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Population Growth, Wood Fuels, and Resource Problems In Sub-Saharan Africa

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ABSTRACT

Rapid population growth has resulted in deforestation and wood fuel shortages in many regions of sub-Saharan Africa. In many urban areas rapid growth of urban demand for wood fuels has caused the growth of deforested rings around cities up to 100 kilometer radius. In some rural areas shortages have caused women and children to walk further for collecting wood fuels, or they have substituted lower quality fuels such as dung and agricultural waste. Population density by itself does not cause household energy shortages. The most serious deforestation and fuelwood problems in sub-Saharan Africa are in the sparsely populated Sahel. Here, rapid population growth is the main problem, since it leads to the simultaneous increase in demand for food and fuels. The increased demand for food is often met by expanding agriculture to new land or possibly by increasing yields by changing traditional agricultural methods. The need for more fuelwood is met through harvesting wood from common land. Expansion of agriculture to new land and harvesting wood from common land are the main causes of deforestation.

Deforestation has been a significant problem in savanna regions with high population densities, in highly populated mountainous regions, in the dry regions such as the Sahel where tree regrowth is very slow, and around rapidly growing urban centers. The regions in sub-Saharan Africa where deforestation has not been much of a problem include areas where fallows are long and significant land is still available for cultivation. In between these two extremes are areas with a wide range of conditions. For instance the price of wood energy may rise, land may begin to erode, and women and children may spend more time collecting wood fuels. These less dramatic consequences can gradually become more serious over time, if the population growth is not diminished or if the proper incentives are not in place for the land use system to adjust to the need for increased production of food and trees.

*Population Growth, Wood Fuels, and Resource Problems in Sub-Saharan Africa**

Douglas F. Barnes

Fuelwood has become increasingly difficult to obtain in both rural and urban areas in many Sub-Saharan African countries. Populations have been growing very rapidly and are therefore using much more wood fuels than in the past. In many regions, the regeneration rate of trees and bush has not kept pace with population growth and the resulting expanding demand for fuelwood. The consequence is deforestation or degradation of the existing tree stocks in some areas.

There are several important reasons for concern about population growth, wood fuel shortages, and deforestation. Wood resources may be overexploited just to maintain current standards of living. When existing resources such as wood fuels are in great demand and yet are not widely traded, the poor are typically most affected by the resulting scarcity. Finally, deforestation may cause significant future problems, such as soil erosion, which takes years to develop. Although the fuelwood crisis in Sub-Saharan African countries specifically is recognized to be a consequence of rapid population growth, most of the solutions offered to improve the situation involve increased production or conservation of wood fuel energy rather than population-related policies.

On the subcontinent, the wood fuel shortages in many regions have three primary causes: an increase in wood fuel consumption; expansion of agriculture into forests or woodlands, which reduces available tree stocks; and overgrazing caused by an increase in the cattle population. Wood fuels are the staple source of household energy in Sub-Saharan Africa, with 90 percent of households using them for cooking. An increase in population translates directly into an increase in demand for wood fuels. As a result, in some parts of Africa the demand for both wood fuels and agricultural land has led to deforestation and desertification (Myers 1980; FAO/UNEP 1981; Anderson and Fishwick 1984; Gorse and Steeds 1987); in other areas, there has been a substantial increase in the price of wood fuels (Chauvin 1981). In addition, many cities have experienced wood fuel problems because of the highly concentrated demand for wood from the rural areas surrounding them (Chauvin 1981; French 1984). In regions with dense populations, trees are being harvested at a faster rate than they can be replenished by natural regrowth (FAO 1983b). The problem is further exacerbated because many other causes of deforestation are also related to population growth. The growth in the number of cattle and sheep often closely parallels human population growth, and grazing is one of the causes of deforestation (Allen and Barnes 1985).

This chapter focuses on how population growth relates to rural energy, land use, development of rural markets, and the availability of alternative fuels. One might speculate that population growth will cause more intensive use of land for agriculture, a significant development of fuelwood markets in urban areas, and replacement of fuelwood with other energy sources if scarcity persists over time. There are problems, however, and sometimes there are lags in these adjustments. I will address these issues after a more general discussion relating population growth to deforestation in a broad socioeconomic framework.

Population and Deforestation: Conceptual Issues

Population growth in isolation is not enough to cause deforestation or household energy shortages. The distribution of population, land use intensity, agroclimate, carrying capacity of the soils, and the level of economic development are all important in determining whether

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there are or will be household energy shortages. Population growth in many land-abundant areas, for instance, will result in an expansion of agricultural land along with no decline in fuelwood availability. In many parts of Africa, land is abundant and populations are relatively sparse, and there is no current fuelwood shortage. In other areas, however, population density is quite high or tree regrowth is very low. In these areas, wood resources have been under extensive pressure from growing populations.

Population Distribution and Land Use

The popular image of Africa as a sparsely populated continent with jungles and forests, although inaccurate, does suggest a low intensity of land use that is characteristic of many parts of the subcontinent. Figure 1 illustrates the danger of making sweeping generalizations concerning population and land use in Sub-Saharan Africa. The vertical dimension represents population density, whereas the horizontal dimension gives the types of land use and vegetation classification. On the extreme left and right of the figure, the population density is very low. These areas represent the opposite ends of the rainfall spectrum: the tropical forests and the desert. In both cases, geoclimatic conditions limit human settlement in the absence of extensive capital investments. In the desert and subdesert, there is not enough water to support high levels of human populations. The tropical forests in many cases are in remote locations, and the high levels of rainfall limit the potential of the land for agriculture.

The wide variation in population density in areas between the extremes of the tropical forests and the desert illustrates the fact that historical circumstances, geographical differences, and the productivity of the land can affect the location of human settlements. About 68 percent of the population is living in 28 percent of the land area in Sub-Saharan Africa. Many countries, for example, Gabon and Sudan, have areas that are underutilized, but others, such as Kenya, have high population densities. Because of national boundaries, geography, and poor infrastructure, movement between the more dense and the less dense regions is not always possible. The higher-density agricultural areas tend to have more intensive levels of agricultural inputs, and likewise the lower-density regions have longer fallow periods to restore fertility to the land. The regions with high population density, for instance, include parts of West Africa along the Gulf of Guinea, whereas the lower-population zones are spread throughout areas such as southern Burkina Faso, Malawi, southeastern Senegal, and many other parts of Africa.

