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Inventory of Biomass,
in Kenya

A Conditionally Renewable Energy

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KEITH OPENSHAW

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THE BEIJER INSTITUTE
The International Institute for Energy and Human Ecology
The Royal Swedish Academy of Sciences
Pack S-104 05 Stockholm Sweden, Tel. 08-160490, 150430

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Introduction

In order to plan for future demand of biomas energy, particular woodfuel (fuel and charcoal), it is imperative to know the existing supply of these conditionally renewable fuels. For convenience, the energy from biomass can be divided into three groups :

(i) annual plants, for example, crop residues and grasses;
(ii) perennial plants - trees and shrubs;
(iii) animal waste - domestic animal and human waste.

All these potential energy forms have other uses and this should be borne in mind when planning for the energy requirements of a region, country or district. It is also most important to realise that these energy forms are only renewable on condition that they are properly managed. If the fertility of a piece of land is not maintained, then the agricultural crop yield will decline, similarly if more wood is cut from a forest than is being added annually, the forest will eventually disappear. Therefore, when assessing supply, it is important to find out whether the supply can be sustained or not. This is particularly important when looking at woody biomass because trees represent accumulated years of growth, and while one can draw on this store over a short period, unless it is replaced by new growth, the store will dry up. Therefore, for woody biomass, one has to assess, not only total stock, but allowable annual cut, or in technical terms, the increment.

Annual plants: assessment of crop residues

Crop residues can be used for cooking and heating, but usually only over a limited period of the year, after the harvest, for not more than about two months.

However, in order to maintain the soil structure and to a certain extent the fertility, it is essential that much of the crop residue ploughed back into the soil. Therefore, only a fraction of the crop residues can be used for energy without leading to a decline in crop yields, unless there are large inputs of fertilizers.

Crop residues are not generally used as a source of energy, but in areas of wood shortage then the population do use them; therefore they can act as an indicator for shortage of wood, the traditional fuel. Similarly, grass is burnt as fuel only as a last resort, except for lighting fires.
Most grasses are consumed as animal feed and therefore their potential is considered an animal waste (dung) rather than as vegetable residue. In order to assess the potential availability of crop residues, it is necessary to divide agricultural crops into distinct types. Also they should be divided at least according to province because residues are usually burnt on the spot by the householder. There is a relationship between the crop yield and the amount of agricultural residue and therefore knowing the crop production figures, an estimate of agricultural residues can be made.

Table 1 KENYA 1980 Estimated output of selected agricultural cro

Units 1000t (1)

Province/Crop	Maize	Other grain crops	Cassava	Pulses	Cotton	Sugar cane	Sisal
NYANZA	319	90	158	18	12	952	0
WESTERN	342	36	99	111	8	2855	0
CENTRAL	171	48	2	32	1	25	2
NAIROBI	1	0	0	0	0	0	0
EASTERN	136	64	15	133	8	15	7
COAST	470	7	107	4	1	111	15
RIFT VALLEY	699	143	1	35	1	50	2
NORTH EAST	0	2	3	0	0	0	0
	2138	390	385	333	31	4008	26

(1) The weights of the various crops have not been totalled because each crop has a different moisture content.

Sources Annual agricultural reports for the various provinces; Kenya Sugar Corporation 1980 Annual Report; Kenya Statisti Abstract 1980. It should be noted that the various source quote different figures with sometimes large discrepancie for the same crop. This is becuase many crops such as maize, cassava, beans are for self consumption and thus are not recorded in commercial trading statistics. The above table is the best estimate but should be taken to give the order of magnitude rather than an accurate picture of output

Table 1 gives a summary of the 1980 estimated crop outputs for specific crops by province. These figures have been compiled mainly from provincial agricultural reports, but checked against other sources. At best, most of the figures(except sugar, wheat, barley and oats) should be treated as an order of magnitude rather than an accurate estimate, because many foods are grown for self consumption and therefore production is hardly ever recorded.

Using the figures in Table 1, an estimate of crop residues can be made by applying various conversion factors which are given as a footnote to Table 2. As is to be expected, maize produces over half of the crop residue total, one quarter is bagasse (residue from sugar) and one tenth are other grain crops, with the remainder divided amongst the other four crops. All in all, an estimated 2 million tonnes of crop residues are produced annually.

Table 2 KENYA 1980 Estimate of agricultural residues from selected crops (1)

Units 1000t air dry weight (15% M.C)

Province/ Crop	Maize	Other grains	Cassava	Pulses	Cotton	Bagasse (2)	Sisal	Total
NYANZA	175	45	32	2	14	124	0	392
WESTERN	188	17	20	14	10	371	0	620
CENTRAL	94	23	0	4	1	3	2	127
NAIROBI	1	0	0	0	0	0	0	1
EASTERN	75	32	3	17	10	2	8	147
COAST	259	3	21	1	1	14	18	317
RIFT VALLEY	384	82	0	5	1	7	3	482
NORTH EAST	0	1	1	0	0	0	0	2
KENYA	1176	203	77	43	37	521	31	2088

(1) The conversion factors that have been used are taken from the U.S. National Academy of Sciences (1977) book, Methane generation from human, animal and agricultural wastes (p.39). They are as follows; Multiplying factors to calculate the air dry (15% M.C.) residues of major crops. Maize 0.55; Wheat 0.47; Barley 0.82; Oats 0.95; Sorgum/Millet 0.50; Cassava 0.20; Pulses 0.13; Cotton 1.20; Sugar cane 0.13; Sisal 1.20. The cassava factor was taken from Energy and agriculture in the Third World by Makhijaniand Poole (p.107), and that for pulses was assumed to be similar to sugar cane.

(2) Bagasse is the residue from sugar cane.

The information in Table 2 is used to provide an estimate of the potential offtake of agricultural residues for energy use in wood equivalent terms, and this is shown in Table 3.

Table 3 KENYA 1980. Estimate potential offtake of agricultural residues for energy use in wood equivalent terms.

Units 1000 metric tonnes of wood equivalent (15% M.C.)(1)

Province	Area of small farms %	Maize (2)	Other grain (3)(4)	Cassava (5)	Pulses (6)	Cotton (8)	Bagasse rural household	Sisal rural household	Total	Bagasse Industrial. (7)	Sisal Ind. (9)	Total Ind.	Grand Total
NYANZA	92	79	22	16	0	10	2	0	129	90	0	90	219
WESTERN	98	91	8	10	2	7	5	0	123	269	0	269	392
CENTRAL	87	40	5	0	1	1	0	0	47	2	1	3	50
NAIROBI	100	1	0	0	0	0	0	0	1	0	0	0	1
EASTERN	95	35	13	1	3	7	0	1	60	2	5	7	67
COAST	67	85	1	10	0	1	0	3	100	10	10	20	120
RIFT VALLEY	30	56	1	0	1	1	0	0	59	5	2	7	66
NORTH EAST	100	0	1	0	0	0	0	0	1	0	0	0	1
KENYA		387	51	37	7	27	7	4	520	378	18	396	916

*Grass has not been included in the above because it will be mainly eaten and some converted to dung. However, it can be and is burnt to a small degree. In order to estimate the amount of crop residues available for energy use the following reduction factors have been applied to Table 2.

(1). Crop residues have on average 82% the calorific value of wood; this factor has been applied throught.

(2) Maize: The % area of small farms(column 1) has been multiplied by 0.6 assuming that60% of Maize stalks and cobs are burnt on small farms. None of the maize on the large farms is burnt as fuel.

(3) Wheat, Barley & Oats, no residue is used as fuel

(4) Sorgum,rice,millet,for all farms 60% of residues is available for energy use.

(5) Cassava all farms 60% of residues is available

(6) Pulses all farms 25% of residues is available

(7) Bagasse: Most of the crop is taken to the factory for industrial processing, this is mainly used as a boiler fuel. 90% of all bagasse is available and of this total 2% is available on farm and 98% for industry.

(8) All cotton has to be uprooted and destroyed within two months of harvest therefore, 90% of the crop is available potentially.

(9) Most of the sisal is taken to the factory for processing but assume 90% of the sisal waste is available for fuel and 20% of this total used on farm. In addition the husks of grains and coffee etc. are potential available at the mill sites and this could amounts to some 3,000 to 6,000 tonnes per year.

