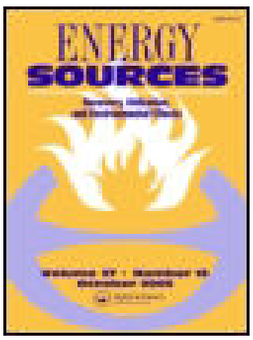

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Consumption, preference, and access of biomass fuels at Ziway town, Ethiopia

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ABSTRACT

Although biomass fuel is principally traditional, it remains the major source of household energy and needs critical consideration in its development. Due to population growth and the consequence of deforestation, biomass fuels become scarce both physically and economically. This paper tries to assess households' energy consumption patterns, price trends, and people's preference of tree species for woodfuel in Ziway town and its preurban areas. One hundred and twenty households, 60 each from urban and preurban, were randomly selected for the household survey. Biomass fuel inflow rate into the town was also recorded for 15 consecutive days. The results show that the per capita biomass fuel consumption for a preurban household was 943 kg/yr and it was 726 kg/yr for an urban household, of which the lion's share was taken by firewood. *Acacia albida* was the top-ranked species for woodfuel by the respondents. Ninety-seven percent of the respondents claimed that access and supply of biomass fuels show a decreasing trend: price increasing. Indeed, most of the respondents use inefficient stoves and did not add value to the biomass fuels. People obtain woodfuel mostly from common property resources and the inflow rate to Ziway town for 15 consecutive days was 826.3 tonnes. Ensuring a sustainable energy supply, while minimizing negative environmental impacts, is key for sustainable urban development in developing countries, particularly in emerging towns. The study suggests the need for intervention in the development of improved stoves and woodfuel value addition so as to save the wood and energy loses during household energy consumption.

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Introduction

Biomass fuel is principally traditional, but could not phase out from being a major source of household energy for cooking and heating, particularly in developing countries like Ethiopia (WEC (World Energy Council) 2005, SEI 2013, Panepinto et al. 2017, Karinkanta et al. 2018). The central highlands of Ethiopia are the most densely populated part in the country. With the alarming rate of increase in population, the carrying capacity of resources to support humankind is swiftly decreasing. This is not only reflected in the degradation of soils and reduced production capacity but also a severe shortage of biomass fuel for household consumption. Despite a drive for the development of modern energy efforts, Ethiopia still maintains a largely biomass fuel dependent society. Both rural and urban households in the central highlands of Ethiopia and elsewhere in the country consume a considerable amount of biomass fuel for cooking and heating (Bekele 2001; Haile, Sandewall, and Urgessa 2009; Mariame 1996; Worku 1997). Globally over 2.5 billion people depend on biomass fuel for cooking and heating (IUCN 2008). In Ethiopia, it has been reported that biomass fuel has met more than 90% of the total energy need (WBISPP (Woody Biomass Inventory and Strategic Planning Project) 2002).

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The contribution of wood fuel, dung cakes, and crop residues for the 1989/90 estimate of household energy consumption in Ethiopia was 82%, 10%, and 8% for rural and 75%, 8%, and 6% for urban households, respectively (Berry 2003). The scarcity of wood fuel has led to an increased utilization of dung and crop residues for cooking. This could otherwise have been used to enhance the nutrient status and texture of the soil and contribute positively to agricultural production (Boers and Eshete 2008). The study by Mariame (1996) at Shashemene town showed that the per capita wood fuel supply was 0.59 m^3 while the demand was 1.23 m^3, indicating a biomass fuel deficit of 0.64 m^3.