Deforestation and Desertification

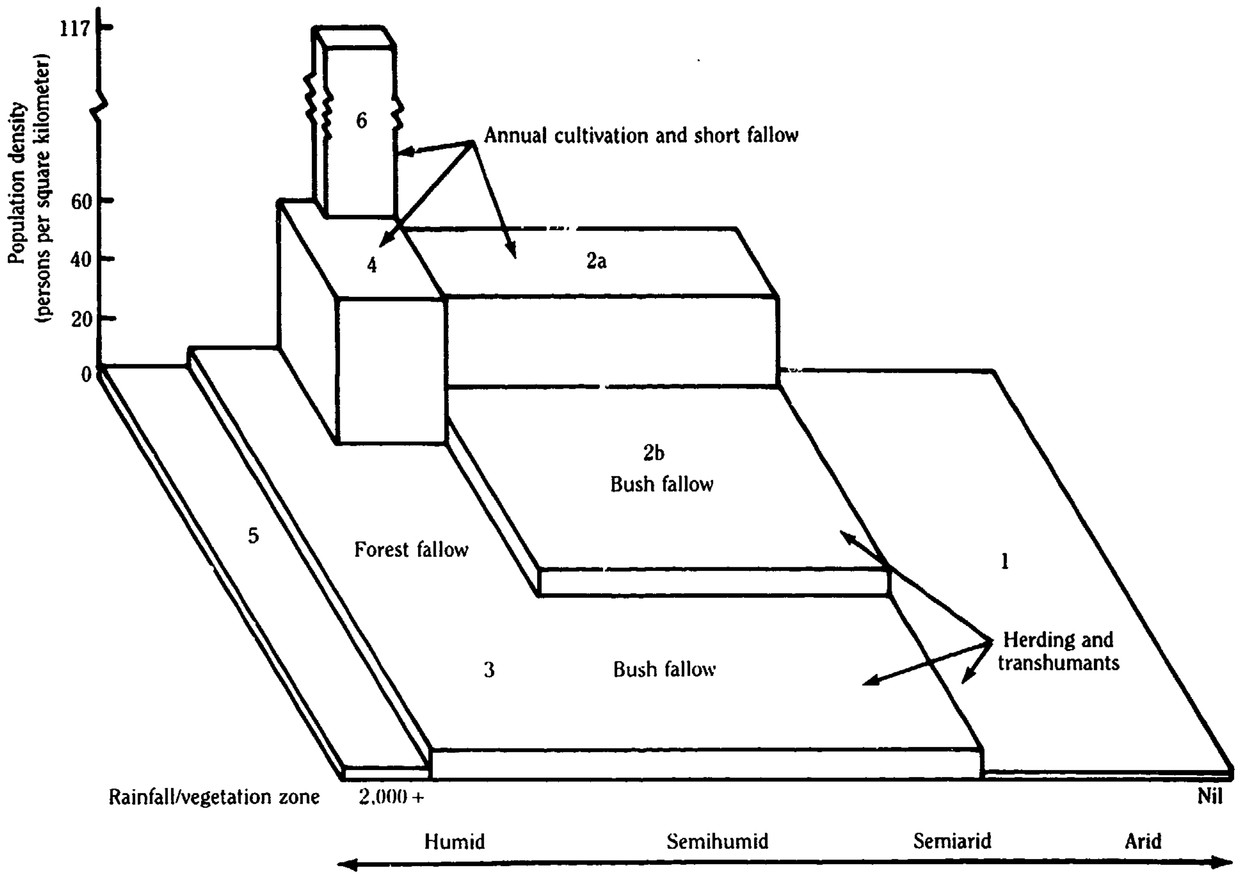
Population and resource issues are very complex and involve a combination of climate, soils, topography, kinds of farming systems, population growth, population density, and level of economic development. The six zones represented in figure 1 illustrate how the causes of deforestation vary by density of human population, agroclimate, and vegetation zone. Desertification, for instance, is a problem in regions with low population density, which have a very low capacity for agricultural production because of the climate and soils (Gorse and Steeds 1987). These same regions have populations of herders and transhumants, which take advantage of grass that regrows annually. The attempt to move from low-intensity agriculture to more intense levels without the aid of irrigation can lead to severe environmental problems, including desertification.

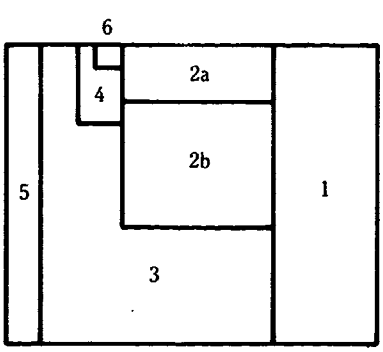
Farming can become much more intensive in areas with more intermediate levels of rainfall, even without irrigation. Many of these areas in Africa have high levels of population density (top of figure 1). These regions can experience loss in soil fertility if fallows are not adequate or if farmers do not use the necessary soil improvement techniques.

In the well-forested regions with high rainfall, deforestation is generally caused not by increased demand for wood fuels but rather by logging or by a decline in fallow periods in forest fallow farming systems (Allen and Barnes 1985; FAO 1983a). Except in the mountainous zones, intense use of the land for agriculture in these areas is generally not possible because the high levels of rainfall leach the soil, so that the land is unsuitable for intensive agriculture. The presence of insects and diseases in many of these regions also keeps human populations from settling in them. The exception is in Burundi, the highlands of Kenya, and Rwanda, where soils are fertile and forests have been depleted because of dense and growing populations.

Agroclimate is also a significant factor in the production of wood fuels for household energy. Regions with a high rate of tree regrowth can meet the needs of a larger number of people than those with low regrowth potential. The regions with wood fuel deficits are generally those with low to moderate rainfall and high population densities. In the areas with very low population density and low rainfall, the demand for wood fuels can outstrip the supply because of the very slow regrowth potential of trees. Where population density is high and rainfall levels are moderate, the problems with scarcity of wood fuels are a consequence of the rapidly growing demand for wood fuels caused by population growth.

Figure 1. *Land Use, Vegetation Zones, and Population Density, 1980*





Note: Surface area represents total land area for Sub-Saharan Africa. Population and vegetation zones (percentage of total land area): (1) desert and subdesert (28 percent); (2) heavily populated woods and savanna (25 percent); (3) sparsely populated wooded savanna and forest area (34 percent); (4) heavily populated forests and plantations (3 percent); (5) very sparsely populated forests (9 percent); (6) very heavily populated, mountainous forest area (0.5 percent).

Vegetation zone 2 has been divided according to figures from the FAO *Production Yearbook 1981.* Zone 2a is arable land, according to the FAO definition, and 2b is the remainder of land in the zone. The population densities are estimated based on the assumption that agriculture in zone 2a is more intensive than that in 2b.

Sources: FAO (1983); FAO/UNEP (1981).

Economic Development, Population Growth, and Deforestation

A brief description of the changes in general energy patterns and land use associated with different stages of socioeconomic development can help put the African population and resource issues in perspective. It should be noted, however, that the following model is an oversimplification, and the economic stages can last decades or longer.

Countries at low levels of economic development but with abundant land have a very low intensity of agriculture. In fact, expansion of food production for growing populations is met through an expansion of arable land, which is often cleared forests. Forest products, including wood fuels, are in relative abundance during this stage. The demand for wood fuels can be met fairly easily through regeneration of trees and bush during long agricultural fallow periods.

Most African countries today are moving beyond the very lowest levels of subsistence cultivation and low population density. With economic development and population growth, deforestation can result from the expansion of agricultural land to meet growing demand for food and from the harvesting of trees to meet the growing wood demand for household energy. At this stage, because of the declining base of forests and rapidly increasing populations, the demand for wood fuels changes from low levels met by extensive use of forests to higher levels met by more intensive use of small areas of forests. Energy sources at this stage are mostly wood fuels, agricultural waste, and, in some cases, dung. Because there has not yet been a transition to commercial fuels, in this period high population growth combined with a lag in the development of more intensive tree production causes a severe strain on forest resources.

As forest clearing, population growth, and economic development proceed in the later stages of development for countries such as the United States and the European nations, several things mitigate the rate at which forests disappear. First, increasing urbanization and rising incomes are accompanied by productivity gains in agriculture due to such practices as irrigation, use of improved varieties, and application of fertilizers, pesticides, or herbicides. At some point, most of the highly productive agricultural land has been brought into production, so that continued clearing results in smaller marginal increases in food production. Urbanization, improvement in the agricultural productivity of arable land, and declining agricultural returns on marginal land reduce the demand for newly cleared land and diminish the rate of forest clearing.

