Working Paper

Population, Biomass and the Environment in Central Sudan

Hassan Musa Yousif

WP-94-108
October 1994

IIASA

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ABSTRACT

This paper deals specifically with population-biomass-environment interactions in the semi-arid central region of Sudan. Most of the links and dynamics operate at the local-scale household level. Living arrangements within the household, household size, size of consuming units, location and mode of living (urban-rural-nomadic) are some of the most important link variables. Biomass fuels use (fuelwood, charcoal, crop residues and animal dung) in the central region varies considerably by location of households. Rural households use fuelwood, crop residues and animal dung; nomadic households are primarily fuelwood users; urban households are mainly charcoal users. Nomadic households are very special not only because this manner of living is gradually shrinking but also because with the spread of irrigated and mechanized agriculture, nomads have become concentrated in ecologically limited areas with drastic consequences to their lives, their animal wealth and the environment.

Households are not the only users of biomass for fuel purposes; two more sectors use fuelwood and charcoal. These are industries such as brick-making and bakeries, and commercial establishments such as restaurants and tea houses. This paper shows that actual consumption of fuelwood and charcoal exceeds the official supply by about 22,000 and 32,000 metric tons, respectively. This indicates deforestation which is substantially enhanced by unofficial cutting of trees. By contrast the balance for crop residues and animal dung is substantially positive reflecting the availability of these biomass resources for fuel use. Policies should encourage the use of these residues for cooking. Also, the need for better management of biomass resources, energy saving, environmental education and awareness and planting of trees is obvious.

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1. INTRODUCTION

The survival of households in arid and semi-arid societies hinges on three main factors: (1) the balance of demographic behavior (fertility, mortality and migration), (2) the principles governing production, consumption and distribution of wealth, and (3) technological adaptation to the environment. These three factors constitute the focus of study and research in the literature on population-development-environment interactions. This paper studies biomass fuels as major factors in population-environment interactions in the central region of Sudan. It has two main objectives. The first is to identify some factors that link population, biomass and the environment, particularly, place of residence (rural-urban), migration, household size, size of the consuming unit, living arrangements, availability of alternative sources of energy and land conversion to agricultural use. The second objective is to study these links at the local-scale level. The semi-arid central region of Sudan is selected for this purpose. The empirical part of the paper is based on two secondary sources of data: the 1983 census results and results of an energy survey conducted in 1987. The paper concludes with some remarks and policy implications on population-biomass-environment interactions.

2. POPULATION-BIOMASS-ENVIRONMENT INTERACTIONS

The nature of the relationship between population and biomass, particularly fuelwood, is a subject of debate and controversy in the literature. Some scholars (Anderson 1986, 1987; World Bank 1987) argue that there is a direct relationship between changes in fuelwood consumption and changes in rates of population growth and urbanization. Others (Cline-Cole *et al.* 1990) believe that this direct link is likely to be distorted by changes in the size of consuming units. One argument frequently encountered in the literature is that population concentration in urban areas leads to an increase in the demand for fuelwood, and that urban demand has much greater potential for depletion of tree stock in surrounding rural areas than rural demand (Moss and Morgan 1981; O'Keefe and Raskin 1985; Anderson 1987). Cline-Cole *et al.* (1990) argue that this notion is "only selectively valid" because depletion of tree stocks around many African cities is primarily "a function of land clearance for agriculture, rather than a supply response to urban woodfuel demand" (p. 514).

However, several studies show that urban populations consume more fuelwood per head than rural populations. One explanation is that often there is a tendency among urban born residents to live in nuclear families. Another explanation is that rural-urban migration, which often is dominated by young males, tends to produce small-sized households. Peil (1986) argues that the predominance of young males among rural-urban migrants in some African societies is gradually declining. This is likely to produce larger urban household sizes as wives and children move to join husbands and fathers in towns and cities.

A crucial factor in the relationship between population growth and fuelwood demand is household size. In most cases people consume fuelwood as one unit in the household. These consuming units may correspond to residential households. In some cases residential households are complex and extended. Therefore it is possible to have more than one fuelwood consuming unit in each household. Two or more fuelwood consuming units in the household may have two or more fireplaces for cooking. Also, they may use one fireplace interchangeably.

Where population growth is associated with an increase in the size of consuming units, more efficient utilization of fuelwood per capita tends to reduce fuelwood consumption relative to population size. The literature supports a wide range of relationships in both urban and rural areas. Also, these relationships have to be understood in the context of related social changes such as changes in family size norm. The dynamics of population change and social and demographic complexities involved therein are shown in Table 1.

Table 1. Population dynamics and the demand for fuelwood.

Sources of change in demographic behavior	Associated changes in variables relating to fuelwood demand		
	Mean household size	Mean consuming unit size	Per capita demand
Births and Deaths			
1) High fertility and declining mortality	larger	larger	smaller
2) Declining fertility and low mortality	smaller	smaller	larger
Migration			
1) Young migrants living with relatives	larger	larger	smaller
2) Young migrants and relatives in small residential units	smaller	smaller	larger
3) Migrant families who tend to correspond more closely to nonmigrant families	larger	larger	smaller
4) Displaced persons	smaller	smaller	larger
Family size norm			
1) Persistence of extended family norms	larger	larger	smaller
2) Nucleation of families and trend away from compound residence towards nuclear residence	smaller	smaller	larger

When the size of a consuming unit begins to grow, marginally decreasing amounts of fuelwood will be used to cook a large amount of food. Economies of scale associated with the size of consuming units may, consequently, tend to lower per capita fuelwood consumption. As the size of a consuming unit increases, per capita fuelwood consumption is likely to decrease. Therefore, the consuming unit size is positively related to the amount of fuelwood consumption per unit, and negatively related to per capita wood consumption. Thus large consuming units are more energy efficient than small consuming units (Hosier 1985; Cline-Cole *et al.* 1990). Results shown in Figures 1 and 2, based on data from three towns in West Africa and two villages in Kenya, support these relationships.

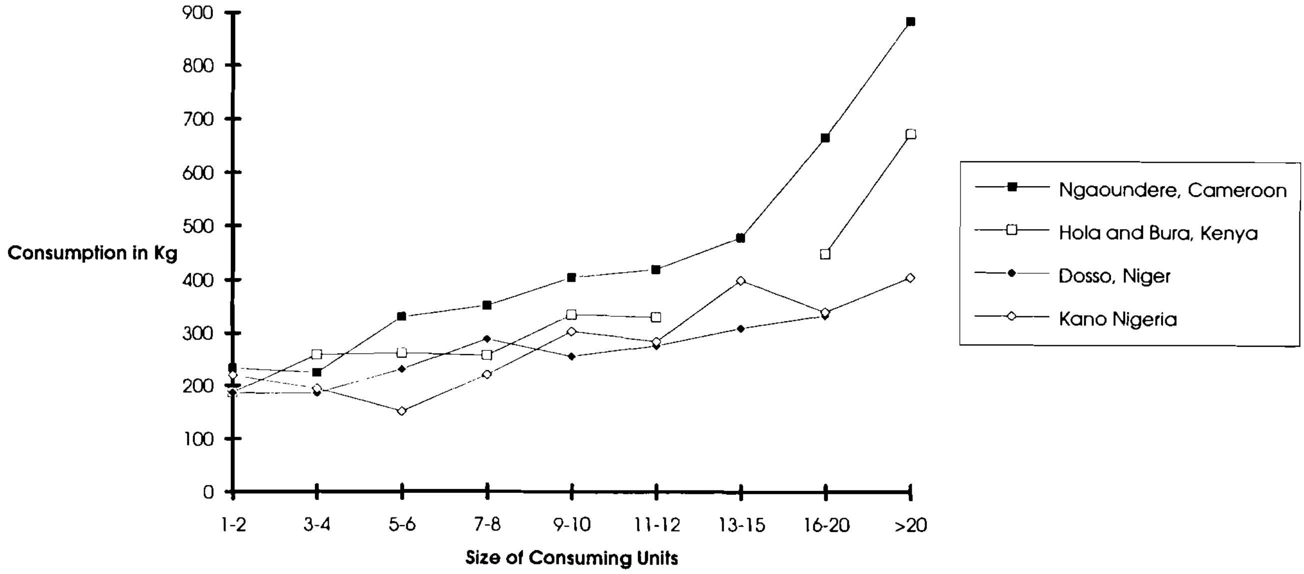

Figure 1. Fuelwood consumption by size of consuming units. Source: Drawn from Table 1 in Cline-Cole *et al.* (1990).