The residues have been divided between household and industrial use because most of the sugar cane waste (bagasse) is used at the sugar factories to produce heat and electricity. Agricultural wastes have about 82 per cent of the energy of wood on a weight for weight basis at the same moisture content, and thusareduction factor has been applied to all the agricutural wastes in Table 2. Various assumptions have been made about the amounts of the different crop residues that can be burned and these are stated on Table 3. It is estimated that 520,000 (wood equivalent) tonnes of agricultural waste could be available for household energy out of an estimated total of 972,000 tonnes. The household consumption survey estimated that 538,000 (wood equivalent) tonnes of agricultural and animal residues were actually used by householders for cooking and heating purposes. The split is approximatley 440,000 tonnes of agricultural residues and 94,000 tonnnes of dung. Therefore the estimated supply for Kenya as a whole is less than demand, but in wood short provinces of Nyanza and Western probaly more crop residue (and dung) are being used for cooking and other household uses than is advisable; thus the soil structure and fertility is under threat.

These two provinces are also the largest producers of agricultural residues, the bulk of it being used by the sugar industry to raise power and heat. Most bagasse when it is produced, goes straight to the boiler house, although there is a surplus at times and some of the older factories do burn wood as well. Consumption of bagasse for boiler fuel is estimated to be about 350,000 (wood equivalent) tonnes, whereas no sisal waste is used as a fuel source by industry. A small quantity of coffee husks, about 40 tonnes, are used annuallly to fire clay, but there is scope to use more of this residue together with sisal waste and surplus bagasse. Briquetting or densifying of such wastes should be considered to see if they are viable propositions. Industrial production removes most of the crop residues from the land, and therefore the fertility of the soil has to be maintained by application of fertilizers or practising shifting cultivation to let the land recover

For the country as a whole the potential offtake is about 0.9 million (wood equivalent) tonnes, and consumption of agricultural residues is of the order of 0.8 million (wood equivalent) tonnes which is equivalent to about 3 per cent of the energy consumption. It is possible to increase the offtake of residues, but this can only safely be done by increasing crop production. Seeing most of the high potential land is already in use, increasing production will have to come through better management and raising per hectare yields. This will entail more fertilizer inputs and improving the soil structure. This could be brought about at a minimum foreign exchange cost by the introduction of 'complementary' trees intimately mixed with the crop or judiouclу spaced within the field. Paradoxically, while such good agro-forestry systems may increase the crop yields, they lessen the need for burning crops residues in the house, for the trees are of course a sustainable source of fuelwood. Such systems are a way of having your cake and eating it.

Perennial plants (trees and shrubs)

In order to estimate the amount of perennial plants growing in Kenya, several surveys were undertaken. These were as follows:-

1. A rangeland survey;
2. A survey of forest lands;
3. A survey of tree cover on high potential agricultural land
4. A survey of urban tree cover;
5. A survey of perennial plantation crops on agricultural land namely, tea and coffee.

The rangland survey has been described elsewhere in this report, but in summary the survey found that the rangelands, which cover 87 per cent of Kenya's land surface support some 600 million over dry tonnes of woody bomass , or some 690 million air dry tonnes (15% per cent m.c.). However, the sustainable production only amounts to some 14 million tonnes (oven dry) or 16 million air dry tonnes.

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The estimated consumption of wood energy for the whole of Kenya in 1980 is of the order of 18 million tonnes, so in theory these areas alone could supply 85 per cent of Kenya's requirements on a sustainable basis. However, wood, and to a lesser extent charcoal, are high bulk, low cost products and have to be within an accessible distance in order that they are of economic use. This means that for the bulk of the rural population, the wood has to be within half a day's walking distance of the house and obtainable at no monetary cost. Over eighty percent of the population live on the 13 per cent of the high potential agricultural lands, and thus the rangelands are out of reach of practically all these people. Urban households, industry and the service sectors that pay for their energy could and do tap this reserve, but here again the economic transport distance is at the most 50-100 kilometres for wood and 200-300 kilometres for charcoal. Many of the rangeland areas lie outside this economic radius and therefore the exploitation of this asset becomes uneconomic. Of course, if the price of alternative fuels increases and / or more roads are constructed in these areas, more wood energy will become accessible.

However, from a management point of view, these areas are particularly fragile, and the increment of woody biomas, even on the best rangeland areas, is rarely more than 1 m^3/ha/yr and usually of the order of one tenth that amount.
Also, not all species are desirable as fuelwood or charcoal; therefore, in many accessible areas, the rangeland tree species have been overcut and it will take many decades for the bush to recover. This is particularly noticeable along roads and round rangland settlements. Here there is a need in fact to encourage tree growth. On the other hand, in other areas there is too much wood for pastaoralists and they burn the rangeland in order to promote grass and to destroy woody biomass that habours such pests as tsetsefly and ticks.

Therefore, although rangeland areas could in theory provide most of Kenya's present day demand for woody biomass from increment most of these areas are too remote and the stocking density too low to make it economically worthwhile to exploit these potential resources. This is very apparent from the destruction of the forests and farm trees on high potential land.

2. Survey of forest lands

a) Areas of forests

By definition a forest is taken as a an area of trees that ha more than 80 per cent closed canopy. Therefore, in Kenya all forests are confined to areas where the rainfall is usually greater than 1200 mm/annum, or where there is sufficient ground water to support 'high' forest trees. The bulk of the forests are round the mountain ranges of Elgon, Mau, Kenya and the Aberdares, that is the high potential agricultural highland zones. There are small areas along the coast including the mangroves, along the main river system - the Tana-and lastly round isolated hills. The survey of closed forest land was divided into two parts. The first part was to ascertain the area of forest by province. This was done using information supplied by the Kenya Rangeland Ecological Monitoring Unit (KREMU)[1] and this gave the total forest area by forest. It included planted as well as natural forests over 10 hectares in size, but excluded non forest areas with the forest such as open grassland, farms and areas of water. The natural forests consist of three broad catagories: exploitable areas, protection areas and national parks. The Central Bureau of Statistics'Annual Yearbook gave the area of national parks and a planimeter plus maps were used to determ

(1) A forest Inventory of Kenya using Remote Sensing Techniques by Doute, Ochanda and Epp. AREMU 1981.

the amount of open areas within the national parks, and the area within each province where national parks straddled provincial boundaries. The inventory undertaken by Sparten Air Services (1978)[1] gave the area of 'erosion protection forest' in each sampling unit. thus an estimated of protection areas by forest and province was complied. The government plantation areas by province and species were supplied by Kenya Forestry Department of the Ministry of Natural Resources; the small areas of private plantations were obtained from various other sources, such as from the companies themselves or from the KREMU report previously mentioned. The planted areas were divided for convenience into land planted with eucalypts and wattle, termed woodlots, and all the other areas, planted mainly with pines and cypress, termed plantations.

Growing within the natural forests were three broad categories of woody biomass, commercial tree species, non-commercial trees and bamboo, either in pure stands with scattered trees or scrub,or scrub w. a mixture of tree and bamboo. The latter category was separated out by sampling unit and area, but commercial and non-commercial species grew intimately within the forest area. However, from a utili- -on standpoint, it is convenient to separate the approximate are commercial and non-commercial species, and this was done in pr... to their growing stock in each smapling unit. Thus, an area estimate by province of forests over ten hectares was compiled by planted and natural forests, by commercial and non-commercial species and by exploitable areas, protection areas and national parks. This is shown by province in Table 4.

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(1) Spartan Air Services Ltd/The Kenya Forest Department (1968)- A reconnaissance inventory survey of indigenous forest areas of Kenya. The Kenya Forest Department, Nairobi, Kenya

Table 4 KENYA 1980

Forest area by province and type

UNITS.HECTARES

Province/Forest		Planted Forest: Eucalypts & Wattle	Planted Forest: Other species	Natural Forest: Commercial tree area	Natural Forest: Non-Commercial tree area	Natural Forest: Bamboo & scrub	All Forest: Total	All Forest: % Forest cover
NYANZA	Exploitable	42	680	960	1865	290	3837)	
	Protection	-	-	80	160	30	270)	0.3
	National Park	-	-	-	-	-	-	
WESTERN	Ex.	535	11245	15160	23698	14807	65445)	
	Pro.	-	-	650	1020	630	2300)	8.3
	NP.	-	-	-	-	-	-	
CENTRAL	Ex.	2675	24958	47340	55558	79675	210206)	
	Pro.	-	-	5610	6590	9450	21650)	20.8)
	NP.	-	-	10910	12810	18380	42100)	)
NAIROBI	Ex.	1502	373	70	253	0	2198)	) 19.9
	Pro.	-	-	-	-	-	-)	)
	NP.	-	-	10	20	-	30)	31.1)
EASTERN	Ex.	1034	8734	1710	34050	85879	131407)	
	Pro.	-	-	140	2760	6960	9860)	0.9
	NP.	-	-	10	110	280	400)	
COAST	Ex.	243	2205	40260 (3)	70581 (4)	5556	118845)	
	Pro.	-	-	570	1290	100	1960)	1.5
	NP.	-	-	-	-	-	-	
RIFT VALLEY	Ex.	14889 (1)	87261	246370	275909	96336	720765)	
	Pro.	-	-	13510	14640	5780	33930)	4.6
	NP.	-	-	7550	8180	3230	18960)	
NORTH EAST		0	0	0	0	0	0	
TOTAL	Ex.	20920	135456	351870	461914	282543	1252703	
	Pro.(5)	-	-	20560	26460	22950	69970	
	NP.	-	-	18480	21120	21890	61490	
GRAND TOTAL		20920	135456	390910	509494	327383	1384163	2.4

