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Research Article

Assessment of Fuelwood Demand and Supply 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, Oromia Regional State, to assess fuelwood supply demand and its forest degradation challenges mainly following the ever-rising apprehensions about growing stock and any contributions that fuelwood 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 fuelwood and service sectors survey by structured interview. The analysis of data was done by using Analysis of Variance and multiple linear regressions. As a 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 78212.2 M^3 per 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 Retailers and wholesalers which contributed 78% and 7.8% respectively. Fuelwood price and distance from fuelwood source had 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

Introduction

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 [19,28]. 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 [8]. Many researchers claimed that fuel wood harvesting in developing countries is so important that it rivals other sources of industrial energy such as electricity, prin-

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cipally 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 biomass forms 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 [7]. 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 [10].

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 [53]. Fuel wood accounts for over 54 % of all global harvests per annum which results in a huge amount of forest loss [62]. 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 [34]. 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 [12].

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 [30]. 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 rely 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 [21].

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 [6]. 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 related to assessment 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 fuelwood utilisation and its implication on the extent of forest degradation in Nagelle town, Ethiopia.

Statement of the Problem

In Ethiopia, fuelwood is the most important source of energy, where 96 percent of the population is dependent on biomass energy sources for cooking and other energy demands [44]. Such extreme dependence on traditional fuels has an impact on the natural environment. Especially the heavy dependence on fuelwood has multifarious and related problems which have to do with deforestation, land degradation, and another circle of fuel wood 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 [44]. 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 urban households are still not similar. According to (Yissehak, 2012), 80 percent of the urban fuel source is from traditional fuels, and in recent years fuelwood alone contributes almost 56 percent of the total energy consumption of 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.

Objectives of the Study

General Objective: To examine the extent of fuelwood utilisation and its implication on forest degradation in Nagelle town, Ethiopia

1. Specific ObjectivesTo 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 environmental implication of fuel wood consumption on forest degradation in the study area
5. To assess Tree species preference for fuel wood at study area

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?

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 [20]. 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 [41]. 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 environmental researchers the impact associated to fuel wood consumption. This study helps as to inform the concerned body about endangered tree species due to household tree preferences for fuel wood collection. It could be informed policy makers and researchers, the factors that were associated with the patterns of demand for wood fuel consumption.

Materials and Methods

Description of the Study Area

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 4°30'58" - 5°42'8" northing latitudes and 41°34'57" - 39°9'34" easting longitudes. It is in the low land of Oromia national regional state [38]. 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 [38].

Climate: The climate 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 agro climate 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).

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 [38].

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 [38]. 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-Aningeria spp, Cordia africana, Croton macrosstachyus, Combretum molle, Podocarpus falcatus, Bushy trees, Acacia spp and Savannah grasses e.t.c.

Research Design

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

Sampling method and sample size: The sampling technique for service giving sectors was done by whole census (Table 1). 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 [12]. The sample size of household was determined based on Kothari's sample size formula which states as follows [37].

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

= 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.

Sampling method and sample size: The sampling technique for service giving sectors was done by whole census (Table 1).

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.

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.

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All the above kebeles were 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.

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.

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

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).

Method of data collection for fuel wood supply: The potential suppliers of fuel wood that is ready for use are local farmers, whole sellers,

Table 3: Sample size allocation of non-household sectors.

Service sectors	Total No	Sample size	Method of sampling
Restaurant and hotels Ifa boru special boarding school	37 1	37 1	Census 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.

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 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

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.

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	32.50%	42.20%	25.30%	100
	Non-User	63.60%	0	36.40%	100
Charcoal	user	32.40%	42%	25.60%	100
	Non-User	70.00%	0	30.00%	100
Cow dung	User	22.20%	40.10%	37.20%	100
	Non-User	47.70%	40.50%	11.70%	100
Crop residue	user	39.60%	43.10%	17.30%	100
	Non-User	8.70%	28.30%	63.30%	100
Kerosene	User	100%	0	0	100
	Non -User	33.30%	40.70%	26.00%	100
Electricity	user	75.00%	0%	25.00%	100
	Non –user	31	43.1	25.9	100

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

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

Name of sectors	Firewood	Charcoal
If a Boru 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

Table 8: Mean household energy consumption by income category.

