The United Nations University

WIDER

World Institute for Development Economics Research

Working Papers No. 117

December 1994

Sustainable Ecosystem in Africa: Managing Natural Forest in Sudan

Siddig A. Salih

SUSTAINABLE ECOSYSTEM IN AFRICA: MANAGING NATURAL FOREST IN SUDAN

SIDDIG A. SALIH

Senior Research Fellow
UNU/WIDER

DECEMBER 1994

* An earlier version of this paper was prepared as a chapter in Anders Hjort af Ornäs (ed.), *Approaching Nature: Insights from the Study of Environment and Security*, EPOS, Linköping University, Sweden.

LIST OF TABLES AND FIGURES

Table 1: Land Use in Sudan 4

Table 2: Domesticated Livestock, 1970-92 6

Table 3: Area of Natural Forests and Plantations in 1990 8

Table 4: Annual Deforestation and Plantations, 1981-90 9

Table 5: Forest Inventory in Sudan, 1983-90 11

Table 6: Total Energy Consumption, 1981-91 14

Table 7: Recent Biomass Consumption 15

Table 8: Energy Consumption by Sector and Energy Source in Sudan, 1981 17

Table 9: Energy Sources in Sudan, 1981 18

Table 10: Woodfuel Production, 1981-91 19

Table 11: Sudan's Per Capita Annual Energy Consumption 20

Table 12: Annual Biomass losses due to Deforestation, 1980-90 22

Table 13: Supply and Use of Wood Energy in 1991 23

Table 14: Total Biomass Residue in 1992 32

Figure 1: Renewable Natural Resource Management Framework for Sudan 31

Glossary of Acronyms, Symbols and Units

ADB	African Development Bank
ARC	Agricultural Research Corporation
BTG	Biomass Technology Group
CFA	Central Forestry Administration
EAP	Environmental Action Plan
ECA	Economic Commission for Africa of the United Nations
ERI	Energy Research Institute
FAO	Food and Agriculture Organization of the United Nations
FNC	Forests National Corporation
FRC	Forestry Research Centre
GCA	Global Coalition for Africa
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GJ	Gega Joule (10^9 Joule)
GPC	General administration of Petroleum Corporation
ha	hectare
IEA	International Energy Agency
IGADD	Inter-Governmental Authority for Drought and Desertification
km	kilometres
LPG	Liquid Propane Gas
MAI	Mean Annual Increment
MJ	Mega Joule (10^6 Joule)
MT	Metric Ton (1000 kilograms)
NEA	National Energy Administration
OECD	Organization of Economic Cooperation and Development
PJ	Peta Joule (10^{15} Joule)
R & D	Research and Development
SREP	Sudan Renewable Energy Project
sq. km	square kilometres
SSA	Sub-Saharan Africa
TJ	Tera Joule (10^{12} Joule)
TOE	Ton Oil Equivalent
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development
UNSO	United Nations Sudano-Sahelian Office
WRI	World Resource Institute

SUSTAINABLE ECOSYSTEM IN AFRICA: MANAGING NATURAL FOREST IN SUDAN

Introduction

There is now an emerging broad consensus among international institutions, United Nations agencies, aid donors, African policymakers and a considerable number of the scientific community concerned with the development of Africa about the major factors deteriorating Africa's ecosystem at an accelerating pace. Unsustainable use of forests (natural ecosystem), mechanized farming, livestock raising (rural practice) and to a lesser extent, urban practice (emission, industrial pollution, waste disposal and overcrowding factor affecting human health) have caused land degradation and will severely undermine Africa's economic future (ADB 1992, pp. 143-146; ECA/FAO 1994:53; Elamin and Ce'sar 1994, pp. ix-xii; FAO 1993:31-46; Salih 1992:2; UN 1994:22; UNEP 1989:4-7; WRI 1994a:10-14; World Bank 1992a, 1992b and 1994a:25-60, 6-12 and 174-179, respectively).[1] Land (or rather the soil) remains the major resource in Africa (UNEP 1989:42-53 and World Bank 1989:75). Both soil and subsoil resources of a nation provide a strong base for sustainable economic development (Baumol 1991:1; Eisner 1989:87-97; Forje 1985:577; Leonard 1988:1-4; Pearce and Warford 1993:36-37; Salih 1992a:3-5 and World Bank 1989:119-133).[2]

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1 Among the six regions of the world, Sub-Saharan Africa (SSA) is characterized by both worsening resource constraints and widespread environmental deterioration: land degradation in the drylands and humid zones and destruction of forests (World Bank 1989:33; Salih 1992a:2 and World Bank 1992a:25). North African countries within the Mediterranean and North Africa region are characterized by the degradation of land and forest resources and the neglect of the regional common (World Bank 1992a:60). However, industrial pollution is a serious environmental problem in the regions of Europe and Central Asia, East Asia and the Pacific and Latin America and the Caribbean (World Bank 1992a:51, 38, and 71 respectively). The combined effect of industrial pollution and pollution from urban practice (for example, raw sewage and garbage) is adversely affecting the health of the population in South Asia region (World Bank 1992a:39).

2 This study adopts the commonly used definition of economic sustainability, in the resource and environmental economics literature, to meet targets of human needs satisfaction without violating environmental and other socio-economic standards, thresholds or capacities. In this setting sustainable economic development stresses the importance of permanent growth and development. In an intertemporal framework sustainable development is defined by the famous Brundtland Commission report to the General Assembly of the United Nations in 1987 as development that meets the needs of the present generation without compromising the ability of the future generations to meet their own needs. Interested readers in the sustainability debate may consult, for example, Falloux and Mukendi (1988), Salih (1992b), Pearce *et al.* (1990a), Pearce and Warford (1993) and the literature cited there.

Sudan is amongst the resource-base countries of Sub-Saharan Africa (SSA) emphasizing proper management of its natural assets to resume and sustain growth. This brings land use to the forefront of the design and implementation of the Environmental Action Plan (EAP) in these countries. The present study is an attempt to look at the deployment of the most potentially renewable resource (forest) in the land use programme (and in turn, EAP) of Sudan and draw insightful remarks to improve the management and sustainability of natural assets in resource-base economies of Africa. This issue is central to the renewed debate on the economic recovery and sustainable growth in Africa. The emerging consensus suggests that even among the resource-base African countries, growth must be led by the agricultural sector (for example, Ayensu 1994:21-22; ECA/FAO 1994:iii; Salih 1994:ii and 70-71; World Bank 1989:89-107 and UNCTAD 1991:27).[3] Here, the role of the forest to enhance agricultural productivity and raising the efficiency of production are highly emphasized. In common parlance, a more comprehensive analysis of all the relationships between protection of forest ecosystems, sustainable utilization of renewable natural resources and socio-economic dynamics of land use pressures is adopted in this study.

The aims of this study are threefold. First, to explain the importance of the natural ecosystem and its underestimated contribution to Sudan economy within the context of the land utilization scheme. The most significant factors contributing to environmental crisis in Sudan are identified in section 2. Second, the extent of the natural resource degradation (as the main environmental problem) is explained and viewed as location specific in densely populated areas. Fuel deficit localities are not necessarily represented by the aggregate supply-demand situation shown in sections 3 through 5. These sections together with sections 6 and 7 assess the comparative

3 Agriculture remains the main source of employment in Africa employing 65 per cent of the labour force in the beginning of the 1990s. The index of total agricultural production rose by 3.1 per cent in the early 1990s; thus accounted for 40 per cent of GDP growth (ADB, 1992:27-28). To maintain a high level of agricultural growth, several factors have to be in place: price incentives, favourable weather conditions; expansion of area under cultivation and rising productivity of land. There is voluminous literature on agricultural pricing policies in developing countries and in particular, agricultural countries in Sub-Saharan Africa such as Sudan (for example, Balassa 1988; Binswanger 1989; Chhibber 1988; Knudsen and Nash 1991; Krueger *et al.* 1988; Salih 1993; and Timmer 1988). Empirical evidence from these studies suggested that price reforms will improve efficiency in the short-run but not necessarily agricultural growth rate. Although the long-run supply responses of individual crops are greater, correction of relative prices alone will not lead to sustained increases in agricultural growth. Non-price factors have been shown to be extremely important in sustaining agricultural growth (Binswanger *et al.* 1987; Chhibber, 1988; Lele and Mellor 1988; and Knudsen and Nash 1991 among others). Neither these studies nor the recent research addition emphasizing the complementarity of price and non-price factors (for example, Hyami and Ruttan 1985; and Mundlak 1988) has the way of understanding the contribution of natural ecosystem to sustained increases in agricultural growth and to Africa's economic future.