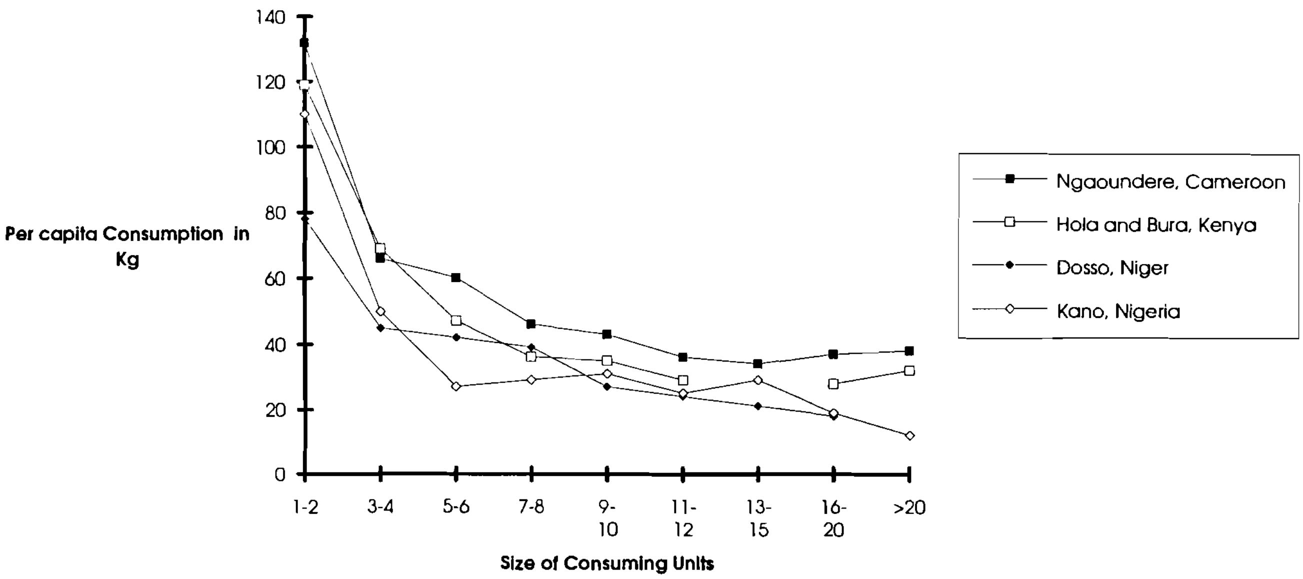

Figure 2. Per capita fuelwood consumption by size of consuming units. Source: Drawn from Table 1 in Cline-Cole *et al.* (1990).

Figure 2 reveals a steep decline in per capita fuelwood consumption as the size of consuming units change from small to medium. The magnitude of this negative relationship is likely to be reduced with the availability of alternative energy sources for cooking. Alternative non-fuelwood sources of energy are attractive to small consuming units, especially to those who cook for themselves. Also, a commonly observed behavior in most countries in Africa is that young males and females living in dormitories and institutional households buy food from street sellers, restaurants and shops. This is likely to depress per capita consumption.

Land conversion to agriculture use is believed to reduce fuelwood supplies in many countries in Africa. In a study of Kano in Nigeria, Eckholm *et al.* (1984) found that rising demand for fuelwood encouraged farmers to overcut trees such that areas within a 40 km radius of the city were stripped of trees. Data cited for Kano (Anderson 1986, pp. 821-822) suggest much higher wood density per hectare in fallow land, forest and woodland than in farm land. Using data from three study areas in the Kano region, Cole-Cline *et al.* (1990) found no evidence to support these arguments. They found the area closest to Kano, which is under the greatest potential for fuelwood demand pressure, to support high and increasing farm tree densities. Moreover, they found no evidence to support the land conversion hypothesis. Farmland in the Kano region has higher wood volume than shrub land and forest reserves. According to Cole-Cline *et al.,* the zones with the highest tree density in the Kano region are those that support the highest rural population densities. A similar finding reported by Bradley *et al.* (1985) for the Kakamega district in Kenya found an increase in planting of trees and shrubs in areas of high population density. In fact, in both Kano and Kakamega, farmers are encouraged by local authorities and agricultural units to plant trees.

3. POPULATION-BIOMASS-ENVIRONMENT MODEL

It is evident from the foregoing discussion that national level analysis of population-biomass-environment interactions may mask local, rural-urban and household imbalances. Even the latter may give a wrong notion if data are not reported for a long period. In fact environmental issues are very sensitive to both timing and space scales. Local level studies are rapidly growing. In Figure 3 a simple, local-scale model on population-biomass-environment interactions is presented. Population size, growth and distribution (rural-urban, etc.) are linked to the environment through biomass use for fuel and non-fuel purposes. Basically, there are four biomass resources; fuelwood, charcoal, crop residues and animal dung. Fuelwood and charcoal are both determined by the size and growth of forests, official licensing, and unofficial wood cut. Crop residues are seasonal by-products of agricultural activities. The amount of crop residues produced each season is determined by the types of crops grown and the area cultivated. The production of animal dung, on the other hand, depends on the size and types of animal herds and presumably on how much they eat. Part of the agricultural residues is consumed by animals.

Population size, growth and distribution are intertwined with the environment through biomass use by three sectors: households, industries and commercial establishments. Households use biomass for various purposes, such as fuel for cooking, production of agricultural implements, for building huts and plastering walls with animal dung. Household use of biomass varies between locations and seasons. The most important location variations are caused by whether the consuming unit is urban, rural or nomadic. The quantity and type of biomass used also vary depending on the size of the household and its socioeconomic status.

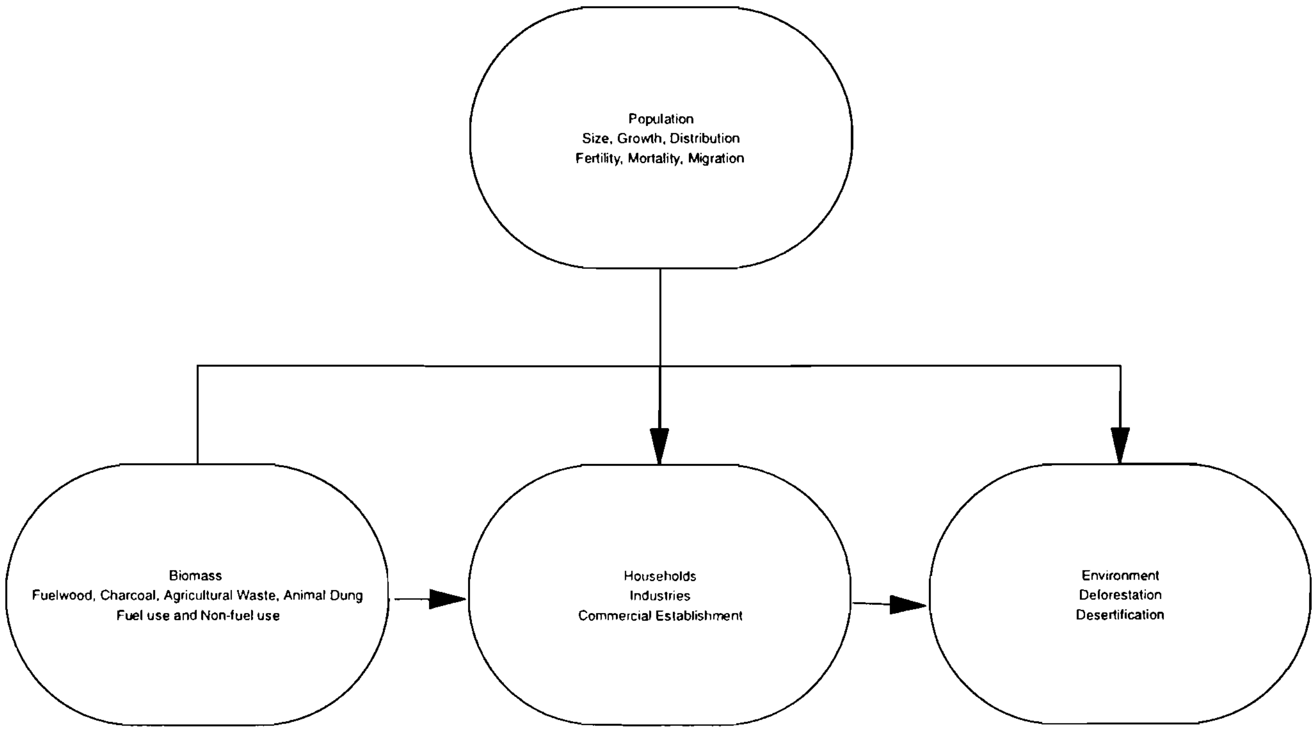

Figure 3. Population-Biomass-Environment Model.