Footnotes to table 4 on next page 13

Footnotes to table 4

(1) Eucalypts 9674 ha, wattle 5215
(2) The commercial and non-commercial species are mixed, the areas of these two groups of species have been divided according to the volume of each group.
(3) The commercial area includes 21,677 ha. of 'commercial' mangrove forest. Total mangrove area is 52,980 ha.
(4) The non-commercial area includes 31,303 ha.of non-commercial mangrove forest.
(5) The area of natural parks is much larger than 61,500 ha. but this is the total forest area within the parks.

b) Growing stock in the forest

Once the area of planted and natural forest were known, the next step was to assess the growing stock and increment on these areas. Different methods were applied to the natural forests and planted areas and these are described separately.

1) Natural forests

An inventory of selected natural forests was undertaken for the Kenyan government by Spartan Air Services of Canada[1] between the years 1963-67. This inventory formed the basis of the assesment of the forest growing stock in the natural forests. Incidentally, the areas of actual forests given in this inventory was for most forests close to the KREMU figures, exceptions being in such areas as Kakamega and Nandi forests which have been under serious threat for many years.

The inventory divided the gazetted area into forest and non-forest land. Only the forest land is dealt with here. The forest land was further sub-divided into land with a majority of trees on it, and other land that was scrub or had bamboo, with or without trees. The inventory confined itself to land with trees on it and therefore other sources for the assessment of the bamboo and scrub areas had to be consulted [2]. It was also assumed that the proportions of tree land bamboo land have not altered since the inventory was undertaken.

The Spartan inventory gave the standing stem volume of commercial and non-commercial trees, by individual species, but seeing that the main aim of the research was to assess the availability of woodfuel, the two broad divisions, namely, commercial and non-commercial trees were deemed satisfactory.

(1) Spartan Air Services Ltd/The Kenya Forest Department (1968). A reconnaisance inventory survey of the indigenous forest areas of Kenya. The Kenya Forest Department, Nairobi, Kenya.

(2) For example Ueda K(1966) Research and Recommendations on bamboo resources for pulp and paper making in Thailand.

On average, the above inventory was undertaken fifteen years ago and of course the forest has not stood still. On the one hand, growth has been proceeding, but on the other, these forests have been exploited for commercial timber and fuel. From talk with various people, it was agreed that the Spartan inventory stem volume be reduced by an average of 17 per cent to account for excess exploitation over growth. However, because some former non-commercial species were now classfied as commercial species, it was agreed to keep the proportion of commercial/non-commercial species the same.

Spartan inventory only gave stem volume but from point of woodfuel assessment, total above ground volume is required, for ~~bench~~ branch-wood burns just as well as stem wood. From studies undertaken in several countries and with different tree species, branch wood accounts for approximately 20 per cent of the stem wood volume and so stem volume was multiplied by 1.2 to arrive at an estimate of total above grou volume. No allowance has been made for root volume, but if one is required, then an additional 15 per cent of stem volume should be added to account for roots.

The above ground volume was them calculated for each forest by province, using the Spartan inventory details. These forest averages are shown in Appendix 1 by commercial and non-commercial species.

Next an assessment of the bamboo and scrub volume was derived by assuming a constant growing stock of $48m^3$ per hectare on all these areas.

Using all these volume figures, the total of the growing stock by province was determined. Finally, the annual yield and the annual firewood offtake were derived after consultation with mensuration and utilization experts. It was agreed that the annual yield from the natural forests is about 1/40th of the the standing volume and that for scrub and bamboo is 1/15th. Similarly, the annual firewood offtake could be of the order of 80 per cent for non-commercial species, scrub and bamboo, and 35 per cent for commercial species. Thus, using these figures, yield and firewood offtake were estimated by province. These are shown in Tables 5 6 and 7, together with the information for plantation grown species.

Table 5. KENYA 1980 Current growing stock of forests by province and forest type

UNITS 000m³

Province/Forest type	PLANTED FOREST		NATURAL FOREST		ALL FOREST		
	Woodlots(1)	Plantation(2)	Commercial	Non.Comm.(3)	Total	Exploitable	Protection
NYANZA	4	163	95	196	458	435	23
(of which protection/NP)			(7)	(16)			
WESTERN (P & NP)	41	2003	4091 (169)	5522 (227)	11657	11261	396
CENTRAL (P & NP)	1021	9290	11434 (2958)	20237 (5238)	41982	33786	8196
NAIROBI (P & NP)	480	149	13 (2)	43 (3)	685	680	5
EASTERN (P & NP)	345	3084	3937 (318)	7924 (616)	15290	14356	934
COAST (P & NP)	101	611	2384 (33)	5103 (91)	8199	8075	124
RIFT VALLEY (P & NP)	2927	26471	45904 (3615)	50409 (3971)	125711	118125	7586
NORTH EAST	0	0	0	0	0	0	0
TOTAL (P & NP)	4919	41771	67858 (7102)	89434 (10162)	203982	186718	17264

NP = National Park P Protection forest

(1) Woodlots are confined to eucalypts and wattle species.
(2) Plantations are all species except eucalypts and wattle, mainly pine and cypress species.
(3) Includes bamboo, with or without trees and scrub areas.

Table 7 KENYA 1980 Estimated sustainable offtake of firewood by province and forest type

UNITS 1000m³

Province/ Forest type	PLANTED FOREST		NATURAL FOREST		ALL FOREST		
	Woodlot	Plantation	Commercial	Non-commercial	Total	Exploitable	P/NP
NYANZA (of which (N & NP)	0.3	1.9	0.8 (0.1)	4.4 (0.4)	7.4	6.9	0.5
WESTERN (N & NP)	1.7	20.1	35.8 (1.5)	135.2 (5.6)	192.8	185.7	7.1
CENTRAL (N & NP)	92.5	111.1	100.0 (25.9)	576.8 (149.3)	880.4	705.2	175.2
NAIROBI (N & NP)	40.0	1.8	0.1 (0.0)	0.9 (0.1)	42.8	42.7	0.1
EASTERN (N & NP)	19.2	14.7	34.4 (2.8)	307.5 (23.9)	375.8	349.1	26.7
COAST (N & NP)	8.4	6.5	31.8 (0.4)	107.9 (1.9)	154.6	152.3	2.3
RIFT VALLEY (N & NP)	253.6	308.9	401.7 (31.6)	1191.2 (93.8)	2155.4	2030.0	125.4
NORTH EAST	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	415.7	465.0	604.6 (62 .3)	2323.9 (275.0)	3809.2	3471.9	337.3

P = Protection NP = National Park

Table 6. KENYA 1980. Estimated yields from forests by province and forest type

UNITS 000m³

Province/ Forest type	PLANTED FOREST		NATURAL FOREST		ALL FOREST		
	Woodlot	Plantation	Commercial	Non-Comm.	Total	Exploitable	P/NP
NYANZA of which P&NP	0.4	5.4	2.4 (0.2)	5.5 (0.4)	13.7	13.1	0.6
WESTERN (P & NP)	2.1	57.2	102.3 (4.2)	168.9 (6.9)	330.5	319.4	11.1
CENTRAL (P & NP)	102.1	319.2	285.8 (73.9)	720.9 (186.6)	1428.0	1167.5	260.5
NAIROBI (P & NP)	48.0	5.0	0.3 (0.0)	1.1 (0.1)	54.4	54.3	0.1
EASTERN (P & NP)	23.0	42.2	98.4 (7.9)	384.3 (29.9)	547.9	510.1	37.8
COAST (P & NP	10.1	20.3	65.2 (0.9)	137.9 (2.5)	233.5	230.1	3.4
RIFT VALLEY (P & NP)	304.4	882.4	1147.6 (90.4)	1489.0 (117.3)	3823.4	3615.7	207.7
NORTH EAST	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL (P & N)	490.1	1331.7	1702.0 (177.5)	2907.6 (343.7)	6431.4	5910.2	521.2

P = Protection NP = National Park

2) Plantation forests

The assessment of plantation volume was undertaken in three stages. First, the plantation areas by species and age were obtained for each project. Secondly, three local volume tables per species, low, medium and high were then used to assess the growing stock of each species by project. This work was undertaken by people familiar with each project, and they assessed which of the three tables to apply to each age class of species. Thirdly, the total volume by project and species was then compiled and this information was then classfied by province and summed. Details of Provincial information by species information by species is shown in Appendix 2. To assess the increment (annual yield) simple reduction factors were used for the main species. Likewise the firewood yield was assessed in a similar manner. These reduction factors are as follows:-

Table 8 Plantation Species:
Annual Yield and Annual Firewood Yield Reduction Factor

Species	Annual Yield Fraction of standing volume	Firewood Yield(2) Percentage of Annual yield
Pine and cypress	1/30	35.0 per cent
Eucalyptus:Western Province(1)	1/20	83.3 per cent
Eucalyptus:Eastern Province(1)	1/15	83.3 per cent
Eucalyptus:Other Provinces	1/10	83.3 per cent
Wattle	1/7	83.3 per cent
Other species	1/30	35.0 per cent

1) In these provinces the plantations are very young and will give a much lower annual yield than in the other provinces (for 1980). Hence the large divisor.