In the later stages of development, other factors also relieve the pressure on forests. At some point in development, forest area begins to increase again. For instance, early settlement in the northeastern part of the United States led to cleared forest land for agriculture. During the last eighty years, however, much of the land has been returned to forests. What is the reason? First, birth rates decline with rising income, and population growth rates decline. Low population growth provides the possibility of constant rather than rising demand for arable land and wood products. At the same time, industrialization results in a pattern of energy consumption based on fossil fuels that hardly depends on forests. It should be recognized, however, that, with the exception of Mauritius, African countries will not reach such a level for many years to come. In the meantime, the high rate of population growth is causing deforestation problems for many countries.

Africa is now in the early stages of the development cycle. Population growth rates are high, urban growth rates are even higher, and in many of the countries economic growth has been very slow during the last decade (World Bank 1984a). Thus in Sub-Saharan Africa, population growth has important consequences for land use and rural energy. The following sections analyze the consequences of rural population growth for (1) household energy consumption, (2) wood fuels collection, and (3) biomass and wood fuels production.

Energy Use in Rural Areas

Energy use in Africa reflects the rather low levels of development of most countries. Energy use per person in the Republic of Korea, for instance, is fifteen times higher than in Tanzania (Allen and Barnes 1985), mainly because of the rather low industrial and urban base in Tanzania. Countries with low-income, largely rural populations generally use more traditional fuels, and household consumption takes a larger share of total energy use (Dunkerley and Ramsay 1983). This trend is clearly illustrated in table 1. In most of the countries in Sub-Saharan Africa, traditional forms of energy and household consumption dominate total energy use.

The increase in demand for household energy will almost parallel population growth. The typical end uses of energy in Sub-Saharan Africa generally are cooking, heating, lighting, ironing, and some small-scale industrial uses such as tobacco curing and brickmaking. It is sometimes difficult to distinguish between end uses. Cooking with wood fuels generally dominates the energy flows and also provides light and heat. Based on studies in the Sudanian and Sahelian zones, figure 2 shows the dominant role of cooking, which also holds for other countries in Sub-Saharan Africa. Although there will be some switching from wood fuels to commercial fuels, interfuel substitution is not ex-

Table 1. ***Gross National Product and Percentages of Traditional Fuels and Household Consumption in Total Energy Use, Selected Countries, 1980***

Country	*GNP per capita*	*Percentage of traditional fuels in total energy consumption*	*Percentage of household sector in total energy consumption*
Burundi	202	80.1	—
Malawi	233	94.1	40.9
Kenya	418	81.0	82.3
Senegal	452	66.9	68.7
Sudan	470	86.8	81.2
Liberia	527	48.2	55.4
Egypt	582	29.8	26.4
Zimbabwe	627	25.6	30.0
Morocco	864	6.0	23.5
Tunisia	1312	17.9	36.3

— Not available.
Source: Dunkerley and Ramsay (1983).

pected to take place on a large scale, at least not in the near future, and population growth will directly affect the need for fuelwood for these activities.

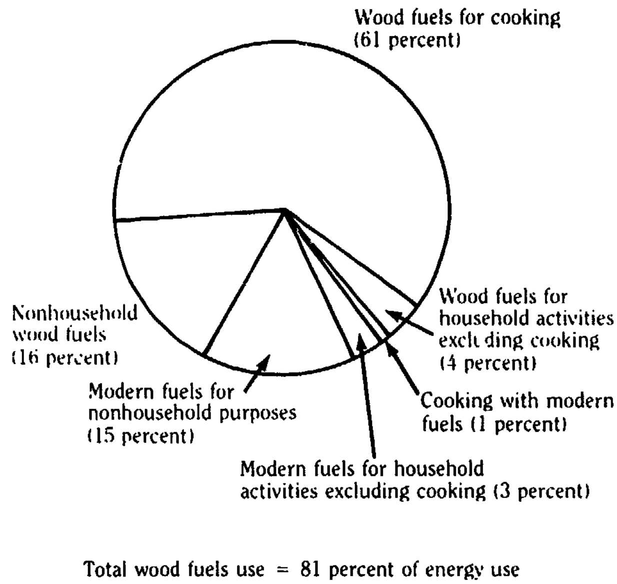
Wood Fuels: Deficit or Surplus?

The fuelwood situation in rural areas of Sub-Saharan Africa is highly location specific (Allen and Barnes 1985; Arnold 1979). In many regions there is a surplus of wood fuels, whereas in other parts severe deficits exist. Even within countries, the situation varies from region to region. In the northern part of Sudan, for instance, the wood fuel crisis is very real, with shortages, rising prices, and environmental degradation. In the south, however, there is a surplus of wood fuels because of the favorable climate and relatively low population densities.

The classification of regions in Africa by population density and vegetation zone allows a more precise statement of the nature of the wood fuels problem. This problem is illustrated in figure 3, which breaks down Sub-Saharan Africa by the same zones as figure 1. The desert and subdesert cover 28 percent of the land area in Sub-Saharan Africa. Many parts of these arid regions are experiencing acute shortages of biomass, and the situation is not likely to improve by the year 2000. Despite low population densities, the carrying capacity of the land is so low that population growth is not sustainable for either agriculture or wood fuels, and as a consequence there is currently out-migration from the region. This is the situation in the northern part of the Sahel and Sudanian zones, including Chad, northern Mali, Niger, and Sudan.

In the heavily populated savanna zones (zone 2), which include approximately one-quarter of the land area in Sub-Saharan Africa, only 25 to 50 percent of the demand

Figure 2. ***Energy End Uses in the Sahelian and Sudanian Region, 1980: Wood Energy Dominates Household Energy Flows***



Source: FRIDA (1980).

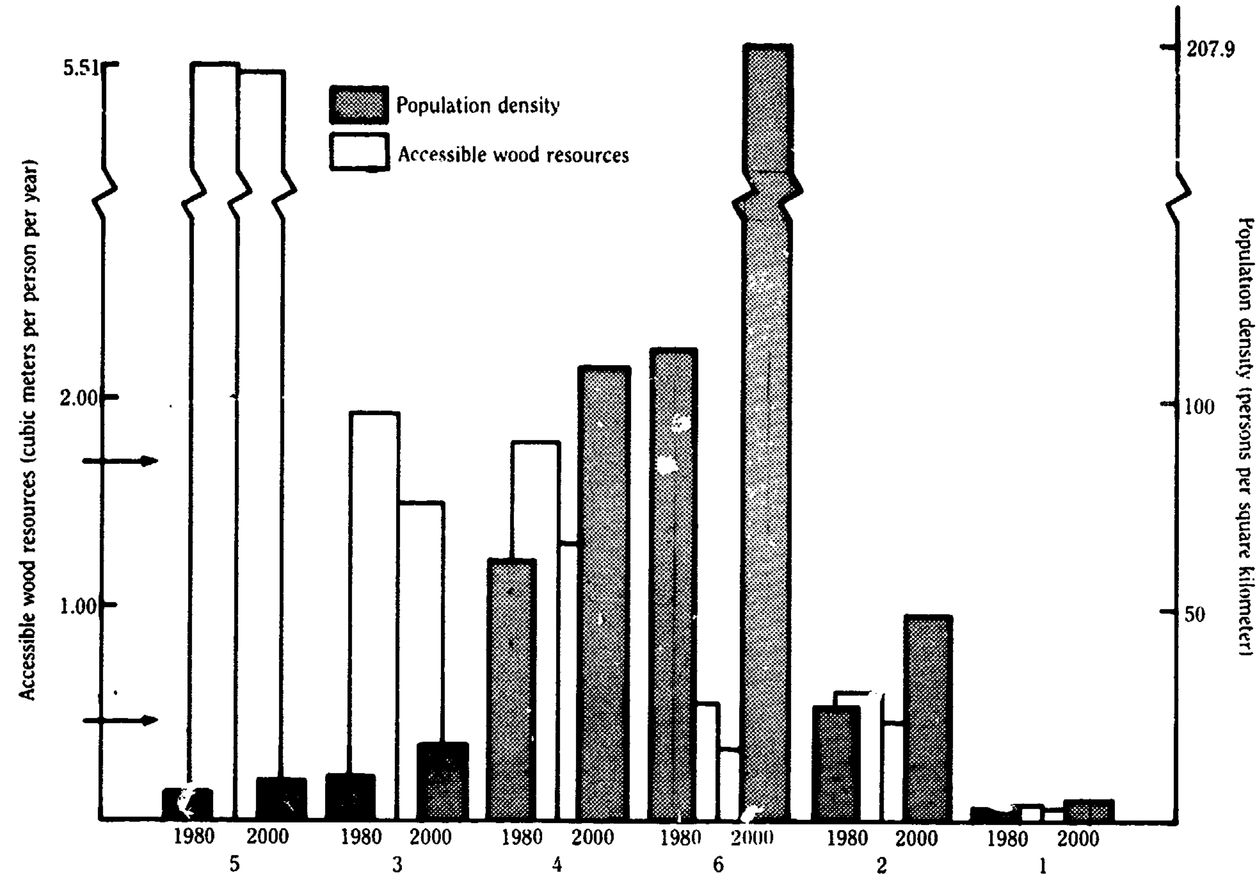
for wood fuels will be met from the yearly regrowth of trees. In spite of favorable conditions for regrowth, the situation is becoming increasingly severe because of rather dense and increasing populations. Included in these zones are parts of central Burkina Faso, Gambia, northern Nigeria, Senegal, and Sierra Leone.

