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REVIEW OF THE EXISTING STUDIES RELATED TO FUELWOOD AND/OR CHARCOAL

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This paper has been minimally edited for clarity and style

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ACRONYMS	
CFW:	Cash for Work
FFW:	Food for Work
MOA:	Ministry Of Agriculture
LRCPD:	Land Resources and Crop production Department
FAO:	Food and Agricultural Organisation of the United Nation
TCP:	Technical Co-operation Program
ToR:	Terms of Reference
GDP:	Gross Domestic Product
CHZ:	Central Highland Zone
WEZ:	Western Escarpment Zone
SWLZ:	South Western Lowland Zone
GBZ:	Green Belt Zone
CPZ:	Coastal Plains Zone
NWLZ:	North- Western Lowland Zone

1. INTRODUCTION

1.1. Country Profile

1.1.1. Geographical Location, Demography and Economy

Eritrea is located in the northeastern part of Africa and covers an area of 124,320 km^2. It is bounded by the Sudan in the west and north west, Ethiopia in the south, Djibouti in the southeast, and the Red Sea in the east (FAO/ Sectoral review, 1994). Administratively, Eritrea is divided into six zones (*zoba*) namely: Makel, Debub, Gash-Barka, Anseba, Semenawi Keih Bahri, and Debubawi Keih Bahri.

The population of Eritrea is about 3.5 million out of whom 80% live in rural areas and derive their livelihood from agriculture. There are nine linguistic groups namely: Afar, Bilen, Tigre, Saho, Tigrigna, Kunama, Nara, Hidareb, and Rashaida (MOA, 1993).

Due to the prolonged liberation war, the economy of the country progressively declined during those years. Between 1985 and 1990, real gross domestic production (GDP) declined by 0.7% per annum, but after independence it is increasing rapidly (E.g. in 1997 an increase of 8% was reported). Agriculture is the main economic sector, both as a source of food and raw material for industry. In 1994, crop production, livestock, forestry, and fishery contributed about one-third of the gross domestic production (FAO, 1996).

1.1.2. Bio-Physical Environment

- **Topography**

Eritrea is a country of great topographical diversity. Through millennia, erosion, tectonic movements and subsidence have occurred and continue to occur accentuating the unevenness of the surface. Highland areas stretch between the eastern and western lowland plains. Altitudes range from the highest peak of Mount Soira, 3018 metres above sea level, down to the Denkel Depression, about 100 metres below sea level (MOA, 1994).

- **Agro-Ecological Zones**

According to FAO (1994), Eritrea is divided into six agro-ecological zones. These are: the Central Highland Zone (CHZ), situated at altitudes over 1,500 m with over 500 mm of rainfall; the Western Escarpment Zone (WEZ), situated at altitudes between 750 and 1,500 m with annual rainfall between 400 and 600 mm; the South Western Lowland Zone (SWLZ), situated at altitudes between 600 and 750 m, with annual rainfall between 500 and 700 mm; the Green Belt Zone (GBZ), located between 750 to over 2000 m, with rainfall from 700 to more than 1000 mm; the Coastal Plains Zone (CPL), from below sea level to 600 m, with less than 200 mm rainfall; and the north-western Lowland Zone(NWLZ), with an altitude from 400 to 1,500 m, and up to 300 mm of rainfall.

- **Climate**

Due to its geographical setting, Eritrea has diverse climates ranging from hot arid, adjacent to the Red Sea to temperate sub-humid in isolated micro-catchments within the eastern escarpment of the Highlands. About 72% of Eritrea is classified as very hot, with mean annual temperature exceeding 24° C, while not more than 14% is classified as mild or cool with mean annual temperature below 21.5^{o} C (FAO, 1996).
Most parts of the country receive rainfall from the southwest Monsoon, from April to September. Some rain falls in April/May while the main rain starts in June, with the heaviest precipitation in July and August. Only the coastal plains and the central part of the eastern escarpment of the central highland have winter rainfall, November through March, that is borne by north and south-east continental air streams that carry little moisture until affected by the Red Sea. The total annual rainfall tends to increase from north to south, from less than 200 mm at the northern border with Sudan to more than 700 mm in the south-western part of the country. The Green Belt Zone, receives the highest annual rainfall averaging about 900 mm (FAO, 1994).

- **Soils**

The soils of Eritrea are complex. In the northern and southern sections of the Red Sea coastal plains, they are predominantly sandy desert soils. In other part of the plains, *ortho-solonchaks*, *regosols*, and *andosols* are to be found. In the Highlands, the predominant soils are chromic, eutric, and calsic *cambisols* of strong red colour. Other soils found in the Highlands are *lithosols*, *xerosols* and *fluvisols*. Soils in the western plains include *vertisols* and *fluvisols* (FAO, 1996).

1.2. Significance of the Study

About a century ago, almost one third of Eritrea's territory was covered with natural forest and extra vast area of acacia woodland. Now the country is left with less than 1% natural forest and very few million hectares of degraded acacia and scrublands (Table 1). As the forests were deteriorated, tremendous important habitat of the wild life was dwindled and so for the degradation of land fertility due to high rate of soil erosion. The main reason for the aggravation of the process were intensive logging for timber, charcoal making, agricultural expansion, poles and post for traditional house '*Hidmo*' and fire wood and generally unwise land use policy of the successive colonial Governments.

Fuelwood is one of the serious detrimental demands on ecology. It is the major source of household energy in the country. Nearly every household in the urban centres and all the rural areas of Eritrea, depend on wood as their main source of energy. It is very evident then many more trees have to be cut down on a continued basis from the limited resource to meet the relentless demand of fuelwood by the population.
A government legislation banning the cutting of live trees is in effect since 1994, but the compelling demand for this energy source makes it hard to hold as people who are left with virtually no energy alternative in their hands will be forced to continue cutting. The biggest share, for cause of forest distraction, lies with tree cutting for the purpose of fuelwood. This is followed by timber cutting for use of construction poles.

This paper reviews the existing studies related to fuelwood and/or charcoal in the country during the last five years at national or regional level, and analyses the past, present and possible future trends of these products in the context of local consumption.

2. FOREST RESOURCES

2.1. Natural Forest Resources

Three major forest/woodland types are distinguished in Eritrea: highland forests, Acacia woodlands and riverine forests. Originally the highland forests of *Juniperus procera* and *Olea africana* would have extended over much of the plateaux, but have been largely destroyed or degraded; only remnants now survive. On the lowlands and lower escarpments, *Acacia* woodlands occupy about a quarter of the surface of the country. Riverine forests fringe river systems of the Gash/ Mereb, Setit and Barka in the Lowlands, where Doum palm is an important constituent. These forests are under the greatest threat as they occupy fertile, well-watered and level sites – suited to development for commercial agriculture. However, they are also vital to the lives of the local population. On the coastal plains tree cover becomes increasingly sparse towards the sea. In places mangroves border the coast, the main species being *Avicennia marina*.

Natural forest cover has been classified according to six major vegetation types following international methodology.

