Journal of Fundamentals of Renewable Energy and Applications

Tadesse and Teketay, J Fundam Renewable Energy Appl 2018, 8:5
DOI: 10.4172/2090-4541.1000269

Research Article Open Access

Supply and Consumption of Household Energy in Central Ethiopia: The Case of Debre Berhan Town

Solomon Ayele Tadesse[1*] **and Demel Teketay**[2]

[1]*Department of Natural Resources Management, College of Agriculture and Natural Resource Sciences, Debre Berhan University, P. O. Box 445, Debre Berhan, Ethiopia*

[2]*Botswana University of Agriculture and Natural Resources, Department of Crop Science and Production, Private Bag 0027, Gaborone, Botswana*

[*]**Corresponding author:** Solomon Ayele Tadesse, Department of Natural Resources Management, College of Agriculture and Natural Resource Sciences, Debre Berhan University, P. O. Box 445, Debre Berhan, Ethiopia, Tel: +251-111-6815440; Fax: +251-111-6812065; E-mail: solomon.ayele1972@gmail.com

Received date: October 9, 2018; **Accepted date:** October 20, 2018; **Published date:** October 29, 2018

Abstract

Energy crisis resulting from complete dependency on biomass fuel is becoming a major challenge for the conservation of forest resources in Ethiopia. The aim of this study was to quantify the main biomass fuel supply and also examine the household energy consumption pattern in Debre Berhan town, Ethiopia. It was hypothesized that there is spatial and temporal variation of biomass fuel entering into the town. Moreover, it was expected that socio-economic variables affect the energy consumption pattern at a household level. Point census was conducted to quantify the amount of biomass fuel brought into the town. As a complement, a structured questionnaire comprised of open- and closed-ended questions was developed and administered to a total of 117 households. This was carried out to collect information on domestic energy consumption pattern in the town. The results revealed that the amount of biomass fuel brought into the town was significantly affected by spatial and temporal factors. Compared with the Addis Ababa direction, the amount of fuel wood brought into the town from Dessie point of entry was statistically higher. Moreover, the amount of biomass fuel entering the town during the market days was significantly greater than that of the non-market days. The multiple linear regression models revealed that several socioeconomic variables significantly affected 'the shortage of energy supply for household consumption' and 'the energy consumption pattern at a household level' in the town. The results revealed that there is a remarkable deficiency of energy supply in the town. Therefore, creating public awareness about natural resources conservation, disseminating energy-efficient technologies (e.g. energy saving stoves), issuing strict government energy policy and providing alternative energy from the government with less taxation may decrease the undesirable consequences of environmental degradation.

Keywords: Biomass fuel; Debre Berhan town; Energy consumption pattern; Environmental degradation

Abbreviations: ANRS: Amhara National Regional State; EFAP: Ethiopian Forest Action Program; EPA: Environmental Protection Authority; GDP: Gross Domestic Product; IEA: International Energy Agency; IUCN: International Union for the Conservation of nature; MME: Ministry of Mines and Energy; WBISPP: Woody Biomass Inventory and Strategic Plan Project

Introduction

Biomass fuels are the most important sources of energy in developing countries in general and Sub-Saharan Africa in particular. It was noted that a large number of fuelwood and forest development projects and policies in those countries have been based on recommendations of the result of what are called "fuelwood gap" models, which usually start with rough estimates of fuelwood demand and supply to predict future excess demand and recommend such programs as afforestation and improved stove dissemination to fill the "gap" [1].

The percentage of biomass fuels in the total energy consumption in Ethiopia is one of the highest in the world, accounting for over 90% of the total energy consumption in the country and about 99% in the rural areas [2,3]. It was claimed that the shortage of biomass fuels has been one of the major causes of deforestation and, subsequent, land degradation in Ethiopia [4]. Moreover, due to the significant use of dung and crop residues as energy sources, rural energy is closely linked with land degradation, which is considered to be one of the most important environmental and economic problems in the country. As a result, it was noted that noted that the gross annual financial losses due to land degradation in the country represent about 3% of the agricultural GDP or about 2% of the country's GDP [5]. Of this, it was claimed that about 98% has been estimated to be caused by nutrient losses due to the removal of dung and crop residues from cropland for use as energy sources, which otherwise could have been used as organic fertilizer [6]. The problems of land degradation have continued to be severe in most parts of Ethiopia, and the large dependency of the majority of the population on biomass energy sources contributes its share to the problem.

In the Amhara National Regional State (ANRS), northern Ethiopia, biomass fuels provide 99% of the total domestic energy supplies, with 64% derived from woody biomass, 14% from crop residues and 21% from cow dung [7]. However, these regional figures concealed considerable local variations both in biomass fuel supply and consumption. In addition, there are temporal changes in these patterns in the face of changing stocks of fuelwood and the opportunity costs in its collection or purchase.

Debre Berhan is a town found in North Shewa Administrative Zone of ANRS, which is situated in the high plateau about 130 km north of Addis Ababa. Its paved road, the high way to Mekele, is traveled by an endless stream of men and women on foot, donkeys loaded with enormous piles of hay, dried dung cake, eucalypt branches, split wood, ancient buses and jangling horse-drawn two wheel carts, which serve as taxis. However, the only trees in the town or surrounding countryside are those of eucalypts, first planted almost 100 years ago during the massive national afforestation program initiated by Emperor Menelik II [8-11]. The people in the town as well as 13,000 farmers in the immediate area, live in poverty and perpetual energy crises. One of the many problems they share with the bulk of the people in the country is an acute shortage of fuelwood for cooking and heating [8].

Like the people in other parts of Ethiopia, most of the dwellers in Debre Berhan town and its surroundings predominantly use traditional fuels, such as wood, crop residues and animal dung for household energy consumption. However, the shortage and ever-increasing demand for fuelwood forced the local people living in the town and its surroundings to use dung and agricultural residues to meet their desperate energy requirements. This, in turn, has resulted in environmental degradation that emanated from the loss of vegetation cover, crop residues and animal dung.

