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Wood Fuel Demand and Sustainability of Supply in South-Western Ethiopia, Case of Jimma Town

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Abstract: In this study it was aimed to evaluate impact of wood harvesting for fuel and its ultimate effect on the sustainability of the forest resources in the study area in the year 2004. To estimate on level of wood fuel consumption, data was collected from stratified and randomly interviewed urban and rural households and non-household sectors using semi-structured survey questionnaire. Harvesting for fuel wood was estimated at established check points and measuring on the amount of inflow to the town. Forest inventory was also executed to estimate on the amount of growing stock and its incremental yields by land use types. The finding revealed as the actual harvest for fuel was 3 times the annual allowable yield from the forest and trees outside forest for fuel. Harvesting above allowable annual cut degrade the forest ecosystem quality which imply local forest product crises, loss of biological diversity and contribute to expand desertification globally. Therefore, efforts need be done to reduce harvesting below annual incremental yields since in this case it is assumed that the standing stock remains untouched and the wood fuel supply is sustainable.

Key words: Consumption, supply, balance, incremental yield, Ethiopia

INTRODUCTION

Wood fuel use in developing regions of Africa, Asia and Latin America was believed to be a key factor in tropical deforestation and the loss of forests was projected to result in widespread wood fuel shortages. Although it is sometimes the case it has become apparent that wood fuel harvesting is seldom a direct cause of deforestation since most wood fuel demand is met by trees and shrubs growing outside of forest areas and from farm clearance (Arnold *et al*., 2006; Bensel, 2008).

It was estimated that over half of the two billion people relying on wood fuels in the 1980s were over-cutting forest resources to meet their needs and that by 2000 over two billion people would be living in areas facing acute wood fuel shortages (De Montalembert and Clement, 1983; FAO, 1994). FAO had compared wood fuel demand and the rates of annual growth in biomass from existing forest resources. In those cases where demand exceeded growth it was assumed that the difference was being met by over-cutting and depletion of forests. In addition, wood fuel demand was projected to grow at roughly the same rate as population, with many studies predicting a growing gap between declining wood fuel supply and rising demand (Bhattarai, 2001; Arnold *et al*., 2003, 2006). Concerns

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over the role of wood fuel extraction in tropical deforestation and the wood fuel shortages that were expected to materialize as a result-the wood fuel crisis narrative reached a peak in the late-1970s and into the 1980s (Arnold *et al*., 2003).

More recent data have shown that the rate of fuel wood use in developing countries is slowing down as a result of urbanization. When incomes increase it is often being replaced by other energy sources such as charcoal, kerosene and electricity. It has also been experienced that society and people adapt to new energy situations by changing their behavior. Despite that, the total wood fuel consumption in some regions, particularly in Africa, is projected to continue increasing at least until 2030 (Broadhead *et al*., 2001).

Currently, over 2.5 billion people depend on biomass fuels for cooking and heating (MEA, 2005; IEA, 2006; IUCN, 2008). 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 to change (IUCN, 2007).

In Ethiopia biomass fuel has met more than 90% of the total energy need (Mekonnen, 1996;Woody Biomass Inventory and Strategic Plan Project, 2002). It is projected to continue to dominate national energy consumption for many years and there are currently no signs that the energy demand-supply gap will be narrowed. Out of 11 regional states in the country most are consuming more than their woody biomass annual increment and the national wood fuel balance was negative (Woody Biomass Inventory and Strategic Plan Project, 2002) (as shown in Fig. 1).

