.143 standard deviation increase in predicted fuel wood consumption, when the other variables are heldconstant. One standard deviation decrease in security problem would yield -0.315 standard deviation increases in the predicted fuel wood consumption. Also, a one standard deviation increase in fuelwood price would yield a 0.112 standard deviation increase in the predicted fuel wood consumption. Household level of education, fuelwood price and distance to fuelwood source had a positive relationship to fuel wood consumption in the study area, while security problems, fuel wood availability and household family sizehad a negative relationship to fuel wood consumption of households. Since a p-value less than 0.05, we conclude that the overall model is a significant relationship to fuelwood consumption.

4.1.7 Factors influencing fuel wood consumption.

Results of a field survey indicate that fuel wood consumption in the study area has been influenced by its availability, which is confirmed by 50.0% of the respondents, followed by fuel wood price which has been high at study area. Whereas distance from the source of fuel wood taken 11.1 % followed by security problem 8.2 % which was mentioned as a factor influencing fuel wood consumption in study area at a time (Figure 3). In line with this result, kasim *et al.*, 2020 reported that fuel wood consumption in AgarfaTown, South-Eastern Ethiopia has been influenced with its availability, which is confirmed by 53.0% of the respondents. The availability of fuel wood has been the implication on per-capita consumption to be increasing as well as the user tends to use forest products, including fuel wood unsustainable; consequently, they must threaten the land through degradation and deforestation. Results revealed that fuel wood availability was relatively site specific.

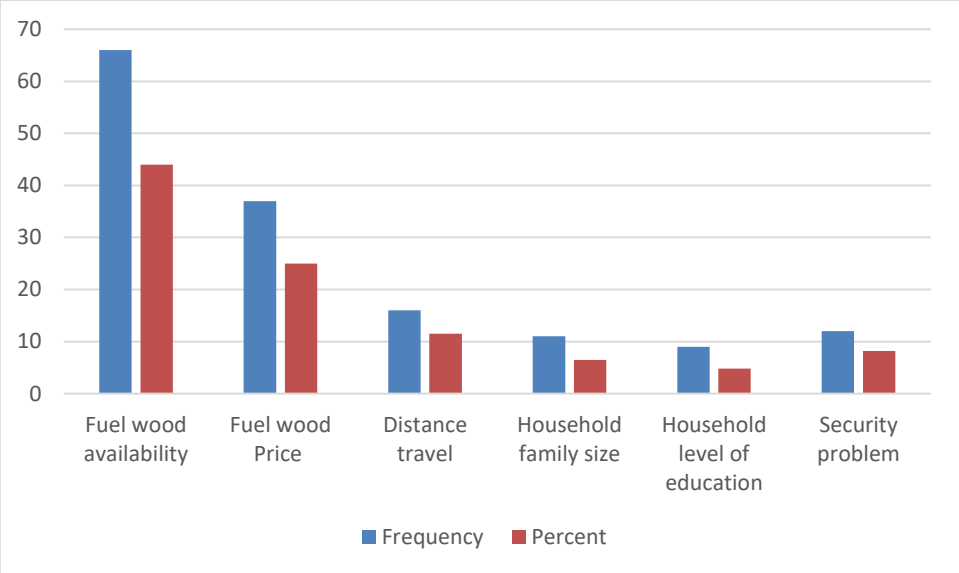

Figure 4: Factors affecting fuel wood consumption *(Source: Field survey.2022)*

4.1.8 Major causes of forest degradation at study area

According to respondents, the distance to get fuel wood is increasing. This shows that there is still deforestation in the study due to fuel wood consumption and other activities.