When Ethiopia's forest cover change is examined since its original extent to the year 2000, there was a sharp decline for the nation in general and to highland forest covers in particular (Berry 2003). The government of Ethiopia has given due consideration in its energy development sector by shifting to the consumption of bio-fuel. Ethiopia on average spends 8.6 billion birr (1 billion USD) annually on importing petroleum, which consumes about 87% of the hard currency the country earns from foreign trade each year (Zenebe 2004). This is mainly to mix it with methanol or ethanol for car fuel consumption and the effort to supplement household traditional fuel consumption is still less and most households in rural areas and rural towns are dependent on traditional biomass fuel for cooking and heating. In 2016, biomass fuel (firewood, charcoal, dung cake, and crop residues) contributed 93% of the household energy for cooking. Firewood, in addition to take 82% of the energy share for cooking, it also contributed 5% of household energy for lighting in the same year (Beyene et al. 2018; Institute and Group 2017). As remarked by FAO (2002), energy is a basic human need, and in many regions of the world the burden of energy poverty is borne by women and children. It is usually the women and children who spend long hours collecting fuelwood, often foregoing other valuable activities such as farming, education, recreation, and rest. This is particularly significant in developing countries like Ethiopia.

Energy constraints to development must be evaluated by balancing energy consumption with other variables and costs which influence demand (Arnold and Dewees 1997). In this case, there are three situations to consider:

- *Income effect* – per capita biomass fuel consumption may increase (or decrease) as the household's endowments of physical and human capital increase;
- *Price effect* – as the price of biomass fuel increases, demand may decrease (or it may increase if, as economists say, it is a 'Giffen' good); and
- *Substitution effect* – as the price of biomass fuels increase, cheaper substitutes may be found; conversely, as the price of alternative fuels increase, demand for biomass fuels may increase.

Biomass fuel scarcity can be occurred either economically or physically. Physical scarcity refers simply to whether biomass fuel resources are physically present or absent while economic scarcity refers to the ability of a household to allocate its land, labor, and capital resources in a way that enables it to actually use this biomass fuel. With regard to fuelwood shortage: in a report to the 1981 United Nations Conference on New and Renewable Sources of Energy, Food and Agricultural Organization (FAO) foretold that almost 2.8 billion people in developing regions would experience a deficit of fuelwood by 2000, and that 356 million would suffer acute shortage (FAO 2002). These figures are more or less remained consistent till 2017 and steadily projected to count to 2040 (IEA (International Energy Agency) 2016, Corfee-Morlot et al. 2019). Since the 2000s although progress has certainly been made toward resolving some of the problems associated with wood energy use in developing countries, there are certain problems remain – including insufficient management of the resources, the labor involved in fuelwood collection, the informality of trade, and pollution and health problems resulting from the inefficient conversion of biomass fuel. The objective of the study was to assess the households' energy consumption patterns, price trends, and people's preference of tree species for woodfuel in Ziway town and its preurban areas.

Materials and methods

Site description: Ziway town is one of the emerging towns in Oromia regional state in the central rift valley of Ethiopia. It is on the shore of Lake Ziway from where the name of the town is derived. It is located at 7°56´N latitude and 38°43´E longitude at an altitude of 1643 m on the Addis Ababa-Hawassa road at about 163 km from the former (Figure 1). In 1994, the population of the town was 20,056 with a male-female ratio of 10,323–9,733 (Central Statistical Agency of Ethiopia (CSA 1994) and in 2007 it has increased to 43,600 with a male-female ratio of 22,956 to 20,704 (CSA 2007). With this trend, the population of the town is estimated to be about 100,000 in 2020. Fishing and vegetable production are the main economic activities in and around the town and maize is the main crop in the preurban areas.

Household survey: One hundred twenty households, 60 each from urban and preurban -were randomly selected for the household survey. The respondents were asked about the demand and supply, accessibility, and market price of biomass fuels in their locality. The households also requested the daily, monthly, and annual consumption of biomass fuels by weighing the biomass fuel of daily use by using balance. The daily consumption has been converted into monthly and to annual bases to get the per capita consumption of a household. Other average annual household expenses were also asked and calculated to compare with the share of biomass fuel expenses of a household.

Species preferences ranking: Repondents were asked to rank the top-prefered tree and/or shrub species for firewood and charcoal production based on 6-point Likert scale with 6 being the most preferred and 1 being the least. The frequency of respondents was multiplied by the rank scale – considered as a weighing factor – to get the weighted rank for a particular tree and/or shrub species. The highest weighted ranked species for either firewood or charcoal has been selected the first preferred species, the second weighted rank, the second preferred species, and so on.