Although there are some previous studies conducted on the energy supply and consumption patterns in other parts of Ethiopia [2,3,12-17], studies focusing on determining the supply and consumption patterns of biomass energy from different sources in Debre Berhan is not available. This study is a new one for the study site. Therefore, the study contributes to increase our understanding on the appropriate management strategies and techniques that may assist energy managers, environmental conservationists, local communities, private and public sectors in addressing opportunities and challenges for conserving and managing the natural resources in the study area. Other than academic purpose, the findings of this study generated quantitative scientific information for policy-makers and planners to guide them for a better and more informed decision-making. This, in turn, will ensure efficient energy use that is geared towards socio-economic development and conservation of natural resources, which could be instrumental in achieving the broad goal of reducing poverty in Ethiopia. The other relevance of the study is that the combined methods used to quantify the amount of biomass energy supply brought into the town by addressing spatial and temporal factors. In addition, a questionnaire survey was used to complement the data obtained through point census. So, the questionnaire survey helped quantify the energy consumption pattern in the town. Therefore, the two methods used in the present study can be adopted by other scholars who are interested to conduct a similar study in other areas in the future. So, this study can serve as a springboard for further studies in the area. The analyzed results are also important to solve the problem of fuelwood shortage in Debre Berhan town.

Therefore, the objectives of this study were to: (i) determine the main local sources of energy and quantify their daily amount of supply to Debre Berhan town; and (ii) examine the household energy consumption pattern in the town. To meet the objectives of the study, two hypotheses were tested: (i) there is spatial, i.e. point of entry to the town, and temporal, i.e. market versus non-market days, variations of local fuelwood supply brought into the town; and (ii) socioeconomic variables, such as sex, age, family size, occupation type, livestock ownership, level of education, annual income and accessibility to various energy sources, i.e. biomass, electricity and petroleum, affect the energy consumption pattern at a household level in the town.

Materials and Methods

The study area

The study was conducted in Debre Berhan town, North Shewa Administrative Zone, ANRS, Ethiopia, located at 9o 40' N and 39o 30' E (Figure 1). The town covers an area of 18,081.95 hectares and has an estimated total population of 110,000 people. It is composed of 10 kebeles, the lowest administrative structures in Ethiopia. The mean annual temperature and rainfall of the area are 6.6°C and 940 mm, respectively. The area is situated at an altitude of 2,750 m. The topography of the area covers 86, 10 and 4% flat, plateau and mountainous terrains, respectively. The soil types of the area are, mainly, dominated by brown colored soil (personal communications with North Shewa Administrative Zone Office, April 21, 2015).

Data collection

Initially, a preliminary survey was carried out in order to get better information about the study area and types of data to be collected. The data collection involved two methods, namely point census as well as household survey and market interview [18-24].

Point census

The point census method was conducted at two main entry points to the town in order to collect data necessary to quantify the amount of local energy supply, i.e. split wood, dung, crop straw, leaves and charcoal brought to Debre Berhan town [14,18-25]. These were the points of entry from Addis Ababa and Dessie cities, representing southern and northern Debre Berhan, respectively (Figure 1). Based on our preliminary study, the usual time that the local people used to bring biomass energy sources into Debre Behan town was found to fall between 8:00-16:00 local time. Accordingly, during the aforementioned time, at the two main points of entry to the town (i.e. Addis Ababa and Dessie points of entry), the data enumerators counted the numbers of piles of split wood, dung, leaves, crop straw and charcoal brought by the local people during market and non-market days. Moreover, piles of each local fuelwood type (i.e. n=50 piles for each local fuelwood type) were systematically taken and weighed using a beam balance [14-25]. This activity was important to quantify the mass of each type of local energy supply (i.e, kilograms of split wood, dung, leaves, crop straw and charcoal) brought into Debre Berhan town as shown in Figures 2 and 3. The data were collected during 20 market days, i.e. 10 days each from Addis Ababa and Dessie points of entry, as well as 20 non-market days, i.e. 10 days each from Addis Ababa and Dessie points of entry. This method was useful to get quantitative data that represent the effects of spatial (i.e. Addis Ababa versus Dessie) and temporal (i.e. market versus non-market days) variations on the amount of local energy supply brought into the town. The data were collected between March and May 2015.

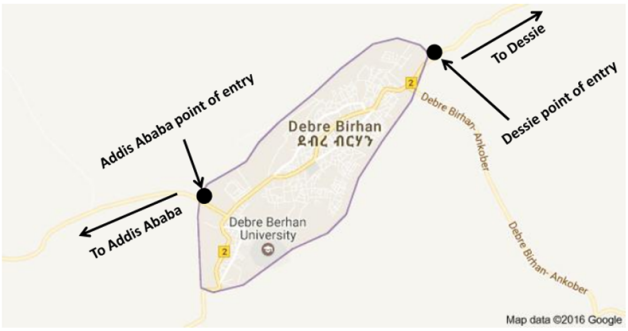

Figure 1: Map showing the location of Debre Berhan town. The two main points of fuelwood entry, i.e. Addis Ababa and Dessie points of entry, to Debre Berhan are shown. (Source: Google map data, 2016).

Household survey and market interviews

A household survey, involving administration of a structured closed- and open-ended questionnaire, was conducted to collect data required to estimate the supply and consumption of household energy and identify factors that determine patterns of household energy consumption in four kebeles of the town [26-29]. The four study kebeles were randomly selected through a lottery system based on kebele numbers.

The questionnaire was developed by considering socioeconomic variables, such as sex, age, family size, occupation type, livestock ownership, level of education, annual income and accessibility to various energy sources, i.e. biomass, electricity and petroleum [26-29]. The questionnaire was administered to a total of 117 households, representing 24 households from each kebele. In addition, 21 respondents were interviewed in the market area where there was selling and buying of dung, split wood, leaves, crop straw and charcoal. The data enumerators conducted the survey in May 2015 via direct house-to-house visits. The households were randomly selected through a lottery system based on their house identification numbers.

The independent variables were derived from the following 8 questions: (i) sex, (ii) age, (iii) family size, (vi) occupation type, (v) livestock ownership, (vi) level of education, (vii) annual income and (viii) access to various energy sources. The dependent variables were derived from the following two statements: (i) 'the shortage of energy supply for household consumption in Debre Berhan town' and (ii) 'the consumption of various energy types, i.e. biomass, electricity and petroleum, at the household level in Debre Berhan town'.

Data analysis

Firstly, the point census data were checked whether they meet the assumptions of ANOVA (i.e. Analysis of Variance) including normality, linearity, homogeneity of variance and equal sample size. So, the nature of the data suggested meeting all the aforementioned assumptions of ANOVA [30,31]. To test the effects of spatial variation, temporal variation and the interaction of spatial and temporal variations on the quantity of local energy types brought into Debre Berhan town, a Generalized Linear Model (GLM) was used with multivariate tests [30,31]. In the same analysis, univariate tests followed the multivariate ones for better interpretation of the multivariate results. The independent variables entered into the GLM included spatial and temporal variations. For the vector of dependent variables, the quantity of fuel types i.e. dung, split wood, leaves, crop straw and charcoal. A post hoc Tukey's HSD test was used for the multiple comparisons across biomass fuel types.