Imbalances between wood consumption and sustainable supply will have serious economic, social and environmental implications. One scenario is that rural households will have to spend a large percentage of their time searching for fuel wood instead of performing productive work in agriculture. Similarly, fuel wood scarcity can lead to increased use of crop residue and animal dung as fuel. This will compromise their other uses such as fertilizer and

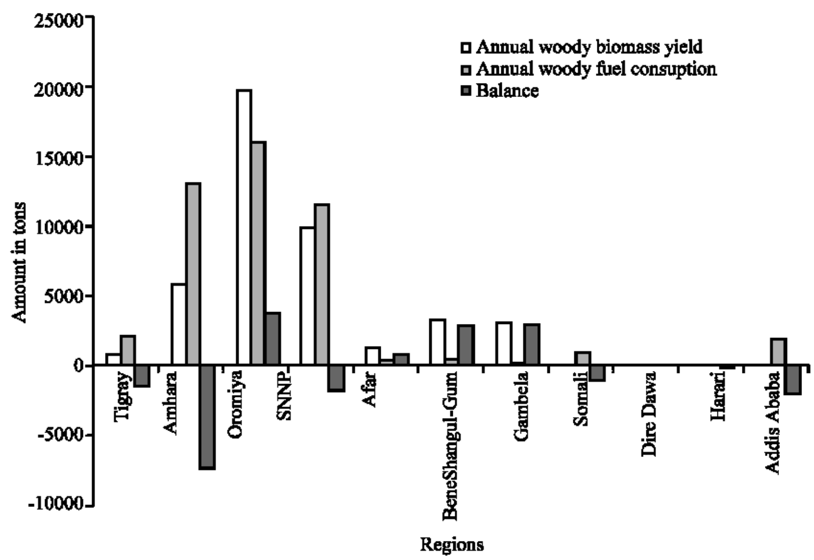

Fig. 1: National woody biomass annual yields, wood fuel consumption and balance in billions of ton, Source: Woody Biomass Inventory and Strategic Planning Project (2002)

animal fodder and could lead to severe reductions in agricultural output at a time when even greater production is expected in the sector (Mekonnen, 1996; Bensel, 2008).

Research has shown that new global and local trends as regards energy use and supply patterns have great impact on the future society and environment. This study was initiated with the aim to address the uncertainty and trends regarding the impact of wood harvesting for fuel and its ultimate effect on the sustainability of the forest resource in a local case study area in Ethiopia. The objectives were to determine current wood fuel demand, supply and balance and to screen factors and trends influencing future development.

MATERIALS AND METHODS

Description of the Study Area

The study area was in south west Ethiopia at 357 km away from Addis Ababa, the capital city. It includes Jimma town and 33 farmers associations that were nearer and living within 20 km of the town and were the potential source for fuel wood supply. The geographic location was between 36°72'12" -36°99'20"E longitude; 7°50'78" - 7°77'04" N latitude (Fig. 2).

Socio-Economic Condition

There are different ethnic groups that are living in the area and the dominant ethnic group is Oromo and most of them are also Muslims. The main economic activity and livelihood of the people in rural area is agriculture (crop, livestock and cash crops such as *Coffee arabica* and *Catha edulis*). The economic activities and livelihood of the people in urban area are mainly private business, government, non-government employees and traders.

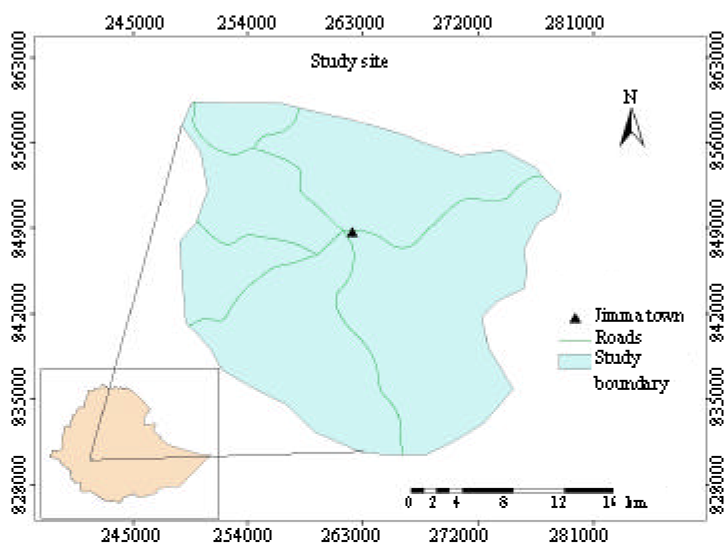

Fig. 2: Map showing location of the study site

Table 1: Population size of the study area

Rural		Urban	
Population (1994)	Projected population (2004)	Total population (1994)	Projected population (2004)
71562	97111	88867	120594

Ethiopian Energy authority (1994)

Population

Both urban and rural populations size were shown in Table 1.