economic costs of woodfuels with alternative technological conversion and end-use efficiency gains. Unlike the conventional wisdom, these sections assert that scarcity and transport costs are capable of pushing woodfuel prices in urban areas to levels higher than alternative commercial fuels. Finally, the analysis indicates the potential for switching to modern commercial fuels in the medium to long-run. A sequential resource management framework is developed including a set of policy options required to achieve sustainable development in the forestry subsector. The initial target of the suggested strategy is to balance needs with existing and potential energy requirements, in the short-run. In turn, it provides incentives to diversify the biomass fuel mix for household sector and rural industries (bakeries and brickmaking) in the medium-term. The strategy also broadens its horizon by providing a wide range of modern and untapped traditional energy sources to deter deforestation in the long-run. Each set of these broad categories of use offers different and at times complementary opportunities for biomass resource management and development as outlined in the implementable action plan in the concluding sections.

Land Use and the Environment

Land use economics requires the ordering of economic activities according to the highest return (yield) among competing alternatives from land use. The salient feature of the resource utilization rule is to analyse the alternative use before selecting the highest return activity. Typically, alternative use for the land resource includes agriculture, pasture, forestry, etc. Table 1 summarizes land use in Sudan for the period 1961-91.

Sudan is the largest country in Africa with a total land area of about 589 million feddans (equivalent to 2.5 million sq. km). Its arable area constitutes more than one third of the total area, of which less than 15 per cent or less than 6 per cent its land area is currently cultivated (Table 1 and ADB 1993:49). Agriculture is, therefore, the backbone of the economy. As a leading production sector, agriculture accounts for 34 per cent of GDP in 1991/92, 95 per cent of exports, employs 62 per cent of the workforce, contributes to the livelihood of half the population and is the major source of raw material supply to industry (ADB 1993:19 and Salih 1994:7). Expansion of the shifting and intensive farming to achieve food security and promote export-led growth have generally neglected ecological aspects resulting in severe environmental degradation. For example, by 1991/92 sorghum area has expanded by 150 per cent, wheat by 216 per cent relative to their areas in the mid 1980s (ADB

Table 1: Land Use in Sudan
(in percentages)

Year	Cropland	Forest	Pasture	Other[(a)]
1961-69[(b)]	2	37	10	51
1970-74[(c)]	5	22	23	50
1975-81[(c)]	5	21	24	50
1982-88[(c)]	5	20	24	51
1989[(c)]	5	19	41	35
1990[(c)]	6	19	46	29
1991[(c)]	6	18	46	30
Total area is 250581 thousands ha.				
Land area is 237600 thousands ha.				

Notes and Sources:

Percentages are calculated to the nearest second decimal.

Data in thousands hectares (ha) can be obtained from FAO. 1976-92. *FAO Production Yearbook*, for several years, Table 1; pp. 5, 7, 47 and 49, Food and Agriculture Organization of the United Nations, Rome.

(a) Other includes fallow land, residential, industrial, government, business and commercial use.

(b) Relative to total area.

(c) Relative to land area.

1993:21-22).[4] The large expansion has led to the removal of tree covers, extension to ecologically fragile zones, destruction of established livestock routes and invasion of traditional agriculture lands. In addition, the expansion of shifting cultivation (basically rural practice) of the traditional rainfed subsector into marginal lands beyond the agronomic dry boundary has led to declines in land productivity, salinity, moving sand dunes and deterioration in rangeland (Ayensu 1994:13; ADB 1993:36 and UNEP 1989:51-52). Further, the development of mechanized rainfed alone annually reduces between 300,000 to 600,000 feddans of rangeland (ADB 1993:36).

Although the total grazing area in Sudan has increased in the past three decades, it is not concomitant with the increasing number of livestock (Tables 1 and 2). The average rate of growth of livestock over the last two decades was 5.4 per cent which is almost double the rate of population growth in Sudan (Table 2).[5] This growth rate is the highest amongst the countries of the Horn of Africa and the average for Africa. This pattern was shared among almost all units of livestock; with the exception of equines in the rest of Africa and camels in the Horn of Africa (Table 2). The increasing number of livestock has exerted severe pressures on the rangeland to the extent that the total area available at present produces only the equivalent of 23 million tons of digestible nutrients sufficient to provide the needs of maximum 22 million animal units (ADB 1993:36). However, the existing number of livestock in Sudan has already exceeded the limit with an overstocking rate of about 25 per cent (Table 2). The overstocking problem is mainly related to the low off-take rate (ADB 1993:21 and 36). The low off-take rates can be explained mainly by the fact that animals are traditionally regarded in Sudan as a mobile store of wealth and a buffer against risk and uncertainties, given well developed available veterinary services throughout the country. Moreover, the inadequate meat processing, marketing and transportation facilities create disincentive for pastoralists to sell their livestock.

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4 The agricultural sector comprises three distinct production modes: irrigation, mechanized rainfed and traditional rainfed. The latter includes livestock subsector. For instance, in the last three years, irrigated areas under sorghum has doubled and wheat tripled at the expense of cotton which is reduced by about 50 per cent. In the mechanized rainfed subsector (entirely operated by private investors), the government has allocated recently large areas of up to 30,000 feddans to companies for an initial lease period of 25 years (ADB 1993:19-20).

5 Livestock accounts for one third of the agricultural sector value-added and 12 per cent of total exports in Sudan. 90 per cent of this huge diversified animal wealth is in the hands of nomadic pastoralists with traditional patterns of production (Table 2 and ADB 1993:21).

Table 2: Domesticated Livestock, 1970-92

Livestock Units / Country (Region)	Total livestock Units (000)		Annual Growth Rate (%)	Stocking Rate (Animal unit/ha) (a)		Percentage of total livestock units in 1970-72					Percentage of total livestock units in 1990-92					Percentage change since 1970-72					Cattle per capita	Grazers to Browsers Ratio	
	1970-72	1990-92		1971	1991	Cattle	Camels	Equines	Goats	Sheep	Cattle	Camels	Equines	Goats	Sheep	Cattle	Camels	Equines	Goats	Sheep	1990-92	1980-82	1990-92
Sudan	17030	27087	5.4	0.14	0.20	60	17	3	8	12	63	12	2	9	14	8	2	0	3	2	0.8	2.5	2.3
Horn of Africa	64389	37713	5.2	0.2	0.33	54	15	9	10	12	56	13	9	9	12	7	34	6	3	2	0.6	2.0	2.1
Africa	179564	230106	5.2	0.15	0.19	63	9	7	9	12	62	8	6	11	14	8	2	14	2	1	0.3	2.5	2.2

Source:

WRI (1994b), Tables 34 and 35.

Note:

(a) Calculated as livestock units/(permanent pasture + 0.30 x other land).

The total area of forest in Sudan is estimated to cover 18 per cent of the land, of which only 1 per cent is reserve forest (Tables 1 and 3).[6] The forestry subsector mainly involves the production of gum arabic, fuelwood and charcoal. Gum arabic accounts for nearly 12 per cent of the total commodity export.[7] The gum trees and in particular Acacia Senegal (called locally *Hashab*) are tolerant to rainfall variation and the vagaries of temperature, thus maintaining the agro-ecological balance in an otherwise fragile ecological gum belt zone (ADB 1993:21, Teklu *et al.* 1991:112 and UNCTAD 1991:78). Because of these environmental benefits coupled with the income supplement to rural households, donor communities have invested in this area such as the United Nations Development Programme (UNDP) and the United Nations Sudano-Sahelian Office (UNSO). The restocking activities of the third and final phase of the project started in the beginning of the 1990s and significant progress and success of the project have been documented in a few studies (for example ADB 1993:21; Teklu *et al.* 1991:113-114 and UNCTAD 1991:78). The benefits of such a project are likely to be felt in the long-run as *hashab* trees mature at age 6 to 8 years (their peak productive age cycle) and consequently lead to improved soil fertility and moisture. Because of the maturity lag, rural households are likely to generate income from other tree products such as charcoal and firewood at least in the short-run. Such activities accelerate the already high and alarming deforestation rate in Sudan.