Descriptive statistics was used to analyze the socioeconomic data and perceived major sources of energy at a household level in the town. Since there were a few number of independent variables (i.e. only eight independent variables per dependent variable), multiple linear regression technique was used [30,31]. However, before running the multiple linear regression analysis, the household survey data were checked to meet the assumptions of regression, such as linearity, singularity (i.e. when the independent variables are perfectly correlated and one independent variable is a combination of one or more of the other independent variables), multicollinearity (i.e. a condition in which the independent variables are very highly correlated (0.90 or greater)), homoscedasticity, heteroscedasticity, homogeneity of variance, and normality [30,31]. There was no problem with all the independent variables to meet the assumptions of multiple linear regression. To analyze and predict the effects of socioeconomic variables on the value of the dependent variables, a multiple linear regression model was employed. For all the analyses, the alpha value was defined at 0.05, and the analyses were performed using SPSS version 16.

Results

Biomass energy supply

The amount of biomass energy supply brought into Debre Berhan town was significantly affected by spatial and temporal factors. Specifically, the spatial variation (point of entry to the town) significantly affected the quantity of split wood, leaves and charcoal (Table 1). The temporal variation significantly affected the amount of split wood, dung, leaves, crop straw and charcoal (Table 1). However, spatial and temporal variations did not interact to affect the quantity of fuel types that were brought into the town.

		GLM	**F Value**				
Factors	Degree of Freedom	Pillai's Trace Value	Dung	Splitted Wood	Leaves	Crop Straw	Charcoal
Spatial variation	1	0.33	NS	4.16	5.02	NS	6.43
Temporal variation	1	0.64	26.89	30.77	25.24	26.64	9.89
Spatial × temporal variation	1	0.06	NS	NS	NS	NS	NS

NS=Not significant at P<0.05. The total sample size (N) considered for this analysis was 40 point counts.

Table 1: Effects of spatial i.e. Addis Ababa versus Dessie points of entry, temporal i.e. market versus non-market days, and the interaction of spatial × temporal variations on the quantity of biomass fuels brought into Debre Berhan town. Different statistical values were shown.

Overall, the amount of local energy supply brought into Debre Berhan town through Dessie point of entry was higher than that of Addis Ababa (Figure 2). Generally, the quantity of biomass energy supply brought into the town during market days was significantly higher than that on non-market days (Figure 3). Also, multiple comparisons across the quantities of biomass energy supply brought into the town during market versus non-market days showed significant differences among dung, split wood, leaves, crop straw and charcoal (Figure 3). Generally, the largest amount of biomass fuel brought into the town during the market days was split wood (Figure 3).

Figure 2: The effect of spatial variation, i.e. Addis Ababa and Dessie points of entry, on the daily amount of biomass energy brought into the town. The number of point counts (N) included in this analysis was 20 each from Addis Ababa and Dessie points of entry. The bars showed mean+1 SE.

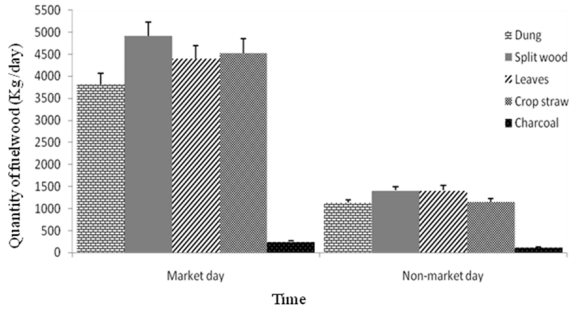

Figure 3: The effect of temporal variation, i.e. market and non-market days on the daily quantity of biomass energy brought into the town. The number of days (N) included in this analysis were 20 each on market and non-market days. The bars showed mean+1 SE.

Supply and consumption of household energy

About half of the 117 respondents were males. The average age of the respondents was about 39 years. The average family size in a household was about 6 persons. A few of the respondents (about 28%) were engaged in local liquor production and sales. Many of the respondents (about 78%) owned livestock. Regarding the level of education, about 38% of the respondents went to primary school. The average annual income of the respondents was about 21,304.00 Ethiopian Birr (ETB), which was equivalent to 983.56 USD. The largest percentage (about 89%) of the respondents had access to energy sources, such as dung, split wood, leaves, crop straw and charcoal. However, most of the respondents noted that they did not have access to electricity (about 72%) and petroleum (about 99%) energy sources (Table 2).

Variables	Descriptive Results	Proportion (%)
Kebele and/or village type	09=24 households	20.51
	08=24 households	20.51
	07=24 households	20.51
	01=24 households	20.51
	Market area=21 households	17.96
Total sample size (N)	117 households	
Sex	Male	49.58
	Female	50.42
Age	Mean=38.48 years; SD=12.60	
Family size	Mean=5.90 persons; SD=5.76 persons	

	Crop cultivation	8.55
	Livestock rearing	0.85
	Mixed farming	8.55
Occupation type	Pension	5.13
	Government employee	19.66
	Local liquor	28.21
	Daily labourer	5.98
	Merchant	22.22
Livestock ownership	Yes	77.78
	No	22.22
Education level	MSc	0.85
	Degree	12.82
	Diploma	6.84
	Primary education	37.61
	Secondary education	13.68
	Illiterate	27.35
Annual income	Mean=21,304 ETB; SD=12,910	
Accessibility to various energy sources	Local	Yes-88.89
		No-11.11
	Electricity	Yes-28.21
		No-71.79
	Petroleum	Yes-0.85
		No-99.15

Table 2: Characteristics of samples and descriptive results.

As perceived by the local communities, the main sources of energy for household consumption in the Debre Berhan town were, in descending order, biomass (dung, split wood, leaves, crop straw and charcoal), electricity and petroleum (Table 3).

This suggested that the preference of the local communities towards different energy source for household consumption in the town is affected by the cost of the energy type.

This is because, for example, as compared to electricity and petroleum, biomass energy is relatively the cheapest one, particularly in most towns that are found in the developing countries like Ethiopia.

This may be attributed to the continuous transportation of high amounts of biomass energy into the towns. Thus, biomass energy can either be economically affordable by majority of the local communities so that they can either buy it from the market or collect it from the nearby areas where biomass energy can freely be accessed.