Inflow rate: The amount of biomass fuels entering to the town of Ziway was recorded by assigning seven enumerators at the five gates into the town from 6 AM to 6 PM for 15 consecutive days. In flows were in human loads, donkey loads, or Isuzu car. Or for charcoal, cow dung, and crop residues, the containers were '*50 kg or 100 kg sacks* of NPK fertilizer.' The weight of 10 samples from each container type were measured with standard balance. The average weight for a human-load of firewood was 21 kg, a donkey load of firewood was 42.33 kg, 100 kg sack charcoal, cow dung, and maize cob were 39.7 kg, 24 kg, and 21.33 kg, respectively. It was also counted that an Isuzu car was loaded 85 each 100 kg sacks of charcoal and maize cob equaling to 3372 kg and 1927 kg, respectively. Similarly, an Isuzu car could be loaded, on average, 100 donkey loads of firewood which equals to 4233 kg. These

Figure 1. Location of Ziway town within Ethiopia (source: GoogleMap).

conversions of local measurements into standard measurement have helped the amount of biomass fuels entering to Ziway town within 15 consecutive days which also helped to estimate the annual inflow rate of biomass fuels into the town.

Results and discussions

Energy consumptions and stove types

The results show that, in average, biomass fuel has taken about 10% of the share of household's annual expense in the study area next to the expense for food and clothing (Figure 2(a)). The per capita biomass fuel consumption for a preurban household was 943 kg/yr and it was 726 kg/yr for an urban household (Figure 3). Of these, firewood contributed the lion's share. As indicated in Figure 2(b), household's energy efficiency to save biomass fuel is minimal as more than 40% and 20% of the respondents have been used three-stone open fire and traditional closed stoves, respectively. In other studies, these are proved to be inefficient in saving biomass fuels as well as energy (Amare, Endeblhatu, and Muhabaw 2015; Ararsa 2015; Dissanayake et al. 2018; Dresen et al. 2014; Sime, Tilahun, and Kebede 2020; Yurnaidi and Kim 2018). Indeed, this is in turn found to cause one of the environmental

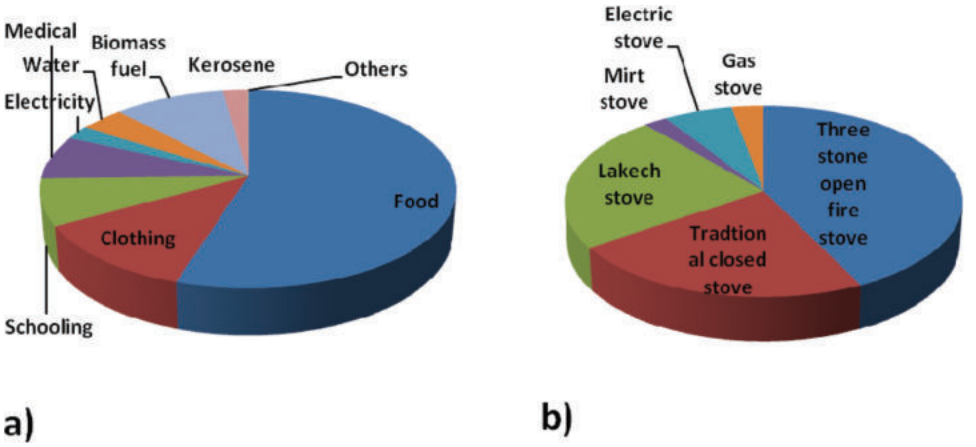

Figure 2. Average annual expense (a) and stove types used (b) in Ziway town and its preurban areas.