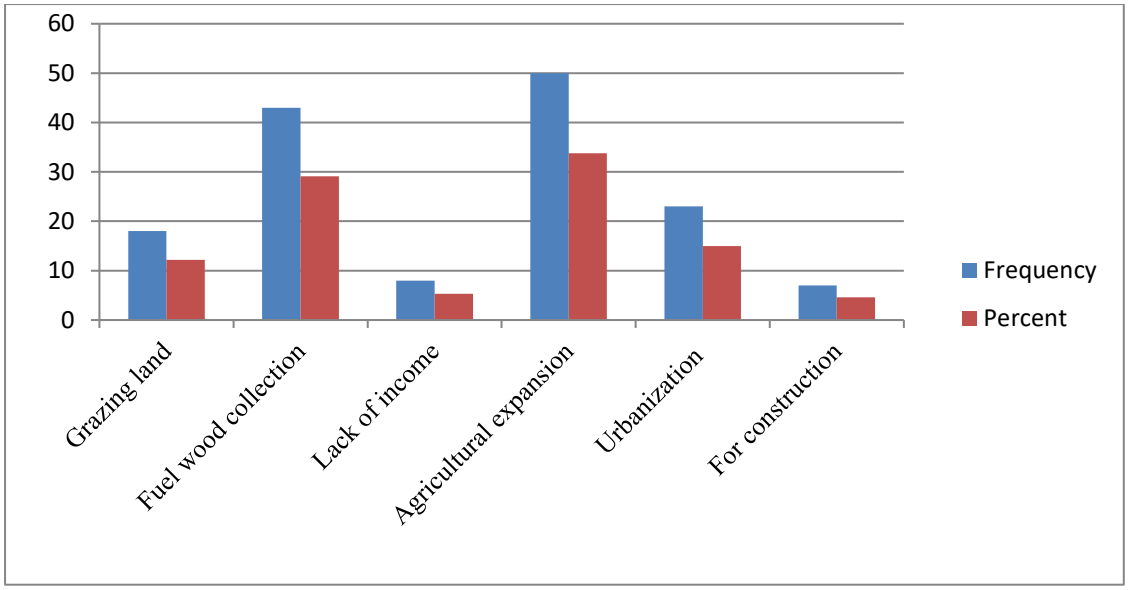

Figure 5: Major cause of forest degradation at study area (Source: field survey 2022)

Out of all respondents, 50 (33.8%) of them pointed out that the agricultural expansion is the major reason for deforestation which was came from high population increment (Figure 4). While 43(29.1%) believe that Fuel wood collection is the second main cause for the deforestation in the study area followed by urbanization which accounts 23(15%) of respondents. Here seek for grazing land is the cause for deforestation which has 18(12.2%) of respondents. In contrast to this study, the research conducted at Agarfaworeda Southeastern Ethiopia also described Agricultural land expansion and fuel wood collection as major cause of forest degradation (Kasim, 2020). Other causes such as sake of construction materials and lack of income take part in deforestation at the study area. Also, respondents described that "there was higher need for agricultural land expansion and urbanization in the study area that remove forests, which brought about high demand for fuel wood. They further added that, over exploitation of forest resources through household, daily activities caused the shortage of fuel wood in which people had to travel a long distance in search of it.

4.1.9 Implication of fuel wood consumption on forest degradation

When carried out on unmanageable basis of fuel wood harvesting, leads to a wide range of local and global environmental impacts, including forest degradation, soil nutrient depletion, climate change, drought and Diminishing wildlife. The finding in Figure below which reveals that wood removal for fuelwood components lead to deforestation (28.8 %), climate change

(22.1 %), Drought (21.47 %), soil nutrient depletion (16.1%) and Diminishingwildlife (11.5 %) respectively.