Kebele	Sample size (N)	Biomass (%)	Electricity (%)	Petroleum (%)
1	24	87.5	25	4.17
7	24	87.5	29.17	0
8	24	87.5	29.17	0
9	24	87.5	41.67	0
Market area	21	95.24	14.29	0
Overall	117	88.89	28.21	0.85

Table 3: Major source of energy perceived by the local communities for household consumption in the town. Biomass energy includes dung, splitted wood, leaves, crop straw and charcoal.

The multiple linear regression model revealed that several socioeconomic variables significantly affected 'the shortage of energy supply for household consumption in Debre Berhan town'. As revealed

from their coefficients, age (ß=0.63) and family size (ß=0.21) positively affected 'the shortage of energy supply for household consumption' (Table 4). The increase in the shortage of energy supply for household consumption with the increase in age could be explained by the fact that, unlike young people, old people may be economically poor and/or physically less capable to travel long distance to acquire alternative sources of energy to meet their household energy consumption. Moreover, the increase in the shortage of energy supply for household consumption with the increase in family size suggested that the amount of energy required for cooking and heating purposes increases as family size in a household increases.

However, livestock ownership (ß=-0.59), annual income (ß=-0.31) and access to sources of energy (ß=-0.37) negatively affected 'the shortage of energy supply for household consumption' (Table 4). One of the possible reasons for the decrease in the shortage of energy supply for household consumption in Debre Berhan town as livestock ownership increases is that livestock can provide the households with dung which, in turn, could be used as a source of energy for cooking and heating. Similarly, the decrease in the shortage of energy supply for household consumption with the increase in annual income of the households suggested that households with high annual income can afford to buy and use various sources of energy to meet their household energy demands. Moreover, the decline in the shortage of energy supply for household consumption with the increase in access to different energy sources suggested that households with high access to various energy sources may have different alternatives to meet their household energy demands. Overall, the multiple linear regression model revealed that there is a 'shortage of energy supply for household consumption in Debre Berhan town' (about 49% variance explained) (Table 4).

Variables	ß	t-value	P-value
Intercept	0.73	1.86	-
Sex	0.44	0.46	0.79
Age	0.63	2.95**	0.003
Family size	0.21	2.28**	0.03
Occupation type	-0.93	1.08	0.49
Livestock ownership	-0.59	3.58**	0.001
Level of education	-0.64	0.7	0.64
Annual income	-0.31	3.45**	0.001
Accessibility	-0.37	4.24**	0.001
[a]Standardized coefficients were reported; ** represents significance at the 95% confidence level; and [b]R2=0.69 (Adj. R2=0.49), df=7; F=9.19, overall P<0.001.			

Table 4: Multiple linear regression model[a] to predict the effects of socioeconomic variables on 'the shortage of energy supply for household consumption in the town'[b] [The total sample size (N) considered for this analysis was 117 households. The signs '+' and '-' indicate positive and negative changes, respectively, in shortage of energy supply for household consumption in the town].

More than half (about 59%) of the respondents noted that one of the major reasons for the shortage of household energy consumption in Debre Berhan town was low annual income (Table 5). This suggested that economic poverty is one of the rampant problems in the town. Like the urban dwellers living in different towns of Ethiopia, the low annual income of the households can predominantly affect the shortage of household energy consumption in Debre Berhan town.

Kebele	Sample size (N)	Annual income (%)	Family size (%)	Access to sources of energy (%)	Shortage of electrical energy supply (%)
1	24	79.17	62.5	50	37.5
7	24	20.83	12.5	33.33	0
8	24	66.67	58.33	33.33	0
9	24	66.67	12.5	54.17	29.17
Market area	21	61.9	19.04	52.38	42.86
Overall	117	58.97	33.33	44.44	21.37

Table 5: Major reasons perceived by local respondents for the shortage of household energy consumption in the town.

The multiple linear regression model revealed that several socioeconomic variables affected the consumption of various energy sources at a household level in Debre Berhan town. As revealed from their coefficients, age (ß=0.94), family size (ß=0.83), livestock ownership (ß=0.39) and access to sources of energy (ß=0.68) had a positively significant effect on 'the consumption of biomass energy in Debre Berhan town' (Table 6). One of the possible reasons for the increase in the consumption of biomass energy in Debre Berhan town with the increase in age suggested that old people may traditionally have developed a high belief towards the use of biomass energy for household energy consumption as opposed to young people do. Moreover, the increase in the consumption of biomass energy with the increase in family size suggested that biomass energy source, such as dung, split wood, leaves, crop straw and charcoal are relatively cheaper than modern sources of energy (e.g. electricity and petroleum) for household consumption so that people with high family size may show high preference towards the consumption of biomass energy. Similarly, the increase in the consumption of biomass energy as livestock ownership increases suggested that livestock can provide the households with dung which, in turn, could be used as a source of energy for household consumption. In addition, the increase in the consumption of biomass energy with the increase in access to various sources of energy suggested that households with high access to biomass energy may have high household energy demands because the cost of biomass energy is the cheapest one and affordable than other sources of energy in the town, such as electricity and petroleum.

However, occupation type (ß=-1.97), level of education (ß=-0.37) and annual income (ß=-0.84) negatively affected 'the consumption of biomass energy' (Table 6). The decrease in the consumption of biomass energy with occupation type suggested that people who have different occupation type may have different options and outlooks to acquire various sources of modern energy, as opposed to the consumption of biomass energy. Moreover, the decrease in the consumption of biomass energy as the level of education increases suggested that people may have developed the knowledge on the risks of using biomass energy for health. In addition, the decrease in the consumption of biomass energy with the increase in annual income suggested that people with high annual income have different options to acquire various sources of modern energy, such as electricity. Overall, the multiple linear regression model revealed that socioeconomic variables had significant effect on 'the consumption of biomass energy in Debre Berhan town' (69% variance explained) (Table 6).