To estimate population size in year 2004, population size of 1994 was projected at 3.1% annual growth (rate which was taken for the year 1994-2004 as shown by EFAP 1994 Vol. II). Population size indicated in 1994 was the census result.

Method

Wood Fuel Consumption

The study was conducted from Nov/2003-Jun/2004. Household and non-household sector in urban area and households in rural area were the target population from which data was collected to estimate fuel wood demand in the area. The number of households that was available from the previous census was considered which were 19146 and 20150 as urban and rural household, respectively (Central Statistical Authority, 1994).

There were variations between urban and rural households in terms of wood fuel consumption both in quantity and pattern and thus the household populations were broadly stratified as rural and urban.

Moreover, urban household population was divided into three strata based on income level since house hold expenditure is affected by income. The income category made by Central Statistical Authority (2002) divide the urban household into three sub-class; low, medium and higher which are 43, 49 and 8% in their proportion. Total sample size was 200 households which was nearly 1% of the total urban household population and was allocated to each stratum based on their proportion. Accordingly sample size in each stratum was 86, 99, 15 households from lower, middle, higher income category, respectively. Rural households collect fire wood from their own farm lands, home garden and open access forest free of any cost and household income was assumed to be not limiting wood fuel consumption. Hence, stratifying the rural households was not necessary for the study purpose and 70 households were the sample size in rural area. Data was collected interviewing the household using semi-structured survey questionnaire and stratified random sampling technique.

To determine the non-household sectors that have been using wood as a fuel, interview was made to organizations administering the non-household sector for tax purpose. Accordingly service giving business organizations (hotels, restaurants, cafeteria and bakery), government institutions (University, colleges, prison and hospital) and cottage industries (black smith, brick factory and pottery) were identified to be a user of fuel wood. 5% from each business organization and cottage industries and all of the government institutions were selected for this survey. Data was collected interviewing samples of randomly selected cottage industries and service giving business organization, where as complete census for service giving government institution.

Wood Fuel Supply

Survey of fuel wood supply ready for consumption and inventory of standing forest stock available as potential source for fuel wood were the two major studies to evaluate current and potential supply.

Wood Fuel Supply Ready for Use

Fuel wood ready for consumption is a wood fuel harvested from trees in forest and non-forestland, split, dried and tied in bundles and charcoal in sacks and is supplied to the town. The potential suppliers of wood fuel ready for use were peri-urban farmers, whole sellers and sawmills consumers own supply. Supply data was collected from wholesaler's depots sawmills and where as the supply by peri-urban farmers, consumers own were measured at established check points through which wood enters into the town. Questionnaire was designed to collect data on the quantity of supply by respective suppliers.

Growing Stock

Forest inventory was carried out to estimate the growing stock and its incremental yields within the study area. Different land uses vary in stock and thus inventory was carried out separately in each stratum. Total sample size was nearly 1% of the study area and allocating the total sample size to each stratum was determined based on the proportions of the area of each land use type.

Data Analysis

Demand Side

Household Sector

From each household, firewood and charcoal consumption was measured in terms of bundle and sacks number which was later converted into weight. Sample of 70 bundles firewood and 30 sacks of charcoal were randomly measured and weighed using spring balance and mean weight per bundle and sack were estimated. Then weighted mean weight household wood fuel consumption per annum was estimated as the product of mean weight per bundle and/or per sack and total number of bundles and/or sacks consumed by a household.