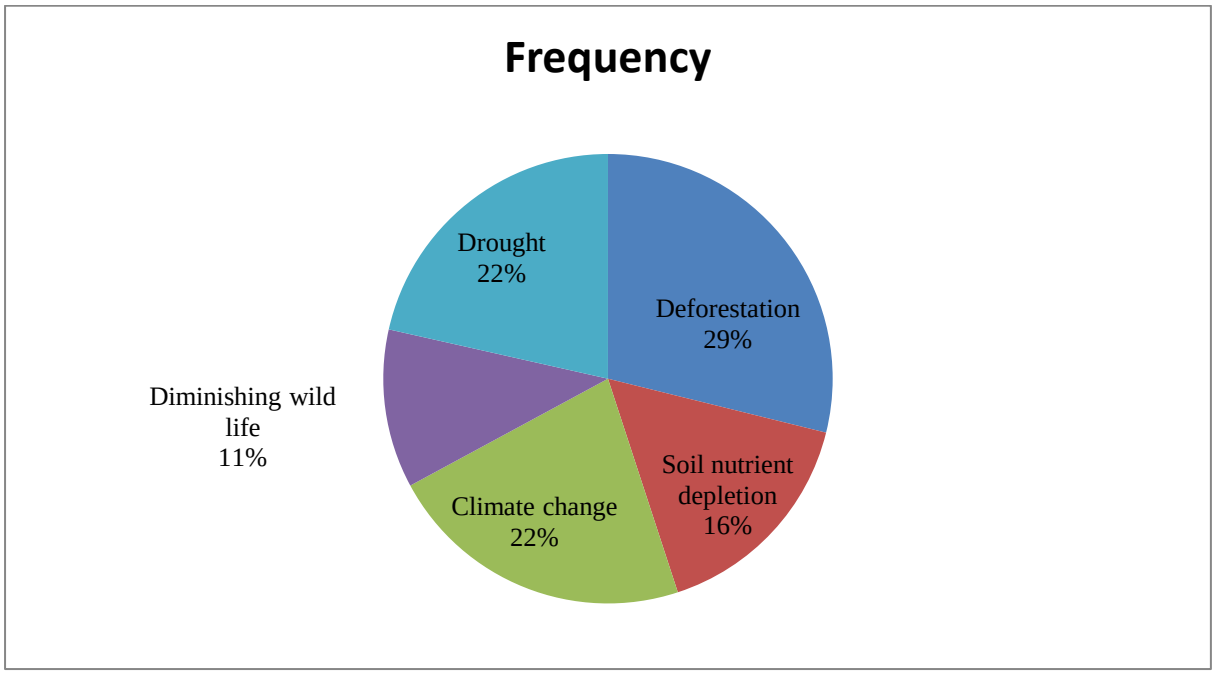

Figure 1: Environmental impact of fuel wood at study area *(source: field survey 2022)*

Respondents and personal observation during the surveys revealed that there has been considerable decrease in the vegetation cover in the study area in terms of number and species diversity. Indigenous trees of the area, such as AningeriaAdolf friedericini/Guduba, Combretummolle/Biiqqa and Polysciasferruginea/Tala has susceptible to disappeared and partly the area is currently converted intofarmland and urbanized area.

4.1.10 Tree species preference for fuel wood

According to household survey, different species of trees and shrubs were identified to be collected from the nearby forest area as a source of energy and supplied by whole sellers and retailers. Accordingly, about nine fuel wood species were identified and out of these three species were ranked as the most preferred and used by the respondents. For instance, some species burn fast; while other species may produce a lot of exasperating smoke or be very difficult to dry well sufficiently. Finding revealed that these species are preferred for fuel because of their attributes such as smokiness and long-lasting flame and light. The most appreciated for cooking are those species with a heavy wood that burns slowly with a lot of

heat and little smoke. Some of the respondents admitted, specifically as, Women Household of FGD participants, a fast-drying time and flammability were important factors taken into consideration when selecting fuelwood species. As of Abraham (2008) a wood that is easy to light and smokiness is preferred for lighting the fire and charcoal is made from species that yield charcoal which produce a lot of heat.