In the less densely populated savanna regions (zone 3) covering 23 percent of the land, the situation is not quite so dramatic. For today at least, these areas have sufficient wood fuels. Without intervention, however, the situation could deteriorate even in these areas by 2000. Such regions include southern Burkina Faso, northern Côte d'Ivoire, southern Tanzania, and central Zaire.

In the central part of Africa, with tropical forests and low population density (zone 5) covering 9 percent of total land area, the ideal tree growth conditions and sparse populations mean that there should be adequate supplies for the year 2000 and beyond. This region includes Angola and northern Zaire along with the Central African Republic and Gabon.

The areas along the Gulf of Guinea, covering 3 percent of land area in Sub-Saharan Africa (zone 4), have satisfactory supplies of wood fuels, but the situation could worsen by 2000. The climate is ideal for growing trees in this region, and many forests have been converted to commercial tree plantations. Therefore people in rural areas will probably not have any shortage of

Figure 3. *Accessible Wood Resources and Population Density, 1980 and 2000*



Note: Arrows on left column represent maximum and minimum per capita wood energy needs. Population and vegetation zones (percentage of total land area): (1) desert and subdesert (28 percent); (2) heavily populated woods and savanna (25 percent); (3) sparsely populated wooded savanna and forest area (34 percent); (4) heavily populated forests and plantations (3 percent); (5) very sparsely populated forests (9 percent); (6) very heavily populated, mountainous forest area (0.5 percent).

Source: FAO (1983b).

wood fuels even by 2000. Because of large urban concentrations such as those at Abidjan, Accra, and Lagos, however, the growing demand for wood by urban centers is likely to cause regional deficits for twenty years or more.

In the densely populated mountainous areas (zone 6) of such countries as Ethiopia, Rwanda, and Uganda, which cover less than 1 percent of total land area, the wood fuels deficit is likely to continue until 2000. Reforestation efforts in such countries as Burundi and Rwanda have been relatively successful, but even there the efforts have been not able to keep up with population growth.

Economic Growth and Social Class

Population growth, economic growth, and type of social structure can have a substantial impact on the need for wood fuels. Two scenarios for Sub-Saharan Africa illustrate what might happen with different types of economic growth. In the first scenario, rapid population growth is accompanied by significant economic growth, causing increases in real income for Sub-Saharan Africa. The demand for wood fuels would first increase and then decline because of interfuel substitution. For Nigeria, Grut (1972) found that wood fuel consumption increases from the lower class to the middle class and then declines in the high-income classes. Similar trends are found in household expenditure surveys in Botswana, Malawi, and Tanzania.

Population growth within the context of dynamic economic growth would not lead to a worsening of the current wood fuel situation. The opposite situation would be economic stagnation, with a significant expansion of a poor underclass. The expansion of a large underclass would mean an almost constant increase in demand for wood energy. Given the relatively slow economic growth in rural areas of many African countries, wood fuels will probably remain the staple fuel for many years to come. In this case, the increase in wood fuel use would be directly related to the population growth.

Even under the most liberal assumption, the shortages of wood fuels in deficit regions are not expected to abate by 2000. Moreover, if there is economic growth but the growth is inequitable, the demand for wood fuels would probably not be significantly altered. Thus, economic growth without equity would result in little interfuel substitution, and consequently the pressure on remaining forest and vegetation would continue.

Rural Interfuel Substitution and Energy Alternatives

In rural areas, interfuel substitution generally means a switch to less efficient and lower-value fuels The most common alternatives to wood fuels in rural areas are agricultural waste and dung. Although wood fuels are preferred fuels in most rural areas, once they become harder to collect or more expensive, rural families turn to whatever is available locally to cook meals. The alternative fuels generally are valuable manure or fertilizers. The detrimental effects of the substitution of agricultural wastes and dung have been vividly described for Ethiopia (Newcombe 1989). The cycle includes deterioration of soil fertility and eventual loss of topsoil. If trees are grown to replace dung, the avoided costs of environmental deterioration and declining yields can be substantial. It has been estimated that, for each additional 1 million people, the resulting demand for the dung and agricultural waste that would replace wood fuels would cost the economy of Ethiopia approximately 102–150 thousand tons of grain production (World Bank 1983). Although the example of Ethiopia is probably an extreme case, it highlights the need for population control or reforestation in some regions.

The impact of interfuel substitution on fertilizer use must be placed in the context of the type of farming system and the agroclimatic conditions. Declining soil fertility is common to the cycle of agricultural intensification. When trees are abundant and population density is low, land is cleared on a rotational basis. The trees and fodder restore the soil's fertility over a period of years. Growing populations put pressure on the system by shortening fallows to grow more food. At this stage, agricultural wastes and dung are worked into the soil to compensate for the declining fallows. The growing demand for wood fuels is accompanied by an intensification of agriculture. Several important questions arise. Will farmers' need for energy take priority over the need for organic fertilizer or other needs? How much agricultural waste can they divert to fuel without reducing agricultural yields? Because food production is obviously very vital to farmers, why would they divert agricultural waste and dung from fertilizer use to cook meals? These are some of the important but unanswered questions on the interaction between population growth and increasing demand for food and the growing demand for biomass energy.

Informal Rural Energy Markets

The wood markets in rural areas are informal rather than formal. In most cases, wood is gathered by individual households for their own needs. In fairly wood-abundant regions, wood is gathered with little labor from the surrounding bush or woodland. In rural areas with higher population density and slow tree regrowth, wood becomes more scarce; in some cases people must walk long distances to obtain wood for cooking (Hoskins 1979, 1980). In such areas, the bundles of wood sometimes become much larger, and the wood is collected less often because it is not available locally (Skutsch 1983). As a result, an informal market develops. Gradually, the trading of wood fuels becomes more common, and wood may be purchased from neighbors or rural markets. The general principle is that population growth combined with increasing labor specialization and costs and increasing wood scarcity in rural areas lead to the development of more formal wood fuel markets (Dewees 1989), which nevertheless are much less formal than their urban counterparts.