Deforestation in Sudan

Early estimates of deforestation rate in Sudan were modest recording an 1.1 per cent per annum (Table 4; Daudon, *et al.* 1984:4; FAO 1993, Table 3a; ADB 1992:143; and Salih 1992b:5). However, recent revised estimates indicate that the proportion of woodland and forest area declined from 37 per cent of total area in the late 1960s to only 18 per cent in the beginning of the 1990s (Table 1 and ADB:36). At present, survey data and official estimates suggest higher average rate of deforestation in Sudan than previously known; ranging between 3.6 to 5.2 per cent (Table 5, Elamin

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6 Forest is defined as ecosystem with a minimum of 10 per cent crown cover of trees and/or bamboos, generally associated with wild flora, fauna and natural soil conditions and not subject to agricultural practices (Elamin and Ce'sar 1994:vii).

7 Historically, Sudan exports of gum arabic met 85 per cent of world demand, with Kordofan region alone satisfying 50 per cent of the demand (UNCTAD 1991:78 and Teklu *et al.* 1991:112). The gum belt of Kordofan (Western Sudan) stretches from west to east within the Sahelian zone. Gum arabic is used for materials such as fibres, dyes, tannin, confectioneries, glue, gum, etc.

Table 3: Area of Natural Forests and Plantations in 1990

Country/ Region	Natural Forest					Plantations	
	Forest Cover 000 ha	ha/capita	Forest Biomass 000 Tons	Tons/ capita	Tons/ha	000 ha	ha/000 capita
Sudan	42976 (18.1%)	1.7	2647934	105	62	290 (0.1%)	11.5
East Sahelian Africa	65450 (13.4%)	0.5	5254247	43	80	762 (0.2%)	6.2
Africa	527586 (23.6%)	1.1	70143999	145	133	3000 (0.1%)	6.2
Sudan's share in East Sahelian Africa	65.7%		51%			38%	

Source:

FAO (1993), Table 3a.

Notes:

ha refers to hectares.

Percentages enclosed between brackets expressed as shares of land area.

Table 4: Annual Deforestation and Plantation, 1981-90

Country/Sub-Region	Deforestation		Plantation	
	Average annual	000 ha	% change 1981-90	000 ha in 1990
Sudan	1.1	482	6	290
Ethiopia	0.3	39	11	270
Kenya	0.6	7	2	168
Côte d'Ivoire	1.1	119	7	90
Horn of Africa	0.9	523	11	566
Sub-Saharan Africa (SSA)	0.8	4100	339	3000

Sources:

Elamin and Ce'sar (1994), Table 3.4:38 and WRI (1994b), Table 38.

Note:

ha abbreviates hectares.

and Ce'sar 1994, Annex 2-3 and FNC 1993, Table 1).[8] The revised estimate is consistent with the modified high deforestation rates in other African countries such as Côte d'Ivoire. Deforestation rate in Côte d'Ivoire was estimated at 5.2 - 6.5 per cent (ADB 1992:143; Ayensu 1994:12; and Ehui and Hertel 1989:703). These estimates place Côte d'Ivoire and Sudan amongst countries experiencing the highest rates of deforestation in the world. Deforestation rate in the Eastern sub-region of Africa is slightly higher than the average for Sub-Saharan Africa (SSA) and exceeded that in the similar sub-regions such as Western and Southern Africa (WRI 1994b, Table 38). Sudan recorded the highest deforestation rate among sampled countries in the Eastern sub-region and its estimated annual deforestation rate relative to its natural forest is slightly higher than the ratio for the sub-region (Elamin and Ce'sar 1994, Annex 3-2). Even the old deforestation rates reported elsewhere for Côte d'Ivoire and Sudan are among the highest in Africa (Table 4). For example, Sudan registered an average annual deforestation rate of 1.1 per cent during 1981-90 which was higher than the average for Africa and significantly higher than the neighbouring countries in the Horn of Africa (Ethiopia) and/or East Africa sub-region such as Kenya (Table 4). In contrast the plantation during the same period was lower than the average for both the Horn of Africa and the continent at large (Table 4). Unlike the rest of the world, manmade plantations are limited in Africa: with only 8.2 ha/1000 capita compared to 20.4 ha/000 capita and 17.8 ha/000 capita for Asia and Latin America, respectively (Elamin and Ce'sar 1994:ix).

Similar to other African countries, the lack of quantified data could be one of the underlying causes of the decline of forests in Sudan since the entire population will not realize the extent of the seriousness of the deforestation. Consequently, the vital role of the forestry sector in economic activities, protecting the environment and sustainable development is underestimated. For example, national income accounts record the contribution of Sudan's forests to GDP at 1 per cent, representing only the traded forest production. Consequently, only 1 per cent of the agricultural development budget was allocated to forestry for the same comparable period, i.e support of the forestry sector in economic development is minimal. However, the contribution will increase to 8 per cent of GDP if fuelwood, charcoal, poles, saw-wood and plywood were taken into consideration (World Bank 1986:7).

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8 The lower bound could be obtained directly for Table 5 and the upper bound is equivalent to comparing the revised estimate of FNC (1993, Table 1) with World Bank (1986) estimate of forest area in 1993. The total area of woodland and forest in 1983 was 93.87 million ha (World Bank 1986:4 and 279) reduced to only 64.36 million ha. The latter is a revised estimate of the projected area at the prevailing rate of deforestation, 84.99 million ha. The difference represents the range and pasture land included in the woodland and forest area.

Table 5: Forest Inventory in Sudan, 1983-90
(in million Feddans[a])

Year	Ending Inventory
1983	179.7
1984	177.9
1985	175.3
1986	172.1
1987	168.2
1988	163.9
1989	158.9
1990[b]	153.2

Sources:

NEA (1984a), Table 1.
FAO (1993), Table 3a.
FNC (1993), Table 1.
Elamin and Ce'sar (1994) Annex 2-3.

Notes:

(a) 1 Feddan = 0.42 hectares (ha); 1 ha = 100 sq. km (square kilometres).

(b) The recent revised estimate of 1990 was converted into feddans from FNC (1993) data files. The 1990 estimate is not significantly different from that reported in Table 3a of FAO (1993). The 1983-89 ending inventories were transformed from fiscal into calendar year. The resulting opening stock in the modified series was 180 million feddan in 1983. In turn, the ending inventory in 1983 was higher than the NEA (1984a) estimate and lower than the World Bank (1986) estimate.

With increased awareness of the importance of the forestry subsector in development programmes, the government has taken recently an important measure to integrate environmental concerns within its strategic development programme. That is, a designated area would be earmarked for forestry in the agricultural sector including 5 per cent of the irrigated land, 10 per cent of the rainfed land and 20 per cent of the newly cultivated rainfed land (ADB 1993:37). Despite this commendable effort, the proceeding deforestation rate would require massive plantation of forest belt to slow the deforestation process. Because of the resource constraints, massive plantations can be realized via concerted efforts with renewed commitment from donor community, the government and the civic society of Sudan. Both the previous successful plantation projects and the ongoing process of developing an Environmental Action Plan (EAP) would cater for such needs.

At present, 25 countries in Africa are formulating EAPs with support from the United Nations Development Programme (UNDP), the United Nations Sudano-Sahelian Office (UNSO), the World Bank and other agencies and bilateral donors (World Bank 1992a:28).[9] It is expected that EAPs will be integrated into the preparation of national long-term perspective studies to promote the full integration of environmental considerations into country strategies for sustainable development. Sustainable development is the central focus of both the Global Coalition for Africa (GCA) and the global plan of action adopted at the Earth Summit (widely known as Agenda 21).[10] A Global Environmental Facility (GEF) was introduced in 1990 to provide grants to finance environmental projects.[11] The facility is likely to play an increasing lending source to Africa in relation to deforestation and land degradation.