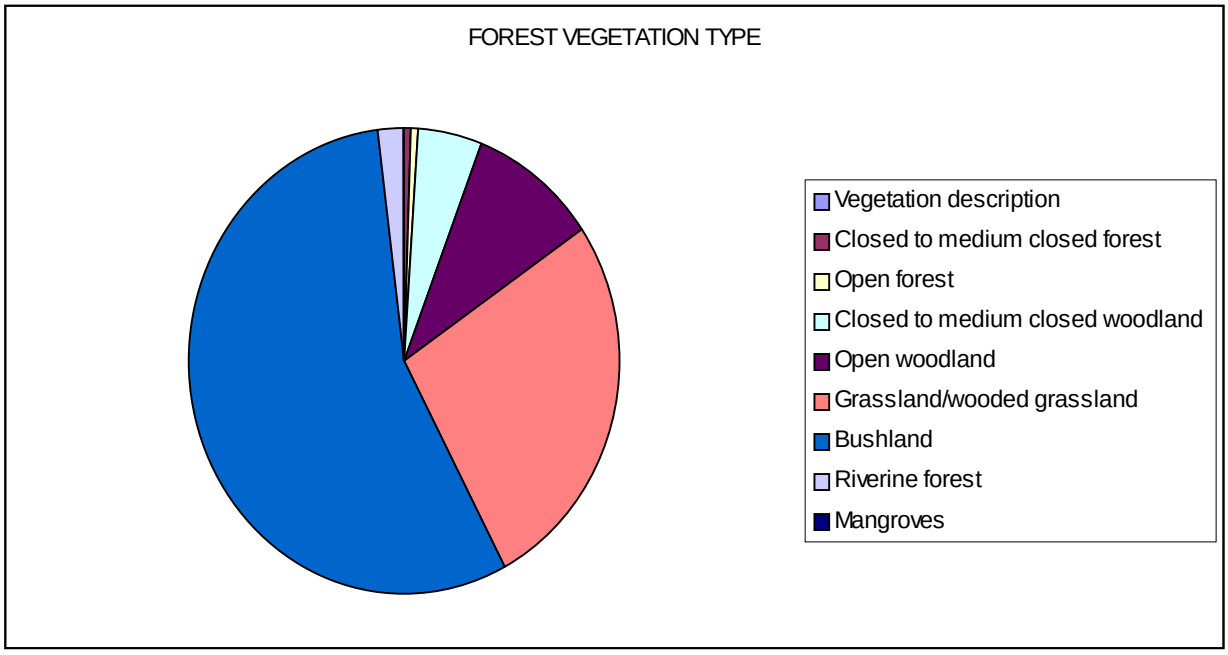
1. Highland forest, composed of a mixture of coniferous species (*Juniper*) and broad- leafed species (African olive and associated species)
2. Mixed woodlands of *Acacia* and associated species, occurring mainly in the southern part of the western lowlands, but also in restricted areas elsewhere in the country;
3. Bush or shrub vegetation, which is the dominant cover in Eritrea;
4. Grasslands and wooded grasslands, which occur in many parts of the country;
5. Riverine forest, composed essentially of Doum palm, which is common in the Western Lowlands and is frequent in the Eastern Lowlands; and
6. Mangrove occurring in many places along the coast and concentrated mainly around Assab and between Tio and Massawa.

The natural vegetation of the country constitutes 0.8% highland forest. Forest and woodlands, including riverine forest and mangroves cover 13.5% of the total area. The category “bush” is the dominant vegetation in Eritrea covering 63% of the total area. The riverine forests and mangroves play important ecological and economic roles for rural communities, and occupy 1.5% and less than 0.1%, respectively.
(Source: Interpretation of Landsat TM by FAO project TCP/ERI/12 (July, 1997)).

The most recent national vegetation cover data is presented in Table 1.

Table 1: Forest/ Woodland Types and Distribution

Forest Type	Km^2	Share of Total Area
Forest		0.8%
Closed to medium forest	591	
Open forest	410	
Woodland		11.3%
Closed to medium closed woodland	4533	
Open woodland	9541	
Bushland		63.8%
Grassland/Wooded Grassland	25,577	
Bushland	53,824	
Riparian forest		1.6%
Riverine forest	1,865	
Mangroves	64	



Source: FAO, 1997

In the above table, it shows that Eritrea has an important vegetation cover composed of woodlands riverine forests and mangroves, in addition to the *Juniper-Olea* forest. The total area of these formations constitutes 13.7 % of the total landmass of the country.

2.2. Planted Forest Resources

Prior to liberation (before 1991), though few accurate records were maintained, tree planting was concentrated within 6 major catchments (namely, Anseba, Nefhi, Damas, Mereb, Ferendayt and Leghede) as part of a soil and water conservation strategy, based on Food- for-Work. In this way over 10,000 ha of plantation were planted, mainly consisting of *Eucalyptus cladocalyx, but also E. globulus,*

E.camaldulensis, Acacia saligna, A.decurrens, A. mearnsii, etc. Such work was nearly always combined with physical terracing operations. Due to the lack of subsequent maintenance, few of these plantations remain.

In the years leading up to liberation, tree planting by farmers appears rarely to have taken place. Tree planting for amenity by municipalities has obviously taken place in the past, to good effect, but due to the uncertainties prevailing over latter years, existing trees have been damaged, or have died, and there has been little management or replacement.

This tree planting was based on approximately 31 nurseries, located principally within territory held by the Ethiopian Government.

Following liberation (1991 - 1998) about 69.9 million seedlings have been planted and 147,580 ha of an area closed for natural regeneration. Details of major activities are tabulated below:

Table 2: Achievements of Afforestation Programme (1991 – 1998)

No	Activity	Unit	Achievements
1	Hillside terrace con.	ha	18,838
2	Check dam con.	km	2,169
3	Micro basin con.	No	1,084,164
4	Seed collection	kg	21,654
5	Seedling- production	No	84,006,154
6	Planting & Replanting	“	69,938,448
7	Road-construction	km	261
8	Spot weeding & cultivation	ha	1,273
9	Nursery establishment	No	47
10	Closure area	ha	147,580
11	Peasant training	No	4,440

The survival rate of the planted seedlings, is about 30 - 40% in the Lowlands and 60 - 70% in the Highlands.

Since Liberation, there has been an upsurge of interest on tree planting by individuals, communities and organisations with large numbers of seedlings collected from nurseries, free of charge. Since 1994, the Eritrean students have been participating in afforestation and soil conservation campaign during summer vacation, in the whole country, which is organised by the Ministry of Education and the Ministry of Agriculture. Since then, about 19,000 students have participated every year and planted about 5.8 million tree seedlings.

The main afforestation programme is directed at soil and water conservation and fuelwood production. There has been a major and commendable commitment by the Eritrean Government to continue a programme that evolved under the Ethiopian regime as an instrument of international food assistance. The old model of Food For Work (FFW) or Cash For Work (CFW) was successful to the extent that it engaged

community participation in the short term. But, it has no mechanism to engage them beyond that because they are unable to identify with the objectives and outputs, hence the government is assessing the cost-effectiveness of continued investment along this lines.