Population growth in combination with the rate of tree regrowth affects the distance that must be traveled for wood and the development of markets for wood in rural areas. Unfortunately, very little information exists on the time necessary for wood collection under different socioeconomic and agroclimatic conditions. In table 2, the figures cited for Sub-Saharan Africa on distance traveled for wood fuels are given by country. A travel range from zero to ten kilometers, with very wide fluctuations, shows that fuelwood collection in many locations requires much time. In countries with severe deforestation problems, people are walking long distances to obtain fuelwood.

The methods of fuelwood harvesting and collecting vary according to the region and the demand for fuels. The regions with low population density and high tree regrowth have abundant wood available for rural populations. As a consequence, fuelwood collection is likely to be very casual; it is sometimes gathered around homesteads and on the farm. In such regions, the supply of wood fuels may be greater than the demand for them. In contrast, the regions with high population density and high regrowth potential may still have very informal collection of fuelwood, but longer hours may be required to collect the fuels for daily needs. In this case, women may combine looking for fuelwood with other activities. For instance, in walking to and from farms, people will collect wood fuels and carry them back to the household (French 1984). In such regions, the extent of the problem depends on population density and

Table 2. *Distance Walked for Firewood Collection, Rural Areas of Selected Countries*
(kilometers)

Country	*Distance*[a]	Year	Source
Fuelwood			
Botswana	7.5	1980	Shaik (n.d.)
Cameroon (Yaounde)	2–6	1980	Roy (1980)
Kenya	1.6–7.0	1979	Openshaw (1980)
Malawi[b]	0–3.6	1980	Malawi (1981)
Sudan (Bara)	1–10	1977	Digernes (1977)
Tanzania	1–5	1980	Araya (1981)
Burkina Faso (Boulenga)	5	1977	Ernst (1977)
Burkina Faso (Koudougou)	5–10	1979	Winterbottom (1979)
Charcoal			
Kenya (Machakos)	3	1979	Openshaw (1980)
Sudan (Bara)	16–25	1977–78	Digernes (1977)

a. One-way distance.
b. For 90 percent of population. The remaining 10 percent collected fuelwood at a distance greater than 3.6 kilometers.
Source: Barnes, Allen, and Ramsay (1982).

whether the rate of population growth is exceeding the rate of tree regrowth. In the dryer regions with low population density, people probably have to walk long distances to collect fuelwood. In many cases, they form groups to walk to forest reserves or other areas where trees are known to be plentiful (Hoskins 1980). The result is that available fuelwood supplies are pushed farther away from the rural communities, especially during the dry seasons.

Women are the most common users and collectors of wood fuels in developing countries (Hoskins 1979; Noronha 1980). The adverse consequences of population growth and resulting deforestation are therefore more severe for women than for men. Time spent on other activities, such as gardening, must be curtailed as wood fuels become more scarce. The amount of time spent collecting wood fuels ranges from six hours per week in Kenya, for instance, (Brokensha and Riley 1978) to about fifteen in Burkina Faso (Winterbottom 1979) to more than forty in central Tanzania (Mnzava 1980; Openshaw and Moris 1979). Many of these estimates overstate the actual time, because wood fuel collection can be combined with other activities. Nevertheless, they do demonstrate that, within some regions, women are already spending a significant proportion of their time and energy collecting fuelwood. Population growth without any change in land use would only further increase the time spent collecting fuelwood.

Energy Use in Urban Households

The growing demand of urban populations for all forms of energy presents difficult choices for urban centers in Africa. For countries without the requisite natural resources, the growth of commercial demand for fuels means higher bills for imported oil. The situation is different for wood fuels, which are rarely imported in significant quantities in Sub-Saharan Africa. The projection of urban needs for wood fuels generally involves a scenario of deforested and degraded rings around most urban centers that sometimes extend deep into the rural countryside. In Malawi there is a "pattern of deforestation radiating outward from urban areas" (Malawi 1984), and Chauvin (1981, p. 18) noted that in Burkina Faso the "situation is critical because the tree cover around nearby towns and villages is rapidly disappearing."

Populations in urban regions of Africa are growing at an extremely rapid rate compared both with rural populations of Sub-Saharan Africa and with urban populations in other parts of the world. The average annual urban population growth rate for Sub-Saharan Africa was 6.1 percent during 1970–82, compared with less than 2 percent for rural areas (World Bank 1984b). The degree of urbanization in a country is closely related to the use of commercial fuels for energy. It is true in Africa, as in Asia and Latin America, that a more developed industrial urban base means a higher use of commercial energy (Dunkerley and Ramsay 1983). Despite these well-established relationships, however, wood fuels continue to play an extremely important role within urban households. In many cities, as much as 90 percent of urban households use wood fuels for cooking (French 1984). The traditional model for analyzing urban household energy demand is to predict a country's urban population in a future year and then calculate a demand for energy based on current needs while allowing for some interfuel substitution (table 3).

Social Class and Fuel Choice

One difference between urban and rural energy consumption is that urban households in most cases have a wider choice of fuels. There is extensive evidence from

Table 3. *Urban Population Growth and Household Energy Projection, Selected Countries*

Country	Annual urban population growth rate 1960–70	Annual urban population growth rate 1970–82	Urban population 1980 Millions	Urban population 1980 Percent	Urban population 2000 Millions	Urban population 2000 Percent	Urban household energy demand[a] 1980	Urban household energy demand[a] 2000
Ghana	4.6	5.0	4.3	36	11.7	56	6.8	18.6
Ethiopia	6.5	5.6	5.0	15	16.7	32	5.1	18.6
Kenya	6.4	7.3	2.2	14	8.3	25	4.1	15.5
Nigeria	4.7	4.9	17.0	20	42.6	26	5.0	25.5
Rwanda	5.4	6.4	0.2	4	0.6	6	0.2	0.5
Sudan	6.8	5.8	4.5	25	16.8	54	6.0	23.0
Tanzania	6.3	8.5	2.3	12	12.1	35	4.7	25.2
Uganda	7.1	3.4	1.6	12	6.0	25	4.1	15.8
Zaire	5.2	7.6	9.5	34	38.2	78	6.1	24.6
Zambia	5.2	6.5	2.3	38	6.7	61	3.8	7.9
Zimbabwe	6.7	6.0	1.6	23	5.6	37	1.5	5.2

a. 10^6 cubic meters fuelwood equivalent.
Source: World Bank (1984b).

household energy use surveys that fuel choice varies with household income (FRIDA 1980; Malawi 1984; Barnes 1987; Hosier and Dowd 1988; Leach and Mearns 1988; Malawi 1984; McGranahan, Nathans, and Chubbi 1980; Milukas 1986; World Bank 1988a, 1988b, 1988c, 1988d). Wood fuels are the overwhelming choice of the poorest households in Sub-Saharan Africa, in large part because wood in many areas has not been as scarce as in other parts of the developing world. In Nairobi, Kenya, more than 65 percent of total energy consumption of the poorest households is estimated to come from wood or charcoal (McGranahan and Nathans 1979). This consumption, however, falls off to less than 3 percent in the wealthiest households, which rely mainly on commercial fuels such as electricity and liquefied petroleum gas (LPG). In four urban regions of Malawi, 96 percent of the low-income households use wood fuels for cooking, compared with 19 percent of the highest-income households (Malawi 1984). More than 80 percent of the high-income families use electricity for cooking. Because there are substantially more poor households, approximately 90 percent of all households use wood for cooking. Essentially the same pattern exists in other countries, with wealthy households consuming a greater share of commercial energy.