2) These figures have been calculated by assuming that for all species, all the branch wood is available for firewood (16.6 per cent of total volume). For pine, cypress and oth species 22 per cent of the stem volume in the form of sawmill slabs etc. is available. For eucalyptus and wattl 80 per cent of the stem volume is available, the other 20 per cent being used for poles and pulpwood.

Note:

The estimation of annual yield from standing volume mainly depend on the area planted in each year. If for example a species is on a ten year rotation, with no thinning, and all the area was planted at one time then there will be no yield until year ten. In this case in year 10 the standing volume will equal the yield and the average annual yield will be 1/10th of the total final yield. However, if 1/10 of the area was planted each year for ten years then the yield in year ten will be about 1/5th of the standing volume, but of course the standing volume in the latter will be about half the standing volume (of year 10) in the former case. If the plantation has an approximate equal area planted each year, that is the plantation is said to be 'NORMAL' then the rule of thumb to estimate yield is to halve the rotation age and divide the standing volume by this. Eg. Rotation 10 years. divisor = 5: rotation 30 years divisor = 15

It should have been more accurate to assess yield by following the precription for thinnings and final felling as issued by the Kenyan Forest Service. These prescriptions are shown in Appendix 3. Briefly, they state the rotation age for each species, the number of thinnings to be carried out and the stems to be removed at each thinning. However, because of lack of funds and poor management, these prescriptions are rarely followed Indeed, there are some eucalypts 70 years old when they should be on a rotation of about ten years. Therefore it was decided to adopt the fractions as given in Table 8 to assess the annual yield. As a check this yield was compared to recorded offtake from plantation forests and the two compared favourably. The growing stock volume, yield and firewood yield for plantations (and natural forecasts) are shown in Table 5, 6 and 7. All these volumes have been converted into mass. This has been done because, for energy assessment, mass is the best measure. For any given species the energy value for a unit weight at a specified moisture content is more or less constant, whereas in unit volume terms the energy value can vary enormously. Appendix 4 gives the volume/mass relationships for different species at air dry weight (15 per cent moisture content - dry basis) and Table 9,10 and 11 give respectively the weights of the growing stock, annual yield and annual firewood yield for Kenya by province. The growing stock and yields on the protection and national parks has been separated from the other areas, for it is assumed that these areas will not be exploited or only ~~out~~ to a very minor extent.

Table 9 KENYA 1980 Weight of current growing stock of forests by province and forest type

UNITS 000 tonnes

Province/ Forest type	PLANTED FOREST Woodlot	PLANTED FOREST Commercial Plantation	NATURAL FOREST Commercial	NATURAL FOREST Non-Comm	ALL FOREST Total	ALL FOREST Exploitable	ALL FOREST P/NP
NYANZA (of which protection&NP)	3	85	73 (6)	140 (11)	301	284	17
EASTERN (P & NP)	33	1148	3147 (130)	3468 (143)	7796	7523	273
CENTRAL (P & NP)	810	4958	8795 (2275)	14455 (3742)	29018	23001	6017
NAIROBI (P & NP)	381	97	10 (1)	31 (2)	519	516	3
EASTERN (P & NP)	274	1622	3028 (244)	5660 (440)	10584	9900	684
COAST (p & NP)	80	336	1959 (27)	3882 (70)	6257	6160	97
RIFT VALLEY (P & NP)	2305	13788	35310 (2781)	36007 (2836)	87410	81793	5617
NORTH EAST	0	0	0	0	0		
TOTAL N & NP	3886	22034	52322 (5464)	63643 (7244)	141885	129177	12703

P= Protection NP= National Park

Table 10 KENYA 1980 Weight of estimated yield from forests by province and forest type

UNITS 000 Tonnes

Province/ Forest type	PLANTED FOREST Woodlot	PLANTED FOREST Plantation	NATURAL FOREST Commercial	NATURAL FOREST Non-Commercial	ALL FOREST Total	ALL FOREST Exploitable	ALL FOREST P/NP
NYANZA (of which protection N & P)	0.3	2.8	1.8 (0.1)	4.0 (0.3)	8.9	8.5	0.4
EASTERN (N & NP)	1.6	32.8	78.7 (3.3)	120.7 (5.0)	233.8	225.5	8.3
CENTRAL (N & NP)	81.0	172.7	219.9 (56.9)	515.0 133.3)	988.6	798.4	190.2
NAIROBI N & NP)	38.1	3.3	0.2 (0.0)	0.8 (0.1)	42.4	42.3	0.1
WESTERN N & NP)	18.3	23.4	75.7 (6.1)	274.5 (21.3)	391.9	364.5	27.4
COAST (N & NP)	8.0	11.2	54.2 (0.8)	106.2 (1.9)	179.6	176.9	2.7
RIFT VALLEY N & NP)	239.1	459.5	882.8 (69.5)	1063.5 (83.8)	2644.9	2491.6	153.3
NORTH EAST N & NP)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL (N &NP)	386.4	705.7	1313.3 (136.7)	2084.7 (245.7)	4490.1	4107.7	382.4

P = Protection NP = National Park

Table 11 KENYA 1980 Weight estimate of sustainable fuelwood offtake by province and forest type

UNITS 000 Tonnes

Province/ Forest type	PLANTED FOREST		NATURAL FOREST		ALL FOREST		
	Woodlot	Plantation	Commercial	Non-Comm.	Total	Exploitable	P/NP
NYANZA (of which protection)	0.2	1.0	0.6 (0.0)	3.2 (0.3)	5.0	4.7	0.3
WESTERN (N & NP	1.4	11.4	27.5 (1.1)	96.5 (4.0)	136.8	131.7	5.1
CENTRAL (N & NP)	67.5	65.9	77.0 (19.9)	412.0 (106.6)	622.4	495.9	126.5
NAIROBI (N & NP)	31.8	1.1	0.1 (0.0)	0.6 (0.0)	33.6	33.6	0.0
EASTERN (N &NP)	15.2	8.2	26.5 (2.1)	219.6 (17.1)	269.5	250.3	19.2
COAST (N & NP)	6.6	3.5	27.4 (0.4)	82.8 (1.5)	120.3	118.4	1.9
RIFT VALLEY (N & NP)	199.2	160.9	309.0 (24.3)	850.8 (67.0)	1519.9	1428.6	91.3
NORTH EAST (N & NP)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL (N & NP)	321.9	252.0	468.1 (47.8)	1665.5 (196.5)	2707.5	2463.2	244.3

P = Protection NP = National Park

Table 9 shows that the estimated growing stock in the forest areas amounts to some 142 million tonnes, but only 129 million tonnes (air dry) is classified as exploitable. Of this exploitable total, 69 million tonnes are made up of commercial (industrial)species and 60 million tonnes of so-called non-commercial species, although of course eucalypts and wattle are grown commercially and can be used in the sawmilling and pulp industries, but their main wood use in Kenya is for fuel. Similarly, non-commercial natural forest trees and bamboos can and are exploited to varying degrees, but not usually for industrial processes such as sawmilling, panel industries and pulp mills.