There are varying opinions on the factors behind deforestation in Sudan and Africa at large (external shocks, poverty, declining income, pricing policies,

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9 Lesotho, Madagascar, Mauritius, Burkina Faso, Ghana, Rwanda, and the Seychelles have completed EAPs. Only the first three countries have begun implementing their plans. New EAP country processes have been initiated in 17 more countries and the number of countries conducting strategic environmental planning is likely to grow (World Bank 1992a:28-29).

10 Agenda 21 is designed to mitigate global warming, to conserve biological diversity, to protect international waters and to reduce ozone-depleting substance (Keating 1993:19).

11 GEF was established in 1990 as a three-year pilot programme to provide grants for investment projects, technical assistance and research. GEF resources are to be used for exploring ways of assisting developing countries to protect the global environment and for transferring environmentally benign technologies. Responsibility for implementing GEF is shared by UNDP, UNEP and the World Bank. The facility was extended beyond the pilot phase to finance implementation measures outlined in Agenda 21 for the achievement of global environmental benefits (World Bank 1992a:19-23).

unavailability of close substitute and/or population growth). Despite these differences, empirical evidence suggest that most studies recognize the increasing demand for woodfuel and high population growth as the main determinants of deforestation in Africa (Elamin and Ce'sar 1994:39; Falloux and Mukendi 1988:5; Salih 1992a:3; and World Bank 1992a:98). The degree of importance of these factors are in variance in each country; thus partly explaining the current practice of designing EAP and forestry sector plan for each country separately.

Energy Consumption

Of the 267 PJ total energy consumed in Sudan in 1991, more than 82 per cent of the energy requirements were from traditional fuels (Table 6). Similar to the SSA countries, traditional energy sources (biomass) dominate the energy sector in Sudan.[12] Both the level and share of biomass in energy requirements in Sudan have increased through time. The share of biomass in total energy consumption increased from 76 per cent in 1981 to 82 per cent in 1991 to reach 86 per cent at present and it comes basically from woody-biomass (Tables 6 and 7). Although the share of biomass in total energy consumption in Sudan is similar to that in the countries of the Eastern sub-region, the components of the biomass are different (Table 7). However, the aggregate level and composition of per capita energy consumption are remarkably similar to those in the Horn and Eastern African countries (Table 6). With the declining or at best stagnant per capita energy consumption, these countries are considered amongst the lowest per capita energy users in the world; thus confirming the high correlation between energy consumption and economic growth (Table 6; Callaghan *et al.* 1995:217-232; de Jong-Boon 1990:85; Michaelides 1983:7 and OECD/IEA 1994:25). However, the aggregate per capita energy use varies regionally and sectorally. For example, energy use in the capital area of Khartoum was more than five times energy consumption in rural areas in the early 1980s.[13]

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12 Biomass is defined as the total amount of above ground organic matter present in all types of vegetation: both woody such as branches, bark, leaves, etc. and non-woody such as agricultural and animal residues (Elamin and Ce'sar 1994:vii). That is, in most energy studies, biomass is synonymous to traditional energy sources. The statistical definition of biomass in the International Energy Agency (IEA) includes fuelwood, bagasse, charcoal, animal and vegetable waste (OECD/IEA 1994:26). Biomass accounts for more than 60 per cent of total energy balance in SSA and the estimated potential biomass in the region covers more than the needed energy requirements (Elamin and Ce'sar 1994:34).

13 Energy use in Khartoum in 1983 was 27 GJ while consumption in rural areas was only 5 GJ.

Table 6: Total Energy Consumption, 1981-91

Country/Region	Commercial Energy						Traditional Fuels[a]					
	Total PJ 1991	% change since 1981	Per capita GJ 1991	% change since 1981	Imports % of consumption		Total PJ 1991	% change since 1981	Per capita MJ 1991	% change since 1981	% of total consumption	
					1991	1981					1991	1981
Sudan	47	-7	2	-31	111	108	220	37	8990	2	82	76
Horn of Africa	95	21	1	-8	130	139	706	31	8140	0	88	87
East Africa	141	167	1	94	117	284	1000	36	10368	-1	88	93
Africa	7767	36	12	1	71	133	4772	33	7219	-1	38	39

Source:

WRI (1994b). Table 59.

Notes:

(a) Traditional fuels include animal waste, bagasse, charcoal, fuelwood and vegetable waste.

PJ (Peta Joule) = 10^{15} Joules
TJ (Teta Joule) = 10^{12} Joules
GJ (Gega Joule) = 10^{9} Joules
MJ (Mega Joule) = 10^{6} Joules
1 TOE (Ton Oil Equivalent) ≈ 42 GJ
1 cu. m wood ≈ 11.4 TJ
1 cu. m charcoal ≈ 33.1 TJ

Table 7: Recent Biomass Consumption (in Peta Joules[a])

	Woody Biomass	Non Woody Biomass	Biomass as % of Total Energy Consumption
Sudan	203	2	86
Eastern Sub-Region	1537	1687	86

Source:

Elamin and Ce'sar (1994), Annex 3-5.

Note:

(a) PJ = 10^{15} Joules.

The household sector consumed 79 per cent (the largest sector) of total energy and nearly 95 per cent of energy from woodfuel (Table 8). Although the use of woodfuel saves about 20 per cent of the total import bill (in kerosene equivalent terms), 80 per cent of kerosene and 98 per cent of liquid propane gas (LPG) were used in cooking by the household sector in 1981 (NEA 1984:18-24 and Hassan and Hertzler 1988:164-165). The household sector was also the largest consuming sector of electricity because it used more than 38 per cent of total electricity consumption in 1981 (Table 9). Ninety-nine per cent of the electrical energy in the household sector is used in lighting, refrigeration and other household activities (Hassan and Hertzler 1988:164-165). Because of frequent electricity cuts and the rationing of petroleum products, the household sector resorts to charcoal (basically in cooking); thus explaining the claim that more than 85 per cent of the woodfuel is used in domestic cooking.[14] That is, cooking uses more than 85 per cent (which confirms the estimated share of biomass in total energy consumption) of wood resources in Sudan (Table 7). In turn, woodfuel production (both fuelwood and charcoal) has increased faster than the population growth in Sudan over 1981-91 (Table 10). Similarly, the analysis of supply over 1981-91 production statistics for both the Eastern sub-region and Africa confirmed a general increase of woodfuel production exceeding the population growth during the same comparable period (Table 10 and Elamin and Ce'sar 1994, Annex 3-4). Frequent increases in petroleum and electricity prices have resulted in a declining rate of the use of commercial energy sources in Sudan (Table 6). Therefore, priority should be given to improve utilization of woodfuel in cooking via a combination of pricing policies in the short-run, technological improvements in the medium to the long-run and a better management of the natural capital to conserve wood resources.

Demand-Supply Imbalance

At the country level, Sudan is amongst the few countries in Africa to exhibit a positive aggregate demand-supply balance (Table 11). However, seven out of the nine administrative units within Sudan are showing a high degree of strain and/or risk areas with an annual negative balance ranging between 0.2 - 0.8 cubic metres per capita.[15]

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14 Table 9 shows that 94.8 per cent of the woodfuel was consumed by the household sector in 1981. If the proportion of the woodfuel used in cooking stayed at its 1981 level (90 per cent), then 85.3 per cent (0.948 x .90) is the share of cooking in woodfuel.

15 This pattern is similar to other countries exhibiting a positive aggregate balance (for example Tanzania and Uganda) in the Eastern sub-region of Africa, showing at the same time negative balance for 68 per cent of the administrative units (Elamin and Ce'sar 1994:46). The negative balance is

Table 8: Energy Consumption by Sector and Energy Source in Sudan, 1981
(Shares in percentages)

Source / Sector	Wood	Charcoal	Other Biomass	Electricity	Petroleum	Sectoral Share
Household	54.2	35.3	8.9	0.5	1.1	79.0
Transport	0	0	0	0	100.0	11.1
Industry	21.1	0	27.8	6.1	45.0	5.9
Public Sector Agriculture	61.6	0	0	5.8	32.6	2.3
Source's Share	45.4	27.9	8.7	1.0	17.0	100.0

<u>**Note and Sources:**</u>

Percentages are calculated from energy consumption data in TOE from:

de Jong-Boon (1990):197-198.
Harran and Hertzler (1988):164.
World Bank (1983):3 and 37.

experienced by 78 per cent of the administrative units in Sudan; i.e. only 22 per cent are low risk areas (Table 11).