Households are not the only users of biomass; other sectors such as industries and commercial establishments compete with them. Industries use wood in various ways as raw material for processing into a range of products such as furniture, tools and fixtures, and for generating energy. Bakeries and brick kilns use wood for production of bread and red bricks, respectively. Commercial establishments, on the other hand, consist of a range of institutions such as hotels, clubs, restaurants, tea houses and pastry shops. They consume wood and charcoal for energy as well as for other uses such as furniture and poles.

These sectors compete for the available biomass resources. Owing to the large demand and high prices of fossil fuels (kerosene, gas and electricity) biomass allocation for fuel uses takes priority over non-fuel uses. Also, fossil energy may sometimes not be readily available in the market because of lack of foreign currency. In such situations competition for biomass is likely to be high, particularly when the biomass resource base is fragile. The focus in this paper will be on biomass use for fuel purposes as major factors in population-environment interactions.

4. POPULATION-BIOMASS-ENVIRONMENT INTERACTIONS IN SUDAN

Little is known about biomass resources and their interactions with population in Sudan. The Sudan National Energy Administration (SNEA 1983) estimated that during the early 1980s, Sudan consumed about 291 petajouls of energy. Most of it (248 PJ) was from biomass resources consumed primarily by households. Using published data collected by the SNEA (1983) from 2443 households (1143 urban + 1300 rural) in every region of the country, Whitney (1987) attributes most of the deforestation between 1960 and 1980 to high population growth in Sudan. He argues (p. 120):

> During the twenty year period 1960-1980, the average annual increase in deforestation was 1,033 km^2, of which 61.8 percent can be attributed to overall population growth, 27 percent to changes in per capita demand for fuelwood, and 11 percent to declining volume of fuelwood. Clearly, increase of population rather than increased per capita demand has been the primary factor in accelerating the rate of deforestation.

There are many problems with this type of analysis. Two observations taken at two different points in time (20 years) are not enough to confirm the role of population growth in deforestation. In Sudan fertility and migration are both high and mortality is improving. Population change, therefore, is rapid. Income levels and urbanization are changing at rapid rates, too. Moreover, energy alternatives and fossil energy, including electricity, are more available in Sudan during the 1980s than during the 1960s (four years after independence). These factors should be taken into account as a group when studying the contribution of population growth in deforestation in Sudan.

One argument relates the interaction between population and fuelwood use to conversion of land to agriculture. Historically, the supply of surface water and rainfall permitted cash crop production in Sudan to win the competition for land use against livestock and forestry. The establishment and subsequent expansion of mechanized rain-fed farming and irrigated agriculture in Sudan was done by clearing shrubs and trees and resettlement of population in villages without caring for their fuel energy needs. In an elaborate study of villages in the Al-Gezira scheme, Culwick (1951) noted the lack of fuel and building timber. This was due, she argued, to clearance of trees several decades earlier for the purpose of introducing irrigated cotton and cash crops in the area. Moreover, Culwick reported opposition to tree planting in the scheme because of pests, reluctance to reduce cotton farms and lack of water. Most of the fuel needs in the Al-Gezira scheme, Culwick noted, are wholly met by purchase of wood and charcoal from outside the scheme. A moderately prosperous family would use about two sacks of charcoal and two camel loads of firewood in one month. This was estimated to make about 6 to 8 per cent of total household income from agriculture.

Also, in Sudan there exist substantial regional imbalances not only in terms of biomass endowment but also in terms of lack of coincidence between population density and allowable cut–the amount of wood that could be cut without depleting the resource base (Whitney 1987; Pearce *et al.* 1990). Most of the wood resources in the country are located in the south, where only 16 per cent of the population live. With the exception of southern Darfur and the southern part of the central region, the rest of the north is barely forested. The northern province and Khartoum are almost barren desert. In Khartoum and the central region, where population density is high, the demand for fuelwood and charcoal is high and the rate of allowable cut is low (0.26-0.08 m^3/ha). By contrast the south, which is barely populated, has a high rate of allowable cut (0.18-1 m^3/ha) (Whitney 1987, pp. 116-117). These regional imbalances, which are very important for population and environment policies, are unlikely to show up in aggregate national data.

Some studies provide a pessimistic view and project an "energy crisis" for northern Sudan. For example, Pearce *et al.* (1990) using World bank data, which often is misleading, argue that woody biomass in northern Sudan decreases by a rate of 5.5 per cent per year and 25 per cent per year for Kordofan. Therefore, with the exception of Darfur, northern Sudan will totally exhaust its wood stock by the end of the century. Pearce *et al.* estimated the overall demand for wood in 1983 to be around 46 million cubic meters of which 43 million m^3 is woodfuel (15.8 million m^3 fuelwood + 27.1 million m^3 charcoal). Khartoum alone accounts for a total of 22 million m^3 of charcoal. Charcoal demand may grow to 45 million m^3 by the year 2000.

Sudan was the location for several studies on the role of the removal of vegetation cover and biomass on the southward creeping of the Sahara desert. Using a vegetation index, Lampry (1976) found that the Sahara desert is moving southward at a rate of 5-6 km per year. Based on analysis of imagery for Darfur, Ibrahim (1984, p. 187) found that 15 per cent of northern and central Darfur is highly affected by desertification, 35 per cent is highly exposed to desertification, and only 20 per cent is less exposed to desertification. According to Ibrahim, the main culprits of desertification are clearance of land around settlements for fuelwood, northwards push for millet production and overgrazing (man-made activities). Several studies done at Lund University in Sweden (Hellden 1984; K. Olsson 1985; L. Olsson 1985; Ahlcrona 1988) reject Ibrahim's findings. For example, in a study on fuelwood and land degradation in Kordofan, K. Olsson (1985) found that no woody species seem to have been eradicated, and there is no evidence to indicate that the ecological zones in Sudan are shifting southward. In a study of biomass and albedo (the ratio of reflected light from the surface of the earth to incident light: the higher the level of vegetation, the lower is albedo since the vegetation absorbs the light), L. Olsson (1985) found no consistent degrading of landscape in Kordofan throughout the period between 1973 and 1979. Studies done at Lund University noted that unless data are reported over a long period, a false impression may be created.

5. THE CENTRAL REGION

The area selected for research is the central region of Sudan. It lies immediately to the south of Khartoum between latitudes 9:30 and 15:30 and longitudes 31:50 and 35:30. This area is approximately 139 thousand square kilometers and constitutes about 9 per cent of the total land area of Sudan. It is divided into three major provinces:

1) Al-Gezira, which lies to the south of Khartoum between the Blue Nile and the White Nile rivers;

2) The White Nile, which lies to the west of Al-Gezira and is physically dominated by the White Nile river.
3) The Blue Nile, which lies to the south of Al-Gezira and extends to the international borders with Eritrea and Ethiopia.