3. TIMBER AND POLE PRODUCTION

Eritrea's timber heritage was expropriated by the Italians. During the Italian colonial era, logging in Eritrea was intensively carried out. Up to 1947, 55 sawmills and small wood processing firms were established in the country. (Aldo, 1947, cited in MOA, 1994).

The major tree species exploited by the logging companies were *Juniperus procera*, *Olea africana*, *Hyphaene thebaica*, *Balanites aegyptiaca*, and *Acacia albida/Faidherbia albida*/. Sawlogs were transported by trucks and, in areas where access was difficult, cable was used (Ramanatan, 1978, cited in MOA, 1994).
At this time, except about four old sawmills, which are most of the time idle in Asmara, all other sawmills were either non-existent or closed due to a lack of sawlogs (personal observation).

A typical home in the highlands (the *Hidmo*) will take about one hundred poles to be constructed, a staggering number which is equivalent to felling of one hundred live trees. Currently in Eritrea, it can be said that there is virtually no timber trees left for construction, all timber is imported. It is estimated that around 60,000 cubic metres of sawn timber and semi-finished wood is imported annually. The landed value of timber is currently around $ 332 per cubic metre. (FAO 1997). Transmission poles and scaffolding are also imported. Matches are produced in Asmara from imported splints. Undoubtedly Eritrea has an expanding need for construction grade softwood timber, spurred by an expanding population and expectations of rapid development.

4. FUELWOOD CONSUMPTION AND SUPPLY

4.1. Fuelwood consumption

There are very few studies conducted on to the availability and consumption of fuelwood and/or charcoal both at national or regional level.

4.1.1. Studies Conducted at National level

A. Study Conducted by the Department of Energy

Where fuelwood consumption is concerned, the Department of Energy in co-operation with Lahmeyer International (a company from Germany) has carried out a project "Strengthening the Department of Energy (DOE)" during February 1996-March 1997. The main objectives of the project were: -

- Strengthening the management capacity and development of the personnel in the DoE in areas of energy policies, planning, analysis, system modelling for energy and the environment, this includes in particular the initiation and establishment of a data base.
- Formulation of recommendations aiming at improvement of energy efficiency and
- Implementation of energy saving measures in the various economic sectors.
- Development of energy standards and regulations in the electric utility, oil refining and distribution system and in the field of renewable energies.

16 different studies have been done, among which the household energy survey and the national energy balance have more relevance in regard to fuelwood consumption.

Household Energy Survey

The objective of the household energy survey is to conduct or guide an undertaking of a household energy survey of demand and supply and compile in a usable form. Beside this, recommendations concerning the following aspects should be provided:

- the environmental impact of the harvesting of forest resources, animal dung and agricultural residues,
- the foreign currency impact of fuel-switching,
- organisational issues in the manufacturing and marketing of improved cooking stoves and
- renewable energy projects including village electrification.

In addition to this, the study team goes somewhat beyond the ToR in two aspects:

- Some preliminary findings are set out based upon an initial analysis of the results, and
- it recommends directions given for further in-depth analysis.

In the absence of reliable national population figures, a range of levels of household energy consumption are presented, and an illustrative example is presented giving estimated area and national energy consumption levels for a specimen set of population figures.

The field survey was carried out with national coverage according to a stratified design which sampled rural, small urban, medium urban and large urban (where applicable) in 11 Household Energy Areas (HEA, see Table 3) which defined for the purpose of the study in order to stratify the samples in homogeneous household energy-consuming zones. 2,065 households were interviewed in all the region of Eritrea.

Table 3: Samples Taken, by Strata and Cluster

HEA	**Stratum**	ACTUAL CLUSTERS SAMPLED	**Actual Sample Size**
Coastal Zone	Rural	Gahtalay (1) Unga	20 45
“ “	Returnees from Sudan	Gahtalay (2)	32
“ “	Large Urban A	Massawa	91
“ “	Large Urban B	Assab	100
N. Read Sea Zone	Rural	Dongolo-Tahtay	49
“ “	Medium Urban	Ghindae	79
Northern Highlands	Rural	Halhal Rural	65
Southern Anseba	Rural	Halib Mentel	62
“ “	Small Urban	Hagaz	50
“ “	Large Urban	Keren	100
NW Lowlands (Barka)	Rural	Aderde	65
“ “	Returnees from Sudan	Tekreret	66
“ “	Small Urban	-	0
“ “	Medium Urban	Agordet	61
S-W Lowlands (Gash)	Rural	Gogne Rural	66
“ “	Small Urban	Tokombia	55
“ “	Medium Urban	Barentu	66
SW Debub	Rural	Adineamin Dirko Adelgse	65 50 50
“ “	Small Urban	Areza	71
SE Debub	Rural	Forto Maereba Kelay Bealtet	54 65 65
“ “	Small Urban	Dekemhare	103
N.Debub	Rural	Tera-Emni	50
“ “	Small Urban	-	0
Maekel	Rural	Tseazega	50
“	Small Urban	Embaderho	67
“	Largel Urban	Asmara City	303
Total	21 Strata		2,065

Data collected covered the following:

- Type and source of all fuels
- Distance and time taken for fuel collection (present and past)
- Price of fuels consumed
- Frequency of fuel collection
- Amount of fuelwood, charcoal, agri-residue, animal dung and kerosene normally consumed, and extent of use of each for cooking, beverages, etc

- Amount of each fuel actually consumed last month, and extent of use of each for cooking, water heating, lighting and other activities
- Level of consumption and uses of electricity
- Consumption of liquid propane gas (LPG)
- Religion, ethnic group, household size and composition
- Annual harvest volume, farm and non-farm income, livestock owned
- Problems and possible solutions concerning household energy

According to this study, 78% of the total national energy consumption is consumed at household level and 59% of the total final national energy consumption is from woodfuel.

According to the household energy survey, 69.4% of the total household energy consumption is from fuelwood and 10.7% from charcoal (table 4).

Table 4: Total Household Energy Consumption: Using a Specimen 1996 Population Estimate of 2.9 million

Fuel	**Quantity**	**Conver -sion Factor**	**Units**	**Million GJ**	**Million TOE**	**%**
Fuelwood	1.29Mil.MT	16.6	MJ/kg	21.41	511.1	69.4
Charcoal	0.114Mil.MT	29.0	MJ/kg	3.31	78.9	10.7
Animal Dung	0.37Mil.MT	12.0	MJ/kg	4.44	106.0	14.4
Agri-Residue	0.047Mil.MT	15.0	MJ/kg	0.71	16.8	2.3
Kerosene	0.0229Mil.MT	35.4	MJ/lt	0.81	19.3	2.6
LPG	0.00125Mil.MT	45.7	MJ/kg	0.06	1.4	0.2
Electricity	36.1Mil.kwhr	3.6	MJ/kwhr	0.13	3.1	0.4
Total				**30.86**	**736.6**	**100.0**

Key Findings

Household size varies geographically, from a mean of 4.23 in Maereba (SE Debub) to 7.34 in Barentu (SW Lowlands). The average household size for the total (unweighted) national sample is 5.52, with 95% confidence limits of ± 0.125.