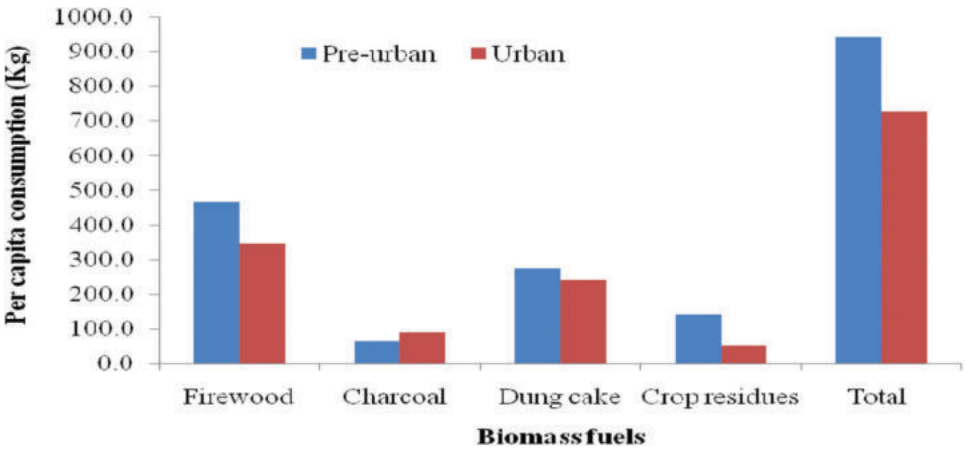

Figure 3. Households per capita biomass fuel consumption in Ziway Town and its preurban areas.

health risks resulting in several millions of deaths in countries like Ethiopia (Beyene et al. 2018; Dissanayake et al. 2018; Geremew et al. 2014; Tefera et al. 2016).

Species preference for woodfuel

The respondents in both urban and preurban areas of Ziway town claimed their top five preferred species for firewood (Table 1) and the top four species for charcoal making (Table 2). The ranking was given based on the reason that the firewood stays a long time during baking and cooking, provides high heat when burning with little ash. It was similarly claimed that the species highly ranked for charcoal gives high-quality charcoal, which is easily carbonized during processing and yields high quantity charcoal with little ash, and the charcoal give high heat in cooking and with little indoor air pollution. Due to the high preference of the people, of these species for firewood and charcoal quality for cooking and heating, the prevalence of these tree species in the landscape has been declining from time to time. It is *Acacia albida* that withstand this pressure. For one thing, farmers do not cut the main steam and retain it on their farm and continuously pollard its top and branches to be used for fodder (leaves and fruit), firewood (small branches and twigs), and charcoal making (bigger branches and top steam). On the other hand, the species has high sprouting ability after pollarded and supply

Table 1. Preferred tree species for firewood by respondents in Ziway Town and its preurban areas.

Species name		Preferred firewood species by respondents (n = 120)							
Local	Scientific	6	5	4	3	2	1	Sum of weighted ranks	Rank
Dodota	*Acacia albida*	234	165	32	15	0	0	**446**	**1**
Ajo	*Acacia oerfota*	258	60	36	6	2	0	**362**	**2**
Bedena	*Balanites aegyptiaca*	24	100	96	24	0	0	**244**	**3**
Lafto	*Acacia senegal*	102	65	20	9	0	0	**196**	**4**
Tatesa	*Rhus natalensis*	18	45	12	12	2	15	**104**	**5**
Ejersa	*Olea europaea*	12	40	16	6	24	0	98	6
Wadesa	*Cordia africana*	0	15	40	15	4	0	74	7
Bahirzaf	*Eucalyptus spp*	36	20	12	0	2	0	70	8
Derersa	*Ocotea kenyensis*	24	20	0	0	0	0	44	9
Karchefa	*Albizia gummifera*	0	5	8	21	0	0	34	10
Kitkta	*Dodonaea viscosa*	6	10	12	3	0	0	31	11
Kerero	*Pouteria altissima*	0	10	8	0	0	0	18	12
Mekenisa	*Croton macrostachyus*	0	0	8	0	2	0	10	13
Digita	*Calpurnial urea*	0	0	4	0	0	0	4	14
Odda	*Ficus sycomorus*	0	0	0	0	0	1	1	15

Table 2. Preferred tree species for charcoal by respondents in Ziway Town and its preurban areas.