The most striking feature of the central region is its flat land. There is uniformity in the type and quality of land and hence of crops produced. With unreliable rainfall in northern Al-Gezira and the White Nile, pasture and rain-fed cultivation are very limited. By contrast, the amount of rainfall in the Blue Nile permits land use for rain-fed cultivation and grazing.

Natural vegetation in the region consists of stands of acacia trees in the savannah woodland belt. To the north of this belt, shrubs and thorn trees are scattered. Vegetation becomes very scarce as one moves north close to Khartoum. The wood area is estimated to be 0.059 million hectares (M/ha) in the Al-Gezira province, 3.376 M/ha in the Blue Nile province and 0.238 M/ha in the White Nile province (Table 2). The total wood area for the whole region is 3.673 M/ha. Wood density in m^3 per hectare is 33.7 for Al-Gezira, 35.8 for the Blue Nile, and only 0.9 for the White Nile province. The overall wood density for the central region is 33.5 m^3 per hectare. Wood resources in the central region were estimated by the Ministry of Agriculture to be about 123 million m^3, mostly located in the Blue Nile province. The White Nile province has the lowest resource base in the central region.

Table 2. Biomass resources in the central region. Source: Sudan National Energy Administration (1989).

Province/Crop	Wood			Crop Residues	Animal Dung
	Volume Mm^3	Wood cut (Mm^3) Licensed	Sustainable	(Mmt)	(Mmt)
Gezira Province	2.226	0.597	0.122	2.802	1.135
Cotton				1.464	
Wheat				0.306	
Sorghum				0.897	
Groundnut				0.135	
Blue Nile	120.773	1.670	4.227	5.157	1.333
Cotton				0.063	
Sorghum				5.094	2.337
White Nile	0.234	1.121	0.008	2.193	
Cotton				0.075	
Wheat				0.030	
Sorghum				2.079	
Groundnut				0.009	
Central Region	123.233	3.388	4.358	10.152	4.805

Agricultural residues produced from cotton, wheat, sorghum and groundnut are estimated at around 10.1 million metric tons. The Blue Nile province alone produces 5.2 million metric tons of agricultural residues, which is more than Al-Gezira (2.8) and the White Nile (2.1) provinces combined. Sorghum, which is cultivated mainly in the mechanized rain-fed farms in the Blue Nile province, produces 8.1 million metric tons of stalks. Most of the cotton stalks, wheat stalks and groundnut shells are produced in the irrigated agriculture schemes. Production of animal dung in the central region is estimated at about 4.8 million metric tons. Most of the dung is produced by animals in the White Nile province where nomadism is widespread. Some dung is produced by cattle and sheep raised by the sedentary village cultivators in Al-Gezira and the Blue Nile.

5.1. Economy

The economy of this region is based on agriculture. Basically, there are three farming systems: (1) traditional rainfed and livestock farming (nomadism), (2) mechanized rainfed farming, and (3) irrigated farming. Traditional farming is mainly subsistence-oriented. It is characterized by low levels of technology, use of traditional implements and high vulnerability to the amount of rainfall. Traditional farmers grow millet and sorghum, and raise animals. By contrast, mechanized rain-fed farming was introduced in the 1940s primarily for the purpose of supplying food for the western allies' army units in East Africa. This type of farming is characterized by private ownership of large farms and use of modern agricultural machinery. Farmers grow sorghum, sesame and sunflowers. Large-scale irrigated agriculture started with the establishment of the Al-Gezira scheme in 1925. Subsequently, several irrigated agriculture schemes were established in Al-Managil (1958), Al-Suki (1972), and Al-Rahad (1979). Farmers grow cotton, wheat, groundnut and sorghum on land under control by the government.

With the expansion of mechanized rain-fed and irrigated agriculture in central Sudan, traditional farming and nomadism became very limited. Expansion of "modern" agriculture has set physical limitations to the migration pattern of nomadic tribes. In particular, long-distance migration that was practiced for centuries has been considerably shortened. As nomads are not allowed to graze their animals in cash crop production areas, pasture has become limited, too. Consequently, the White Nile Arabs and their animals have been pushed to the dry dune areas to the west of the river (Kates and Haarmann 1992, p. 10). Also, the Blue Nile nomads who used to cross the river during the dry season for pasture and water in Al-Gezira are no longer doing so because of the establishment of the Al-Gezira scheme. Moreover, they have been pushed farther to the east as a result of the establishment of the Al-Rahad scheme on the east side of the river. Therefore, nomads in central Sudan have become concentrated in ecologically limited areas with drastic consequences to their lives, their animal wealth and the environment.

5.2. Population

Labor intensive agricultural activities in the central region have lead to major population changes. The population of the region became more ethnically and culturally diverse than ever before. People came from neighboring provinces as well as from abroad to work and, later on, to live in these schemes. They live in villages and small towns scattered all over the vast plains. The censuses of 1956, 1973 and 1983 give figures on the population size of the central region. The total population increased from 2.07 million in 1956 to 3.8 million in 1973 and to 4.03 million in 1983. The small growth between 1973 and 1983 was due to double counting of cotton pickers. More recent preliminary results of the 1993 census give a total of 5.5 million persons in the central region. The population size of the region has doubled in 27 years. This implies rapid population growth at a rate of about 2.4 per cent per annum (1956-1983), which is slightly less than the growth rate for Sudan as a whole (2.8%) during the same period.

The urban population[1] in 1983 was six times its size in 1956. With a growth rate of 5.2 per cent, the urban population will double its size every 13 years. At the time of the 1983 census there were 53 town councils in the central region; 22 in Al-Gezira province, 14 in the Blue Nile province and 17 in the White Nile province. Al-Gezira had 42.2 per cent of the total urban population, the Blue Nile province had 25.3 per cent, and the White Nile province had 32.5 per cent. The average size of urban households is 6.3 with minor differences between the three provinces.

The rural population, though much larger than the urban population, grew by a slower rate of 1.78 per cent during the period 1956-1983. It grew from 1.8 million in 1956 to about 3 million in 1983. Of the total rural population of the central region 53 per cent live in Al-Gezira province, 26 per cent in the Blue Nile province and the remaining 21 per cent live in the White Nile province. The average size of rural households is 5.7 persons, which is slightly less than urban households. The nomadic population, on the other hand, is much more smaller than urban and rural populations. Nomadism in Sudan is shrinking. In Sudan the proportion of the total population that are nomads has declined from 13.6 per cent in 1956 to 11.5 per cent in 1973 to 10.9 per cent in 1983. About 6 per cent of the population of the central region in 1983 was nomadic.

The median age, the age which separates the population into two equal-sized groups, is 16.8 years. Young age structure indicates an age pyramid with a broad base and rapid narrowing. This young age pattern has several important implications. It shows that an increasing number of girls are expected to enter the reproductive age which implies a potential for increasing fertility or at least maintaining it at a high level. Similarly, an increasing number of people are expected to enter the working age groups. Also, young age structure creates continuous demand pressure on social services such as schools and health facilities.

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[1]The definition of *urban, rural* and *nomadic* merits special consideration here as these terms are important for understanding the forthcoming analysis. An urban/rural area is defined as "an area with a population of five thousand or more or an area administered by the town council irrespective of the size of its population was considered as urban. Also if an area was considered, by the local authorities, of administrative or commercial importance without the town council and with less than five thousand population, it was also classified as urban. The rest of the settled population was classified as rural" (Department of Statistics 1989, p. 12). Nomadic population, on the other hand, consists of "tribes who tend to live in mobile houses (tents or temporary huts usually made of wool or hyde). They raise livestock and are continuously moving in search of water and pasture and do not stay in specific areas for a long time. Administratively, they pay their allegiance to tribal omodias/chiefs/sheikhs/farigs" (Department of Statistics 1989, p. 12).

The central region has the highest fertility level in the Sudan. The 1979 Sudan Fertility Survey gives a total fertility rate of 6.8 and a completed family size of 7.4 for women 45-49 years old. More recent evidence from the Sudan Demographic and Health Survey (Department of Statistics 1991) gives a total fertility rate of 5 and a completed family size of 7.9 for women 40 to 49 years old. Rural-urban fertility differences are negligible. For example, the 1983 census results show a completed fertility level (women 45-49 years) of about 6.8 for urban and 6.7 for the rural areas. Recent fertility data for nomads is not available. However, Henin (1969) found that nomads have a very low total fertility rate of 3.6 compared to a rate of 8.2 for people settled in villages in the Gezira scheme and a rate of 6.7 for semi-settled population in the Al-Managil area. There is no evidence to show that these fertility difference do not currently exist.