Variables	bBiomass Energy Source			cElectrical Energy Source			dPetroleum Energy Source		
	ß	t-value	P-value	ß	t-value	P-value	ß	t-value	P-value
Intercept	3.87	5.98	-	-0.53	2.99	-	-0.26	1.89	-
Sex	0.34	0.77	0.46	0.66	0.75	0.37	-0.57	0.89	0.35
Age	0.94	3.98**	0.001	-0.36	2.68**	0.004	0.28	2.89**	0.002
Family size	0.83	4.78**	0.001	0.76	3.89**	0.001	-0.97	4.94**	0.001
Occupation type	-1.99	5.78**	0.001	0.297	4.49**	0.001	-0.78	3.58**	0.001
Livestock ownership	0.39	2.99**	0.002	-0.3	2.29**	0.021	-0.09	0.94	0.56
Level of education	-0.37	2.98**	0.002	0.39	4.0*	0.001	-0.58	3.94**	0.001
Annual income	-0.84	4.83**	0.001	0.94	4.59**	0.001	-0.95	5.07**	0.001
Accessibility	0.68	3.30**	0.001	0.59	2.97**	0.002	-0.24	1.05	0.18

[a]Standardized coefficients were reported; ** represents significance at the 95% confidence level; [b]R2=0.89 (Adj. R2=0.69), df=7; F=13.85, overall P<0.001; [c]R2=0.91 (Adj. R2=0.70), df=7; F=13.94, overall P<0.001; and [d]R2=0.81 (Adj. R2=0.62), df=7; F=12.78, overall P<0.001.

Table 6: Multiple linear regression model[a] to predict the effects of socioeconomic variables on the consumption of various energy, i.e. biomass[b], electricity[c] and petroleum[d], at a household level in the town [The total sample size (N) used in this analysis was 117 households. The signs '+' and '-' indicate positive and negative changes, respectively, in household energy consumption in the town].

As revealed from their coefficients, family size (ß=0.76), occupation type (ß=0.30), level of education (ß=0.39), annual income (ß=0.94) and access to sources of energy (ß=0.59) had positively significant effects on 'the consumption of electrical energy in Debre Berhan town' (Table 6). The increase in the consumption of electrical energy with the increase in family size suggested that people may look for efficient sources of energy to meet their household energy demands because the household energy consumption (e.g. for cooking and heating) rises as the family size increases. Moreover, when people have better occupation and/or when their levels of education increases and/or when their annual income increases and/or when they have better accessibility to different energy sources, they prefer to rely on modern and efficient source of energy like electricity.

However, age (ß=-0.36) and livestock ownership (ß=-0.30) had negatively significant effects on 'the consumption of electrical energy' (Table 6). The decrease in the consumption of electrical energy with the increase in age suggested that, unlike young people, old people may prefer traditional source of energy, like biomass energy, to meet their household energy demands because their traditional taboos may restrain them not to shift their energy usage from traditional to modern energy, such as electricity. Moreover, the decrease in the consumption of electrical energy with the increase in livestock ownership suggested that people can use dung as a source of energy for household consumption. As a result, people with livestock may not be interested to use modern energy, like electricity, for cooking and heating. In addition, they may be afraid of the costs of using electricity.

Overall, the multiple linear regression model revealed that socioeconomic variables had significant effect on 'the consumption of electrical energy in Debre Berhan town' (70% variance explained) (Table 6).

As revealed from their coefficients, age (ß=0.28) had a positively significant effect on 'the consumption of petroleum energy in Debre Berhan town' (Table 6). One possible explanation is that, unlike young people, old people used to rely on petroleum as a source of light in their households for a long time in the past in different parts of Ethiopia, including Debre Berhan town.

However, family size (ß=-0.97), occupation type (ß=-0.78), level of education (ß=-0.58) and annual income (ß=-0.95) had negatively significant effects on 'the consumption of petroleum energy' (Table 6). One of the possible reasons for the negative correlation between the consumption of petroleum energy and family size is that the cost of petroleum is increasing from time to time at an alarming rate and, as a result, people may not economically afford to use it as a source of energy for household consumption when the family size increases as the household energy demands rise with family size. The other possible explanation is that the smoke that pollutes the house when the petroleum is burnt during cooking and/or heating may not be tolerated by people when they have a better occupation or high level of education or high annual income because the emitted smoke due to petroleum burning could affect the health of the family in the household. Overall, the multiple linear regression model revealed that socioeconomic variables had significant effect on 'the consumption of petroleum energy in Debre Berhan town' (62% variance explained) (Table 6).

Discussion

Biomass energy supply

Five major types of biomass energy were identified entering Debre Berhan town. These were split wood, dung, crop straw, leaves and charcoal. The results revealed that the supply of biomass energy brought into the town is affected by spatial and temporal factors. Also, the majority of the fuelwood supply brought into the town was contributed by rural farmers whereas some of it was supplied by whole sellers. The supply of domestic energy to the town for household consumption was obtained, mainly, from nearby open access plantation forests, trees on farmlands, crop residues, dung and charcoal. Other studies also noted a similar source of biomass energy to various towns in different parts of Ethiopia [2,3,12-14,32-34].

In line with the first hypothesis, the results revealed that there was spatial variation in the quantity of fuelwood brought into the town depending on points of entry. Accordingly, the present study revealed that the amount of fuelwood brought into Debre Berhan town through Dessie point of entry was higher than that of Addis Ababa point of entry. One of the possible explanations for such a distinct variation in the supply of biomass energy brought into the town could be the difference in livelihood strategy of the rural people living in the adjacent area of the town. For example, the higher amount of biomass energy brought into the town through Dessie point of entry suggested that the nearby rural people heavily rely on the sale of various types of local fuelwood to manage their lives. The other possible explanation is that there may be higher quantity of biomass energy source or access to plantation forests or trees on farm lands for the rural poor who heavily depend on the sale of fuelwood in the vicinity of Dessie point of entry than in the surroundings of Addis Ababa point of entry. This is why the amount of split wood, leaves and charcoal brought into the town via Dessie point of entry were all higher than that of Addis Ababa point of entry.

In support of the second hypothesis, the quantity of fuelwood brought into the town during market days was higher than that of the non-market days. The results revealed that temporal variation significantly affected the amount of split wood, cow dung; leaves, crop straw and charcoal brought into the town, and their quantities were all higher during the market days than that of the non-market days. This suggests that the rural people living in the adjacent area of Debre Berhan town may heavily depend on the sale of fuelwood that, in turn, may lead to the supply of higher amount of biomass energy during the market days than that of the non-market days. Generally, compared with the other type of biomass energy, the results showed that split wood had significantly the largest amount brought into the town during the market days, which may be attributed by its highest market price for the rural poor who heavily rely on the sale of fuelwood to support their lives. Even though sources of energy that are mostly biomass-based are available in unlimited amount in nature [3,13,16,35], the continuous and excessive supply of fuelwood to different towns from nearby rural areas may aggravate the rate of deforestation, and subsequent land degradation [2-4,12-14,16,35], which, in turn, may result in the reduction of agricultural production and productivity [3,5,12,14]. Moreover, the excessive dependence of the majority of the people on biomass energy with very low use efficiency exacerbates the problem of deforestation and land degradation in Ethiopia [3,4,14,36,37].