Table 9: Energy Sources in Sudan, 1981
(Shares in percentages)

Sector \ Source	**Biomass**	**Electricity**	**Petroleum**
Household	94.8	38.3	5.3
Transport	0	0	65.2
Industry	3.5	36.7	15.6
Public Sector	1.7	13.3	4.4
Agriculture	0	11.7	9.5
Total	100	100	100

Note and Sources:

Calculations adapted and compared with energy data expressed in TOE from:

de Jong-Boon (1990):197-198.
Harran and Hertzler (1988):164.
World Bank (1983):3 and 37.

Table 10: Woodfuel Production, 1981-91

Country/ Region	1981		1986		1991	
	Fuelwood 000 cu. m	Charcoal 000 M.T.	Fuelwood 000 cu. m	Charcoal 000 M.T.	Fuelwood 000 cu. m	Charcoal 000 M.T.
Sudan	15818	1831	18444	2135	21279	2463
Eastern Sub-Region	119226	3670	139664	4333	163043	5094
Africa	346615	6880	411005	8911	472850	10397

Source:

Elamin and Ce'sar (1994), Annex 3-4.

Notes:

Cu. m abbreviates cubic metre (or m^3).

M.T. abbreviates Metric Ton (1000 kilograms).

1 cu. m wood = 11.4 TJ (Tera Joule ≈ 10^{12} Joules).

1 cu. m charcoal = 33.1 TJ.

Table 11: Sudan's Per Capita Annual Energy Consumption (Woody Biomass) in TJ[(a)]

Administrative Unit	Land Area 000 ha	1990 Population in 000s	Annual Population Growth Rate in % 1980-90	Forest 1990		Average Biomass T/ha	Total Biomass Million Tons	MAI[(b)] cu. m/ ha/ year	MAI capita cu. m/ year	Demand per capita cu. m/ year	Balance
				000 ha	% of land area						
North Region	50023	1116.7	0.7	0.0	0	0	0	0	0	0.80	-0.80
East Region	34642	2765.8	3.4	1659.9	4.8	3.6	124466	0.51	0.31	0.80	-0.49
Central Region	14275	3373.6	-1.8	2859.3	20.0	14.5	206370	0.44	0.37	0.81	-0.44
Kordofan	38991	3947.9	3.6	5869.6	15.1	10.2	398116	0.34	0.51	0.81	-0.30
Darfur	52784	4176.5	4.4	8822.9	16.9	9.7	504629	0.33	0.70	0.82	-0.12
Khartoum	2105	2376.4	4.1	0.0	0	0	0	0	0	0.80	-0.80
Equatorial Region	20022	2045.9	5.6	9040.8	45.2	67.3	1348114	2.30	10.20	1.00	9.20
Bahr-Al-Ghazal	20099	3031.9	4.3	12686.5	63.1	60.9	1224244	1.43	6.00	0.99	5.01
Upper Nile	23991	2360.8	5.8	2037.1	8.5	7.7	184823	0.63	0.54	0.93	-0.39
Country	256431	25195.5	3.0	42976.1	16.8	88.6	3990762	1.10	1.87	0.86	1.01

Source:

Elamin and Ce'sar (1994), Annex 3-11-31.

Notes:

(a) TJ (Tera Joule) = 10^{12} Joules.

(b) MAI abbreviates Mean Annual Increment in cu. m/ha/year, ha stands for hectares and cu. m for cubic metres.

Summary of Biomass change by Land Cover Using High Resolution Satellite Data reported in Elamin and Ce'sar (1994) Annex 3. Note that the interpretation of Satellite Data can only discriminate a canopy of approximately 20% or more. Consequently, the reported biomass is higher than that reported by FORIS in FAO (1993). FORIS refers to both open and closed formations. FORIS open forest includes tree formations with canopy cover between 10% and 40%. Whereas, the Satellite Data refers to closed forest only.

Khartoum and Northern states registered the highest woodfuel deficit in the country (Table 11). Fifteen per cent of the population reside in the two urban states and the rate of urbanization is among the highest in Africa, estimated at 4.5 per cent per annum; thus reflecting a long haulage distance of woodfuel from the remote surplus states at a distance of 600-800 km to Khartoum (ADB 1993:36; de Jong-Boon 1990:284; Elamin and Ce'sar 1994:64, World Bank 1986:49 and World Bank 1994b:325). In addition to the hardship that people will experience in the provision of the energy need for survival, the country will bear financial and potential real resource costs. For example, the increased expenditure of foreign exchange in fossil fuels alone reached 81-94 per cent (de Jong-Boon 1990:323 and Callaghan *et al.* 1985:217-232).

The high ratio of population affected is expected to increase if the previously announced policy measures of conservation and protected areas within the agricultural sector are adhered to and implemented in Sudan. Similar to the countries in the Eastern sub-region, the resource potential in Sudan has already reached a level that cannot meet present requirements without jeopardizing its sustainability. Since the Eastern region and in particular Sudan are characterized by the highest proportion of woody-biomass usage in the continent, deforestation is becoming a significant factor in deteriorating the resource potential and in particular biomass losses (Tables 7 and 12). The Western sub-region reported the highest annual biomass loss of 0.9 per cent due to deforestation, in the continent during 1980-90 (Elamin and Ce'sar 1994:37). The Eastern sub-region (including Sudan) is the second to the Western sub-region, with a rate of annual biomass loss of 0.8 per cent for the same period (Table 12). When the losses are expressed as a ratio of Mean Annual Increment (MAI), the Eastern sub-region recorded 62.3 per cent; which is higher than the ratio for the Western sub-region of 24.7 per cent (Elamin and Ce'sar 1994:37). In fact these losses cover partially the 1991 supply of biomass energy in the Eastern sub-region including Sudan (Table 13). Past experience indicates that these losses are rarely recovered and are generally burned into ashes to clear the land for cultivation (Elamin and Ce'sar 1994:37). Sudan is a case in point where large quantities of the biomass potential in excess of the capacity of local demand was cleared and burned to provide additional land for mechanized and shifting agriculture during the 1980s (ADB 1993:20-23).

Similar to the countries in the Eastern sub-region, Sudan is characterized by high woodfuel production levels and the highest charcoal proportion in the supply mix relative to the other sub-regions in Africa (Tables 6, 7, 8 and 9 and Elamin and Ce'sar

Table 12: Annual Biomass losses due to Deforestation, 1980-90

Country/ Region	Losses in Million Tons	Losses % of the Sub-Region	Losses % of 1991 Potential	Losses in Million Tons by Ecological Zones		
				Wet/Moist	Dry/Very Dry	Montane
Sudan	29.9	32.6	0.8	13.2	15.9	0.8
Eastern Sub-Region	91.5	100	0.8	37.9	36.1	17.5

Source:

Elamin and Ce'sar (1994), Annex 3.3.

Table 13: Supply and Use of Wood Energy in 1991[a]
(in Teta Joules[b])

Country/ Region	Production	Imports	Exports	Primary Supply	Kilns	Net Supply	Use		
							Households	Industry	Others
Sudan	242581	0	0	242581	137973	104608	81594	23014	0
Eastern Sub-Region	1858690	0	0	1858690	285362	1573328	1226940	346388	0

Source:

Elamin and Ce'sar (1994), Annex 3-8-3.

Notes:

(a) Woody-biomass constitutes more than 80% of all biomass in Eastern sub-region and more than 90% for Sudan (Elamin and Ce'sar 1994 Annex 3-5). Biomass satisfies 88% and 86% of total energy consumption for Eastern sub-region and Sudan, respectively.

(b) TJ = 10^{12} Joules.

1994:x). The underlying factors explaining this phenomenon are high population growth, urbanization rate, deforestation and degradation over long periods of time (Elamin and Ce'sar 1994:x and Salih 1992b:4-5).