The 129 million tonnes of wood from 'high' forests should be compared to the estimated 690 million tonnes from trees on rangeland areas, but while the latter comes from an area of about 49 million hectares, the forests only occupy about 2.4 per cent of the land area, some 1.4 million hectares. Therefore on average the forests have a growing stock of 103 tonnes per hectare , while the rangelands only have 14 tonnes/ha. Also the forests are situated in areas of high population density, thus they are much more readily accessible. However, as has been stated previously, it is not the growing stock per se that is important, but the annual increment that can be removed while keeping the growing stock intact.
Table 10 estimates that only some 4.1 million tonnes can be removed from the exploitable forests on a sustainable basis, and of this, 2.5 million tonnes can be used for woodfuel. This is well short of of the estimated demand of 18 million tonnes. As will be seen later, some of this demand is met from trees on agricultural land and some from rangeland trees, but with such a gap between sustainable forest supply and demand the forest capital is being eroded.

3) Survey of tree cover on high potential agricultural land

(i) Introduction

The high potential agricultural land in Kenya contains three quarters of Kenya's population: about 12½ million people in 1980, and occupies an area of near eight million hectares. It provides most of the food for the entire population, and it will be called upon to meet the bulk of the increase in demand for food caused by the projected doubling of the population by the year 2000. At the same time, the tree cover on this land meets some of the local requirements for fuelwood. The total area of high potential land including forest area is shown in Table 12.

Table 12. Area of high potential land by province

Units.1000ha

Province	High potential Agric.area (potential/actual)	Forest area	Total high potential area	Percentage of total	Total area
Nyanza	1157	4	1161	93	1252
Western	720	68	788	96	823
Central	939	274	1213	92	1318
Nairobi	30	2	32	46	70
Eastern	1950	142	2092	13	15576
Coast	430	121	551	7	8304
Rift Valley	2565	773	3338	20	16883
North East	0	0	0	0	12690
Kenya	7791	1384	9175	16	56916
Percentage	85	15	100		

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It will be seen that 85% of high potential area is classified as agricultural land, and 15% as forest land, but there is hardly any forest land in Nyanza whereas 23% of the land is classified as forest in Central Province. It will also be noted that each person has on average ½ hectare of high potential land, of which less than 1/10 hectare is forest land. Much of the wood for cooking (and building) comes from the surrounding forests and woodlands, but also a considerable amount woood must come from the trees and shrubs on farm land because fuelwood for the subsistence farmer has to be within walking distance. Therefore it is necessary to obtain an estimate of the tree and shrub cover on agricultural land.

(ii) Survey methodology

The survey was undertaken on the high potential land with the help of the Kenyan Rangeland Ecological Monitoring Unit (KREMU) and the Forestry Department of the University of Nairobi. The high potential area was surveyed in a light aircraft and ten distinct farming types were recognised. The boundaries of these farming types were drawn on a map and the areas measured.
It should be mentioned that one farming type may be represented in a number of areas, for example, large scale maize, wheat and barley farms. Also there was some overlap between 'rangeland' areas and agricultural lands. The fringes of the rangeland areas are being opened up; therefore, to avoid double counting, the actual area measured for tree cover is less than the area of high and medium potential agricultural land which now accounts for nearly 10 million hectares but it is as shown in Table 12.
The largest difference is in Eastern province.

Table 13 shows the farming types, the area of each type by province and where the sample area for each type was chosen.

Table 13. Farming type in the high potential areas of Kenya by area and province UNITS 1000 ha

	Sampling Unit	Area in each province							
		Nyanza	Western	Central	Nairobi	Eastern	Rift V	Coast	Total
1) Large scale maize, wheat, barley & fruit trees.	Kitale		63	40		23	1144		1270
2) Sisal farm, maize & beans with sugar, tea & coffee (tea & coffee)	Kakamega (1)	262	561 (3)				380		1203 (3)
3) Estate sugar, plus some rice & small farms	Kisumu	188					130		318
4) Small farms, maize & beans	Homa Bay	202							202
5) Estate tea/coffee small holding maize, beans, bananas (tea/coffee)	Kisii/ Kericho	407 (18)					498 (40)		905 (58)
6) Estate sisal, rape seed, med & small farms	Nakuru			292			68		360
7) Small farm maize, beans, coffee, sisal (tea/coffee)	Muranga			336 (82)	25 (5)				361 (87)
8) Small farm maize, beans rice, tea & coffee (tea/coffee)	Embu/Meru			37 (11)		308 (67)			345 (78)
9) Grazing & small farms	Machakos					1552			1552
10 a) Estate sugar & small farms plus pastoral	Coast								
10 b) Coconut, cashew tree small farms & pastoral	Coast							430	430
Total area excluding tea & coffee areas		1059	624	705	25	1883	2220	430	6946
Tea & coffee areas		18	3	93	5	67	40	0	226
Total high potential farm area in sample		1077	627	798	30	1950	2260	430	7172
Actual high potential area in the main report (2)		1157	720	939	30	1950	2565	430	7791

(1) A reserve sampling unit was also flown in this area and covered a strip of Busia district which is referred to as sample no.11.

(2) The difference in area between the high potential area used to estimate tree volume, 7,172,000 ha. and the high potential area as described in the main report 7,791,000 ha is accounted for by the fact that some land is included in the rangeland survey and other land is open park or grassland.

It was intended to choose a typical area in each of the ten plots and ~~the~~ to photograph a strip about 30 kilometres long in each area. However, Ecosystems Ltd. of Nairobi had already done photographs for Machakos and time did not permit the coastal area to be photographed. Also in the end because of poor weather conditions Muranga and Embu/Meru were not photographed, but ground surveys were done in these two areas as well as the first six areas mentioned in Table 13. Seven photo lines were taken, Busia being the additional (reserve) line, and the photographs were analysed for tree cover. Seven types of tree cover were recognised, ranging from natural woodlands to hedges, and these are described in Table 14. Natural woodlands are the most important type of tree cover and they occupy nearly half of all the tree areas, as can be seen from Table 14.

Table 14. KENYA 1981 Tree cover as a percentage of total cover on high potential land - an analysis of aerial photographs

UNITS % of total area

Photo line/ Tree type	Natural wl/sh bush	Riverine trees	Planted woodlots	Farm Trees: Along Fields boundaries Roads	Farm Trees: Scattered farm trees	Farm Trees: Hedges	Farm Trees: Round compound	Total cover
1. Kitale	5.20	2.00	0.69	0.60	0.99	0.03	0.28	9.79
2. Kakamega	1.77	1.73	0.93	0.55	0.98	0.45	1.73	8.14
3. Kisumu	4.83	1.61	0.26	0.25	0.95	0.33	1.30	9.08
4. Homa bay	4.80	0.76	0.69	0.30	0.80	0.80	0.80	8.80
5. Kericho/ Kisii	3.10	1.22	2.20	0.40	1.53	0.63	0.14	9.22
6. Nakuru	5.40	0.16	0.17	0.88	0.20	0.03	0.20	6.98
11. Busia	5.10	0.75	0.68	0.89	0.43	0.10	4.20	12.15
MEAN	4.25	1.16	0.79	0.55	0.84	0.34	1.23	9.16
5a. Kericho Large tea estates	4.34	0.84	4.67(1)	0.36	0.50	0.05	0.04	10.80
9. Machakos (Eco Systems)	12.80(2)					4.20		17.00

(1) Practically all of these woodlots are more than 10 hectares and have already been included in the forest survey.

(2) This area includes woodlots and natural forests of more than ten hectares which have already been included in the forest survey.

wl = woodlands, sh = shrub.

Planted woodlots on farm/estates on average accounted for less than one per cent of the land cover, but in the tea growing areas on the estates themselves, the, accounted for nearly five per cent of the land cover. However, many of these woodlots are over 10 hectares in area and have been included in the forest survey previously mentioned. Therefore an adjustment has to be made to avoid double counting. Actual farm trees and hedges accounted for two per cent and if trees round compounds are included the total comes to 3½%. All in all, just over 9% of the land area was occupied by tree crowns. However, it is important to point out, especially when farmers are to be persuaded to plant more trees, that the actual area occupied by the tree and hedge stems is somewhere in the region of 5 m² per hectare, which in percentage terms is 0.05% or 1/180th of the crown cover - an extremely small area. Even if 15% to 20% of farm lands were to be planted with 'complimentary' trees, then the actual stem area occupied by these trees could only be between 7.5m² and 10m² per hectare, or 0.1% of the land area. Thus, what might seem like a large part of farmland to be surrendered is in fact only an extremely small portion, and the protective nature of the trees usually more than compensates for the small amount of land given up.

After the aerial photograph had been interpreted for tree cover, ground crews were sent into eight sample areas and line or 'relascope' sample plots were conducted in the areas that were photographed (except for Muranga and Meru where no photographs taken). Fifteen sample plots 50 metres long by 10 metres wide were taken every 200 metres for fifteen days, so all in all 225 sample plots were measured covering just over eleven hectares. All tree species were recorded and breast height diameter and total height were measured. By applying a form factor of 0.7 an estimate of stem volume was determined; the stem volume was then multiplied by 1.2 to give an estimate of totalabove ground volume.