Weighted mean weight wood fuel (fire wood and charcoal) consumption by a household per annum was calculated as Steel *et al.* (1997):

$$\mu = \frac{1}{N}\sum_{i=1}^{l}(Ni)(\gamma l)$$

Where:

μ	=	Weighted mean weight wood fuel consumption by a household per annum
γi	=	Mean weight wood fuel consumption by a household in stratum l per annum
Ni	=	Total sample size
N	=	Total household population size
l	=	No. of strata

Weighted mean weight firewood consumption by an average household was converted to conventional unit, i.e., m^3 as:

$$X = \frac{\mu}{600}$$

where, X is mean volume of fire wood consumption per household per annum (m^3); μ is weighted mean weight household fire wood consumption per annum (kg); 1 m^3 air dry tropical hard wood weighs 600 kg.

The total amount of wood consumed as firewood was estimated as the product of mean volume of wood consumed as fire wood per annum per household and total number of household populations in the area.

Weighted mean weight charcoal consumption by an average household was converted to conventional unit, i.e., m^3 as:

$$P = Y/180$$

where, by P = Mean volume of charcoal consumption per household per annum (m^3); Y = weighted mean weight charcoal consumption by a household (kg); From 1 m^3 tropical hard wood 180 kg of charcoal can be produced.

The total amount of wood consumed as charcoal was estimated as the product of mean volume of wood consumed as charcoal per annum per household and total number of household populations in the area

Non-Household Sector

Estimating wood fuel consumption by the non-household sectors was calculated as:

$$Y = \sum_{i=1}^{n}(pi)(q)$$

where, by Y = Wood fuel consumed by all non-household sector per annum (m^3); Pi = mean volume of wood fuel consumption by non-household sector i (m^3); q = sample size of non-household sector i; n = total number of non-household sectors

Supply Side

Wood Fuel Ready for Consumption

Once data were measured on the amount of wood fuel inflow to the town by peri-urban, whole sellers, sawmills and consumers own, the amount of supply was calculated as:

$$A_n = (\frac{365}{21}.\frac{\sum_{j=1}^{n} yi}{600} + \frac{365}{21}.\frac{\sum_{j=1}^{m} zi}{180}) + \left(\frac{wi}{600}\right)365 + \sum^{r}(l - l.pi) + \sum_{i=1}^{s}(q - q.pi) + \left(\frac{bi}{600}\right)365$$

where, A_n is total annual wood fuel supply to the town (m^3), yi is weight of fire wood supplied per day by peri-urban farmers, zi is weight of charcoal supplied per day by peri-urban farmers, wi is weight of firewood supplied per day by whole sellers, l is m^3 of logs sawn for lumber per annum, q is m^3 of logs peeled for ply-wood per annum, pi is recovery rate both for lumber and ply-wood, bi is weight of consumer own supply per day, 1 m^3 of air dry wood is 600, 180 kg charcoal can be produced from 1m^3 of tropical hardwood, 365 is number of days/year, 21 is number of days for data collection on supply side, n is number of peri-urban farmers supplying fire wood, m is number of peri-urban farmers supplying charcoal, r is number of sawmills sawing timber, s is number of saw mills peeling timber for ply wood.

Potential Supply

Volume of the Growing Stock by Land Use Type and Total Volume of the Growing Stock

To estimate volume of each tree, diameter at breast height (D.b.h) and total height of the tree was measured using diameter tape and hypsometer and then volume of each tree was taken from the volume table developed for south western parts of Ethiopia (Chaffey, 1982). Then, volume per hector was determined by the following formula Philiph (1994):

$$\text{Vol ha}^{-1} = \frac{\sum_{j=1}^{m}\sum_{i=1}^{k} vi}{ma}$$

Where:
vi = Volume of kth tree
k = No. of tree in plot m
m = No. of plots
a = Area of each plot

Volume of the growing stock by land use type was determined as a product of volume per hector and area of respective land use type i.e.,

$$S = \left(\frac{\sum_{j=1}^{m}\sum_{i=1}^{k} Vi}{ma}\right)A$$

Where:
S = Volume of the growing stock in land use type l
A = Area of land use type l