Charcoal supply is associated with relatively high conversion (transformation) losses. Preliminary estimates of such losses indicate that the Eastern sub-region (including Sudan) registered the highest losses in Africa (Elamin and Ce'sar 1994:39-41). This has serious implications on the resource base. The present trend in Sudan indicates that more charcoal use is associated with urbanization and as a result *supply catchment areas* are gradually pushed away up to 800 km from urban centres (Elamin and Ce'sar 1994:65 and Hassan and Hertzler 1988:164). That is, as the distance to the *catchment area* extends, charcoal rather than fuelwood becomes the dominant urban fuel. In contrast rural catchments do not generally extend beyond 5 km radius around the village. In addition to charcoal and kerosene, rural Sudan also uses firewood as energy supply source. Firewood can be obtained from areas outside the forest formations, while charcoal supply can only be concentrated in natural forest formations or plantations.

Woodfuel Pricing

Woodfuel pricing is an important indicator for the realization of the scarcity value of the energy resource, introduction of interfuel substitution and management of biomass resources at least in the short-run. Resource economics calls for appropriate pricing policy as a pre-requisite to generate economic returns in the short-run and to create incentives for investments, production, distribution and marketing in the medium to long-run.

Fuelwood cutters and charcoal producers pay a negligible royalty of four per cent of retail price for the naturally growing savannah wood in Sudan and less than 10 per cent of the low stumpage fees are actually collected (Elamin and Ce'sar 1994:68; UNDP/World Bank 1984; World Bank 1986:55 and Barton *et al.* 1991:1).[16] This fee is insufficient to cover the cost of afforestation (Elamin and Ce'sar 1994:68). Although woodfuel prices have rapidly increased in recent years, the increase does not reflect the scarcity price of wood in Sudan. Rather it represents the high transportation

16 The administrative difficulty of collecting stumpage fees is also reported in Zambia and Tanzania where less than 10 per cent of the fees are actually collected. The low rates coupled with collection-inefficiency provide very little revenue to develop and manage woodfuel and, in turn, discourage private investment in the subsector.

costs of the ever increasing haulage distance for woodfuel to urban centres.[17] Therefore, government intervention is required to impose stumpage fees to correct pricing of the natural resource.[18] The government has to demonstrate willingness to protect the forest and readiness to apply stiffer penalties on tree felling, particularly for rural population. Revenue generated from royalties must be allocated to support afforestation practices.

The correct pricing of the wood in Sudan is not only meant as a remedial action to deter overcutting in the short-run, but also to trigger spontaneous private investment by small traditional farmers and by mechanized farmers on areas in which declining agricultural crop yields are leading to abandonment of the land. More important is the signal to the users and the citizens at large of the true economic value of the natural capital, at which level repercussions may be felt in the consumption level such as the desire for improved stoves and the substitution of woodfuel by alternative forms of biomass in the short-run and gas stoves in the medium to long-run.

End-Use Efficiency Gains and Conversion Technology

The inefficient three-stone stove became a symbol of the fuelwood problem in Africa and in particular rural areas and low-income urban poor. Stoves made of sand, mud and traditional metal stoves had poor durability and low capacity to save fuel. In contrast efficient stoves capable of saving 50 per cent or more energy were developed in various laboratories and some of these efficient stoves have been introduced in few African countries in the late 1980s and the early 1990s (de Jong-Boon 1990:301, Elamin and Ce'sar 1994:60-62 and Salih 1992b:12). Sudan is among these countries where urban stove programme enjoyed a reasonable measure of success.[19]

17 Wood reserves are currently underpriced by the value of the user cost (Hassan and Hertzler 1988:165-167 and Barton *et al.* 1991:2-13). The user cost includes the price of afforestation; hence the market price of fuelwood should double to cover the cost of replacement of trees (Barton *et al.* 1991:13 and World Bank 1986:113).

18 Stumpage price is the price the government or individuals receive for the use of wood from trees. In many countries, it has been fixed without reference to the cost of growing the wood. In Sudan, wood is far from the market and transport is the dominant variable cost in determining the retail price of the product. Consequently, the maximum stumpage price in Sudan is given according to transport means and distance from the market. Theoretically stumpage prices set the limits to the cost of growing trees either in the natural forest, woodland or plantations. Stumpage prices for charcoal, sawnlogs (softwood and hardwood) were calculated for Sudan by World Bank (1986:114-116).

19 Success of limited commercialization has been reported in Burkina Faso, Kenya, Niger and Zimbabwe (Elamin and Ce'sar 1994:61-62 and Salih 1992b:17).

It is assumed that charcoal conversion factors (utilization efficiency) from harvested fuelwood to charcoal in Sudan is only 4.4 per cent (Callaghan 1985:217-232, World Bank 1986:44 and Hassan and Hertzler 1988:165).[20] Work carried out by Sudan Renewable Energy Project (SREP), NEA, FAO and USAID has demonstrated that 30-50 per cent of the wood could be saved by simple measures. For example, handling of charcoal can be improved by using cheap and simple kiln design (or brick kilns) coupled with better handling, briquetting of powder and fines, and proper drying of wood (World Bank 1986:44 and Hassan and Hertzler 1988:165). Simple designs of kilns and stoves alone can improve utilization efficiency by 30 per cent. Briquetting to provide an industrial fuel for rural industries (bakeries and brickmaking) have shown success in Sudan where bagasse blocks are now produced and marketed by private sector. Carbonization and briquetting technologies for agricultural wastes (cotton stalks) developed by the Energy Research Institute (ERI) of Sudan and the Biomass Technology Group (BTG) through UNDP/Netherlands financing was technically successful to produce charcoal as a household fuel (Elamin and Ce'sar 1994:2).

Engineering experiments also suggest that utilization of the traditional kiln within charcoal production programme and the improved metal charcoal stove (called *Canun-el-duga*) can play a significant role in long-term strategies for fuelwood conservation and reforestation in Sudan (Satti and Dorré 1985:1 and Ali and Huff 1984:1). *Canun-el-duga* is 39 per cent more efficient than the traditional metal stove; indicating that traditional methods were not quite as bad as thought. More importantly, the new design is easy to use, reduced charcoal consumption and decreased cooking time.[21] The improved stove programme is likely to succeed in Sudan if a public awareness campaign of the energy crisis and the serious long-term implications of deforestation are realized in the urban areas.[22] Despite technological

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20 More than 80 per cent of heat content of air dried wood is lost when converted into charcoal by using current method and kiln designs. Moreover, 78 per cent of the heat content of charcoal burned by households is wasted by the traditional charcoal stove (called *Mangad*). Hence, an overall heat content of woodfuel wasted is 1-0.2 x .22 = 95.6 per cent.

21 SREP began work on improved metal charcoal stoves in 1983. The basic design was developed by the University of Khartoum and Ahfad College of Women. Interested artisans and other metalworking enterprises were invited to comment and improve the design in Khartoum. An open-draft model and a controlled-draft model close to the original design were made and advertized to promote public interest and some were sold (de Jong-Boon 1990:301).

22 Unlike the failed experiments of marketing improved stoves in rural areas in West African countries, Sudan initiated the experiment in the largest urban centre (Khartoum) where the perception of the energy crisis is witnessed everyday (Floor and Gorse 1988:89 and de Jong-Boon 1990:301).

success, there remains management and marketing of the modern stove on a large scale (Elamin and Ce'sar 1994:62). However, the initial success of the Sudanese experiment reveals that the economics of producing an efficient modern stove is feasible when fuelwood and charcoal prices are driven by high scarcity and unavailability of substitute fuels. Similar efforts are likely to be repeated in rural areas in the future since the scarcity of biomass in rural areas have driven it from a common property resource to a traded biofuel in less than a decade (Elamin and Ce'sar 1994:65-66). In the meantime, biofuels could be more accessible and efficiently used in rural areas. Sudan has rich reserves of cotton woody stalks, sorghum straws, groundnut shells and other crop residues that can be utilized with minimal impact on traditional land use (Callaghan *et al.* 1985:217-232).[23]

Both the alternative biomass and efficient fuelwood utilization involve simple technologies and, therefore, have potential for immediate application. Other untapped energy resources in Sudan include hydro-electric power, potentially proved natural gas reserves, solar and wind energy conversion. Although solar and wind energy sources will not be depleted, their technologies are not yet developed in Sudan and such large scale costly programmes are uneconomically viable at the prevailing state of the art. However, medium to long-term contractual and extraction agreements of hydro-electric and natural gas reserves are viable options (Ayensu 1994:16 and GPC 1993:3-6).