Fuelwood is consumed by 88% of the households sampled, mainly for cooking. Per capita consumption of fuelwood varies from an average of 116 kg/y in Zoba Maekel Rural to 965 kg/y in Coastal Rural. When fuelwood is not readily available in the rural areas, the substitute is generally animal dung or agricultural residues.
The price of fuelwood ranges from 140 to 800 Nakfa/T, the higher end of the price range applying to Asmara. The (round-trip) distance travelled by household members to obtain fuelwood has risen significantly in many areas over the last 30 years to between 10 and 20 km, although the emergence since independence of traders selling fuelwood door-to-door has effectively eliminated this journey in several areas, particularly in small urban centres.

The pattern of charcoal consumption in Eritrea is a complex one. In the lowlands, some households report buying it locally. In other areas, most of the charcoal consumed is taken in the form of partially burned fuelwood from the injera cooker. The unweighted mean consumption per capita of charcoal by the households interviewed is 42 kg/cap/y. Of this, between 10 and 14.5 kg/cap/y is obtained commercially. Charcoal ranges in price from 390 to 2,800 Nakfa/T, with an unweighted mean price of 1,400 Nakfa/T.

Animal dung is used principally not as a preferred fuel but as a substitute for fuelwood in areas where fuelwood is not easily available. Most of it is obtained locally and individually. It is not yet common for animal dung to be marketed commercially. The unweighted mean consumption rate of the household interviewed is 111 kg/cap/y.

The consumption of agricultural residues as a household fuel is not as widespread in Eritrea as other biomass fuels. As in the case of animal dung, the majority of the consumption takes place in the fuelwood-scarce parts of Debub. The unweighted mean consumption rate of the households interviewed is 13 kg/cap/y.

National Energy Consumption Levels

In order to illustrate the type of aggregation that will be possible to carry out for the estimate of national household energy consumption when the forthcoming population census has been conducted, energy intensities for each fuel consumed, and for each HEA, have been combined with an estimated population estimate of 2.9 million to provide illustrative figures for regional and national household energy consumption and possible scale of consumption of forest resources.

The following Table sets out estimated consumption of biomass fuels by households given a hypothetical 1996 population of around 2.9 million

Table 5: Estimated Consumption of Biomass Fuels by Households given a Hypothetical (1996 Population of around 2.9 Million)

Biomass Fuel	Consumption Rate (weighted)	Annual Consumption (Million MT)
Fuelwood	440 kg/cap/ann	1.29
Charcoal	39 kg/cap/ann	0.114
Animal Dung	126 kg/cap/ann	0.37
Agri-Residue	16 kg/cap/ann	0.047

These volumes refer to energy consumption. The supply of these fuels is more complicated, as much of the fuelwood reported above is re-used in the form of charcoal taken from injera cookers and from the brewing of drinks such as *suwa* (some of which is sold to informal sector and small-scale enterprises, which are not included in the survey). Thus, despite the figure of 114,000 T/y of charcoal consumed, the ban on charcoal has been quite successful. According to the household energy survey, it is estimated that only between 15,000 and 21,000 T/y of the total of 114,000 T/y are bought from markets or shops, and a substantial amount of this originates from “recycled” fuelwood. Much of the balance of between 93,000 and

99,000 T/y is also derived from recycling fuelwood already shown in the above table. However, the actual proportion of charcoal that originates in this way is unknown. Nonetheless an estimate may be made that if between 30 and 60% of households cooking *injera* adopt the practice of "recycling" fuelwood for their own or other use, then the total quantity of charcoal so produced (including from *suwa* brewing) would be between 42,500 and 82,500 T/y. This would mean that the fuelwood used for kiln-produced charcoal could be between 195,300 and 443,300 T/y. This possible estimate charcoal tonnage range from partially burned domestic fuelwood is based on tentative estimates of the prevalence of this "recycling" practice and a charcoal conversion ratio in *injera* cooker of 8:1.

Table 6: Annual National Energy Demand, Fuel by Sector

Fuel type	Household (in tonnes)	Social Institutions	Commercial Enterprises	All other sectors	Total
Fuelwood	1,293,631	462	39,977	0	1,334,070
Charcoal	114,159	13	3,247	0	117,419
Animal Dung	366,170	0	5,162	0	371,332
Agri-Residues	47,146	0	1,627	0	48,773

Note:
Social institution includes such as hospitals, boarding schools, hostels, and the like.
Commercial enterprise sector includes such as hotels, guest houses, traditional drinks (brewery), tea shops, snack bars, restaurants, bakeries, injera baking, biscuits and pastries, grain mill, laundry, puncture repair, garage, pottery, lime kiln, brick making, wood workshop, metal workshop, jeweller, and blacksmith.

Based on the above study, the national woodfuel (both fuelwood and charcoal) consumption level is estimated at 1.48 million tonnes per annum, most of which comprised firewood (90.5%). This figure (1.48 million tonnes) is obtained from the table figure of 1.45 million tonnes on the assumption that all the charcoal consumed on national scale as not carbonised charcoal (i.e., kiln charcoal), rather a substantial amount of this quantity comes from the recycling process of fuelwood at the hearth. Thus, out of the total charcoal consumption, estimated at 117,419 tonnes, only 20% is considered to be kiln produced, i.e., 23,484 tonnes, and a kiln conversion efficiency of 30% is assumed (i.e., 6:1 ratio).

B. Study Conducted by FAO/ MOA

There was a Socio-economic study conducted by the FAO-TCP with the Ministry of Agriculture (MOA) in 1997. The general objective of the study is to improve the level of available data regarding socio-economic interactions with forest and wildlife in specific selected interventions. These include:

- Inventory of surrounding villages of existing permanent closures and assessment of encroachment on these closures
- Inventory of surrounding villages of proposed potential closures and existing actual use and claims on these areas.

- Inventory of surrounding villages of the proposed potential forest plantation and existing use and claims on the area.
- Inventory of village(s) to which temporary closure belong and assessment of fodder availability and existing pressure on the closure.
- Inventory of village(s) in and near to the proposed potential game reserves and assessment of actual encroachment by concessions and logging;
- Assessment of actual use of the area and threat or damage by wildlife.

Data is collected from twenty-six sample villages located in different Zobas and Sub-Zobas. Means of collecting data, was mainly from a group discussion in a sub-structured interview and from officials for some technical questions.
Parameters used to collect the required data include:

- geographical and demographic parameters
- Socio-economic parameters

Parameters which would help assessing forestry and wildlife aspects out of the twenty-six sample villages:

- twenty six discussions on village inventories
- thirteen on existing permanent closures
- five on potential forest plantations
- five on temporary closures
- fourteen on potential game reserve
- and three on existence of wildlife in some study sites

The output of this study in regard to fuelwood consumption is stated shortly as follows:
Fuelwood consumption for cooking purposes is very high in the Eritrean cities, towns and countrysides. In big towns, where electric power is available, few households use electric power and liquid propane gas (LPG) as an alternative for fuelwood, specially for baking *Ingera* (traditional leafy bread), which requires the highest energy consumption rate in a household. Kerosene is slowly being introduced in the countryside for cooking. Dung and agricultural residue, though they can not replace fuelwood (because of their poor energy output), could be mentioned as an energy alternative in households with livestock and cultivation areas, especially with maize field-aftermath. The following table indicates the estimated consumption rate of fuelwood / five headed household and other alternatives of energy sources used for cooking.