Then total volume of the growing stock in the area was estimated as the sum of the volume of the growing stock in each land use types, i.e.,

$$TVG = \sum_{i=1}^{l}\left(\frac{\sum_{j=1}^{m}\sum_{i=1}^{k} Vi}{ma}\right)A$$

Where:
TVG = Total volume of the growing stock
l = No. of land use types

Incremental Yield

Estimate of Allowable Incremental Yield by Product Type

Allowable incremental yield by product type from each land use type was calculated as the product of total annual incremental yield from a given land use type and percentage of incremental yield allowable for a given wood product type (fuel wood, construction, fodder):

$$TIYP = \sum_{j=1}^{l}(AIY)P_i$$

Where:
TIYP = Total allowable incremental yield for product i form all land use type
AIY = Total annual incremental yield from land use type l

P_i = Proportion of incremental yield allowable for product i in land use j
l = No. of land use type

Balance

- The current balance is calculated by the difference between total volume of wood fuel harvested and estimated demand
- The difference between allowable yield as incremental yield and harvest amount determines the sustainability of the resource in the area

RESULT

Wood Fuel Consumption by Sector

The finding displayed in Table 2 shows, in the area about 0.062 million m^3 woods was consumed by the urban households whereas 0.133 million m^3 was consumed by the rural households. 0.011 million m^3 wood was consumed by urban non-households sector. The finding reflects as the rural households took the first line share in wood fuel consumption in comparison to urban household, the reason might be, the urban household had alternative modern fuels. In general in the area 95% of the total wood fuel is consumed by the household sector where as 5% of the wood fuel was consumed by non-household sectors.

Energy Consumption Pattern

The total energy need was estimated at 0.27 millions m^3 of wood equivalent of which 0.207 million m^3 was derived by consuming wood as a fuel (fire wood and charcoal), where as about 0.02, 0.03, 0.003 and 0.0027 million m^3 of wood equivalent was derived from crop residue, cow dung, electricity and kerosene (Fig. 3). Wood fuel (fire wood and charcoal) covers 77% of the energy need in the area; where as the rest of the energy demand was satisfied utilizing cow dung, crop residue, electricity and kerosene while each of them was contributing 7, 12, 3 and 1%, respectively. In general 96% of the need was satisfied by the supply from biomass (firewood, charcoal and cow dung and crop residue).

Table 2: Total wood fuel demand by sector in millions of m^3 per annum

Target population	Total wood fuel consumed	Percentage by sectors
Urban household	0.062	
Rural household	0.133	
Subtotal	0.195	95
Urban non-household	0.011	5
Total	0.206	100

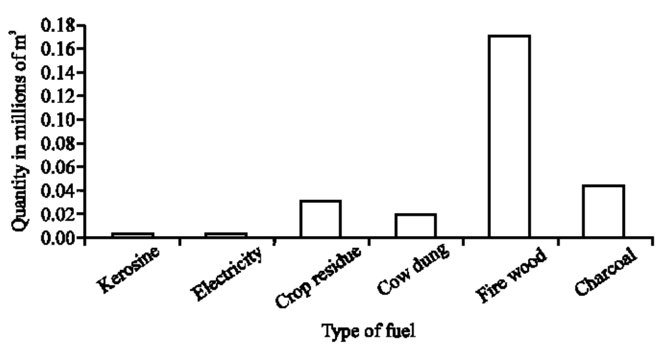

Fig. 3: Contribution of different fuels as a source of energy as expressed in wood

Fuel Wood Supply Ready for Consumption

The total urban wood fuel demand was estimated at 0.073 million m^3 (0.062 million m^3 for household consumption and 0.011 million m^3 for urban non-household sector) (Table 3). 86% of the total supply was by peri-urban suppliers; where as 8, 0.84 and 6% of the supply was by whole sellers, sawmills and consumer owns, respectively. In rural area it was expected that consumption was equivalent to the supply amount as there were no factors limit harvesting and consumption during the study time. Thus the supply amount was estimated at 0.133 million m^3.

Potential Supply and its Annual Incremental Yields

Allocation of incremental yield by wood product category is based on the % break down of incremental yield by land use type and product category (industrial, construction, fuel wood and fodder). Figure in Column 2, 4, 5, 6, 7, 8 and 9 were findings generated by this research; where as figures in column 3 was taken as annual incremental yield by land use type, annex 2.1.3, page 16 of 27.