6. BIOMASS FUELS CONSUMPTION

The 1983 census contains a separate section on housing characteristics which includes questions on the type of dwelling units, source of drinking water, type of lighting and cooking fuel. This information could be used for analyzing the interrelationships between types of households,[2] living arrangements and the use of modern fuels (electricity, gas, kerosene) and traditional fuels (charcoal, wood) for cooking. The 1983 census results are shown in Charts 1, 2, 3 and 4. The great majority (95%) of private settled households (urban + rural) in the central region use wood and charcoal for cooking (see Chart 1). Only a small fraction uses electricity, gas and kerosene for cooking as these are too expensive fuels to import or produce locally.

Use of cooking fuel is more interesting when data are classified by place of residence (urban/rural) and type of living quarters *(menzil, villa or flat and gottia)*[3]. Wood and charcoal stand out as the most used fuels for cooking in both urban and rural households of type *menzil* and *gottia* (see Charts 2 and 4). *Menzil* households resemble the medium and poor classes of the population; most of them cannot afford to buy modern cooking stoves. Therefore, it is not surprising that 94.7 per cent and 94.3 per cent of *menzil* households in urban and rural areas, respectively, in the central region use wood and charcoal for cooking. In fact, the central region is the largest producer of charcoal in Sudan. Large quantities of charcoal are distributed locally in the region and transported to other regions such as Khartoum and the north. The ratio of charcoal to wood users in *menzil* households is approximately 7.2:1 in urban areas and 1.9:1 in rural areas. By contrast the ratio for *gottia* households is 1.2:1 for urban areas and 1:15.1 for rural

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[2]A household, as defined by the 1983 census, "is a unit consisting of a group of related or unrelated individuals who normally share living quarters and eat together. Also there are single person households and institutional/collective households such as 10 or more unrelated persons living together. The institutional households include such institutions as soldiers' camps, boarding houses, prisons and hospitals. The household units were classified into: private settled household, collective institutional household; nomadic household; and homeless" (Department of Statistics 1989, p. 9).

[3]Menzil is the Arabic name for a house consisting of some square rooms, veranda and surrounded by a wall 1.5 meters high. Gottia is the Arabic name for hut. It is a round shaped hut made of mud layers and a thatched roof made of grass. Gottia is commonly believed to be suitable in areas of high rainfall in southern Gezira and the Blue Nile.

households. *Gottia* dwellers in rural areas are primarily wood users, probably because it is freely available for them. Most of urban *gottia* households are located in the outskirts of cities and towns where there is no access to electricity or gas. These poor urban households use both wood and charcoal for cooking.

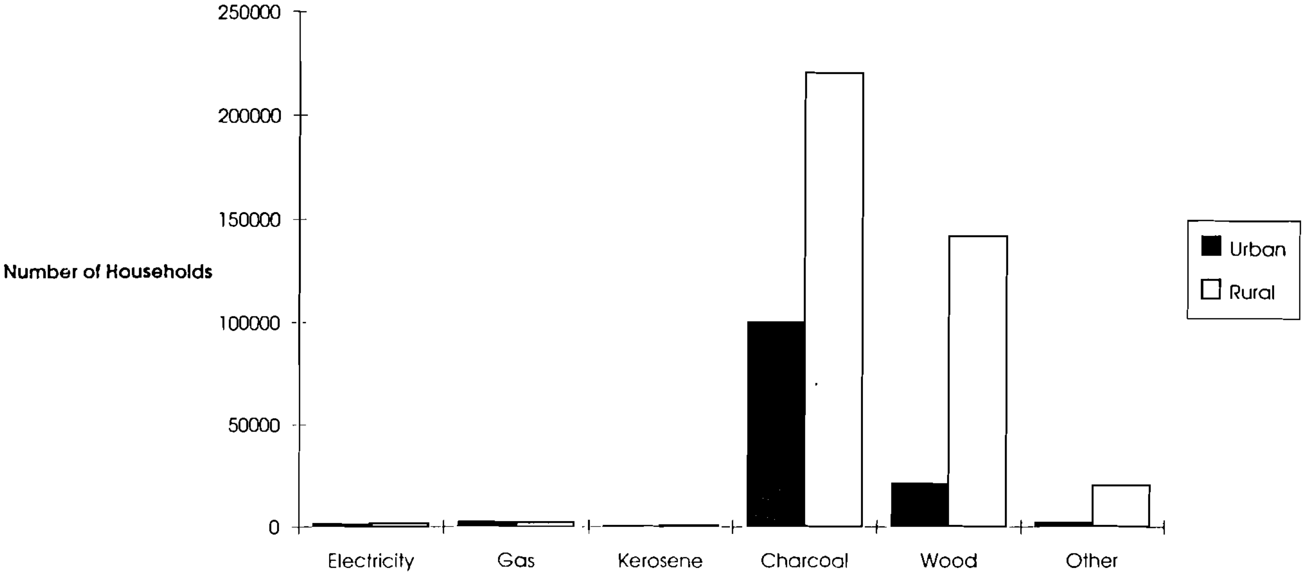

Chart 1. Private settled households by type of cooking fuels (1983 census).

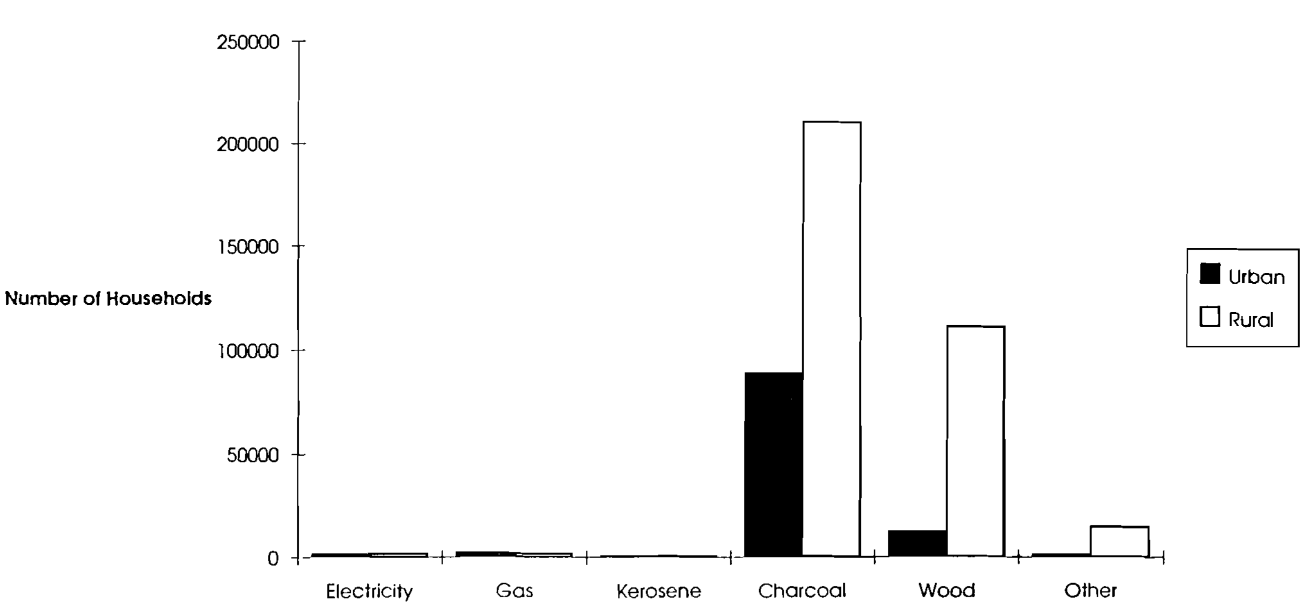

Chart 2. Private settled *menzil* households by type of cooking fuels (1983 census).