Table 14: Tree species preferred by household at study area (source field data collection 2022)

Tree species mostly preferred	**Frequency**	**Percentage (%)**	**Rank**
Aningeria adolf-friedericini	36	23.4	1st
Combretum molle	29	19.46	2nd
Polyscias ferruginea	25	16.7	3rd
Syzygium guineense	10	6.7	7th
Prunus africana	15	10	4th
Albizia gummifera	8	4.69	8th
Podocarpus falcatus	12	8.05	5th
Acacia abyssinica	11	7	6th
Croton macrosstachyus	7	4	9th
Total	152	100	

Accordingto thehouseholdviews,*Aningeriaadolffriedericini*,*Combretummolle*and *Polysciasferruginea* are highly preferred for energy consumption. This situation was proofed by observing from the everyday supply of fuel wood to the town. The dependence of the community more on the three species for fuel wood was day to day needs, so that it creates high pressure on degrading the status of the tree species in the forest. Their growth habit is very slow, and the extraction of these three species is also high. Therefore, the implication on the forest was that this species may go into extinction in that order if this demand continued

to be high in place. Berhanu*et al.,* 2017 described as mostpreferred species are the most impacted by the fuel wood collection. This implies rather than planting a single species for fuelwood, a basket approach of providing more than one species be adopted to encourage agroforestry adoption.

4.2 Discussion

Throughout the developing world, biomass energy is the primary source of energy for domestic use. The most widely used form of biomass is fuel wood, although in a mass of natural or human imposed scarcity of wood, other biomassforms such as crop residues and dung become more relevant. Fuel wood remains the main energy source for most of the people in Ethiopia. In many instances, it has been argued that the widespread use of fuel wood is linked to the number of environmental problems including deforestation, biodiversity loss, climate change and land degradation (Sitaula*et al.,* 2001). Present rate of fuel wood consumption and cutting may soon convert our forests to savannas and grasslands (Gebreegziabher*et al.,* 2007). Annual demand for fuel wood (45 million m3) is close to twenty times the demand for other forest products combined.

Finding revealed that most of the respondents are in a condition of ability to participate in any economic activity in the study area. Thisimplied that, labour resources in most households were sufficient for activities like farming, fuelwood collectionand charcoal production for income generation. This study supported by (Makwaia,2003), reported that the age of individuals between 15 to44 plays an important role in application of indigenous knowledge and innovations, which could have eithernegative or positive impact to forest resources conservation, Afforestation, deforestation, and encroachment ofrestricted area.

Result shows that *Aningeria adolf-friedericini* and *Combretum molle*species with regardless of its availability were noted to be used for fuelwood consumption was threatened species in study area. This finding was similar with (FAO,2010), reported thatconsumption of fuelwood regardless of species importance as source of energy for cooking indicates fuelwoodscarcity in a particular local area.Results from regression analysis showed that independent variable such as household level of education, fuelwood price and distance to fuelwood source showed positive significant while security problem, fuelwood availability and household family size showed negatively significant.

This study supported by (Abebaw,2007; Jumbe and Angelsen,2011). Results showed that availability of fuelwood had negative relationship with fuelwood consumption. Finding reveal that, the annual quantity of fuelwood consumed in the study area was found 200.7 and m3 /year while amount of fuelwood supply to the town was 130m3 which shows deficit. This can accelerate forest degradation to meet demand of fuelwood. In line with this studyKiflu *etal.*,2009 described that when the rate of harvesting is more than annual increment mining of the fuelwood is said to be taking place which would bring fuelwood deficit.

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The finding revealed that deforestation was the result of high population increment that increased demand for agricultural land and was the cause for conversion of forest land to other land use types. Moreover, agricultural land expansion and high population growth rate have increased forest product demand that caused the forest to be harvested above its annual incremental yield in the area with current dependency of the local people on the forest particularly for wood fuel and with the existing population growth rate. This situation will worsen unless measures are taken to improve forest resources management. Fuelwooddemand and supply is dynamic with time i.e., it changes from time to time due to the changing nature of those factors that affect wood fuel demand and supply.Fuelwood consumption was influenced by many factors such as Fuel wood availability, fuel wood price, and distance travel to fuel wood source and security problems which significantly indicate both negative and positive relationship to the fuel wood consumption. Fuel wood availability and security problemwere the main determinantfactors that affect households' fuelwood consumption in the study area.Moreover, wood fuel demand and supply assessment and challenge on forest is an important issue since it helps us in having information on fuel wood balance and rate of deforestation (either deficit or surplus) for current and future. By providing information it enables us to design or choose the right strategy to make the right decision today to control far reaching fuelwoodcrises.