As incomes rise from lower to middle class, the typical pattern is for wood energy use first to increase and subsequently to decline when kerosene is substituted for wood. As incomes rise from the middle class to the upper class, however, kerosene gives way to electricity and LPG in cooking (see Alam, Dunkerley, and Ramsay 1984). As a result, because a greater variety of commercial fuels is available in urban areas than in rural areas, urban areas have a greater potential for switching from wood fuels to commercial energy. This potential will, however, depend upon the economic growth and income distribution within cities.

Despite the availability of commercial fuels, urban households may prefer wood fuels, even though price per unit of useful cooking energy is sometimes similar. The cost of wood as opposed to commercial fuels depends on the resources available in individual countries as well as on pricing policies. As table 4 indicates, wood energy is not always the cheapest fuel, once end use efficiency is taken into consideration. Estimates of comparative prices should be made with caution, however, because factors other than price enter into household energy choice. Wood fuels are generally easier to obtain than many other energy sources; biomass can be collected or purchased; wood fuel stoves are cheap though not very efficient; heat from wood fuels cooking is used for warmth in regions with colder seasons; and the smoke from wood fires in some cases is a deterrent to pests.

Although commercial fuels can be very convenient, intermittent supply has plagued some countries. During the past ten years, for example, there have been sporadic shortages of commercial fuels, such as kerosene. Electricity supplies at peak demand periods also are not always reliable. The sometimes unreliable supply complicates cooking with commercial fuels, however convenient it may otherwise be. Nevertheless, the dramatic increase in the use of commercial fuels among higher-income classes in urban areas in Sub-Saharan Africa is testimony to their desirability. As lower-income families move up the income ladder in urban areas, they will consume more commercial fuels. Wood fuel use will probably first increase with a rise in income and then decrease as incomes reach higher levels (Grut 1972).

Urban Wood Fuel Prices

Compared with the informal trade in the rural areas, the wood markets in urban areas are well developed.

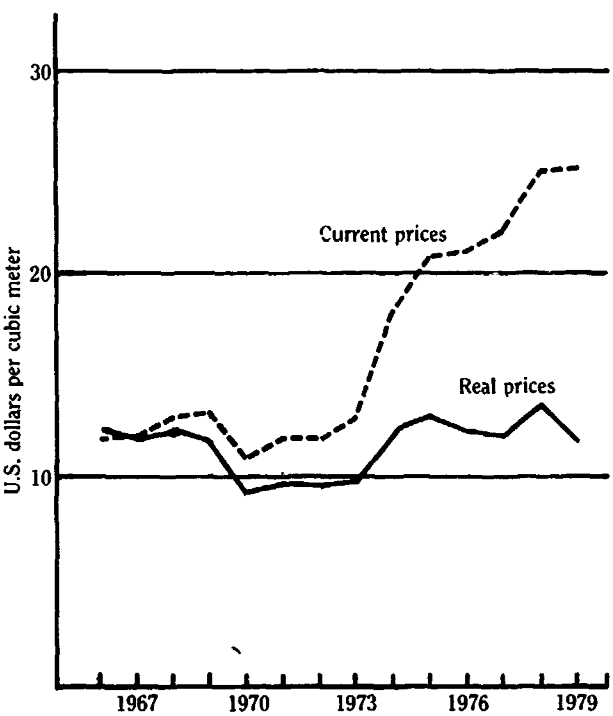
Table 4. *Relative Costs of Fuelwood, Charcoal, and Commercial Energy for Cooking, Selected Countries*

Energy source	*Cameroon*	*Senegal*	*Northern Nigeria*	*Niger*	*Ethiopia*
Relative costs[a]					
Fuelwood	1.0	1.0	1.1	1.0	1.0
Charcoal	3.4	0.9	2.4	1.4	1.6
Kerosene	10.0	1.7	0.6	1.7	0.7
Liquified petroleum gas	—	1.3–1.9	2.0	2.0	1.1
Electricity	11.1	3.3	1.1	2.8	2.0
Fuelwood costs[b]	4	9	11	9	26

— Not available.
a. All costs are adjusted for thermal efficiencies and include cost of appliances.
b. Cents per kilowatt hour of useful heat absorbed by the pot.
Source: Anderson and Fishwick (1984, p. 30).

The price of wood fuels in urban markets has increased dramatically during the last fifteen to twenty years. According to Wardle and Palmieri (1981), the delivered price of wood fuels for developing countries increased by about 12 percent a year between 1970 and 1979 (figure 4). The increase in the price of wood fuels is parallel to but somewhat lower than the increase in the price of oil for the same period. Once wood fuel prices are adjusted for the inflation rate, there is only a small real price increase of about 1.5 to 2.0 percent per year for the same period. This general trend, however, masks the fact that, in specific urban markets, wood fuel prices have taken a dramatic jump, although in other markets prices have remained relatively flat or even declined somewhat, a disparity that once again highlights the location-specific nature of deforestation and wood fuel problems. In Burkina Faso, for instance, the real price of wood fuels has jumped from $2.50 per cubic meter to $5.14 in just nine years, a real annual compound growth rate of more than 9 percent (Barnes and others 1982). In a survey conducted in four towns in Malawi, the three larger towns with insufficient natural resources surrounding them had higher wood fuel prices than the smaller town with better resources. The stock around the smaller town had not yet been significantly degraded, and households could obtain wood at roadside markets just outside the town (Malawi 1984). Rapidly growing cities or towns, and especially those with climates not conducive to the growing of trees, are thus likely to have higher wood fuel prices and larger degraded rings surrounding them.

Figure 4. *Mean Yearly Price for Fuelwood in Nineteen Countries: Current and Real Prices*

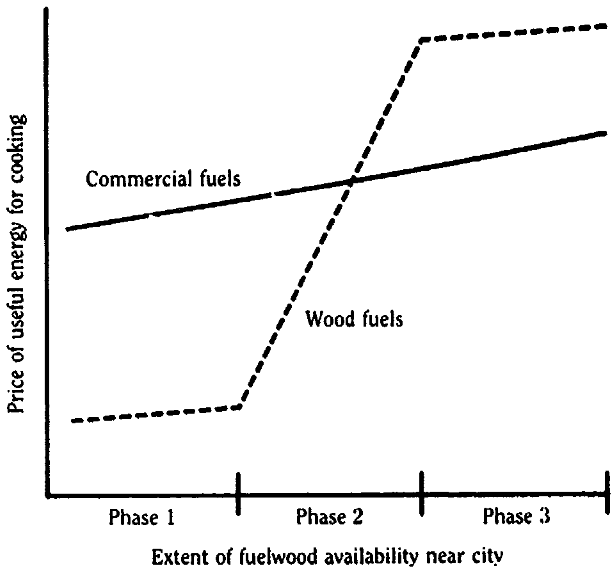


Note: Real prices were calculated using the U.S. Consumer Price Index.

Source: FAO (1981).

The price rise is illustrated graphically in figure 5. In Phase 1, population growth causes agricultural expansion, shorter fallows, and increasing demand for wood fuels, which means that trees and bush are harvested from common and private land without replanting. At this stage, the most common source of energy for sale in urban markets is fuelwood. In Phase 2, the prices flare up because the tree stocks have been severely eroded with the rapid growth of demand. Fuelwood availability is pushed farther from the city, and charcoal begins to replace wood in urban markets. Deforested rings may begin to appear around the city. Farmers and others begin to perceive the fuelwood scarcity, but trees continue to be harvested from savanna and farms to meet wood fuel needs, and there is

Figure 5. ***Relationship between Energy Prices and Wood Scarcity***



Note: Phase 1 is relative abundance. Phase 2 is growing scarcity. Phase 3 is significant scarcity.