Technological Improvements

Similar to the modern stove designed for urban areas, technological improvement in rural stoves to suit rural areas should be based on traditional methods. The experiences of previous initiatives in Sudan demonstrated that the adaptation of traditional methods in technological experiments funded by USAID and FAO report efficiency gains of 30 per cent; hence disproving the claim that traditional methods were inefficient (Elamin and Ce'sar 1994:61). Three stone fire stoves are widely used in rural areas and these stoves are free. Efficiency utilization of the three stone firewood stove is 15 per cent at best. However, wood is becoming increasingly scarce to the extent that it is estimated to reach the critical scarcity level in 20 years at the prevailing deforestation rate (NEA, 1984). High scarcity values will make improved

23 For example, the energy content of the under-utilized burned stalks of cotton in the fields each year is about 0.42 million TOE. This is equivalent to current consumption of 1 million people (Callaghan *et al.* 1985). To a lesser extent groundnut shells, animal waste and water hyacinth in the White Nile could be utilized as additional sources of biomass fuel.

stoves a viable option for rural families to demand.[24] At the same time, improved knowledge from the modern stoves experience in urban centres (learning-by-doing) coupled with the economies of scales in producing energy-efficient stoves for rural areas will reduce the cost of production. Assuming that cost savings are passed on to consumers, then low-income households can afford buying modern stoves. It is apparent that under high scarcity and unavailability of affordable close fuelwood substitute, the chances for success in introducing improved energy utilization technologies are much higher in the household sector than elsewhere.

The reader may recall from the preceding analysis that the use of electricity is modest in Sudan (Tables 6-9). Although huge hydropower projects in Sudan were and are still designed to meet long-term power needs of the country, installed capacity represents only 2 per cent of the total potential recoverable resource (Ayensu 1994:16).[25] Hydroelectric power potential from the river Nile and its tributaries is perhaps among the largest in the continent. Hydropower is an untapped renewable energy resource in Sudan that can provide a substitute for woodfuel in the long-run at a relatively low cost.

There is an increasing utilization of gas stoves in urban centres in Sudan (Hassan and Hertzler 1988:164-165). Proven and probable reserves of natural gas in the Red Sea of Sudan in just three fields contain over 85 billion square metres and were considered commercially profitable by the contracting companies of Chevron, Total and IPC (GPC 1993:3-6). There is a need to accelerate agreements with oil companies to develop and utilize these proven natural gas reserves in order to satisfy the domestic demand for natural gas in the medium to the long-run. If serious attempts and aggressive marketing strategies in exploration and extraction of natural gas and petroleum are pursued as demonstrated by the joint venture of the Canadian-registered Arakis and its Sudanese partner State Petroleum Corporation, a substantial reduction of more than 50 per cent in foreign exchange could be realized in the future. In addition current and projected investments in huge hydropower projects will also improve the utilization of electricity in the long-run at a reduced cost.

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24 In the meantime immediate technological improvements to the three stone fire will reduce woodfuel consumption in rural areas if directed to a wind shield and sinking the stove with or without a grate (World Bank 1986:45).

25 For example, the potential of the Roseires dam is not fully utilized and other large reservoirs have been considered seriously such as the recent efforts to construct Al-Hamadab dam and to utilize the potential of Lake Tana in a joint venture with neighbouring Ethiopia. In contrast to the generally unfavourable effects of large reservoirs in Africa, the secondary effect of Roseires reservoir were favourable (de Jong-Boon 1990:197).

Consideration should also be given to utilization of the irrigation possibilities of these dams to meet Sudan's future demands for fuelwood, poles, timber and to foster greater resilience into traditional farming systems. A variant of this theme can be developed by plantations along irrigation canals and roads or by establishing irrigation plantations near major urban centres (de Jong-Boon 1990:199). Past experience shows that this recommendation will have a high probability of implementation if considered part of an intersectoral plan linking the protection of forest ecosystems and sustainable utilization of biomass resources with the socio-economic dynamics of land use pressures. This is what the natural resource management framework intends to accomplish. This long view approach was previously overlooked in the literature and is currently sought to bring agroforestry, social forestry and community forestry to the forefront of sustainable development.

Natural Resource Development and Management

There is an emerging development literature recognizing the use of natural resource management approach as an appropriate framework to value and deploy natural resources to achieve sustainable growth and development (for example, Baumol 1991; Eisner 1989; Elamin and Ce'sar 1994; Goldsmith 1985; Jorgenson and Pachon 1983; Leonard 1988; Pearce and Turner 1990; Salih 1992a and Usher 1980). The forward looking approach suggests that the social benefit of the renewable ecosystem (forest) far exceeds its cost of maintenance. The initial condition of the suggested approach calls for planting more trees to achieve the socially necessary (optimum) stock in a short and technically feasible time with a long conservation view. That is, the harvest rate of the forest should not exceed its natural regeneration rate in the long-run.[26]

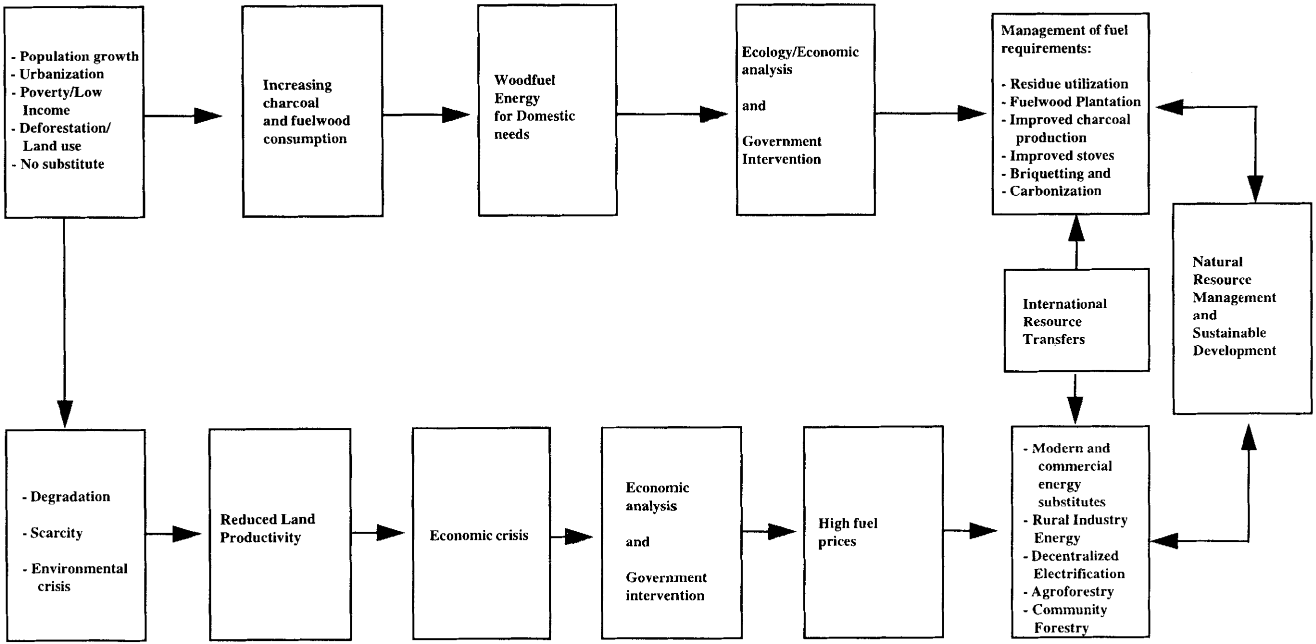
The suggested strategy is consistent with some themes and activities developed for dryland management of natural resources in the Sahelian and Sudanian zones of Western and Eastern sub-regions of Africa, Nairobi Plan of Action, UN Conference on Renewable Sources of Energy, Sudan Forestry Sector Plan and successful practice of national grassroot community forestry (Elamin and Ce'sar

26 Theoretically conservation of the forests is a sound risk-averse strategy in Sudan in particular in the long-run. However, the reality facing the government in the short-run (basically shortages of foreign exchange and petroleum products coupled with an increasing cost of developing and extracting natural gas) makes conservation a non-viable option for the designated government entity responsible for forest management (forestry department) to do it alone. Such a task is far beyond the meagre financial and managerial resources of the underfunded forestry agency.