5.2 Recommendations

Based on the finding as stated in section Four the following recommendations could be forwarded mainly from Supply side intervention.

1. Wider adoption of Agroforestry system, expansions of community woodlots and plantation, and development of private sector plantation that will increase the available growing stock for wood fuel supply. It is an immediate action that should be taken to prevent the immediate wood fuel problem. Raising seedling and distributing it to the farmers free of any cost can achieve this. Moreover, training the farmers how to raise the

seedling, plant and manage their own forest is the way to address the immediate wood fuel problem.

2. Increasing the productivity of existing forests that are the potential sources for wood fuel through effective forest management practices. Generating research output and using the output, especially silvicultural research output is the other measure to address wood fuel problem in the area.
3. Creating new fuel wood forest plantations around the town by private investors. This will be a good business for investors. Moreover, this will help to improve the worsen gap between wood fuel supply and demand.
4. Replacing open access extraction with controlled fuel wood and other wood product extraction from the forest.

Form demand side intervention, the following recommendations are made based on the result obtained.

1. Improving the end- use efficiency in the use of traditional fuels through improving efficiency of the existing cooking stoves and introducing new and more efficient stoves. This is expected to be achieved with by good energy policy.
2. Strive for less dependence on single type of fuels for energy (e.g., wood fuel). This is achieved through developing other domestic fuels like natural gas, electricity, wind energy and geothermal energy.
3. In the study it was observed that there was high dependence on fuelwoodto satisfy the energy needs in the area. As a result, family planning is a necessary step to be taken to check population growth rate. This is achieved with strengthening family planning policy.
4. The implications fuel wood consumption on the environmental are obvious: deforestation, declining agricultural productivity and destruction of the ecological systems leading to loss of biodiversity and important wildlife. To address such unattractive communal, financial and natural consequences, various interventions such as promotion of improved energy technologies; community awareness creation on consequences of forest degradation associated with fuel wood consumption and other alternative modern energy supplies are recommended assuming the existing technology.

Recommendation forwarded regarding fuelwood supply demand balance side.

1. Development and implementation of forest management plans to ensure sustainability. This should mainly address community forests management

2. Creating energy policy which ignores the costs andbenefits attributable to wood fuel use.

3.strengthning forest sector institution and implement forest research finding

on appropriate tree species, good management practices and relevant technologies.

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APPENDIX 1: STRUCTURED QUESTIONNAIRE

General information

Introduction: I am 3rd year post graduate student of Agroforestry at Dilla University, Department of Natural Resources Management Agroforestry. I am intended to conduct primary data collection to accomplish my thesis work on a research project entitled "**Fuel wood Supply Demand and its forest degradation Challenges in Nagelle town, south-eastern Ethiopia.** Thus, this is to kindly ask for your cooperation to provide me with your imaginative opinions and thank you for your help.

Purpose: The questionnaires are aimed to capture first-hand information on Linking fuel wood supply demand relationship and its deforestation challenges in Nagelle town, southeastern Ethiopia

Confidentiality: Questions asked are purely for research purpose and answers from respondents will be anonymously combined in the research analysis.

Name of interviewer: _____ date: _____

Time started: _____ finished: _____

Background information

Make the sign **X** in the box in front of each item

Government	
Own residence	
Rented house	
Camp for displaced	

1. How many people are there in your house (how many people do you cater for?

Number of people you cater for	
Male	Female

2. How old is the head of the household?

Age of household		
	Male	Female
Below 40		
Mid 40		
Above40		

1. Can you read and write?

Illiterate household	M	No	
	F		
Literate household	M	No	
	F		

4. How far did you go with formal education?

No formal education	
Adult literacy	
Primary school	
Secondary school	
College	
University	