Energy use in tone of oil equivalent (toe) (means ±std) /day					
Income	Firewood	Wood charcoal	Cow dung	Crop residue	Electricity kerosene
Category					
Rich	5.03±0.4a	35.11±2.a	2.303±1.a	0.099±0a	0.83±0.26a 0.024+0.17a
Medium	3.58±0.1b	20.38±1.43b	5.026±0a	1.2±0.42b	0.02±0.015b 0.001±0.01a
Poor	1.79±0.1c	6.30±0.75c	3.51±0.6a	2.31±0.4c	0.241±0.12cb0.0002±0.003a
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

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**

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 [24]. 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 [12].

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

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).

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,

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

Table 12: ANOVA*a*.

ANOVA*a*					
Model	Sum of Squares	Df	Mean Squares	F	Sig.
Regressio	1.403	6	0.234	3.471	.003b
Residual	9.637	143	0.067		
Total	11.04	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

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	

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.

Results and Discussions

Results

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 [6].

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.

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.

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.

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 shows that increase in Fuel wood collection and use was substantially responsible for deforestation and the increase in atmospheric carbon dioxide concentration [31]. 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 capital 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.

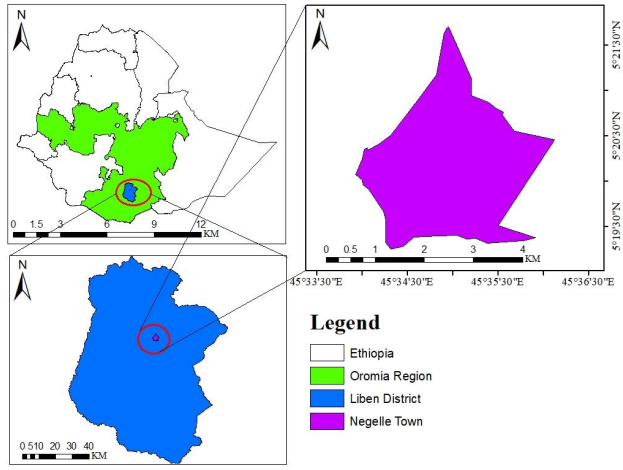

Figure 1: Location Map of study area *(Source: Ethio GIS Data).*

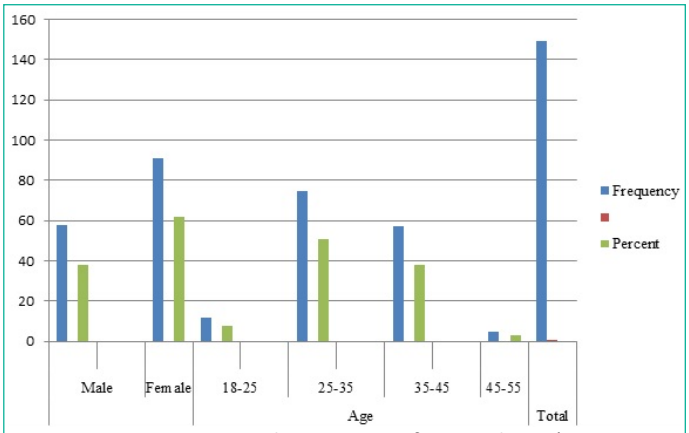

Figure 2: Socioeconomic characteristic of respondents *(Source: field survey, 2022)*.

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).

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.

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.

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).

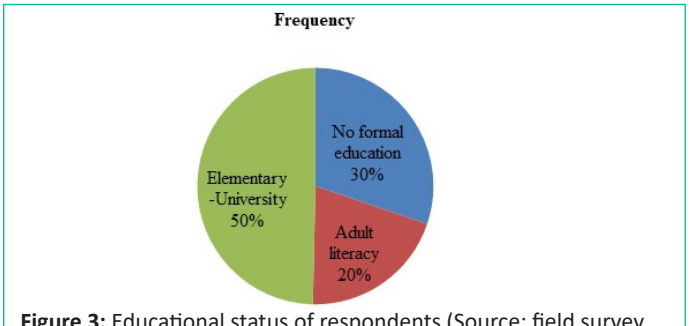

Figure 3: Educational status of respondents (Source: field survey, 2022).