Table 7: Estimated Fuel Wood Consumption and other Alternatives of Energy Sources

Sample Villages	Selected in Relation to	Consumption Month/ Kg.	Purpose	Source	Distance (km)	Availability	Other Alternative of Energy Used
Adi sherbot	EPC	750	Cook/light	Surrounding area	3.0	Fair	-
Dekemhare	EPC,PC PGR	100	Cooking	Bahri	12.0	Scarce	Agri. Residue, Dung, kerosene 20 lt/mon.
Dongolo Tahatai	EPC ,PGR	150	"	Surrounding area	5.0	"	Kerosine 25 lt/mon
Embatkala	EPC,PGR	200	"	" "	4.0	"	Agri. Residue, kerosene 20 lt/mon
Laiten	EPC,PGR	150	Cook/light	Ghobo Barud	1.0	"	Dung
Ghaden	EPC,PGR	150	Cooking	Ghelata	30.0	Fair	Agri. Residue, Dung, kerosine 15 lt/month
Mirara	EPC, PGR	100	"	Tekel Abamaitan	3.0	"	Agri. Residue, Dung,kerosine
Fishe	EPC, PGR	120	"	Surrounding area	0.5	"	Agri. Residue, Dung, kerosine
Woki	EPC ,PGR	200	"	Kelkel, Bahri	10,18	Fair/scarce	Agri. Residue Dung, kerosine 20 lt/mon
Zagir	EPC ,PGR	150	"	Midri Zagir	5-6	Fair	Kerosene, dung
Geza Medebai	EPC	150	"	Emba-Aila	7	"	-
Shiketi	EPC	22.5	"	Western side of Menguda	3-4	"	Agri. Residue, kerosine 20 lt/mon Dung 75 Kg/month
Lalai saro[1]	EPC, PFP PC	300	"	Mai Lela	1.5	Scarce	-

[1]EPC= Existing Permanent Closure PFP =Potential Forest Plantation TC= Temporary Closure PC= Potential Closure PGR = Potential Game Reserve

Table 7 Continued

Sample Villages	Selected in Relation to	Consumption Month/ Kg.	Purpose	Source	Distance (km)	Availability	Other Alternative of Energy Used
Adi –Nefas	PFP, PC	50	Cooking	Asmara market	5.0	Good /Exp.	-Dung kerosene(20lt/ month)
Zigib	PFP,TC, PC	Can not afford	--	--	-	-	Dung, (80kg/month) Kerosene
Tselot	PFP	200	Cooking	Asmara market	9.0	Good/ Exp.	Dung 45 kg/month Kerosene(20lt/month)
Ad- Selahait	TC	300	Light/Cooking	Surrounding area	1.0	Good	--
Aderde	TC	200	"	" "	2-10	Fair	-
Ad- Berbere	TC	350	"	" "	1-3	Fair	-
Berak	TC	10	Cooking	Fallen branches & bushes, surrounding area	4	Fair	Dung 75 kg/month Kerosene 20 lt/month
Shariki	PC	150	Light/ cooking	(aye hadro) surrounding area	1.0	Fair	Agr. Residue, Dung
Menkalile	PGR	450	"	Barzole	24	Scarce	Dung
Engel	PGR	could not be estimated	"	Surrounding area	0.5	Good	-
Duluh	PGR	300	"	" "	3-10	Fair	Dung
Elit	PGR	700	"	" "	1.0	Good	-
Ad-Abraha [2]	PGR	100	"	" "	2.0	Fair	Agricultural residue, 100 Kg / Month

[2] EPC= Existing Permanent Closure PFP =Potential Forest Plantation TC= Temporary Closure PC= Potential Closure
PGR = Potential Game Reserve

The fuelwood consumption differs greatly from place to place, depending on the availability and price. Remote villages which have a better access to forests with adequate deadwood of trees and bushes use to consume more than villages located near big towns where they have no or little access to forests and they are forced to buy with higher prices. In addition for cooking, there are also villages where fuelwood is also used for light purposes. Such villages let fuelwood burning for the whole night to avoid darkness.

Having this in mind, one could imagine how far the wood consumption would differ from place to place and from household to household. The highest monthly fuelwood consumption in a household with five heads was given to be 700 kg, with no other additional source of energy. On the other hand, the lowest is 10 kg, with adequate other alternatives of energy (75 kg. dung /month and 20 litres of kerosene/month).

To collect fuelwood, people of some villages use to go as far as 30 km. and there are villages which do not need to go more than half a kilometre. All in all, the average distance, from study villages to the areas where fuelwood could be collected, would be estimated to be 6.5 km. The opinion of the village elders towards the availability of fuelwood in areas, mentioned to be, the centre of fuelwood collection, is summarised to be scarce 26%, fair 61% and good 13%, excluding the survey villages which buy fuelwood from Asmara.

The major uses of wood within Eritrea are for fuel and construction poles, while minor uses include sawn timber for utility and furniture, transmission poles and many splints.
In general, the rural communities and most urban households including some commercial enterprises depend on biomass fuel for energy, but the supply has dwindled. Hence, the rural people who used to enrich farmlands with animal manure and agricultural residues have minimised their traditional practice, not out of choice, but need. Instead, they are using such by-products for fuel due to the scarcity of fuel-wood. This is causing environmental deterioration and the reduction of soil fertility.

4.1.2. Studies Conducted at Regional Level (Western Lowland)

The FAO-TCP Project (1997) commissioned a study to assess fuelwood consumption and potential availability from the natural forests/ woodlands of the western lowland region, and to make an evaluation of the existing forest products regulation and licensing systems. The main objectives were as follows:

- To assess the potential fuelwood availability from the natural forests/ woodlands of the Western Lowlands;
- To gather information on the current levels of fuelwood and charcoal consumption derived from those forests/ woodlands;
- to assess the sustainability of current production from those forests/ woodlands; and
- To evaluate various options for better forest management, improved forest regulation and monitoring and for more efficient fuelwood utilisation.

The study is based on information and data gathered from a literature survey, concerned institutions and organisations, and from field studies to assess the woody biomass stock of the existing natural forests/woodlands in the region.

Literature survey relied upon for the study of fuelwood consumption and forest products regulations or monitoring and licensing systems. For the assessment of fuelwood consumption, this study has heavy drawn from the information and data obtained from the Ministry of Energy and Mines (MEM), and from other fuelwood and related studies carried out in Eritrea. For the forest product regulation and licensing, much of the information was obtained from the Ministry of Agriculture (MOA), Forestry and Wildlife Division.

Field survey was used mainly to collect information and data concerning the potential fuelwood availability from the natural forests of the Western Lowlands. The survey was mainly focused on the assessment of the biological production in order to determine the existing stock of the natural forests in the area, with details of species. In addition, the survey has also included the assessment of the existing deadwood stock in the region.