From Table 4 it can be observed that the total growing stock and annual incremental yield was 4.14 and 0.121 million m^3, respectively. The total annual incremental yields allowable for industrial, construction, wood fuel and fodder were 0.01, 0.02, 0.07 and 0.02 million m^3, respectively. Thus 0.07 Million m^3 was allowable annual yields for fuel wood.

Balance

From the finding it was observed that the actual growing stock was estimated at 4.14 million m^3, where as the annual allowable incremental yield for fuel was estimated at 0.07 million m^3. The accrual harvest to supply the current demand were 0.211 million m^3.

Table 3: Total quantity of wood fuel supply in millions of m^3 per annum

Area	Supplier	Quantity
Urban	Peri-urban Farmers	0.067
	Whole sellers	0.006
	Saw mills	0.0007
	Consumers own	0.005
	Sub-Total	0.078
Rural	Sub-Total	0.133
	Grand Total	0.211

Table 4: Growing stock, incremental yield/hectare total incremental yield by land use type, break down of annual incremental yield by land use type and wood product category (wood fuel, construction, industrial and fodder)

Land use type	Growing stock in million (m^3)	Incremental yield ($ha\ year^{-1}$) (m^3)	Area of each land use types (ha)	Total annual yield (AIY) by land use type in millions (m^3)	Break down of total annual incremental yield by wood product category in millions (m^3) Industrial	Construction	Wood fuel	Fodder
Intensively cultivated land	0.90	1.10	0.0200	0.02	0.00	0.002	0.014	0.006
Potential agricultural land	0.522	2.10	0.0060	0.013	0.00	0.001	0.008	0.003
Natural high forest	1.128	9.50	0.0040	0.038	0.01	0.006	0.023	0.00
Coffee forest	0.725	4.30	0.0050	0.022	0.00	0.005	0.004	0.012
Riverine forest	0.0732	5.20	0.0006	0.003	0.001	0.0005	0.002	0.00
Shrub	0.186	1.20	0.0020	0.002	0.00	0.00	0.002	0.00
Grazing	0.207	1.56	0.0030	0.0045	0.00	0.0005	0.003	0.001
Community wood lot	0.113	9.60	0.0005	0.005	0.00	0.001	0.003	0.00
Industrial plantation	0.1494	14.40	0.0006	0.009	0.002	0.002	0.005	0.00
Settlement	0.135	1.10	0.0030	0.004	0.00	0.001	0.002	0.00
Total	4.14	-	0.045	0.121	0.012	0.02	0.067	0.022

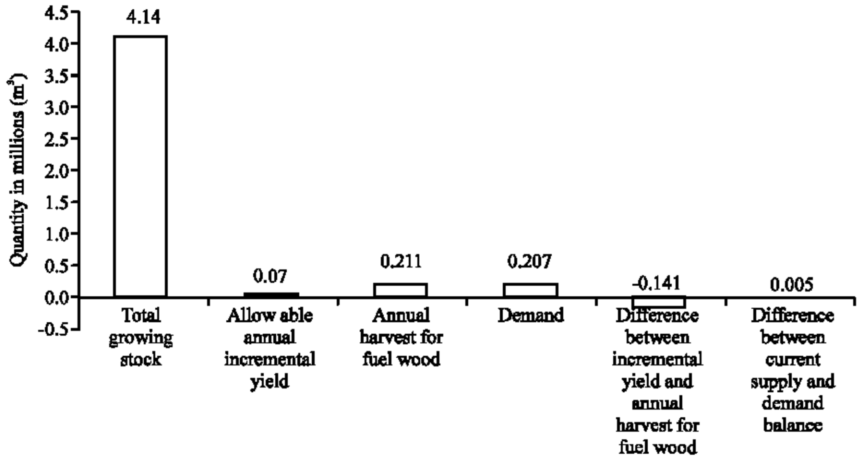

Fig. 4: Growing stock, annual allowale yield and annual harvest for fuel wood, consumption and balance

Annually there was an over supply of wood fuel to the town by 0.005 million m^3 in the year 2004 (as shown in Fig. 4). The annual harvest amount exceeds the annual allowable supply for fuel wood by 141 million m^3 and this amount was met by extracting growing stock. The difference between the allowable annual quantity of wood for fuel from incremental yield and the quantity of wood harvested to meet the demand was negative 0.141 million m^3 (as shown in Fig. 4).