Species name		Preferred charcoal species by respondents (n = 120)							
Local	*Scientific*	6	5	4	3	2	1	Sum of weighted ranks	Rank
Dodota	*Acacia albida*	228	205	24	3	0	0	**460**	**1**
Bedena	*Balanites aegyptiaca*	24	110	112	21	0	0	**267**	**2**
Lafto	*Acacia senegal*	180	50	4	12	0	0	**246**	**3**
Ejersa	*Olea europaea*	72	20	4	3	24	1	**124**	**4**
Wadesa	*Cordia africana*	0	10	28	30	4	0	72	5
Tatesa	*Rhus natalensis*	12	15	4	12	4	14	61	6
Derersa	*Ocotea kenyensis*	24	5	0	0	0	0	29	7
Karchefa	*Albizia gummifera*	0	5	8	12	0	0	25	8
Prosophis	*Prosopis juliflora**	0	5	12	6	0	0	23	9
Mekenisa	*Croton macrostachyus*	0	0	8	0	2	0	10	10
Odda	*Ficus sycomorus*	0	0	4	0	0	0	4	11

*The charcoal of this species has come from Afar region to Ziway by traders.

Note: Weighted rank is the product of the frequency of respondents and rank (*e.g.* 228 for *Acacia albida* in Table 2, is the product of 38 and 6).

Table 3. Sourcing options of biomass fuels for households in Ziway town and its preurban areas.

	Respondents (%) – summations need not to be 100% as households can obtain from multiple sources			
	Preurban		Urban	
Sourcing sites/options	Firewood	Charcoal	Firewood	Charcoal
Common property resources	70	45	0	0
Natural forests	50	33	0	0
Own farms	37	27	5	0
Purchase from markets	13	33	93	98
Others	0	0	2	2

sustainable products. However, most of the top-ranked species for firewood and charcoal preference by the people do not have such abilities and people will cut the whole steam and it will not sprout again.

Accessibility and price trend of energy fuels

For the question concerning any change in biomass fuel access and supply, 97% of the respondents claimed that there is a decreasing trend. They supported their claim for the decreasing trend to deforestation of the preferred species for woodfuel which contributes more than 90% of the biomass fuel requirements in the study area. In line with this, for any change in demand for biomass fuel, 48% of the respondents claimed that there is an increasing trend and 38% of them claimed a decreasing trend while the remaining claimed as there is no change. Regarding value addition on biomass fuel, only 20% of the respondents add value in terms of preparing the firewood in splitting into proper length, storing in dry places for avoiding moisture adsorption. Nevertheless, 57% of the respondents did not add value and the others did not have a hint of what value addition is. Respondent households in preurban areas of Ziway town have sourced their biomass fuel mostly form common property resources, natural forests, and own farmlands while those in the town sourced it by purchasing from the markets Table 3 and Figure 5 . As shown in Figure 4(a & b), in the three consecutive years, 2010–2012, the price of biomass fuels as well as kerosene and electricity have shown an increasing trend in both Ziway town and its preurban. However, the magnitude of increase in price is higher in charcoal and firewood as compared to other biomass fuels such as cow dung and crop residues. This might lead to a substitution effect that people will shift to lower price biomass fuels with lower energy