(1) Woodfuel Consumption from Woodlands in the Western Lowlands

Compared to the national situation, the western lowlands are comparatively more dependent on woodfuel consumption for energy. Woodfuel contributes around 96.5% of the total energy used in the area, while the remaining 3.5% is met by other energy sources, mainly oil products. This heavy dependence on woodfuel is likely to continue for the near future as long as suitable alternative fuels are not able to substitute in terms of price, availability and customary preferences.

In the Western Lowlands, the household sector was found to be the dominant consumer of energy (94.7% of the total energy consumed), followed by the commercial enterprise sector (4.8%). Based on a study for a comparable area of Eritrea (Mendefera) Zoba Debub, household cooking consumes more than 95% of the total energy delivered into the household sector which means that the availability of fuelwood is intractably linked to the issue of food security.

The Western Lowlands of Eritrea encompasses 3.69 million hectares, mostly of Bush/Scrubland, Grassland/ Wooded Grassland, Closed to Medium Closed Woodland, Open Woodland, Reverine Forest, Agricultural Land and other unclassified land.

Table 8: Annual Energy Consumption of the Western Lowlands, in TJ

Fuel type	Household	Commercial Enterprises	Social Institutions	Total	Percent
Fuelwood	6925	331	1	7257	93.7
Charcoal	201	17		218	2.8
Oil, gas & electric	210	20	40	270	3.5
Total	7336	368	41	7745	100.0
Percent	94.7	4.8	0.5	100.0	
Source: Modified (MEM, 1996).					

According to the study of the Department of Energy, total annual woodfuel consumption for the Western Lowlands was estimated at around 0.48 million tonnes; that is around 33% of the annual national woodfuel consumption. The current per capita woodfuel consumption level in the Western Lowlands was found to be higher (0.75 t/cap/annum) compared to the national average (0.5 t/cap/annum). This can be explained by:
(i) Comparative abundance of woodfuel in the western lowlands;
(ii) The poor availability of alternative fuels; and
(iii) The consequential price advantage of woodfuel consumption.

Table 9: Annual Consumption by Energy Inputs for the Western Lowland Areas of Eritrea in tonnes

Fuel type	Household	Commercial Enterprises	Social Institutions	Total
Fuelwood	417,180	19,950	68	437,198
Charcoal	11,579	995	0	12,574
Woodfuel	458,864	23,532	68	482,465

Source: Modified (MEM, 1996).

Note:
The figures for woodfuel are based on the assumption that in the Western Lowlands carbonised charcoal accounts for 60% of the total charcoal consumed in the area, with the kiln conversion efficiency estimated at 30%. About 7338 t/yr. of charcoal are marketed annually in the areas, and this accounts for approximately 63% of the total charcoal consumed in the area. The Western Lowland is the main area where marketed charcoal is produced, and the figure 7338 t/yr. is around 50% of the total marketed charcoal supplies at national level.

A high proportion (83-87%) of the annual off-take is consumed locally, and the remainder is used elsewhere, mainly by the major urban centres in the highlands. More than 95% of the total quantity of woodfuel is consumed in the form of pure fuelwood, as opposed to charcoal (in fact, charcoal production in Eritrea is permitted only as a by-product of firewood combustion).

(2) **Biomass Assessment and Fuelwood Potential from Woodlands in the Western Lowlands**

The study under the FAO-TCP project assessed from field studies the woody biomass stock of the existing natural forests/woodland in the Western Lowland region.
To collect the information on woody biomass (including deadwood), stratified systematic sampling was used. Using physiognomy as the key, the natural forests in the study area were stratified as follows:
Shrubland / Bushland: composed of woody vegetation of less than 4 meters height (average) with or without scattered trees; and crown cover over 10%.
Closed to medium closed woodland: woody vegetation composed of one layer of trees of touching or non-touching crowns but with more than 40% crown cover. Average height around 5 meters.

Open woodland to scattered trees: composed of woody vegetation of a single layer of trees with crown cover of 10 to 40%. Average height around 5 metres.
Riverine forests / Riparian woodland formation: composed of stands of trees, with or without understory shrubs or bushes, occurring on the major riverbanks and their major tributaries.

Wooded grassland or Grassland: bare soil with very sparse shrubs and/ or trees but low crown cover (1 to 10%) and some seasonal grass during the rainy period.

Agricultural land. The last category is included because agricultural lands can be a good source of woody biomass especially in areas where the practices of cultivation are not so intense and/or where traditional agroforestry is a common practice, just like the case of the Western Lowlands

Further sub-stratification by canopy cover percent was carried out for shrubland (stratum I) and riverine forest (stratum IV), and agricultural land was sub-divided into two categories.
A total of 68 samples were taken among the strata as shown in Table 10 below. The overall sampling intensity was 1.11%, although this ranged from 0.20% in shrubland to 14.7% in agricultural land.

Table 10: The MainLand Cover/Use Surveyed in the Field and the Number of Samples Taken

Land cover/use	Plot size (m^2)	No. of samples	% of the sample area to the total cover area
Shrubland Cover > 70% Cover 70-40% Cover 40-10%	100	24 8 8 8	0.20
Closed to medium closed woodland	400	5	0.70
Open woodland to scattered trees	400	5	0.30
Riparian woodland formation Cover > 70% Cover 70-40% - Cover 40-10%	400	17 7 5 5	4.50
Wooded grassland	400	7	0.30
Agricultural land use Moderately cultivated Intensively cultivated	2500	10 5 5	14.71
Total		68	1.11

A road through each stratum was used as a base line, along which transepts were positioned at systematic intervals. Along each transept, the sample plots were positioned at random intervals.
The methods used to gather the data on the quantity of woody biomass at the plot level were of two types:

Shrubs and Bushes. For shrubby and bushy structures less than 4 meters height, the “cut and weight” method was used. Measurements for woody and foliar biomass were recorded

separately. Where appropriate, diameter measurements of the main stems were also recorded with the aim to construct regression relationships between woody biomass and total biomass with diameter.

Trees exceeding 4 metres. For such trees, volumes were estimated on a standing basis using the "log rule method". Measurements were made of diameter at breast height (dbh), height, form factor and type of the species. In calculating the volume, the form factor was inflated so that volume estimates might include an allowance for branch wood as well as the main bole volume.

Data Analysis for Biomass Assessment

Based on field measurements, predictive equations were developed for green wood biomass (GWB) and green total biomass (GTB) in terms of the square of stem diameter (DIAM), measured at 1.3 metres above ground for trees and 0.3 metres for bushes and shrubs.

$$\mathbf{GWB\ (kg) = 7.88 + 0.168 * DIAM^2 \quad (R^2 = 0.73)}$$

$$\mathbf{GTB\ (kg) = 14.0 + 0.298 * DIAM^2 \quad (R^2 = 0.75)}$$

Green mass measurements were converted to airdry basis on the assumption that green moisture content was 20%, and air dry moisture content was 12%.
Volumes were converted to a mass basis using the airdry wood density for each species recorded. The weighted average woody biomass per unit area for each stratum was then applied to the area of the stratum, in order to derive the total woody biomass stock in the Western Lowlands.