The results of the line survey are shown on Table 15 together with the final adjusted volumes which were used to estimate woody biomass volume on farm land.

Table 15. Kenya 1981. Stem volume and total volume per hectare of trees on agriculutral land — Units m³

Line plot	Average stem volume ha	Estimated total volume per ha	Adjusted total volume per ha.
1. Kitale	11.9	14.3	14.3
2. Kakamega	9.2	11.0	11.0
3. Kisumu	1.2	1.4	10.8(1)
4. Homa Bay	8.8	10.6	10.6
5. Kisii/Kericho	26.9	32.3	16.6(2)
6. Nakuru	14.2	17.0	17.0
7. Muranga	25.3	30.4	30.4
8. Meru/Embu	25.4	30.5	30.5
Estimated volumes from above information			
9. Machakos			18.0(3)
10. Coast			25.0(4)

Notes

(1) The estimated stem volume was much too low due to poor sampling Table 14 indicates that the tree cover is similar to Homa Bay and Kakamega lines. Therefore the voulme per hectare has been adjusted upwords to fall between these two totals.

(2) The final figure was adjusted downwards because the original includes woodlots of more than 10 ha. which have already been included in the forest survey. When these were excluded, the adjusted total was arrived at.

(3) Like Kericho, Machakos included some woodlots and natural forests of over 10 ha. Towards the north the farm tree cover is similar to Embu/Meru, and in the south the tree cover is less than Homa Bay.

(4) The coast region contains two distinct types - the sugar, pastoral, small farm belt to the south of Mombasa and the pastoral, small farm coconut/cashew nut to the north. It has been estimated that there are the equivalent of 29,000 ha of cashew nut trees and 32,000 ha of coconut palms. Therefore for the coast as a whole it is estimated that half the area has a volume of about $32m^3$/ha. and the other half $18m^3$/ha. giving an average volume of $25m^3$/ha. The per hectare total volumes were then multiplied by the farm type areas by province as given in Table 13. The tea and coffee areas were excluded from these totals as a seperate estimate was made of woody biomass growing in these areas.

Table 16 gives the estimate of woody biomass growing on agricultral land together with the estimated annual yield and the firewood yield. It will be seen that the growing stock is estimated to be 84 million tonnes of which 73 million tonnes are reckoned to be exploitable. This compares with 142 million tonnes in the forests, of which 129 million tonnes are exploitable (Table 9).

Table 16. KENYA 1981. Estimated volume and weight for trees on agricultural land by province

UNITS 1000t except where stated

Province	Area of Agric.land 1000 ha	Woody biomass growing stock standing Vol.1000m³	weight of which:- Total	Protection	Exploitable	Estimated exploitable yield Total annual yield (3)	of which firewood yield (4)
NYANZA	1059	13809	9864	1253	8611	574.1	459.3
WESTERN	624	7072	5051	641	4410	294.0	235.2
CENTRAL	705	16878	12056	1531	10525	701.7	561.4
NAIROBI	25	760	543	70	473	31.5	25.2
EASTERN	1883	37659	26899	3416	23483	1565.5	1252.4
COAST	430	10750	7679	975	6704	446.9	357.5
RIFT VALLEY	2220	31366	22404	2845	19559	1303.9	1043.1
NORTH EAST	0	0	0	0	0	0	0
KENYA	6946 (1)	118294	84496	10731	73765	4917.6	3934.1
Av.t[m³]/ha	(7565)	[17.0] [(15.6)]	12.2 (11.2)	1.6 (1.4)	10.6 (9.8)	0.7 (0.7)	0.6 (0.5)

(1) Excluding tea and coffee areas 226,000 hectares and excluding 619,000ha of land included in the main report as high potential but which was already included under rangelands or is open park or grassland if this is included then the exploitable growing stock is reduced to 9.8t/ha, yield to 0.65t/ha and firewood yield 0.5t/ha (see last line).

(2) The protection volume/wt of trees has been taken as the area of riverine trees, these cover an area of 12.7% of all tree cover(table 14).Of course dead branches are collected and some of these trees will be exploited, but on the other hand there are trees on steep slopes that are left, therefore, this fraction is felt to be reasonable and has been used to calculate the weight of trees that should not be exploited.

(3) This has been calculated by taking 1/30 of the growing stock. It assumes a rotation of about 60 years. If trees were managed exclusively for firewood, then the rotation could be as little as 2-3 years and much more volume could be removed annually. However, short rotation firewood trees are not common in Kenya today and trees are managed for commercial timber and poles as well as firewood.

(4) This has been taken as 80% of the yield. It assumes that the other 20% is used for poles and pitsawn (roughly hewn) timber.

The estimated yield is nearly 5 million tonnes, of which 4 million could be used for firewood. The comparable figure for forest areas are: yield 4 million tonnes and firewood yield 2½ million tonnes (Table 9 and 10). The smaller yields from the forests, although the growing stock is larger, is accounted for longer rotations and the fact that much more wood is used for industrial purposes than on the farm; hence a smaller proportion of increment going to fuelwood. However, it is possible by better management and by choosing the correct tree species to increase the yield considerably without affecting the growing stock to any large extent.

The estimate sustainable firewood removal from high potential agricultural areas and forest lands is 6.4 million tonnes, whereas the demand for woodfuel in these areas, both urban and rural, is about 18 million tonnes. Clearly there is a large shortfall, some of which can be made up from supplies from rangeland areas, may be of the order of 5 million tonnes, but the accumulated tree capital must be meeting the difference of 7 million tonnes of wood. Of course the estimated capital on high potential land is some 260 million tonnes, and so, in the short run, the shortfall can be withdrawn from capital; but unless efforts are made to balance sustainable supply with demand, the farm and forest trees will come under increasing threat. Ways of tackling this problem will be discussed shortly, but in order to complete the supply picture, the tea and coffee areas plus urban trees have to be considered and this is now done.

4. Tree cover on urban land

While the trees on urban land occupy only a small part of the total vegetation, nevertheless they do satisfy the fuelwood requirements of the poorest strata of the urban population. Many gardens and roads have a considerable number of trees as can be seen when one drives through most of the major towns; therefore, to make the picture complete, an estimate of tree cover was undertaken. This estimate excludes the forests and woodlots of 10 hectares or more for they are already included in the forest inventory in the previous sections.

The areas of urban environment are shown in Table 17, together with an estimate of the equivalent area covered by trees. From this, the volume and yield have been derived using growth figures from plantations and natural forests within the area. The urban environment areas are usually less than the municiple township areas for these have been expanded recently and include much farm and open land; these areas are included in the previous section.

Table 17.

Kenya 1980 Areas of Urban built up environment with an estimate of tree area, volume and mass

Province	Area-1000ha Total area	Estimated Forest area	Volume-1000m^3 Growing Stock (G.S)	Yield	Firewood out-turn	Weight - 1000t G.S	Yield	Firewoc out-turn
Nyanza	4	0.2	18	1.2	1.0	13	0.9	0.7
Western	2	0.1	22	1.5	1.2	16	1.1	0.9
Central	8	0.3	56	3.7	3.0	40	2.6	2.1
Nairobi	5	0.2	32	2.1	1.7	23	1.5	1.2
Eastern	4	0.2	38	2.5	2.0	27	1.8	1.4
Coast	6	0.2	21	1.4	1.1	15	1.0	0.8
Rift V.	8	0.4	64	4.3	3.4	46	3.1	2.4
N.Eastern	2	0.0	2	0.1	0.1	1	0.1	0.1
Total	39	1.6	253	16.8	13.5	181	12.1	9.6

Of course the existing trees in urban areas can only supply a fraction of urban demand, but if urban forests were established on a large scale they could supply a considerable quantity of wood products, especially fuelwood and poles and also be a recreation area for the urban population who wish to relax and get away from the urban jungle.

(5) Coffee and tea land: survey of woody biomass

Coffee and tea, especially coffee are large export earners for Kenya and the area of land devoted to these crops has been steadily rising. Tea and coffee are perennial plants whose rotation age is generally about five to seven years, although the main stem is not removed until after about 24 years. Throughout their lifetime they are clipped and pruned and therefore the clippings and branches are a source of fuel. Also the trunks of the tea and coffee bushes are used as fuel when they are eventually cut down. A number of studies have been done on the yields of woody bomass from tea and coffee, and estimates for Kenya have been based on the works of Cannel[1] and Magambo and Cannel [2]. The general concensus is that clippings of tea and coffee be used for mulch. However, invariably these clippings are removed for fuel. In consequence more fertilizers have to be applied. Bearing these facts in mind, the growing stock and removals of wood from tea and coffee have been estimated as follows:-

Average growing stock per hectare: Tea 3.5 tonnes; Coffee 3.0 tonne.
Annual yield per hectare: Tea 1.3 tonnes; Coffee 1.1 tonne.