On the other hand, villa or flat households in both urban and rural areas in the central region resemble the well-off class: those who enjoy high income. They are the ones who can afford to buy modern cooking equipment and machines. They use electricity, kerosene and gas for cooking. A large number of them in both urban and rural areas use charcoal for cooking as gas sometimes is not available throughout the year because of import shortage due to lack of foreign exchange (see Chart 4). Also production of electricity is very unstable due to fluctuations in the level of the river Nile.

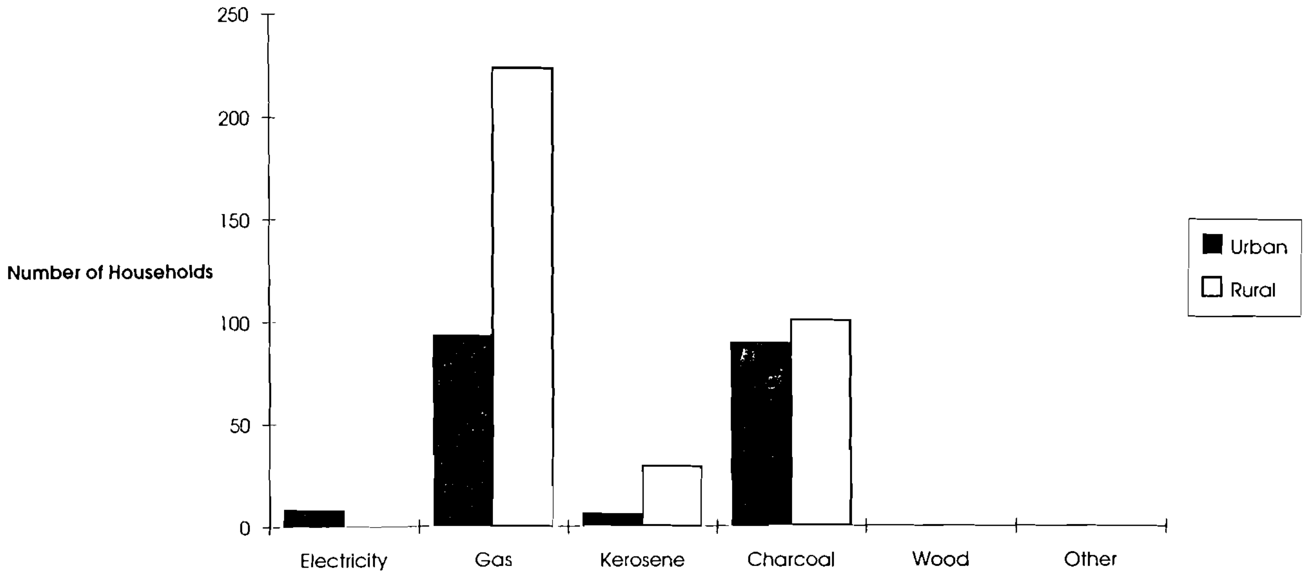

Chart 3. Private settled villa or flat households by type of cooking fuels (1983 census).

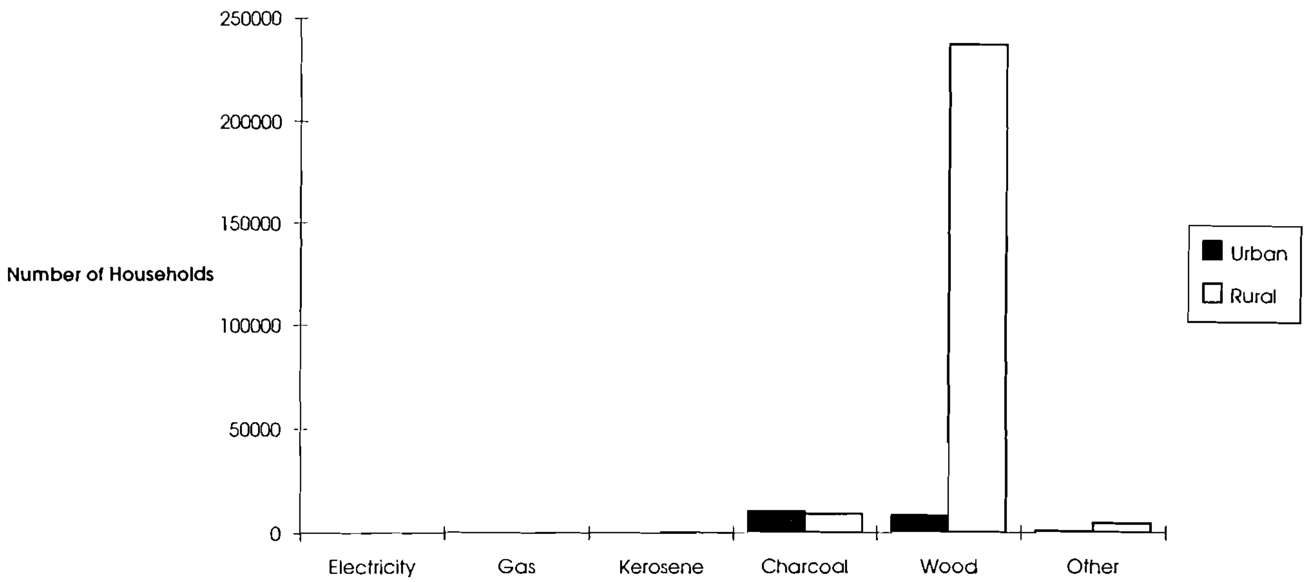

Chart 4. Private settled *gottia* households by type of cooking fuels (1983 census).

Census data have several limitations. It shows who consumes biomass but not how much biomass is consumed. Another limitation is that information on biomass consumption is for private settled households; nomadic and institutional households are excluded. Also census data on biomass consumption are for the household sector, not the industrial and commercial establishment sectors. There were no data in the census on crop residues and animal dung, which are an important source of fuel for rural households, as we shall see later.

To answer some of the questions that were left unanswered by the 1983 census, published data on energy assessment for the central region were examined. In 1987 the Sudan National Energy Administration did an energy assessment survey[4] in the central region. Its main objective was to provide a basis for the central region energy plan through the year 2000, and to determine the rate of deforestation due to consumption of wood and charcoal. A random sample of 6000 households in urban, rural and nomadic areas of the central region were asked how much biomass fuels they consumed every day. Also, a total of 631 establishments in 11 industrial categories were covered in the survey. The degree of coverage ranged from 3.3 per cent for bakeries to 100 per cent for sugar, cement, food and leather factories. These data, combined with the 1987 population estimates, were then used to estimate the total biomass consumption for households, industries and commercial establishments for each province separately and for the central region as a whole.

6.1. Fuelwood Consumption

Households in the central region consume 593 thousand tons of wood annually, most of it by the Blue Nile (49.9%) and the White Nile (44.4%) households. Al-Gezira households account for only 5.6 per cent of wood consumption in the region (Table 3). The difference here is likely to be due to availability of alternative sources of energy for cooking. Crop residues, particularly cotton stalks, are freely available for rural and urban households in Al-Gezira. Moreover, wood resources in Al-Gezira are very much under government control. By contrast, wood resources in the Blue Nile are freely accessible to rural and nomadic households and are available at low cost for urban households. Unfortunately, the survey data does not include information on prices of biomass fuels to substantiate these differences.

Low fuelwood consumption in Al-Gezira province is clearly reflected in small per capita figures for rural and urban households, but not for nomadic households (Table 4). Per capita fuelwood consumption is only 3 kilograms for rural households and 50 kilograms for urban households, compared to 279 kilograms for the nomads in Al-Gezira province. In fact, nomadic households in each of the three provinces are the major consumers of fuelwood. On a per capita basis, nomadic households consume 413 kilograms of fuelwood in the White Nile and 311 kilograms of fuelwood in the Blue Nile province. Fuelwood consumption for one person in nomadic households is 93 times a person in rural households, and 6 times a person in urban households in Al-Gezira province. Similar nomadic-rural-urban ratios are 1:1.06:2.45 and 1:1.44:3.39 for the Blue Nile and the White Nile provinces, respectively. These differences cannot be due to differences in household size, but most likely because rural households in Al-Gezira consume very little wood. Also, consuming units in nomadic households are likely to be smaller than in rural and urban households. Moreover, nomadic households in Al-Gezira are not allowed to

[4]This survey was conducted under this author's supervision. The data were processed at the Population Studies Centre, University of Gezira.

graze their animals in the irrigated scheme. Consequently, their movement and access to wood resources are concentrated in areas in the province, but outside the Gezira scheme.