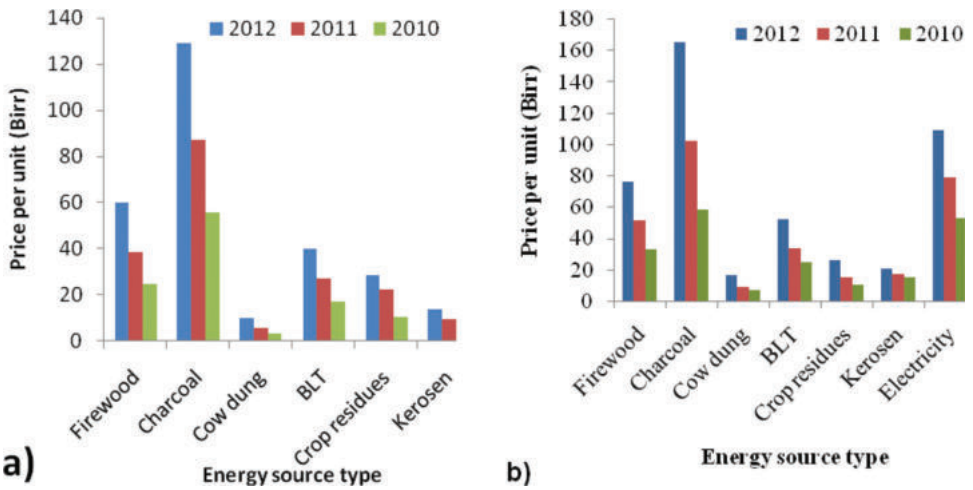

Figure 4. Market price trend for energy types in preurban (a) and Ziway town (b).

Figure 5. Firewood : the biomass fuel that need important consideration in finding alternative energy sources (top left *injera* baking with *Mirt* stove, top right *injera* baking with three-stone open fire, bottom left firewood transporting to market by farmer, and bottom right pile of firewood at road side for sale).

which affects proper cooking (*e.g.* Guta 2014). In line with Mekonnen et al. (2007), this is in turn will have an indirect effect on food production as farms will not get the nutrient supplying potentials of cow dung and crop residues when left on the field. The biomass fuel inflow for 15 consecutive days recording showed that 455.2 tonnes of firewood, 371.1 tonnes of charcoal, and 89.6 tonnes of cow dung and crop residues were entered into Ziway town.

Conclusion

The major bottleneck for sustainable urban development in developing countries, particularly in emerging towns, is ensuring a sustainable energy supply while minimizing negative environmental impacts. The results indicated that both urban and preurban households, Ziway town in Ethiopia, have consumed a greater amount of biomass fuel by which firewood takes the lion's share. In addition, most of the households in the two settings use traditional stoves which make low energy efficiency in the use of biomass fuel leading to energy and wood loss. Indeed, the value addition made by the people on woodfuel is also minimal which leads to inefficient use of energy. These suggest the need for intervention in the development of improved stoves and woodfuel value addition so as to save the wood and energy loses. In the study town and its preurban areas, people prefer some tree species types for firewood and charcoal and this has created pressure in the overutilization of those tree species. This is in turn brings an impact on ecological degradation in the surrounding landscapes including the siltation of Ziway and Abijata Lakes. The deforestation impact on those preferred tree species for biomass fuel has been reflected in the decreasing trends in biomass fuel access and supply which is mostly sourced from common property resources while there is an increasing trend in the demand side. This has lead to an increase in the price of biomass fuels, especially in Ziway town leading to

a substitution effect by which households may shift to lower quality fuels. Since this research result shows that the naturally grown species preferred for woodfuel are declining, it highlights the need for energy plantation and/or the development of alternative energy sources to fulfill the growing demand for biomass energy in the study area.

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Disclosure statement

The author declares that there are no potential conflicts of interests.

Notes on contributor

Dr. Zenebe Mekonnen is director of climate Science Research directorate with research focus of climate change modeling and risk management as well as climate change mitigation and adaptation at Ethiopian Environment and Forest Research Institute. He has PhD from Hwassa University, Ethiopia, in Climate Change and Bioenergy Development (Climate change mitigation and adaptation). He has been also researcher at Ethiopian Institute of Agricultural Research with key research duties focused on the socioeconomics of non-timber forest products, agroforestry, medicinal plants and woodfuel energy. He had worked in government and non-government institutions in different technical and expert positions. He has over twenty-three papers published in peer reviewed journals, chapters in books and conference and/or workshop proceedings.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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