In addtion, some coffee areas, especially those in the west, over 2000 metres, have shade trees of such species as Grevillea robusta and Sesbania maorantha. These trees have an average growing stock of 3.6t/ha and an annual yield of 0.3t/ha. The estimated area of shade or shelter belt trees is shown in Table 18. Many tea estates also grow eucalypts as boiler fuel for drying the tea. However, these areas have already been included in the forest survey.

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Cannel M.G.R.(1970)

(1) Production and distribution of dry matter in trees of Coffee arabica in Kenya as affected by seasonal climate differences and presence of fruits. Ann.Appl.Biol.(1971) 67 97-120.

(2) Magambo M.J.S. Cannel M.G.R.(1980) Dry matter production and partition in relation to yield of tea. Expl.Agric.(1981) vol. pp.33-38.

Table 18. Kenya 1980. Area of land under tea and coffee

Units 1000 ha.

Province	TEA			COFFEE				
	Estate	Small holder	Total	Estate	Small holder	Total	Grand Total	Estimated Coffee Are with trees
Nyanza	1.0	5.4	6.4	0.0	11.4	11.4	17.8	9.1
Western	0.0	1.8	1.8	-	1.2	1.2	3.0	1.0
Central	2.9	39.5	42.4	17.7	33.5	51.2	93.6	7.7
Nairobi	-	-	-	5.0	-	5.0	5.0	0.8
Eastern	-	11.0	11.0	2.2	53.6	55.8	66.8	11.2
Coast	-	-	-	-	-	-	-	-
Rift Valley	30.9	3.6	34.5	5.5	0.1	5.6	40.1	4.5
North East	-	-	-	-	-	-	-	-
Kenya	34.8	61.3	96.1	30.4	99.8	130.2	226.3	34.3

Source. Kenya agricultural statistics

The above per hectare figures can be arplied to the areas of tea and coffee to obtain an estimate of growing stock and yield. This has been done and is shown in Table 19. To estimate the quantity of shade and edge trees growing on coffee areas, an area figure was assessed after consultation wit the coffee regions. This is given in the end column of Table 18.

While the average growing stock on the tea and coffee areas is relatively low (3.7 tonnes/ha.of woody biomass), because of intensive management, the annual yield - an estimated 1.2t/ha of woody biomass - is relatively high. This may be one of the keys to agro-forestry and fuelwood plantation - short rotations and intensive management. This completes the estimation of wood biomass and the only other major source of renewable biomass is animal waste

TABLE 19 KENYA 1980. Growing stock and annual yield of woody biomass of tea, coffee and shade trees on coffee areas.

UNITS 1000t

Province	Tea		Coffee		Trees in coffee Area		Total	
	Growing Stock	Yield	Growing Stock	Yield	Growing Stock	Yield	Growing Stock	Yield
NYANZA	22.4	8.3	34.2	12.5	32.8	2.7	89.4	23.5
WESTERN	6.3	2.3	3.6	1.3	3.6	0.3	13.5	3.9
CENTRAL	148.4	55.1	153.6	56.3	27.7	2.3	329.7	113.7
NAIROBI	-	-	15.0	5.5	2.9	0.2	17.9	5.7
EASTERN	38.5	14.3	167.4	61.4	40.3	3.4	246.2	79.1
COAST	-	-	-	-	-	-	-	-
RIFT VALLEY	120.8	44.8	16.8	6.2	16.2	1.4	153.8	52.4
NORTH EAST	-	-	-	-	-	-	-	-
KENYA	336.4	124.8	390.6	143.2	123.5	10.3	850.5	278.3

iii) Animal residues

To complete the biomass picture, mention should be made of animal residues. Already some householders use dung, and in a survey undertaken at the same time as the survey of tree cover on agricultural land, seven households out of 113 were found to burn dung for cooking, and it is estimated that these families used the energy equivalent of 1.2m³ of wood per family per year (0.16 m³ per person). However, the average annual per capita consumption for the whole sample only came to the energy equivalent of 0.01m³ of wood and the dung was only burnt in the wood scarce areas of Kisumu and Homba Bay. Usually dung is only burnt where wood is scarce or where animals are taken into a stable at night and tribal custom permits the burning of dung. The Masai keep their cattle in bomas but do not burn dung. On the contrary a person's wealth or prestige is judged by the height of dung outside his house and of course, being mainly milk and blood eaters, their requirements for fuel are less than other groups.

Ideally, dung should be returned to the ground as a fertilizer, preferably after methane has been extracted from it, but this presents a number of problems which are fully described in Methane Generation from human, animal and agricultural wastes(1). Briefly, the capital cost for a family of six digester could cost between K.shs.2,500 and 10,000, requires 90kg of wet dung - all the product of 9 to 12 cows, 90 litres of water, an optimum temperature of 33-38°C and good maintainance and control.

Some or all of these requrements are beyond the means of most rural Kenyans and therefore, at best, methane gas energy as a substitute for other energy form will only have a marginal effect on energy supply. What will happen is that when wood and crop residue is scarce, dung will be burnt instead of being returned to the soil. If the per capita consumption of 0.01m³ wood equivalent is anything near correct,

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(1) National Academy of Sciences 1977. Washington D.C. U.S.A.

then today in Kenya, 128,000 air dry tonnes of dung, equivalent of about 135,000m³ or 96,000 tonnes of wood (1.5 Peta Joules) are burnt annually. This is approximately 2% of the estimated yearly production of dung, as the following tables indicate. The quantity of dung produced by various animals per year is as follows. Table 20

Table 20. Conversion Factors for dung production

	Daily production per 500 Kg. Wet weight Kgs	Estimated No of animals per 500kg	Tonnes per year per animal Wet Wt.	Dry Wt.(1)
Dairy cattle	38.5	3.85	3.65	0.36
Beef cattle	41.7	2.75	5.53	0.65
Swine	28.4	10	1.04	0.10
Sheep/goats	20.0	20	0.36	0.09
Poultry	31.3	150	0.08	0.02
Donkeys	28.0	3.33	3.07	0.54
Camels	28.0	1.25	8.18	1.44

Source National Academy of Sciences 1977. Methane Generation, Adapted,

(1) Dry weight 15% moisture content.

Table 21 gives an estimate of the number of animals by province in Kenya, and Table 22 gives the quantity of animal waste produced by these animals using the dry weight figure in Table 20.

Table 21. Kenya 1980 Number of animals by province

UNITS - millions

Province	Cattle (1)	Sheep/goats	Pigs	Poultry	Donkeys	Camel
NYANZA	1.20	0.60	0.00	3.30	0.01	-
WESTERN	0.80	0.20	0.01	2.30	0.00	-
CENTRAL	0.60	0.70	0.02	1.10	0.00	-
NAIROBI	0.01	0.00	0.00	0.05	0.00	-
EASTERN	2.00	2.20	0.00	3.00	0.04	0.20
COAST	0.40	0.50	0.00	1.10	0.00	-
RIFT VALLEY	4.20	3.70	0.03	1.00	0.13	0.20
NORTH EAST	0.40	0.20	0.00	0.00	0.00	0.10
KENYA	9.61	8.10	0.06	11.85	0.18	0.50

Source 1978 Statistical abstract

(1) Presume 2/3 beef and 1/3 dairy

Table 22 KENYA 1980 Estimate of animal waste by province

UNITS - millions of tonnes air dry weight (15% M.C)

Province	Cattle	Sheep Goats	Pigs	Poultry	Donkeys	Camel	Total	Practical Availability	Peta Joules(1) of energy Total	Peta Joules(1) of energy Practical Availability (2)
NYANZA	0.66	0.06	0.00	0.07	0.01	-	0.80	0.016	9.60	0.19
WESTERN	0.44	0.02	0.00	0.05	0.00	-	0.51	0.010	6.12	0.12
CENTRAL	0.33	0.07	0.00	0.02	0.00	-	0.42	0.008	5.04	0.10
NAIROBI	0.01	0.00	0.00	0.00	0.00	-	0.01	0.000	0.12	0.00
EASTERN	1.10	0.22	0.00	0.06	0.02	0.29	1.69	0.034	20.28	0.41
COAST	0.22	0.05	0.00	0.02	0.00	-	0.29	0.006	3.48	0.07
RIFT VALLEY	2.31	0.37	0.01	0.02	0.07	0.29	3.07	0.061	36.84	0.73
NORTH EAST	0.22	0.02	0.00	0.00	0.00	0.14	0.38	0.008	4.56	0.10
KENYA	5.29	0.81	0.01	0.24	0.10	0.72	7.17	0.143	86.04	1.72

(1) Assume that one tonne air dry dung contains 12.0×10^{9} Joules or 12.0 Giga Joules of energy

1.0×10^{15} Joules = 1 Peta Joule

(2) It is assumed that only 2% of the total animal waste is practically available. This percentage may increase as other energy sources become scarcer.