Table 3. Biomass fuels consumption by households (mt). Source: Sudan National Energy Administration (1989).

Biomass Fuel	Province			
	Gezira	Blue Nile	White Nile	Total
Wood	33335	296053	263551	592939
%	5.6	49.9	44.4	100
Charcoal	234842	128838	117736	481416
%	48.8	26.8	24.4	100
Crop Residues	721194	104977	43565	869736
%	82.9	12.0	5.0	100
Animal Dung	142027	10065	4924	157016
%	90.4	6.4	3.1	100
Total	1131398	539933	429776	2101107

Table 4. Annual per capita biomass fuels consumption by households and mode of living (in kilograms). Source: Sudan National Energy Administration 1989.

Province	Wood	Charcoal	Crop residue	Animal dung
	Urban			
Gezira	50	110	162	23
Blue Nile	127	125	44	4
White Nile	122	141	9	10
	Rural			
Gezira	3	108	172	76
Blue Nile	292	114	112	11
White Nile	287	111	62	4
	Nomadic			
Gezira	279	99	142	0
Blue Nile	311	77	31	0
White Nile	413	37	30	0

6.2. Charcoal Consumption

Households in the central region consume about 481,000 metric tons of charcoal. Almost half of this amount is consumed by households in Al-Gezira province (Table 3). Unlike fuelwood, charcoal is produced in commercial quantities in the Blue Nile and transported by road to Al-Gezira and the White Nile provinces. Also, a large part of it is transported to Khartoum where the market for charcoal is good.

Settled rural households consume 73 per cent of the charcoal, urban households 23 per cent, and nomads 4 per cent. However, for each of the three provinces, urban per capita charcoal consumption is higher than rural and nomadic. The urban rural difference is more pronounced in the White Nile province. The highest per capita charcoal consumption is 141 kilograms for the White Nile urban households, and the lowest is 37 kilograms for nomads in the same province (Table 4).

On the other hand, similarity of per capita charcoal consumption between the urban and rural Al-Gezira is not unexpected (Table 4). Rural settlements in Al-Gezira are highly monetized because of cash crop production in the irrigated schemes. By contrast, rural households in the Blue Nile and the White Nile practice subsistence agriculture. Therefore, they tend to rely less on commercial fuels, preferring to gather wood instead. Similarly, nomadic households in the White Nile and the other two provinces have free access to wood. They consider it free goods, readily available whenever needed.

6.3. Crop Residues and Animal Dung

Households in the central region consume about 870,000 metric tons of crop residues and 157,000 metric tons of animal waste each year (Table 3). Al-Gezira households use 83 per cent of crop residues and 90 per cent of animal dung of the total of each biomass fuel for the region as a whole. While less in other areas, the use of crop residues, particularly cotton stalks, is quite noticeable among the rural households of Al-Gezira.

Per capita results reveal more interesting findings. The rural residents of Al-Gezira have the highest per capita consumption of both crop residues, particularly cotton stalks, and animal dung followed by the urban residents of the same province. The rural-urban difference is not large, except for dung which is used more by rural than by urban households. In the Blue Nile province, per capita crop residues consumption is 112 kilograms for rural households, 44 kilograms for urban households and 31 kilograms for nomadic households. The White Nile households (urban, rural and nomadic) use the least amount of crop residues for cooking.

Interestingly, none of the nomadic households in the three provinces consume animal dung. Rural households in Al-Gezira are the largest consumers of animal dung followed by urban households of the same province. We should distinguish between dung produced by animals in *zeriba*[5] and dung produced by animals on the move. The first type of dung is accessible to rural inhabitants where animals are kept in fences. The second type of

[5]Zeriba is a fenced-in pen where animals are kept.

dung is scattered and is, therefore, difficult and more time-consuming to collect. In view of this and the fact that fuelwood is a free good for nomads, it is, therefore, not surprising that nomadic households in the White Nile are not using dung as fuel for cooking.

6.4. Consumption by Other Sectors

Households are not the only users of biomass for fuel purposes; two more sectors use fuelwood and charcoal. These are industries such as bakeries, brick making, carpentry and workshops, and commercial enterprises such as hotels, restaurants, clubs, tea houses and pastry shops. Industries consume an average of 202,000 tons of fuelwood, most of it by bakeries (51%) and brick kilns (48%) (Table 5). Commercial establishments consume an average of 22.5 thousand tons of charcoal and 2.4 thousand tons of fuelwood a year almost entirely (99%) by the urban-based commercial enterprises (Table 6). Pastry shops and restaurants are the major consumers of wood accounting for 41 per cent and 35 per cent of total fuelwood consumption, respectively.

Table 5. Wood consumption by industries (mt). Source: Sudan National Energy Administration (1989).

Province	Consumption in metric tons
Gezira	128291
Blue Nile	41210
White Nile	32535
Central Region	202036

Table 6. Wood and charcoal consumption by commercial establishments (mt). Source: Sudan National Energy Administration (1989), Tables 27, 28, 29, and 30.

Commercial Establishments	Wood				Charcoal			
	Central Region	Al-Gezira	Blue Nile	White Nile	Central Region	Al-Gezira	Blue Nile	White Nile
Inns	0	0	0	0	104	22	0	82
Hotels	0	0	0	0	532	471	0	61
Clubs	0	0	0	0	785	503	164	118
Buffets	0	0	0	0	2443	1445	148	850
Tea Houses	0	0	0	0	2683	1326	985	372
Akshaks	133	12	57	64	3465	972	587	1906
Restaurants	828	358	470	0	6942	3411	1993	1538
Pastry Shops	980	179	74	727	1250	737	390	123
Laundries	0	0	0	0	518	226	101	191
Cinemas	9	0	9	0	58	17	34	7
Others	447	445	0	2	3696	2857	501	338
Total	2397	995	610	793	22476	11987	4903	5586

7. BIOMASS FUEL BALANCE

Table 7 shows biomass fuel balance for the central region. The fuel balance (supply minus consumption) is negative for wood and charcoal, and positive for crop residues and animal dung. The actual consumption of fuelwood and charcoal exceeds the official supply by 219,041 and 320,173 metric tons for each, respectively. This difference indicates the existence of unofficial wood and charcoal suppliers. As forests in the central region are freely accessible to people, unlicensed wood cutting is not an unexpected phenomenon. Also, this imbalance indicates that the actual consumption of wood far exceeds official estimates. In fact, official estimates are misleading for studying population and biomass interactions and are, therefore, unreliable for understanding the process of deforestation in the region.

Table 7. Biomass fuel balance for the central region. Supply of wood and charcoal is based on official licensing of wood cut (Table 2). Consumption is computed from Tables 3, 5 and 6.

	Wood	Charcoal	Crop residues	Dung
Supply				
Al-Gezira	15757	61111	2802573	1135422
Blue Nile	321212	78518	5156797	1333056
White Nile	241363	44090	2193658	2336751
Central Region	578332	183719	10153028	4805229
Consumption				
Al-Gezira	162621	246829	721194	142027
Blue Nile	337873	133741	104977	10065
White Nile	296879	123322	43565	4924
Central Region	797373	503892	869736	157016
Balance				
Al-Gezira	-146864	-185718	2081379	993395
Blue Nile	-16661	-55223	5058120	1322991
White Nile	-55516	-79232	2150093	2331827
Central Region	-219041	-320173	9283292	4648213

Fuelwood and charcoal imbalance are more pronounced in Al-Gezira, which is the most populated part of the central region. Fuelwood imbalance in Al-Gezira is more than twice the imbalance for the other two provinces. Also, charcoal imbalance for Al-Gezira exceeds the imbalance for the sum of the Blue Nile and the White Nile provinces by about 51,000 m^3. Considering unofficial licensing of wood cut and the considerable consumption of wood by households, industries and commercial enterprises, the extent of deforestation would appear far more greater than implied by official licensing alone.