Overall, the field study under the FAO-TCP project found that the average standing wood biomass (air-dry basis) was 22.5 t/ha. Minor branches (less than 3-cm diameter) and foliage brings this figure up to about 31.5 t/ha. Deadwood, which was measured separately, had an average mass of 1.5 t/ha.

Table 11: Assessment of the Live and Deadwood Biomass Stocking (in tonnes per ha) in the Natural Forest/Woodland of the Western Lowlands

Vegetation class	Live wood biomass (air dray)	Total live biomass (air dray)	Dead wood
Bush/ scrubland	13.6	22.0	1.9
Grassland/ wooded grassland	3.2	4.5	0.5
Woodland: Closed to Medium	51.3	72.5	1.4
closed	39.0	56.0	1.7
Woodland: Open	133.0	164.5	6.0
Riverine Forest	5.4	6.5	0.1
Agricultural land	23.0	31.5	1.5
Weighted Average (all strata)	17.0	25.0	
Weighted Average (excl.riverine forest)			

Note: Deadwood refers here to both the naturally fallen deadwood and as well as that found cut and dried in the field The figure for air-dry weight were calculated in ranges assuming a 25-35% MC of the Total biomass weight.

It is clear from the above biomass stocking rates that the reverine forests exert a powerful influence on the average biomass stocking of 23 t/ha for live wood. A figure of 17 t/ha, disregarding the riverine forests, provides an average more typical of the prevailing vegetation types.

Applications of the estimates of biomass stocking to the areas of each stratum, enables an estimate of living and dead biomass for the western lowlands, as shown in Tables 11 and 12.

Table 12: Assessment of the Total Live and Deadwood Biomass from the Natural Forest/Woodland of the Western Lowlands (in million tonnes)

Vegetation class	Area in million ha	Total wood biomass (air dray)	Total Dead wood
Bush/ scrubland	1.23	16.7	2.3
Grassland/ wooded grassland	1.07	3.4	0.5
Woodland: Closed to Medium	0.28	14.4	0.4
closed	0.61	23.6	1.1
Woodland: Open	0.15	19.3	0.9
Riverine Forest	0.17	0.9	0.01
Agricultural land	3.50	78.3	5.2
Total	3.69	83.0	5.5
Grand total			
Note: The figures for Grand total were calculated taking into account the non-classified 5.5% of the total Western Lowland areas.			

The biomass energy consumed within the country is estimated to constitute about 82% of the whole, and of that of this, wood energy is estimated to be about 70%. The share of energy supplies for Asmara is estimated to be:

Fuelwood and charcoal	80%
Cowdung and crop residue	5%
Electricity	10%
Gas stoves and kerosene	5%

4.2. Fuelwood Supply for Asmara

Asmara the Capital City of Eritrea is found in the Central Highlands of the Country with total inhabitants of about 400,000 individuals. Fuelwood which is consumed in this city (total annual fuelwood consumption is about 60,000 tonnes) is obtained mainly from the Western Lowlands and some from Eastern Lowlands of Eritrea.

Fuelwood supply for this city, according to the Ministry of Agriculture reports is tabulated in table 13.

Table 13: Annual Fuelwood Supply to Asmara City

No	Year	Wood Supply (in tonnes)
1	1974	33,392.5
2	1975	22,900
3	1976	10,471
4	1977	-
5	1978	6,000
6	1979	6,840.3
7	1980	10,000
8	1981	15,402.9
9	1982	19,647
10	1983	38,312.3
11	1984	18,988.1
12	1985	11,695.4
13	1986	13,056.3
14	1987	29,859.7
15	1988	24,535
16	1989	18,224.8
17	1990	19,833
18	1991	13,058.2
19	1992	42,603.8
20	1993	25,835.2
21	1994	12,485.6
22	1995	10,466.5
23	1996	19,707.4
24	1997	20,927
25	1998	7,752.9

Even the 1992 record of 42,603.8 tonnes (or 85,207 m^3) supplied under license into the city Asmara begs some questions. Based on the total annual fuelwood consumption at national level, the city should be importing more than the recorded supply figures. Therefore, the possible explanation for the huge difference is:

More wood comes into the city than is licensed, through loose guarding of roadblocks, or through unguarded routes.

5. DISCUSSIONS

5.1. Fuelwood Consumption

Based on the fuelwood consumption study made by the Department of Energy, the national woodfuel (both fuelwood and charcoal) consumption is estimated at 1.48 million tonnes per

annum. This figure is significantly less than the earlier estimate made by the MOA (NEMP-E, 1995) which amounts to 2.2 million tonnes annually. The MOA figure may be an overestimate because:

There is rapid switching to non-wood fuels by the population, especially that of the highlands, where around 65% of people live, and most economic activities are concentrated. The alternatives, such as oil-based fuels, dung and agricultural residues have a considerable role in the area. This trend is now slowly penetrating in the rural areas and has consequently contributed to the gradual decline of woodfuel's importance. For instance, according to a previous estimate, woodfuel contributes around 80% of the total national energy consumption; but in the study made by the Department of Energy (1996), woodfuel was found to contribute only around 68% of the total national energy consumption.

The substitution against wood fuel may be attributed to modernisation, scarcity factors and government policy which rations the supply to deadwood sources.

Although all commercial fuelwood trading in Eritrea should be controlled through licenses, doubts have been expressed concerning the effectiveness of the system. For example, a survey by the Ministry of Energy and Mines (MEM) found that less than 20% of the fuelwood entering Zoba Maekel (i.e. Asmara) during 1995 came from licensed sources (Estimated fuelwood consumption for Zoba Maekel was 57,853 t/y; licensed quantity was 10,467 tonnes). The Ministry of Agriculture restricts licensed fuelwood to deadwood, except in the case of licensed clearing of agricultural concessions. It is widely acknowledged that, rather than extending the search time and area for dead wood, collectors may clandestinely kill off trees. In the case of concessions, some fuelwood marketers have used the device of concessionaire to get around the restriction on live cutting.

The total annual fuelwood off-take from the Western Lowlands, which is the major supplier of fuelwood, for 1995 was estimated at 0.55-0.58 million tones. Based on information obtained from Ministry of Land, Water and Environment (MLWE), about 100,000 tones of fuelwood were supplied in 1995 from land clearances by commercial agricultural concessions, equivalent to approximately 4,000 hectares. Of this total, a high proportion (83-87%) of the annual off-take is consumed locally, and the remainder is used elsewhere, mainly in the major urban centres in the highlands. More than 95% of the total quantity of fuelwood is consumed in the form of pure fuelwood as opposed to charcoal. (Charcoal production in Eritrea is forbidden by low. Only charcoal of by-product of firewood combustion is used within the households for cooking).

The long term sustainable use of the forest resources for fuelwood production would require that annual off-take should not exceed the annual increment of the forest concerned. The area of the natural forests/woodland of the western lowlands is estimated in this study as 3.5 million ha, of which around 60-70% is judged to be accessible. Assuming an average mean annual increment (MAI) of 0.15 t/ha/yr. in mass units for an accessible area of 60% of the total area, the total fuelwood production, on sustainable basis, was estimated at around 0.336 million tones annually.