Supply and consumption of household energy

Currently, over 2.5 billion people around the world depend on biomass fuels for cooking and heating [38-40]. Although all people have a legitimate right to and need for energy services, which are affordable, healthy, reliable and sustainable, energy issues are particularly challenging for developing countries where high energy costs exert tremendous pressure on fragile economies that have little capacity to adapt or change [41].

Previous research findings revealed that there is no change in the pattern of energy consumption where biomass fuels remained the principal energy resources in Ethiopia. According to the estimate made by [37,42], more than 92% of Ethiopia's current total energy demand is met using biomass fuels. The finding from this study revealed that about 89% of the total energy demand in Debre Berhan town is met by biomass fuel (Table 3). This showed that there is still high dependency on biomass fuels for household consumption in Debre Berhan town. The critical implication of high dependency on biomass fuel is its association with continuous transportation of high amounts of biomass energy into the town. This finding is in agreement with that reported [43] who noted that consumption of fuelwood energy by households in Ethiopia is much higher than the total consumption of commercial energy for all purposes.

The results revealed that energy supply and consumption pattern of households in Debre Berhan town were affected by several socioeconomic variables. For example, the results obtained through the multiple linear regression model suggested that there is a shortage of energy supply for household consumption in the town. Thus, our results revealed that the shortage of energy supply is significantly affected by age, family size, livestock ownership, annual income and access to sources of energy.

The increase in the shortage of energy supply for household consumption with age could be explained by the fact that, unlike young people, old people may be economically poor and/or physically less capable to travel long distance to acquire alternative source of energy to meet their household energy consumption. The results suggest that when family size increases, the shortage of energy supply for household consumption also increases. One of the plausible reasons is that the amount of energy required for cooking and heating purposes increases as family size in a household increases. However, the results suggested that the shortage of energy supply for household consumption decreases as livestock ownership increases. One of the possible reasons is that livestock can provide the household with dung that could be used as a source of energy for cooking and heating. Similarly, the study revealed that the shortage of energy supply for household consumption decreases as annual income of households increases. This is because households with high annual income can afford to buy and use various sources of energy to meet their household energy demands. Moreover, the study revealed that the shortage of energy supply for household consumption decreases with the increase in access to different energy sources. This is because people will have different alternative sources of energy to meet their household demands when their access to energy sources increases.

The multiple linear regression model further revealed that several socioeconomic variables affected the consumption pattern of various energy sources, i.e. biomass, electricity and petroleum at a household level in Debre Berhan town.

The consumption of biomass energy increases with increasing age, family size, livestock ownership and access to energy sources. Biomass energy source, such as dung, split wood, leaves, crop straw and charcoal are relatively cheaper than modern sources of energy (e.g. electricity and petroleum) for household consumption. Previous studies also noted that in Ethiopia, like in many developing countries, biomass fuels are the major sources of energy and the household energy consumption pattern is heavily dependent on these sources [2,3,12-14,16,17,36,44]. Almost all the rural and majority of the urban populations are dependent on biomass fuels, mainly, for cooking, because access to modern fuels is a constraint and the price is also unaffordable. Moreover, livestock can provide households with dung that could be used as a source of energy. Similarly, having access to energy sources provides the opportunity to alternative source of energy that helps meet household energy demands. This is why access to energy plays a central role in natural resources conservation and environmental protection [3,12-14,33].

However, the study revealed that the consumption pattern of biomass energy is negatively affected by occupation type, level of education and annual income. One of the possible reasons is that when people have different occupation types or their level of education increases or their annual income becomes high, they will have different options and outlooks to acquire different sources of modern energy. As a result, their dependence on biomass energy decreases. This is why the people in the developed nations highly rely on modern energy. As a result, people may eagerly look for modern and efficient source of energy, such as electricity. A number of factors influence as to what sort of energy is used by which household, the most significant of them being the socio-economic status of households. For example, previous studies noted that households with higher socio-economic status, in terms of income and level of education, are expected to consume more energy, decrease using biomass fuels and increase the use of modern forms of energy [2,3,12-14,16,33,45]. Among other factors, family size of a household in terms of amount of energy and expenditure, access to various energy sources and household income could be considered as determining factors for domestic energy consumption.

The present study suggested that the consumption of electrical energy is positively correlated with family size, occupation, level of education, annual income and access to energy sources. When family size increases, the household energy consumption also increases. As a result, people may look for efficient source of energy to meet their household energy demands. In addition, when people have better occupation or their level of education increases or their annual income increases or they have better accessibility to different energy sources, they prefer to rely on modern and efficient source of energy like electricity. However, our study revealed that the consumption of electrical energy is negatively affected by age and livestock ownership. Unlike young people, old people may prefer traditional source of energy like local energy to meet their household energy demands because their traditional taboos may restrain them not to shift their energy usage from traditional to modern energy, such as electricity, as revealed in this study. Moreover, livestock can provide households with dung that could be used as a source of energy for household consumption. As a result, people with livestock may not be interested to use modern energy like electricity for cooking and heating. They will be afraid of the costs of using electricity. Previous studies also noted that majority of urban populations are dependent on local energy, mainly for cooking and heating, because access to modern energy is a constraint and the price is also unaffordable [3,12-14,16,36,44].

The consumption of petroleum energy in Debre Berhan town was positively correlated with age. One possible explanation is that, unlike young people, old people used to rely on petroleum as a source of light in a household for long time in the past in different parts of Ethiopia, including Debre Berhan town. However, the consumption of petroleum energy was negatively correlated with family size, occupation type, level of education and annual income. There are a number of possible explanations for this. One of them is the cost of petroleum is increasing from time to time at an alarming rate and, as a result, people may not economically afford to use it as a source of energy for household consumption. The other possible explanation is that the smoke that pollutes the house when the petroleum is burnt during cooking and/or heating may not be tolerated by people when they have a better occupation or high level of education or high annual income because the emitted smoke due to petroleum burning could affect the health of the family.