5. In what type of economic activity are you involved?

Periodic piece of job

Family farm

Look for job

Government employee

Non-activity

Others specify

APPENDIX 2: PATTERN OF FUEL WOOD CONSUMPTION

1. What type of energy do you use to cook or heat your food?

Electric	Light	Cooking	Heat
Firewood	Light	Cooking	Heat
Liquid petroleum gas	Light	Cooking	Heat
Charcoal		Cooking	Heat
Kerosene	Light	Cooking	Heat
Cow dung		Cooking	Heat
Crop residue	Light	Cooking	Heat

2. Which of the following equipment do you use in your home?

Equipment	Mark with sign **'X'**
Three stone oven	
Mud stove	
Metal stove	
Kerosene stove	
Refrigerator	
Freezer	
Electric light	
Kerosene light	
Kerosene lump	
Charcoal iron	

3. Average monthly expenditure for different fuels

Amount of monthly purchase					
Electric bills	Charcoal	Kerosene	Firewood	Crop residue	Cow dung

4. How many bundles of firewood do you use per day and on special occasions

Bundles used per day	No
Christmas day	
Ramadan month	
New year's day	
Regular day	
Specify if any other especial use	

5. Where do you get your firewood?

Suppliers	
Whole sellers	
Pre urban farmers	
Retailers	
Saw mills	
Own forest/ tree	
Other specify	

6. In what form do you use firewood
   - Green wood spilled and dried
   - Dead wood from the forest
   - Small green stem spilled and dried
7. What tree species do you prefer for firewood?
8. What is the price of firewood per bundle/M^3 in Birr?
9. **Charcoal consumption**

   Do you use charcoal in your home?
   - Where do you get charcoal?
   - What is the price of charcoal either in bigger sacks or smaller sacks?
   - How much charcoal do you use per month?
   - What was the price of charcoal three years ago?
10. What energy alternative do you use in addition to wood fuel

11. Have you ever failed to cook food do you to lack of wood

12. What influences you to switch to other forms of modern fuel alternatives?

Name of fuels	Availability	Dirty	Price	Dangerous	Taste of food cooked	Cost of modern fuels	
Electricity							
Kerosene							

APPENDIX 3: SURVEY QUESTIONNAIRE FOR NON-HOUSE HOLD SECTOR

1. General

Location of the institution higher kebele house No

2. Type of business
3. Quantity of firewood and charcoal they are using per day
4. Where do you get your fuel wood
    - Whole sellers
    - Pre-urban suppliers
    - Saw mills
    - Own forest
    - Specify if other
5. Type of energy you use other than wood fuel

Type of fuels	Amount of energy used		Birr
	Unit	Quantity	
Electric	KWH		
Fuel wood	Bundle		
Liquid petroleum gas	Litter		
Charcoal	Kg		
Kerosene	Litter		
Cow dung	Kg		
Crop residue	Kg		

6. Have you ever failed to cook/ heat food in your business due to lack of wood fuel?

Format to collect information on fuel wood supply that is ready for use (from wholesalers)

APPENDIX 4: SOURCE/SUPPLY FUEL WOOD DATA COLLECTION FORMAT

Date of data collection: -

Data enumerator: -

Source fuel wood: - Sources of fuel wood: -Natural forest= Na, Plantation = Na=, Bush land = Bl, Scattered tree on farmland = TOF, community woodlots = CW, Please try to write the code attached to each source of fuel wood.