DISCUSSION

Wood Fuel Consumption by Sector

Past studies indicate that, the household sector utilize 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 trend of household energy consumption was 88, 93, 86, 89 for the year 1982, 1989/90, 1992/3, 1995/96, respectively (Bereket *et al*., 1996). However, the pattern of household energy consumption is noticeably different among settlements. In Ethiopia household energy means rural energy and rural energy means biomass. In some parts (especially western Ethiopia), firewood remains principal household fuel source (Alemu and Tekie, 2003). The out come from this local case study also indicate as the household sector is the dominant energy consumer of which biomass for fuel is the principal, 96% of the energy comes from biomass (fuel wood, cow dung and crop residue) (Fig. 3). Such dependency on wood for fuel (fire wood and charcoal) would put pressure on the forest resource potential and tree stock out side forest in the area.

Energy Consumption Pattern

In the past, biomass fuels (firewood, charcoal, twigs, leaves, straw, stalks, crop residues and animal dung) contribute about 94 percent of the gross energy supply of Ethiopia, which is one of the highest in the world. The percentage of biomass fuels to the total energy in Africa is only 37% in 1989; it was 94% for Ethiopia and 79% for Kenya and 67% for Ghana (Alemu and Tekie, 2003).

Recent research findings also show there is no change in pattern of energy consumption, where biomass fuels remained the principal energy resources in the country. According to the estimate made by (Mekonnen, 1996; Woody Biomass Inventory and Strategic Plan Project, 2002) more than 92% of Ethiopia's current total energy demand is met using biomass fuels, where as the finding from this study revealed that 96% of the total energy need is met using biomass fuel in the study area. Moreover, this research finding reflects as there was high dependency on biomass for fuel locally. The most significant implication of high dependency on biomass for fuel is its association to deforestation and tree stock decline. According to Anderson (1986), consumption of fuel wood energy by households in Ethiopia is 10 times the total consumption of commercial energy for all purposes.

Combustion of crop residues and dung leads to lower inputs of soil organic matter, poor soil structure, lower retention of available nutrients in the crop root zone and reducing protection from erosion by heavy rainfall, exerting its impact on agricultural yields. Thus, the increasing of biomass consumption which goes partly with population growth has an influence on the ecological balance and consequently lowers food production and implies poverty (Alemu and Tekie, 2003).

Fuel Wood Supply Ready for Consumption

In the year 2004 the total amount of wood harvested to supply the current demand was estimated at 0.211 millions m^3 of which 0.078 million m^3 and 0.133 were consumed in urban and rural area, respectively. Most of the wood fuel supply to the town has been by peri-urban farmers; where as nearly 14% of the total supply to the town was supplied by whole sellers, saw mills and consumers own supply from community wood-lots, natural high forest, industrial plantation forest and private wood lots and farmlands. The supply for consumption in the rural area is from the open access forest, trees on farmland, coffee forest and home garden, privately owned woodlot and natural high forest. Households in rural area were supplied by women's and children, which might put additional work load on top of other agriculture activity.

Potential Supply and its Incremental Yields

In the area the potential sources for wood fuel were trees and shrub from farm and settlement land, natural high, coffee and riverine forest, shrub and grazing land, community woodlot and industrial plantation. Historical transect was conducted to evaluate the causes of forest depletion over time in the area revealed that rapid increment in human population size has been the underlying causes to increase demand for agricultural and grazing lands, firewood, charcoal, timber, construction and many other uses which have put very high pressure on the growing forest stock and its incremental yields (Kiflu, 2004). The trend analysis was further synchronized with the quantitative estimates made by Woody Biomass Inventory and Strategic Planning Project (2002); the rate of forest depletion in Jimma zone is 3.1%. With such rate of deforestation in the area, 55% forest will be lost within in the years 2004-2023. Rate of destruction can be exacerbated if disturbance for coffee cultivation and the rate of population increment by immigration were taken into account. Moreover, the extent of forest depletion due to over harvesting for fuel was quantitatively evaluated through supply-demand and balance analysis as shown in wood fuel balance analyses in this study.