Table 14: Estimated Quantity of Fuelwood (air-dried) that can be produced on sustainable basis from the Natural Forest/ Woodland of the Western Lowlands

Vegetation class	Area in million ha	Estimated Fuelwood Yield (t/ha/yr.) [1]	Total Sustained Yield (Mill.t/yr.)	Sustained Yield on readily accessible (Mill.t/yr.) [2]
Bush/ scrubland	1.23	0.05	0.062	0.037
Grassland/ wooded grassland	1.07	0.03	0.032	0.019
Woodland: Closed to Medium	0.28	0.50	0.140	0.084
closed	0.61	0.25	0.153	0.092
Woodland: Open	0.15	0.38	0.057	0.034
Riverine Forest	0.17	0.50	0.085	0.051
Agricultural land	3.69	0.15	0.560	0.336
Grand total				

Notes:
[1] These estimates were adopted from the estimates made by FAO (1983) for Africa, south of the Sahara and the figures are assumed on air-dried basis.
[2] Accessible yield is calculated on the assumption of 60% accessibility.

At present, however, the Ministry of Agriculture has promulgated a ban on the cutting of live trees. Consequently, only the stock of deadwood may be collected officially from the natural forests and woodlands of Eritrea. Considering the area of forests and woodlands (3.5 million ha), and including agricultural lands, the extent of accessible dead wood collection area is estimated to be 3.69 million hectares. Based on actual field measurements of an average 1.5 t/ha of dead wood, the total existing stock of deadwood in the western lowlands is estimated to be 3.3 to 3.9 million tones.

5.2. Fuelwood Gap

Although the availability of woodfuel is not sufficient in the Western Lowlands at the moment, the situation is compared better to the other parts of the country, particularly in the highlands. These differences in woodfuel situation are manifested in the utilisation of energy sources. In the highlands fuel especially the households, to ensure fuel security have long adapted diversification. However, such fuel diversification strategies are not yet prominent in the Western Lowland region, which implies that the shortage of woodfuel is not such a big problem.

However, this does not mean that the present woodfuel consumption and production systems of the region are fully sustainable. The situation of the woodfuel scarcity is worsening, as can be illustrated by the ever-increasing distance and hardship in collecting fuelwood. Taking the distance and time of fuelwood collection as indicators of the situation of woodfuel scarcity, between year 1960-1991, for instance, the average distance of fuelwood collection in the Western Lowlands has increased from 2.1 to 17.1 km, and the time from 1.2 to 6.3 hours.

This condition has been partly aggravated by the woodfuel dependency of the highlanders in the region. Although the proportion of the transported woodfuel quantities from the region is

small at the present, the dependency of the urban centres in the highlands has its impact on the use of the natural forests/woodlands of the region. And the effect of this would be even more serious, in the foreseeable future as a result of the increase in woodfuel demand (both nationally and at local level), on one hand, and ever declining productivity of the natural forests/woodlands, on the other hand.

When the annual fuelwood off-take quantity of 0.55-0.58 million tones is compared with the annual sustainable fuelwood production from the Western Lowlands natural woody vegetation, say 0.336 million t/yr., it is evident that there exists a substantial fuelwood gap of, say, between 0.21 – 0.24 million tones annually, and that the present level of fuelwood off-take from these natural forests/woodlands is not sustainable. Even now, without clearance for agricultural concessions, this gap would be larger by 100,000 tones per year.

If the present fuelwood gap was to be met by over cutting of the standing trees/shrubs from the natural forests/woodlands, then it would require an area varying between 9,100-10,400 ha to be clear-cut each year. This would be incompatible with national policy on environmental protection. If, in accordance with current policy and directives, reliance were placed on filling the fuelwood gap from the stock of deadwood, then this palliative would become exhausted within 15 years period, leaving the fundamental problem of sustainable use unaddressed.

The above conclusions are based on assumptions that:
(i) Present woodfuel consumption levels remain unchanged;
(ii) Accessibility does not alter; and
(iii) productivity of the natural forests/woodlands will remain unchanged.

The availability of dead wood supply for, say the next 15 years up to year 2010, provides a unique opportunity to bring about a fundamental realignment of fuelwood consumption demand with sustainable production levels in the western lowlands. This would require:

- The reduction of demand for fuelwood by around 20% (i.e. from 0.75-0.60 t/cap/yr.);
- The enhancement of biological productivity by 37% (from 0.15 to 0.21 t/ha/yr.) of
- The natural forests/woodlands;
- The improved utilisation of the available deadwood stock and live wood increment resource stock – effectively increasing accessibility by 20% to around 80% of the forest resources.

But, if the business as usual scenario is considered, fuelwood consumption may be expected to increase owing to natural population growth of around 3% per year, and the annual woodfuel gap might increase to as much as 0.36 million tonnes by the year 2010. Thus, this is a clear indication that the woodfuel energy crisis is a very serious issue in the country.

6. CONCLUSION AND RECOMMENDATIONS

From the review of the studies conducted on the availability and consumption both at national and regional level of Eritrea, there is a gap between the actual production of fuelwood and the demand/ consumption rate. To alleviate this problem the following actions have to be promoted:

- **Live wood harvesting from the existing eucalyptus plantations has to be enhanced**

Eventually, the wood obtained from planted trees will partly replace the fuelwood gap and other sources of energy like kerosene, liquid petroleum gas (LPG) and electricity reducing the destruction of forests.

From previously planted *eucalyptus* plantations (currently about 15,000 ha with annual increment of 2000 ha of afforestation area) an estimate of 10% is reached for pole production. Thus, about 0.5 million poles will be harvested which can serve for house construction. This can replace, to some extent, the poles that are imported.
From this harvest, if we assume mean annual increment of 5 m^3 /ha/yr. about 33,750 tonnes with annual increment of 4,500 tonnes of fire wood can be collected annually, which can greatly minimise the shortage of fuel wood.

On the other hand, the fuelwood supply for the major urban centres of the highlands that is obtained from the eastern lowlands, although it is not well documented, is estimated to be only 10% of the total annual consumption.
Fuelwood obtained from plantation forestry is estimated to be 34,000 tonnes/annum. However further study is required on to the amount of sustainable yield of the existing plantation and their increment.

- **Programmes that are directed towards increasing wood production should be promoted. These are:**
  - Creating awareness on tree planting for woodfuel
  - Increasing the availability of quality tree seeds
  - Encouraging the establishment of on-farm tree nurseries to meet the high demand for healthy tree seedlings and the appropriate species
  - Encouraging the adoption of agroforestry to facilitate intercropping of food crops and woody perennials with or without livestock, since average land holdings are small
  - Encouraging on-farm wood lots especially in areas where household land parcels are fairly large

- **Programmes that will affect the reduction of woodfuel demand have to be encouraged. These include:**
  - Promotion of energy efficient wood-stoves
  - Promotion of fireless cookers
  - Promotion of other conservation measures like: covering food when cooking, soaking dry grains overnight, chopping food into small pieces before cooking, preparing food before lighting the fire and planning to have a small family
  - Encouraging change to use alternatives like biogas, solar energy, wind energy and other energy conservation techniques.

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