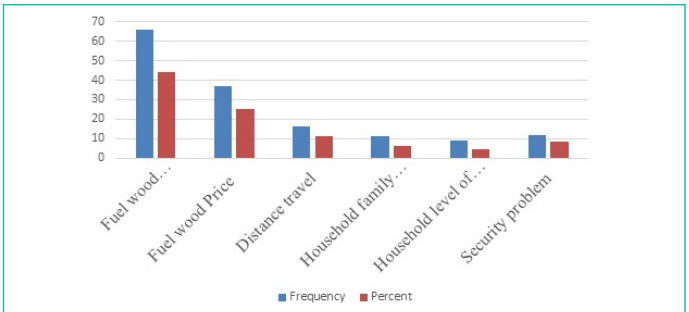

Figure 4: Factors affecting fuel wood consumption *(Source: Field survey.2022).*

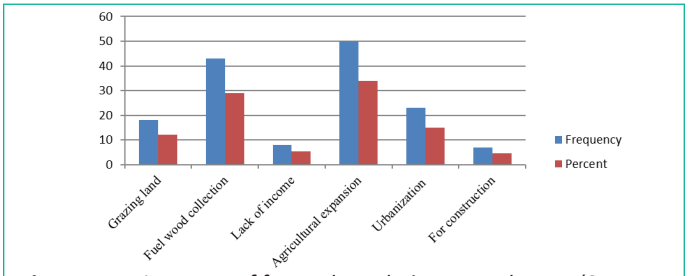

Figure 5: Major cause of forest degradation at study area (Source: field survey 2022).

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).

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 Fuel**-wood supply quantities cannot meet the current demand quantities and needs to be improved.

Multiple linear regressions

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

Variables as stated in Tables 11 to 13.

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.

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 education has the largest β coefficient, around 0.143, and security problem has the smallest β

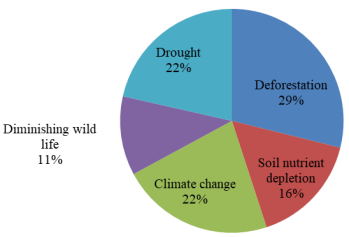

Figure 6: Environmental impact of fuel wood at study area *(source: field survey 2022).*

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 held constant. 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 size had 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.

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 Agarfa Town, 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.

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.

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 Agarfa woreda Southeastern Ethiopia also described Agricultural land expansion and fuel wood collection as major cause of forest degradation [31]. 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.

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 Diminishing wildlife (11.5 %) respectively.

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 Aningeria Adolf friedericini/Guduba, Combretum molle/Biiqqa and Polyscias ferruginea/Tala has susceptible to disappeared and partly the area is currently converted into farmland and urbanized area.

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.

According to the household views, *Aningeria adolffriedericini*, *Combretum molle* and *Polyscias ferruginea* 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 most preferred 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.

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 biomass forms 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 [53]. Present rate of fuel wood consumption and cutting may soon convert our forests to savannas and grasslands [12]. 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. This implied that, labour resources in most households were sufficient for activities like farming, fuelwood collection and charcoal production for income generation. This study supported by (Makwaia, 2003), reported that the age of individuals between 15 to 44 plays an important role in application of indigenous knowledge and innovations, which could have either negative or positive impact to forest resources conservation, Afforestation, deforestation, and encroachment of restricted 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 that consumption of fuelwood regardless of species importance as source of energy for cooking indicates fuelwood scarcity 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 [1] (Jumbe and Angelsen, 2011). Results showed that availability of fuelwood had negative relationship with fuelwood consumption. Finding reveals 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 study Kiflu *et al.,* 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.

Conclusions and Recommendations

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. Fuelwood demand 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 problem were the main determinant factors 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 fuelwood crises.

Recommendations

Recommendation from Supply side intervention:

6. 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.

7. 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.

8. 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.

9. Replacing open access extraction with controlled fuel wood and other wood product extraction from the forest.

Recommendation From demand side intervention: 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.

6. 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.

7. In the study it was observed that there was high dependence on fuelwood to 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.

8. 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 and benefits attributable to wood fuel use.

Strengthning forest sector institution and implement forest research finding on appropriate tree species, good management practices and relevant technologies.

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