The present study revealed that some of the respondents preferred biomass energy because of the low cost it had and associated with its acquiring method (e.g. free supply through self-collection). About 47% of the respondents, who have low income in Debre Berhan town, have been using biomass energy because it is "the only option" that they have with respect to reliability and their living standards. Even though household income is the main factor that determines the type and amount of energy, the majority of the respondents in this study noted that they have been using local energy for the day-to-day cooking and heating activities in their households. Surprisingly, none of the respondents mentioned environmental reasons for choosing the source of energy, even those households who have been using electric energy for their cooking and heating activities. This suggests that respondents in the different study kebeles did not take environmental issues into consideration in their day-to-day household energy consumption while using local energy. In addition, traditional household energy is

renewable, but the rate of consumption is much greater than the rate of production [3,12-14,33].

Generally, the study suggested that there is a continuous supply of biomass energy from the nearby rural areas to Debre Berhan town during market and non-market days. Although there is a continuous supply of biomass energy, the study showed that there were spatial and temporal variations in biomass energy supply brought into the town. This suggested that the living condition of the rural poor people residing in the surrounding areas of the town is heavily reliant on the sale of split wood, dung, leaves, crop straw and charcoal. The study also suggested that the majority of households in the town are heavily dependent on biomass energy to meet their day-to-day cooking and heating activities. The main reason for this dependency is that there is a problem of reliable access to modern energy. Moreover, the cost of modern energy (i.e. electricity and petroleum) is relatively higher and unaffordable to the poor dwellers in the town. Therefore, income level and family size may force the town dwellers to use biomass energy since the cost of modern energy is, generally, higher than the living standards of the poor people. In addition, livestock ownership is also another reason that leads the urban dwellers in the town to use biomass energy (e.g. dung) because they can access it easily. However, the study revealed that the consumption of electrical energy increased with the increase in family size, occupation type, level of education, annual income and accessibility to different energy sources. This suggested that people may look for efficient sources of energy to meet their household energy demands. Moreover, they prefer to rely on modern and efficient sources of energy like electricity.

Conclusion

The present study suggested that most of the urban residents in Debre Berhan town predominantly use traditional fuels, such as wood, crop residues and animal dung. However, the shortage and ever-increasing demand for fuelwood forced the local people living in the town to use dung and agricultural residues to meet their desperate household energy requirements. This, in turn, may lead to environmental degradation that is resulting from the loss of vegetation cover, crop residues and animal dung, which, otherwise, could be used as sources of organic manure that help improve the agricultural productivity. By addressing spatial and temporal factors, the present study quantified the amount of biomass energy supply brought into Debre Berhan town. In addition, the questionnaire survey measured the energy consumption pattern in the town. Therefore, the two methods used in this study can be adopted by other scholars who are interested to conduct a similar study in other areas in the future. The analyzed and quantified results are also important to solve the problem of fuelwood shortage in Debre Berhan town. Hence, the study contributes towards increasing our understanding on appropriate management strategies and techniques that may assist energy managers, environmental conservationists, local communities, private and public sectors in addressing opportunities and challenges for conserving and managing natural resources. Moreover, other than academic purpose, the findings generated quantitative scientific information for policy-makers and planners to guide them for a better and more informed decision-making. This, in turn, will ensure efficient energy use that is geared towards socio-economic development and conservation of natural resources, which could be instrumental in achieving the broad goal of reducing the rampant economic poverty in Ethiopia.

Recommendations

Based on the findings this study, the followings were recommended:

The exclusive dependency of the local people on biomass energy for household consumption accompanied by high rates of human population growth will worsen environmental degradation. Thus, public education about natural resources should be comprehensive enough ranging from the very practical definition of management of natural resources. This may, in turn, narrow down the knowledge gaps that the local communities have about biomass energy consumption with natural resources degradation in the study site.

There should be collaboration between Bureau of Education, Environmental Protection Authority, energy sector, and Bureau of Agriculture and Natural Resources to disseminate energy know-how, i.e. awareness creation among the local people living in the town.

Dissemination of energy-efficient technologies (e.g. energy saving stoves) is crucial because it helps reduce indoor air pollution and also decreases the amount of extra fuel consumption. In doing so, energy saving stoves improve health risks as well as reduce the growing pressure on the natural environment in the study site.

Creating job opportunities, family planning, strict government energy policy and provision of alternative energy (other than biomass energy) by the government with less taxation may decrease the undesirable consequences. Solutions to alleviate the unsustainable use of biomass energy, in turn, reduce environmental degradation.

The use of other sources of energy, such as hydropower, wind power, solar energy and natural gas can potentially offer Ethiopia major economic development opportunity, thereby, reducing poverty and environmental degradation.

Future research should consider the season of the year since supply and consumption of biomass energy in Debre Berhan town may vary depending on seasons.

Acknowledgements

Authors appreciate Debre Berhan University for the financial support. They extend their thanks to the local people residing in the different study kebeles of Debre Berhan town for sharing their fruitful ideas and abundant experiences about local household energy supply and consumption during the survey. They are grateful to the data enumerators for their assistance in the point census and survey.

Funding

The authors would like to appreciate Debre Berhan University for covering all costs of the research that helped in the design of the study and collection, analyses, and interpretation of the data and also in writing of the manuscript.

Authors' Contributions

SAT designed and conducted the field research, analyzed the data, and drafted the manuscript. DT interpreted the results and helped in the manuscript writing. Both authors read, revised and approved the final manuscript.