Source: Barnes (1985).

still no replanting. Finally, in the third phase, the price of charcoal and fuelwood exceeds that of the alternative commercial fuels, and people begin to switch to commercial fuels. Because wood fuels can be supplemented with gathered wood, the price probably stabilizes somewhere above the commercial alternatives. At this stage, farmers have more of an incentive to plant trees for wood fuels and other tree products. There is no adequate information on producer prices for trees or other factors to enhance understanding of the incentives for farmers to grow trees, an issue that I examine in the next section.

Markets and Transport: Links between Producers and Consumers

The most poorly understood aspect of urban household energy in Sub-Saharan Africa is the link between producers and consumers, a link involving collection, transportation, and marketing that is well developed in many countries. As indicated, people in urban areas commonly purchase wood fuels, whereas those in rural areas generally collect them from the natural woodlands or their own farm plots. Therefore, retailers either organize wood collection themselves or, more likely, purchase it from an intermediary who transports it from rural areas or regions in close proximity to the city. The seller in urban areas can be an individual, a small neighborhood shop, a friend or neighbor, a large retail market, or, in rare instances, a producer. At the point of sale, the price of wood fuels depends on the costs of production or collection, transportation, and marketing and distribution and includes a profit markup for each transaction along the way. The distribution system can be very elaborate, depending on the quantities of wood fuels necessary for the growing urban population. The difference between the farm-gate or "stumpage" price and the price in the urban market can be quite substantial.

In most countries, the majority of wood fuels are harvested from bushland or private farms rather than from forest reserves. The producers collect fuelwood or make charcoal and transport it by some simple mechanism to the city (Chauvin 1981; French 1984). There are generally many pickup points along roadsides, and the transport of wood fuels can be very informally arranged between producers and truck or donkey cart drivers or others.

In the context of such a transport and marketing structure, rapid population growth in urban areas leads to a rapid increase in demand for wood fuels. The deforested rings or degraded forests surrounding the growing city then expand steadily outward as the available trees are harvested from the points closest to the city and closest to the roads leading into the city. Since fuelwood is heavy and bulky, most cities with trees within 50–100 kilometers have fuelwood in the marketplace. Transport costs dictate that, beyond this point, fuelwood is transformed into charcoal (with energy being lost in the conversion), which can be transported more cheaply into the city because it is very light (Chauvin 1981).

The costs of transporting wood fuels from rural to urban areas are not well known. In a recent study by French (1984), transport costs are estimated to be about one-third of the total urban price of wood fuels, whereas the price paid to producers is a mere one-fifteenth of its urban price. According to French, the producer prices are so low that it is possible to harvest existing wood fuels, but the costs of planting, growing, and maintaining trees may be too high in the context of current prices.

Production of Wood Fuels and Intensity of Land Use

The rapid growth of urban and rural populations has had an impact on regional agricultural development. Agriculture is more intensified and labor and input costs are higher near urban areas than in more distant rural areas. As demand for agricultural products increases, high-value crops replace some of the staple grain crops in the farming system. Rather than grow sorghum or some other low-value grain crops, the areas around cities will grow vegetables, rice, and other high-value crops, depending on the agroclimatic conditions. The intensification of agriculture is also accompanied by a shortening of fallow periods and perhaps even annual cropping. Additional inputs such as labor, fertilizers, and manures are applied to the land to produce higher yields. Similar changes in predominantly rural areas have taken place on a smaller scale.

In the past, the fallow system of agriculture combined with low population density allowed the land to produce more than enough wood for cooking and other energy uses. Wood fuels have traditionally been readily available from fallow land and wasteland in Sub-Saharan Africa. Because of the low population density and long fallows, trees had a chance to regenerate with little active management by rural people. The situation varied by climate and geographic region, of course. Very long fallow periods are required in the dry regions to restore moisture and fertility to the soil. In the zones more suitable for agriculture, trees can regrow in shorter periods of time, and in these regions, fallows can be shorter. Trees grow very fast in the tropical forests, and population densities there have been very low.

Land under Production: Food or Fuel?

Some of the deforestation observed around urban centers in Sub-Saharan Africa may be caused in part by an increasing intensification of agriculture. As the fallow periods shorten, the wood and bush are cleared from the land and sold to urban markets at fairly low prices. Trees and bush may even be viewed as an obstacle to agricultural production. Agricultural intensification near cities makes perfect sense, as food is necessary for the growing urban markets. Still, the question may be asked: why is tree production different from food production? Why is there no intensification of tree production?

As I have indicated, part of the reason is that, in the early stages of land intensification, the price of wood fuels is not competitive with the price of food commodities, but other factors are also involved. The price of wood fuels at the farm gate may admittedly be too low to support tree production. The price of transport can be quite high, however, and profit margins for intermediaries such as sellers are also high. There may be no inherent tradeoff between food and tree crops, because in many locations trees would be more suitable than food crops. Trees could easily be grown on open fields, along roads, beside crops, and in other locations. Thus the question really is: why is there not both agricultural and tree production near the cities?

The model adopted in this chapter suggests that an increase in the intensity of agriculture is not initially accompanied by an increase in tree planting incentives. With a few exceptions, trees were never really managed in the earlier stages of development but rather were simply allowed to regrow on fallow ground. In fact, some hav› argued not only that the concept of growing trees is unfamiliar but that trees are viewed as a constraint to cultivation activities (see, for example, Openshaw and Moris 1979; Skutsch 1983). When population densities were low, no real need existed to manage tree growing extensively. With an increase in population density, the demand for wood fuels increase‹, and trees continue to be harvested from fallow ground. Because sufficient quantities are initially available from cleared agricultural land, the increase in the intensity of tree production lags behind agriculture. Only in the later stages of the cycle are the consequences of deforestation and degradation recognized. At that time, the incentive for growing trees increases; wood fuels become more scarce, prices rise, and markets develop.

The increase in population density in the short term leads to expansion of land-extensive systems of agriculture; over the long term, it leads to agricultural intensification. Over the short term, as more land is brought under cultivation, there is actually an excess supply of trees and biomass harvested from cleared land. Once this short-run supply has been cor med or sold to urban markets, the harvested stocks are not replanted. As a consequence, over the long there is a decrease in the growing stock, and wood fuels may become more scarce. The long-run decline in forests and wood fuels is well documented (Myers 1980; FAO/UNEP 1981; World Bank 1983; se› Allen and Barnes 1985 for a review). The present problem is thus that people in many African countries are mining the existing stocks of trees, and private incentives for managing them for the future are lacking.

A Problem of the Commons?

The deforestation and fuelwood problems are often attributed to the harvesting of wood from ground held in common, so that there is no incentive for individuals to replant the trees. Communities or individuals have no incentive to protect the land from deforestation because no one really owns the trees or the land. Individuals overuse the common land for short-term private gains, and in the long run society suffers from a declining volume of tree stocks.

One problem with such an analysis is its assumption that the common land is available to anyone who wants it. In actuality, there is informal agreement over rights to use of common land by various populations even in sparsely populated areas. The problem of the commons occurs only after population growth or other changes have precipitated conflicting claims of private or communal right to manage the land (Repetto and Holmes 1983; Noronha 1984).

The relevance of this discussion for population growth is that the land traditionally used for fallow or grazing will increasingly be managed by farmers for use in agriculture. Land not under cultivation is stripped of trees by people selling wood fuels. Wood fuels are thus harvested at very low cost. This is what is commonly described as overuse of common property resources. In reality, the overuse results from a situation in which population density and intensity of land use for agriculture have increased, whereas the rules and customs governing rights to own or manage trees have become outmoded (Thomson 1981).