Estimated production of dung is of the order of 7 million air dry tonnes and has an energy value of approximately 86 Peta Joules (10^{15} Joules) or 20% of Kenya's current demand. However, it is physically and economically impossible to collect even a fraction of this total and what is more, unless it went through a digester it would deprive the soil of about 0.7 million tonnes of nitrogen and phosphorus fertilizer as well as loss of soil structure. Therefore Kenya will have to be content with using about 2% of this total. It is also possible to use human waste and refuse as energy sources. There are about 65,000 air dry tonnes of human waste produced, and in towns such as Nairobi, this waste could be collected centrally and put through a digester. Also refuse could be used as boiler fuels, but of course such schemes are relatively capital intensive and provide very little energy. The main biomass energy source and indeed the main energy source is wood. It is pertinent to look at the supply/demand position for all biomass to see where the shortfalls are and to see what must be done to counter these shortfalls.

The supply and demand of biomass

Table 23 gives the estimated supply and demand for biomass in Kenya for 1980. Animal and agricultral residues have been kept separate from woody biomass because, for household use at least, these are second best alternatives and will only be used if wood is is scarce, or when these residues are in plentiful supply, for exampl after harvest. Normally dung and crop wastes are left on the land to maintain the fertility and soil structure. The overall picture for these energy forms is one of slight surplus but there are areas of shortage such as Nyanza and Western Provinces when too much residues are removed from the land to the detriment of the soil. Overall, thes fuels supply about 5% of the biomass energy demand, and this fraction cannot be increased greatly unless agricultral imputs increased substantially, especially fertilizer.

Woody biomass suppliers 95% of all biomass energy and indeed it supplies an estimated 71% of total demand, so it is the single most important fuel. However, fuelwood, and to a lesser extend charco is very site specific in that it has to be available usually within walking distance of the rural consumer or within an economic transport distance of the urban/industrial consumer, which is usually no more than 100 Kms for fuelwood and 200-300 Kms for charcoal. It is no use having a surplus in one part of the country if it is too costly in terms of effort or cash to transport it to where the demand is. This is well illustrated in Table 23 by observing that the rangeland areas could theoretically supply nearly 90% of the demand for woodfuel, but because many of these areas are very remote from the large consumption centres, namely the high potential agricultral land, it is economically too expensive to meet this demand. Hence, the situation arises that, in spite of the 'physical' surplus in the rangeland areas, the high potential areas cannot meet current demand from the local annual woody production, and thus the trees are being cut down faster than they are growing.

Table 23 KENYA 1980 Annual production and consumption of biomass energy in wood equivalent terms

UNITS - 1000 tonnes wood equivalent

Biomass / Province	NON WOODY			WOODY BIOMASS						
				from high potential land					from	
	Agric.	Animal(1)	Total	Forest	Farm(2)	Coffee /Tea	Urban	Total	Rangelands	Total
NYANZA	219	12	231	5	459	23	1	488	2	490
WESTERN	392	8	400	132	235	4	1	372	0	372
CENTRAL	50	6	56	496	561	114	2	1173	7	1180
NAIROBI	1	0	1	33	25	6	1	65	0	65
EASTERN	67	26	93	250	1253	79	1	1583	4476	6059
COAST	120	4	124	118	358	0	1	477	2434	2911
RIFT VALLEY	66	46	112	1429	1043	52	3	2527	4432	6959
NORTH EAST	1	6	7	0	0	0	0	0	4749	4749
KENYA: Sustainable production.	916	108	1024	2463	3934	278	10	6685	16100	22785
KENYA: Estimated consumption	794	94	888	5195	8297	278	10	13780	4980	18760
Percentage	89	11	100	28	45	2	0	75	25	100
Surplus/ deficit	+122	+ 14	+ 136	-2732	- 4363	0	(0)(3)	-7095	+11120	+ 4025
Estimated capital of woody biomass				129177	73765	850	181	203973	690000	893973
Wood for charcoal				1750	875	-	-	2625	3200	5825
Wood for firewood				3445	7422	278	10	11155	1780	12935

(1) Practically available

(2) Includes rural built-up environment

(3) It is assumed that the bulk of the urban wood energy comes either from the rangelands or the high potential lands and that no inroads are being made into urban tree capital

while there seems to be a large store of wood, of the order of 262 million tonnes, if the current consumption pattern continues and with the anticipated increase in population, then by the year 2000, supplies will be exhausted. Farm trees and bushes supply about 47% of the wood energy demand, whereas forest trees supply 28%, the remaining 25% coming from the rangeland areas. If Kenya is going to continue to rely on wood as a major energy source, clearly there must be a massive effort in tree planting, and the greatest effort will have to be by the farmers themselves to meet their own requirements. But in order to protect the forests, a large increase in fuelwood plantation within the existing forest estate is required. This is perhaps the best way to protect the forests, for no amount of policing will stop people obtaining the means to cook their meals. Also plantations round towns and cities could act as an urban green belt and be a place for the urban dwellers to relax, while at the same time be a source of his energy supply.

Finally, although the rangelands are surplus areas, there ecological balance is very fragile, and if areas are clearfelled in order to produce charcoal, it will take many decades for the area to recover. Therefore there is a need to put some effort into maintaing the tree cover. However, the largest effort must be in the high potential agricultural areas where the greatest shortfall in supply occurs.

APPENDIX 1

Total above ground volume in various forests(districts) of Kenya.

UNITS - m^3/hectare

Region	Forest/District	Non-commercial species	Commercial species	Total per hectare
NYANZA	Kisumu/S.Nyanza	59	31	[illegible]
WESTERN	Bungoma	94	122	[illegible]
	Kakamega	176	50	[illegible]
CENTRAL	Kiambu	123	36	[illegible]
	Kirinyaga	87	117	[illegible]
	Murang'a	123	36	[illegible]
	Nyandarua	119	76	[illegible]
	Nyeri(1)	119	76	[illegible]
	Nyeri(2)	87	117	[illegible]
NAIROBI	Nairobi	123	36	[illegible]
EASTERN	Machakos	90	46	[illegible]
	Kitui	107	41	[illegible]
	Embu	113	179	[illegible]
	Meru	122	164	[illegible]
	Marsabit	55	22	[illegible]
COAST	Kwale	55	22	[illegible]
	Taita	90	46	[illegible]
	Mangrove areas	10	66	[illegible]
RIFT VALLEY	Kajiado	59	31	[illegible]
	Narok	77	83	[illegible]
	Kericho	139	50	[illegible]
	Nakuru	64	128	[illegible]
	U.Gishu	65	65	[illegible]
	T.Nzoia	94	122	[illegible]
	E.Marakwet	78	143	[illegible]
	Baringo	65	69	[illegible]
	Laikipia	64	117	[illegible]
	W.Pokot	120	81	[illegible]
	Turukana	55	22	[illegible]
	Samburu	59	31	[illegible]
	Nandi	127	57	[illegible]

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APPENDIX 2

Kenya 1980 Area of plantations by species(1)

UNITS - Hectares

Province/Species	Woodlots			Plantations				
	Eucalyptus	Wattle	Total	Cypress	Pine	Other species	Total	Grand Tota
NYANZA	42	-	42	236	398	46	680	722
WESTERN	535	-	535	885	8635	1725	11245	11780
CENTRAL	2675	*	2675	11379	10750	2829	24958	27633
NAIROBI	1502	-	1502	121	1	251	373	1875
EASTERN	1034	-	1034	3320	4485	929	8734	9768
COAST	243	-	243	130	1483	592	2205	2448
RIFT VALLEY	9674	5215	14889	43799	38715	4747	87261	102150
NORTH EAST	0	0	0	0	0	0	0	0
KENYA	15705	5215	20920	59870	64467	11119	135456	156376
Percentage	10	3	13	39	41	7	87	100

(1) Ten hectares or more

* The wattle that feeds the tannin factory at Thika is in areas of under 10 hectares.