No	Wholesaler, retailers Code/ name	Amount they sale per day	Price per unit	Source of fuel wood
		M^3		

Format to collect information on fuel wood supply that is ready for consumption (pre-urban suppliers)

Date of data collection: -

Transportation system: - A = car, B=donkey, C=Human, D=cart, e for others. To record transportation systems please give them the assigned letters

Sources of fuel wood: -Natural forest= Na, Plantation = Na=, Bush land = Bl, Scattered tree on farmland = TOF, community woodlots = CW, Please try to write the code attached to each source of fuel wood**.**

No	Transportation system	Kinds fuel wood: Charcoal = CC Wood fuel= WD Crop residue= CD Others = OT	Amount entering in Load/buddle/sacks/ M^3	Price per sacks/M3/bundle	Distance transported	Source of fuel wood

APPENDIX 5: SURVEY QUESTIONNAIRE ON IMPLICATION OF FUEL WOOD CONSUMPTION ON FOREST DEGRADATION

1. How do you gain fuel wood?

1. Buy
2. Collect
3. Other _____

2. Where did you get the fuel wood from?

1. Side of the road
2. State Forest
3. Other homestead Land
4. Your own land
5. Other private land
6. Communal forest

3. Which tree species do you prefer to make charcoal or to buy from the market? Please mention _____

4. Which forest resources will be impacted by the fuel wood collection?

1. Wild life
2. Medicinal plant
3. Biodiversity

5. Impact of firewood collection on forest resources and socio economic impact

6. Did you collect fallen or live trees for fuel wood?

1. YES
2. NO

7. What do you think the effects of fuel wood consumption on the forest resources?

1. Deforestation
2. Soil Nutrient Depletion
3. Bush Fires
4. Diminishing Wildlife

5. Climate change
6. Health effect
7. Drought
8. More grazing area around
9. Better outdoor air
10. Others

8. What did you observe the impact of forest reduction on the socio-economic of the people in terms of?

1. Decline of forest product (quality and quantity)
2. Agricultural production
3. Distance to be travelled to collect forest product

9. What do you think are the reasons for forest degradation in your locality?

1. Natural
2. Human impact

10. What will be the benefit if the pressure of the fuel wood extraction reduces on the forest resources?

1. Better water quality
2. Increase Biodiversity
3. Reduced kitchen smoke
4. Better health
5. More forest around the village
6. Better sanitation
7. All can occur due to forest degradation for fuel wood

11. What do you think are the factors that affect fuel wood supply demand relationship?

Thank You for Your response!

APPENDIX 6 : CONVERSION FACTOR

(I) Energy equivalents

1 MJ = 239 kcal

1MJ = 0.278Kwh

$1M^3$ of air dry wood = 600Kg

$1M^3$ of air dry wood = 207 ton oil equivalent

1 Litre of kerosene is equivalent to 0.824 Kg of kerosene oil.

Charcoal = 3700 Kcal/Kg

Crop residues = 3700 Kcal/ Kg

Dung (at 15% moisture content) = 3500Kcal/Kg

Fire wood (air dry) = 3500 Kcal/kg

Kerosene= 10300 Kcal/Kg

1 toe = 44.2 GJ

= 0.969 ton of kerosene oil

= 0.043million cu ft of natural gas

= 2.48 tone of firewood

= 1175 litter of kerosene oil

Energy equivalency

1 kg of wood is equivalent

To

0.34 kg of kerosene

4.03 KWH

0.94kg crop residue

1.06 kg of cow dung

0 .94 kg of charcoal

0.345 ton of oil equivalent

Sources: EFAP, 1994) and (FAO, 1990b)

BIOGRAPHICAL SKETCH

TemesgenGiriNagari was born in IlugalanWoreda, West shawa Zone OromiaRegional State, Ethiopia in 1982 E.C. He completed his elementary at Ejaji School and secondary education at Ejaji high school in 2001 E.C and 2003 E.C respectively. He attended a BSc. degree inGeneral Forestry at Madawalabuuniversity, college of Natural Resource management and Biodiversity Conservation from 2004-2006 E.C. After graduation, he was employed as an expert at Oromia Forest and Wildlife Enterprise (November 2007 E.C –June 2009E.C). Latter, he was employed as Agroforestry Junior researcher at Oromia Agricultural Research Institute, Bore Agricultural research Center,Guji zone Oromia Regional State in June 2009E.C -October 2013 E.C. Finally, he joined Dilla University, College of Agricultural, and Natural Resources in 2013 E.C for his study of MSc. degree in Agroforestry.