References

1. Leach G (1992) The Energy Transition. Energy Policy 20: 116-123.

2. Alem Y, Beyene AD, Kohlin G, Mekonnen A (2015) Household fuel choice in urban Ethiopia: A panel multinomial logit approach. Working Papers in Economics 632: 1-40.
3. Mulugetta Y (1999) Energy in rural Ethiopia: consumption patterns, associated problems, and prospects for a sustainable energy strategy. Energy Sources 21: 527-539.
4. Ethiopian Forest Action Program (EFAP) (1993) The challenges for development. Ministry of Natural Resources Development and Environmental Protection, Transitional Government of Ethiopia. Addis Ababa, Ethiopia.
5. Bojo J, Cassells D (1995) Land degradation and rehabilitation in Ethiopia: a re-assessment. AFTES working paper, Washington D. C, World Bank.
6. Sutcliffe J (1993) Economic assessment of land degradation in Ethiopia: a case study. National Conservation Strategy Secretariat, Ministry of Planning and Economic Development, Addis Ababa, Ethiopia.
7. Amhara Forest Action Progra (AFAP) (1999) Challenges for forest development in Amhara National Regional State. Bureau of Agriculture, Bahir Dar, Ethiopia.
8. Ayele ZE (2008) Smallholder farmers' decision making in farm tree growing in the highlands of Ethiopia. PhD Dissertation. Oregon State University, USA.
9. Hailu Z (2002) Ecological impact evaluation of Eucalyptus plantations in comparison with agricultural and grazing land-use types in the highlands of Ethiopia. Doctoral thesis. Institute of Forest Ecology, University of Natural Resources and Life Sciences, Vienna.
10. Hailu Z, Sieghardt M, Schume H, Ottner F, Glatzel G, et al. (2003) Impact of Eucalyptus globulus and Eucalyptus camaldulensis small scale plantations on chemical and physical soil properties and on soil hydrological parameter in the highland of Ethiopia - a comparison with other land-use systems.
11. Teketay D (2000) Facts and experience on eucalyptus in Ethiopia and elsewhere: ground for making wise and informed decision. Walia 21: 5-46.
12. Asfaw A (2012) Sustainable Household Energy for Addis Ababa, Ethiopia. J Sustain Dev 8: 1–11.
13. Beyene AD, Koch SF (2012) Clean fuel saving technology adoption in urban Ethiopia. Energy Economics 36: 605-613.
14. Ejigie DA (2007) Household determinants of fuelwood choice in urban Ethiopia: a case study of Iimma town. J Dev Areas 41: 117-126.
15. Embassy of Japan in Ethiopia (2008) Study on the energy sector in Ethiopia.
16. Kebede B, Bekele A, Kedir E (2002) Can the urban poor afford modern energy? The case of Ethiopia. Energy Policy 30: 029-1045.
17. Tolemariam A, Mamo D (2016) Gender-energy nexus in Ethiopia. In: Mihyo PB, Mukuna TE (eds.) The gender-energy nexus in eastern and southern Africa. Organization for Social Science Research in Eastern and Southern Africa (OSSREA), Addis Ababa, Ethiopia.
18. Abdalla KL (1994) Energy policies for sustainable development in developing countries. Energy Policy 22: 29-36.
19. Byrnes J (1998) The economics of sustainable energy for rural development: a case study of renewable energy in rural china. Energy Policy 26: 45-54.
20. Guta DD (2012) Assessment of biomass fuel resource potential and utilization in Ethiopia: sourcing strategies for renewable energies. Int J Ren Ener Res 2: 191-139.
21. Shanko M (2000) The role of the private sector in alternative energy supply for household use. Paper Presented on Earthday Workshop Organized by forum on the Environment, Addis Ababa, Ethiopia.
22. Wolde-Ghiorgis W (1984) Energy supply requirements in Ethiopia: an end-use assessment. Paper Presented at the Global Workshop on End-Use-Oriented Energy Strategies, Sao Paulo, Brazil.
23. Wolde-Ghiorgis W (2002) Renewable energy for rural development in Ethiopia: the case for new energy policies and institutional reform. Energy Policy 30: 1095-1105.
24. Wu K, Li B (1995) Energy development in China: national policies and regional strategies. Energy Policy 23: 167-178.
25. Loiter JM (1999) Technology policy and renewable energy: public roles in the development. Energy Policy 27(3): 80-85.
26. Hills AM (1995) Empathy and belief in the mental experience of animals. Reviews and research reports 8: 132-142.
27. Kelboro G, Stellmatcher T (2015) Protected areas as contested spaces: Nech Sar National Park, Ethiopia, between 'local people', the state and NGO engagement. Environmental Development 16: 63-75.
28. Tadesse SA, Kotler BP (2016) Attitudes of local people towards the mountain nyala (Tragelaphus buxtoni) in Munessa, Ethiopia. Afr J Ecol54: 488-499.
29. Tadesse SA, Teketay D (2017) Perceptions and attitudes of local people towards participatory forest management in Tarmaber District of North Shewa Administrative Zone, Ethiopia: the case of Wof-Washa Forest. Ecological Processes 6: 1-16.
30. Tadesse SA, Kotler BP (2014) Effects of habitat, group-size, sex-age class and seasonal variation on the behavioral responses of mountain nyala (Tragelaphus buxtoni) in Munessa, Ethiopia. J Trop Ecol 30: 3-43.
31. Zar JH (1999) Bio-statistical analysis. 4th edn. Prentice-Hall, London, United Kingdom.
32. Alemu M, Tekie A (2003) Fuelwood situation in Ethiopia: pattern, trend and challenges. CIFOR occasional proceeding prepared at Goteborg, Germany 39: 106-152.
33. Desta M, Mulugeta T (2002) Energy in Ethiopia: status, challenges and prospects. Proceeding of energy conference. Professional Associations' Joint Secretariat, UNCC, Addis Ababa, Ethiopia.
34. Getachew O (2002) Some socio-economic aspects of biomass energy in Ethiopia: status, challenges and prospects. Proceeding of energy conference. Professional Associations Joint Secretariat, UNCC, Addis Ababa, Ethiopia.
35. Environmental Protection Authority (EPA) (2003) State of environment outlook: environment for development. Addis Ababa, Ethiopia.
36. Asress WG (2002) Overview of energy status and trends in Ethiopia: status, challenges and prospects. Proceeding of energy conference. Professional Associations Joint Secretariat, UNCC. Addis Ababa, Ethiopia.
37. Woody Biomass Inventory and Strategic Plan Project (WBISPP) (2002) A strategic plan for the sustainable development, conservation and management of the woody biomass resources for Oromia regional state. Final Report, Addis Ababa, Ethiopia.
38. International Energy Agency (IEA) (2006) World energy outlook. IEA, Paris, France.
39. International Union for the Conservation of nature (IUCN) (2008) Energy, ecosystems and livelihoods: understanding linkages in the face of climate change impacts. Switzerland.
40. Ministry of Mines and Energy (MME) (2009) Energy resource potential of Ethiopia: energy development, follow-up and expansion development. Addis Ababa, Ethiopia.
41. International Union for the Conservation of nature (IUCN) (2007) Energy, ecosystems and livelihoods initiative. IUCN, Gland, Switzerland.
42. Mekonnen K (1996) An overview to the energy situation in Ethiopia. Ethiopian Rural Energy Development and Promotion Center, Ministry of Mines and Energy, Addis Ababa, Ethiopia.
43. Anderson D (1986) Declining tree stocks in African countries. World Development 14: 853-863.
44. Aklilu D (2008) Environmental education: a handout on the principles and practices of environmental education focus in Ethiopia. Addis Ababa University, Addis Ababa, Ethiopia.
45. Bereket K, Haregewoin, D, Getnet A (1996) Petroleum pricing and taxation: the case of Ethiopia, Kenya and Malawi.