Balance

In the study area harvesting for consumption was 3 times higher than the incremental yield, allowable to be harvested for fuel in 2004. Hence to meet the demand, there is over harvesting of wood by 0.141 million m^3 for fuel which even exceeds the total annual incremental yield by 116%. Over harvesting results in degradation and depletion of certain amount of the growing stock that would have been available for future growth. With reduction of the growing stock future incremental yield will decline which will hasten rate of forest depletion. From past studies it was observed that, the annual rate of consumption has reached the point where it is estimated to exceed the mean annual incremental growth of local tree stocks and forest reserves by 150 percent in Ethiopia. This intensifies the spread of deforestation, which is accompanied by readily visible ecological damage and economic costs, as measured in terms of a threat to the carrying capacity or fertility of soil (Anderson, 1986).

In recent studies, wood fuel demand in various regions of the developing world were compared with the rates of annual growth in biomass from existing forest resources and in those cases where demand exceeded growth it was assumed that the difference was being met by over-cutting and which may result in depletion of forest resources (Arnold *et al*., 2003; Woody Biomass Inventory and Strategic Plan Project, 2005; Arnold *et al*., 2006). As forest resources diminish rural households will have to spend a large percentage of their time searching for fuel wood instead of performing productive work in agriculture. Similarly, fuel wood scarcity can lead to increased use of crop residue and animal dung as fuel. This will compromise their other uses such as fertilizer and animal fodder and could lead to severe reductions in agricultural output at a time when even greater production is expected in the sector (Mekonnen, 1996).

Moreover, coupled with other causes of deforestation, over extraction of the forest resources for fuel and other forest products may degrade the quality of the forest in terms of species composition, diversity and growing stock which may cause destruction of ecosystem structure and function. Forest ecosystem structural and functional degradation imply local forest product famine, loss of biological diversity which may contribute to the expansion of desertification globally.

CONCLUSIONS AND RECOMMENDATION

In this study it was tried to address the level and changing pattern of wood energy demand and supply and to discuss impact of current wood harvesting on the future condition of the potential resource and consequence of its loss on human wellbeing due to loss of biological resources and subsequent forest product famine and climate change.

The finding reveled 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, high population growth rate have increased forest product demand that caused the forest to be harvested above its annual incremental yield in the area. In the survey of fuel wood demand and supply it was found that, the volume harvested from the forest far exceeds the annual allowable cut resulting in negative balance.

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. Consumption need is met by actual harvest, in 2004 harvesting to satisfy wood fuel demand is 3 times grater than the allowable annual harvest.

When the rate of harvesting is in excess of the annual increment mining of the wood fuel stock is said to be taking place which would bring a wood fuel deficit. Once mining begins, amount of stock figure is reduced; which is assumed to lead to a reduction in annual increment which, in turn, leads to increase the deficit and rate of stock depletion. Annual increase in consumption, coupled with other causes of deforestation accelerates total depletion of forest stocks. Thus, intervention is needed to achieve sustainability. Efforts have to be done to reduce harvesting below annual incremental yields. If the projected wood fuel consumption is lower than the annual increment, the standing stock remains untouched and the wood fuel supply is sustainable.

On the supply side, wider adoption of agro-forestry system, expansions of community fuel wood lots and plantation, increasing the productivity of existing forest resources, replacing open access with regulated harvesting are expected to increase the growing biomass stock as a potential supply. Whereas the demand side intervention could be: Improving end- use efficiency of traditional fuels stoves, developing alternative renewable domestic fuels, reforming family planning, economic policy which might cut down the demand side for resource utilization.

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