1994:77-78; Falloux and Mukendi 1988:3-9; Teklu *et al.* 1991:112-114 and World Bank 1992a:32-36). The natural resource development strategy is designed to satisfy needs intertemporally and to manage the requirements in a sustainable way. That is, biomass and in particular woodfuel resources in Sudan are viewed as household fuel in the short to medium-run and as fuel for development in the long-run (Figure 1). Although the figure is self-explanatory, the following sequencing and timing of the action plan are hardly overemphasized.

The strategy suggests improved management of existing natural forest, emphasizing end-use efficiency and conversion technology by both household sector and rural industries and creating enabling environment to attract private investment in forestry, distribution and marketing in the short to medium-run. The main ingredients in the short to medium-run strategy are threefold. First, to bring the existing forest resources under more structured and effective protection and management both inside and outside government owned reserves. Second, to realize the importance and abundance of non-woodfuel biomass in Sudan. Sudan has more than 42 per cent of agricultural and animal residue in 1992 (such as cotton woody stalks, sorghum straws, groundnut shells, animal dung and other crop residues) which is the highest among the countries of the Eastern sub-region (Table 14 and Callaghan *et al.* 1985:217-232). In addition large quantities of biomass potential have been burned to ashes during the last two decades with an estimated annual rate of biomass losses of nearly one full percentage point (Table 12). The unutilized biomass losses alone were sufficient to meet the excess demand experienced in the energy-deficit regions of the country during the last decade (Table 11). If these untapped resources were utilized, the biomass fuel mix would have been improved considerably throughout the country. Third, to upgrade abandoned land and to augment large-scale plantations at the same time. That is, to establish new fuelwood with special emphasis on low cost technologies such as direct reseeding of abandoned mechanized farming or degraded forest land. This activity will complement both government restocking measures aimed at earmarking 5-20 per cent of agricultural land into forestry and UNDP/UNSO restocking of the Gum Arabic Belt of Kordofan region (ADB 1993:37, Teklu *et al.* 1991:113 and UNCTAD 1991:78).

Figure 1: Renewable Natural Resource Management Framework for Sudan



<u>**Note:**</u>

Adapted from Elamin and Ce'sar (1994), p. 73 and Salih (1992b), p. 10.

Table 14: Total Biomass Residue in 1992 (in GJ[(a)])

Country/ Region	Wood Residue[(b)]	Agricultural[(c)]	Animal[(d)]	Total
Sudan	168260	77507	44672	290439
Eastern Sub-Region	1101067	364205	209270	1694542
Africa	3170657	1856338	673379	5722314

Source:

Elamin and Ce'sar (1994), Tables 2-7, 2-8, 2-9, 2-10-1, 2-10-2, 2-10-3, 2-10-4, 2-10-5, 2-10-6, 2-11-1, 2-11-2 and 2-11-3.

Notes:

(a) GJ (Giga Joule) = 10^9 Joules and 1 TOE (Ton Oil Equivalent) = 42.6 GJ.

(b) Wood residue includes industrial wood, fuelwood and charcoal.

(c) Agricultural residue contains cereal, roots and tubers, bagasse, cotton, coconuts and green coffee. Note that the latter was not available in Sudan.

(d) Animal residues include dung from cattle, sheep, goats and chicken. The latter is the smallest in Africa and is negligible in Sudan.

The medium-term initiative will focus on the management of the process of energy transition. Introduction of biomass electricity production which is developed in several developing countries have been overlooked in the past. For example, he use of gasifiers for producer gas can feed gas combustion engines and biomass integrated gasifiers/gas turbines producing steam can support electricity production in the main electricity-generating stations in urban centres. These techniques are required to mitigate the frequent electricity cuts in Sudan (Elamin and Ce'sar 1994:62). In this scheme biomass fuels can contribute up to 20 per cent of energy mix sources; with the view of increasing electricity supply in Khartoum and major urban areas. Urban areas in Sudan have relatively higher incomes than rural Sudan. As income rises, urban households will begin to switch from traditional energy sources to kerosene, gas and electricity as witnessed in the last decades. That is, increased remittances from Sudanese working in the rich Gulf countries have encouraged their families to switch to gas and electric stoves.

There is also limited possibilities of substituting fuelwood by agricultural residues; assuming the availability of the appropriate energy conversion technologies. In these areas, various efforts have been made in briquetting of various types of waste in Sudan. Briquetting to provide an industrial fuel for rural industries (basically bakeries and brickmaking) utilizing agricultural and animal wastes are now managed by the private sector in rural areas (Elamin and Ce'sar 1994:62).

In the medium to long-term the suggested approach calls for the development and dissemination of sustainable biomass energy system intersectorally. At the macro level, the successful management framework requires important policy decisions such as the enactment of woodfuel prices to reflect the resource cost, revision of woodfuel legislation to allow private and communal ownership of woodfuel and to hasten integrated strategic approach for woodfuel resources as a component of an overall land use policy for sustainable development.

A central issue for sustainable development and management of natural woodfuel resources in Sudan concerns the degree of public, private and community participation in the programme and the relative roles for each. The Forestry department in Sudan is under-funded and biomass energy production problems occupy low-ranking in its priorities. In addition, resource management and development to increase fuel supply goes beyond its mandate. Agricultural expansion, livestock development, land use practices and the remaining factors that lead to increased demand for energy fuels cannot be addressed by the forestry authorities alone. These factors deem it necessary for the plantations option to be seriously considered intersectorally. Initially, the private sector involvement can be attracted by appropriate incentives. Subsequently community forestry must be encouraged by adopting policy measures that worked in the past such as tree and land tenure at the local level, promotion of participatory approach of woodstock management and management by woodstock users, etc.

Although on-farm programmes are inherently more likely to succeed in Sudan as discussed previously than communal ones, communal programmes have also shown successes in similar countries like Niger (Elamin and Ce'sar 1994:75). The extension of the successful on-farm experiments throughout the country would require more structured and systematic support from reliable government agencies. The Ministry of Agriculture, Animal and Natural Resources in Sudan can play a co-ordinated role by integrating tree plantations with the farming system (agroforestry) in order to protect crops and soils and to provide essential needs like fruit, fodder, fuelwood and poles. Research results on the effects of shelterbelt over a range of environmental, crop and management conditions in similar countries have been encouraging (World Bank 1986:87).[27] The high expectations from industrial forestry and its contribution to the Sudan economy must be examined carefully and its viability can only be established by more R & D. The limited success of the Gum Arabic Belt of Kordofan region, assumed, *inter alia*, more involvement of the forestry extension in the process. Hence, there must be continued commitment by the government to strengthen the forestry extension services. In addition forestry extension services can be linked with the central Agricultural Research Corporation (ARC) to co-ordinate agroforestry research.

Similar to SSA countries, biomass fuels will continue to play an important role in Sudan. Therefore, the importance of regional programmes in biomass fuels could facilitate collaboration and communication among SSA countries. Regional and/or sub-regional institutions such as the Inter-Governmental Authority for Drought and Desertification (IGADD) of which Sudan is a member can play an instrumental role to build technical capacity in natural resource management, community forestry, wood-based energy technologies and conservations in the sub-region. However, when the

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27 For example, crop yield increase attributable to shelterbelts and pertinent to irrigated and rainfed conditions similar to Sudan are numerous: 17-74 per cent for maize, 38 per cent for wheat and 35 per cent for cotton in Egypt; 23 per cent for millet in Niger and 50 per cent for overall agriculture in Kenya (World Bank 1986:86-88 and World Bank 1992a:99). Comparison from the Sahelian and Sudanian zone show that gains with shelterbelts are appreciable relative to the crop failure in unprotected areas.

extent of the flourishing and officially-unrecorded border-trade in charcoal and fuelwood is realized by the participating member countries, various actors may find it beneficial to establish such a link.

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