The process described in the previous section has often been characterized as a problem of the commons. Under conditions of low population density and growth, land is abundant, and ownership of land is not really an issue because the value of land is very low. Someone belonging to a community who wants to cultivate new land simply clears it, farms it for a few years, and then returns it to fallow. This is the case in southern Sudan and many other countries. In a sense, the phrase "communal land" in such cases really means that the land cannot be claimed by outsiders. As a consequence the commons are not really communally managed but rather include land to which community members have rights, whereas others outside the community do not. This statement clearly defines community rights, but it says nothing about who manages the land. Land may be managed by an entire group, by a representative of a group, or by an individual tribal or family leader within the group (see Noronha 1984 for a review)

Conflicts between agriculturalists and herders also arise because of the growth of both human and animal populations. As fallows shorten, land rights of individual farmers generally take precedence over the rights of herders. With agricultural expansion, herders are forced into more marginal land, and within a short time the bush and pasture begin to degrade because of overgrazing. Expansion of the population of herders and animals further complicates the problems.

The reaction of herders to an increase in their herds and a decrease in available pasture has differed, depending on the region. In Sudan, the relatively wealthy herders obtain the rights to tenancies in the irrigation schemes and are settled while part of their families continue to herd. Other, less wealthy herders hire themselves out as agricultural laborers during the peak agricultural season. In Somalia, the strategy for coping has been to have one family member as a herder, another in trade, and others in government service (Noronha 1984). In other areas, pastoralists have been forced to settle. The question of what should happen to pastoralists and transhumants in Sub-Saharan Africa is still unsettled, with some advocating range management and others stressing the need to integrate livestock management into small farms. Whatever the solution, the rights of pastoralists are typically abused under conditions of agricultural intensification and population growth.

Farm-Level Incentives to Grow Trees

From the perspective of the producer-harvester of wood fuels, the incentives for harvesting without planting are currently greater than the incentives for doing both. In the context of rapidly growing urban demand for food, farmers near urban centers are producing food, which has a higher value than wood. There is no reason, however, why private farms cannot produce wood fuels on land that is not being used for crops. Trees often produce environmental benefits that would enhance agricultural yields. Also, expansion of agricultural land should not be considered an unequivocal degradation of the land. In fact, a certain amount of tree loss near cities is to be expected. The issue is not whether trees are being harvested near the cities, but how to obtain the maximum social and economic benefit from the land under changed socioeconomic conditions.

The farm-level incentives to grow trees depend on a complex interaction between population growth, prices, institutions, climate, and stage of deforestation. As indicated, population growth is related to the incentives for planting trees, but unfortunately a time lag may be involved. The growth in the demand for wood fuels eventually results in scarcity. If the price of wood fuels rises or more labor is required to collect fuelwood, then farmers would have greater incentives to grow trees for themselves and perhaps for a market (Skutsch 1983; French 1984). In regions with low rainfall where trees provide important environmental benefits, greater incentives for managing trees would be expected because they would be indirectly linked with agricultural production. Rising prices alone are probably not sufficient to sustain spontaneous tree planting. Other programs, such as seedling distribution and forestry extension, may be necessary. The regions in which deforestation has reached a more advanced stage are probably more likely to offer farmers greater incentives to plant trees (Skutsch 1983). Because of the time lags involved in creating the incentives, the situation may become very severe before enough incentives develop to stimulate tree planting. Until tree stocks are depleted and biomass energy becomes unavailable locally, or until stumpage fees rise to more realistic levels, people will continue to harvest "free" wood fuels for their household energy needs (Spears 1983).

A number of obstacles may block the growing of trees for urban consumption on farms near urban areas. Trees will not be grown in regions where they are abundant on common land. Farmers in most African countries are accustomed to harvesting trees or bush from fallow land, without the need for replanting (Spears 1983). Though they are familiar with traditional agricultural techniques, the planting and maintenance of trees for a wood fuel market is for the most part a rather new concept, even though trees may be planted for a variety of other reasons. Another difference is that trees require a long period in which to reach maturity, which may represent a severe constraint for farmers who are trying to produce income in the current year rather than ten years down the road. In many countries institutional support, including forestry extension for smallholder tree farming, is nonexistent.

The key to understanding the incentives to grow trees on common property is that agricultural systems have not kept pace with altering circumstances. By the time the issues of common property resources are recognized, past solutions to land use management have become outmoded and new solutions are required. Africa is just now encountering the limits of growth for its traditional system of agriculture. The new methods of resource management that evolve in the coming years will involve not just the protection of existing resources but also the participation of African farmers and herders.

Conclusions

Rural energy consumers in many parts of Sub-Saharan Africa are experiencing shortages of wood fuels. Because of poor infrastructure and markets for commercial fuels, interfuel substitution in rural areas means moving from wood to agricultural wastes and dung, which are lower-grade fuels and also valuable fertilizers. Rural energy markets, which are fairly informal, rely mostly on women's and children's labor for collecting wood. Although regional variation is significant, population growth generally means that wood fuels become increasingly scarce, and women must walk long distances to collect them. Population growth in the context of limited supply of wood fuels means that a more formal market for wood fuels should develop. Currently, however, the production of wood fuels generally receives low priority compared with the production of food. Areas where the intensity of agriculture has increased have often not experienced a similar growth in the intensity of tree production. Meanwhile, traditional forestry reserves and trees on fallow land are harvested without replanting.

Often overlooked in evaluating the deforestation problem is the fact that high population density does not cause all of the problems associated with deforestation. In fact, cities or countries with high population densities may benefit from economies of scale that are not possible in sparsely settled countries and cities; markets can be more efficient and infrastructure less expensive per person. The population growth rate rather than population density causes the problems associated with deforestation. Agricultural systems over the long term change to accommodate the higher levels of population density by use of fertilizers, new inputs, and new technologies to increase both agricultural and tree production. Still, it takes time for the land use system to adjust to growing population pressure. Most of the land-extensive cultivation systems in Sub-Saharan Africa are reaching their production limits. The critical problems occur when increasing population pressure pushes the present agricultural techniques and system of land use to the limits of their ability to produce additional food. In other words, rapid population growth puts pressure on the traditional methods of cultivation and tree production and, except in very arid areas, is not really limited by the potential of the land itself.

In the face of high rates of population growth, no one doubts that there needs to be more land under cultivation to produce more food or that people need more fuelwood for cooking. The important point is that such needs are being met in an environmentally unsound way in many regions and that something should be done about it. Although many areas have location-specific problems, the general problems are population growth, poor land use practices in the face of changing situations, outmoded land tenure systems, and conflicts between private incentives for farmers and larger social goals.

Population growth as a key to increases in household energy use and expansion of agricultural land should be explicitly recognized as part of both the problem and the solution. There are short- and long-term solutions to the deforestation problem. Over the short term, energy conservation and the substitution of modern for wood fuels are the two most promising ways to remove pressure on the natural resource base in affected regions. In critical areas, such as the Sahel, a policy to encourage out-migration from the most severely affected regions may be appropriate. Over the long term, the promotion of appropriate agricultural practices, the development of methods to reinforce local management of bushland and natural forests, the increase in private tree production, the promotion of family planning programs, and general economic development would all take pressure off forests and wood fuels. Such programs can improve human productivity and the quality of rural life in countries or regions most affected by population growth and ameliorate the present or impending fuelwood crisis in Sub-Saharan Africa.

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