The consumption of agricultural residues and animal waste, on the other hand, is far below the average annual supplies. Only 8.5% of the former and 3.3% of the latter are consumed by households. Aside from the fact that nomads are required to keep their animals away from the crop production area, agricultural residues are free and within easy access to all people in the region. Therefore, there is great potential for expanded use of crop residues and dung as substitutes for fuelwood and charcoal.

8. CONCLUDING REMARKS

Urban, rural and nomadic households depend substantially on fuelwood, charcoal, crop residues and animal dung for cooking. Wood and charcoal stand out as the most commonly used fuels in the central region. The 1983 census results indicate that use of biomass energy is related to living arrangements. *Menzil* and *gottia* households, which represent the middle income and poor classes of people, use charcoal and fuelwood. By contrast villa and flat households consume gas and sometimes charcoal as fuelwood may not be adequate to use in this type of housing.

Results from the energy assessment survey give more insights on population and biomass interaction. Biomass fuel use in the central region varies considerably by location of households. Rural households use fuelwood, crop residues and animal dung for cooking. Nomadic households are primarily fuelwood users. By contrast, urban households are mainly charcoal users.

Households are not the only sector using biomass for fuel purposes. Rural and urban industries, and commercial enterprises use fuelwood and charcoal too. Therefore, various sectors of the economy compete for available biomass resources. This competition is likely to increase with increasing population size in the region. To mitigate these conflicting demands, improved stoves and other measures of energy-saving are necessary to increase the efficiency of biomass fuel uses. Also, since the use of wood and charcoal for fuel contributes to deforestation, resorting to alternative sources of energy for cooking would be environmentally desirable. Planning for suitable alternative fuels should, therefore, reduce dependence on wood and charcoal. As biomass fuels are increasingly becoming scarce because of unsustainable wood cut, better management of biomass resources is needed. Official licensing of wood cut should not exceed sustainable cut; unofficial licensing should be stopped and planting of trees should be encouraged. In the same way, people who are getting wood for free should learn that wood will soon become scarce, and that planting trees is therefore necessary. This could be done through environmental education awareness programs to sensitize people to environmental issues.

Wood resources and wood supplies are not identical terms, although they may seem to be. Wood resources refer to the standing stock of wood. Wood supplies, on the other hand, refer to the annual cut (flow) of wood. Sustainable wood supplies are those which can be cut without depleting the initial stock of wood. If the annual cut of wood exceeded annual growth of standing stock, the resource base would be depleted. The standing stock of forests, their renewal process, amount and rate of growth of consumption all interact to determine the rate of wood resources depletion.

The average annual licensing of wood cut in the central region is approximately 3.4 million m^3 which is equivalent to 578,332 tons of wood fuel plus 183,718 tons of charcoal production (Tables 2 and 7). Assuming a cut rate of 3.5 per cent of the standing stock for the Blue Nile and the White Nile, and a rate of 5.5 per cent for Al-Gezira,[6] we can derive the annual amount of sustainable cut. This refers to the supplies of wood which would leave the standing stock unchanged. The overall sustainable cut is estimated to be 4.3 million m^3, most of it in the Blue Nile province (Table 2). Licensed wood cut is 78 per cent of the sustainable cut. The licensed cut of wood, according to the official estimates, is short of the sustainable cut by about 0.97 million m^3.

Licensing of wood cut in Al-Gezira and the White Nile provinces exceeds sustainable cut by about 0.475 and 1.113 million m^3, respectively. In the White Nile province, licensed wood cut is more than the standing stock of trees. Official licensing of wood cut in these two provinces encourages deforestation. If the standing stock of wood is short of the official licensing, as is the case in the White Nile province, people may cut wood from other places like the Blue Nile, for example.

References

Ahlcrona, E. 1988. *The Impact of Climate and Man on Land Transformation in Central Sudan.* Geografiska Institutioner Publication 103. Lund, Sweden: Lund University Press.

Anderson, D. 1987. *The Economics of Afforestation: A Case Study in Africa.* Baltimore, MD: Johns Hopkins University Press.

Anderson, D. 1986. Declining tree stocks in African countries. *World Development* 14(7): 853-863.

Bradley, P.N., N. Chavangi, and A. Van Delder. 1985. Development research and energy planning in Kenya. *Ambio* 14(4-5):228-236.

Cline-Cole, R.A., H.A.C. Main, and J.E. Nichol. 1990. On fuelwood consumption, population dynamics and deforestation in Africa. *World Development* 18(4):513-527.

Culwick, G.M. 1951. *Diet in the Gezira Irrigated Area, Sudan.* Khartoum: Sudan Government Printing Press.

Department of Statistics, Republic of the Sudan. 1991. *Sudan Demographic and Health Survey 1989/1990.* IRD/Macro International.

Department of Statistics, Republic of the Sudan. 1989. *Population and Housing Census of Sudan 1983.* Khartoum: Department of Statistics.

Eckholm, E.P., G. Foley, G. Barnard, and L. Timberlake. 1984. *Firewood: The Energy Crisis That Won't Go Away.* London: Earthscan and IIED.

[6]Because of more intensive tree planting in Al-Gezira.

Hellden, U. 1984. *Drought Impact Monitoring: A Remote Sensing Study of Desertification in Kordofan, Sudan.* Report No. 61. Lund, Sweden: Naturgeografiska Institution, Lund University.

Henin, R.A. 1969. Fertility differentials in the Sudan. *Population Studies* 22(1):147-164.

Hosier, M. 1985. Development research and energy planning in rural Kenya. *Ambio* 14(4-5):225-227.

Ibrahim, F. 1984. *Ecological Imbalances in the Republic of the Sudan. With Special Reference to Desertification in Darfur.* Bayreuth: Druckhaus Bayreuth Verlagsgesellschaft.

Kates, R.W. and V. Haarmann. 1992. Where the poor live. Are the assumptions correct? *Environment* 34(4):4-11, 25-28.

Lamprey, H. 1976. *Survey of Desertification in Kordofan Province.* Nairobi: United Nations Environmental Programme.

Moss, R.P., and W.B. Morgan. 1981. *Fuelwood and Rural Energy Production and Supply in the Humid Tropics.* Dublin: Tycooly International.

National Energy Administration, Republic of the Sudan. 1989. Energy Assessment Survey of the Central Region. Unpublished report.

O'Keefe, P. and P. Raskin. 1985. Fuelwood in Kenya: Crisis and opportunity. *Ambio* 14(4-5):220-224.

Olsson, K. 1985. Remote Sensing for Fuelwood Resources and Land Degradation Studies in Kordofan, Sudan. Doctoral Dissertation. Lund, Sweden: Geografiska Institution, University of Lund.

Olsson, L. 1985. *An Integrated Study of Desertification.* Lund, Sweden: Geografiska Institution, University of Lund.

Pearce, D., E. Barbier, and A. Markandya. 1990. *Sustainable Development. Economics and Environment in the Third World.* London: Edward Elgar.

Peil, M. 1986. Migration and achievement in Sierra Leone towns. Pages 156-162 in A. Jones and P.K. Mitchell, eds. *Proceedings, Sierra Leone Studies at Birmingham.* Birmingham, U.K.: University of Birmingham.

Sudan National Energy Administration. 1983. *Sudan: National Energy Assessment.* Khartoum: Ministry of Energy and Mining.

Sudan National Energy Administration. 1989. *Sudan: Energy Assessment Survey of the Central Region.* Khartoum: Ministry of Energy and Mining.

Whitney, J.B.R. 1987. Impact of fuelwood use on environmental degradation in the Sudan. Chapter 6 in P.D. Little and M.M. Horowitz, with A.E. Nyerges, eds. *Lands at Risk in the Third World: Local-Level Perspectives.* Boulder and London: Westview Press.

World Bank. 1987. *World Development Report.* New York: Oxford University Press.