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LOCATIONAL AND ECOLOGICAL ASPECTS OF PERI-URBAN FUELWOOD PLANTATIONS IN THE WEST AFRICAN SAHEL

By

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ABSTRACT

LOCATIONAL AND ECOLOGICAL ASPECTS OF PERI-URBAN FUELWOOD PLANTATIONS IN THE WEST AFRICAN SAHEL

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Countries of the West African Sahel are dependent on fuelwood for meeting their energy requirements. Traditional practices of collecting wood from areas surrounding cities and towns have led to large-scale deforestation around many of the region's urban centers. An often-cited approach to assure urban energy needs, reduce deforestation, and arrest environmental degradation in rural areas is the establishment of fuelwood plantations.

The main objective of this study is to examine the conditions under which fuelwood could be produced as a crop in a peri-urban plantation system. Concepts related to Thunen's model of agricultural land use are employed to determine the best location for the establishment of a fuelwood plantation. Data are analyzed for agricultural crops and a hypothetical plantation representative of the conditions in this semi-arid area. Results indicate that for plantations to be economically viable fuelwood market prices must be substantially higher than current levels. Economic and political difficulties posed by higher fuelwood prices in urban areas render the establishment of peri-urban plantations problematic.

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CHAPTER I

INTRODUCTION

Wood has served humankind's energy needs over the millennia. Its importance as a source of energy has waned in societies that have gone through the stages of economic development which have led to the use of fossil fuels such as coal, oil, and natural gas. However, for the overwhelming majority of people in the developing world, dependence on wood for satisfying energy needs remains prevalent and a decline in such dependence is generally assumed to be unlikely in the near future.

In Africa, most nations depend heavily on wood-based fuels to meet their energy requirements. This is especially true in the domestic sector, where firewood and charcoal account for virtually all of the energy consumed for cooking and heating. In the countries of the West African Sahel, an ecological zone located between the Sahara desert to the north and the more humid subtropical savannahs to the south, the environmental consequences of fuelwood dependence have reached severe proportions. Large-scale deforestation has taken place around most of the urban centers in this region, resulting in expanding zones of degraded land surrounding large cities and towns. Although the exploitation of fuelwood resources is only one of many factors of land degradation in the environs of Sahelian urban areas, the continued dependence on this energy source promises to exacerbate the ecological deterioration now in progress.

The current practice of fuelwood production mainly involves the collection, processing, and transportation of what has hitherto been considered a 'free good'.[1] With respect to urban areas, this process begins first with the collection of wood from the most proximate areas outside the city or town, followed by a progressive outward

[1] The idea of fuelwood as a 'free good' is reflected in the fact that no consideration is given to the replacement costs of trees felled to provide wood energy. In essence, forested lands are being 'mined' in order to produce fuelwood energy.

expansion of the collection zone as nearby resources are depleted. In the most extreme cases, fuelwood in the West African Sahel is now transported to urban markets over distances of several hundred kilometers. Due to the fact that the supply of fuelwood to urban markets must now overcome increasingly greater distances, this energy resource is no longer a 'free good' for urban inhabitants but instead a monetized good that entails a significant cash expenditure.

Statement of the Problem

This study entails an analysis of a fuelwood production system for meeting domestic energy needs in the urban centers of the West African Sahelian region. Emphasis will be placed on the locational and ecological aspects of a possible alternative spatial pattern of fuelwood production in peri-urban environments.

The objective of this study is to demonstrate how one could determine an economically and ecologically viable location for peri-urban fuelwood plantations designed to supply the energy needs of urban centers in the countries of the West African Sahel. Although rural populations are undeniably faced with equally pressing problems regarding fuelwood provision, this analysis is intended to deal exclusively with fuelwood supply systems for urban centers. The nature of rural fuelwood supply differs from that of urban areas primarily due to the absence of a medium of exchange between buyer and seller. However, in the urban context, the evolution of a complex market apparatus for what has now become a monetized good requires an analytical approach specific to the question of fuelwood consumption in cities and towns. Nevertheless, there remains an important connection between the supply of energy from forested rural areas and the attendant demand for fuelwood on the part of urban populations. Thus, the present study will address relevant rural-urban components of the fuelwood problem.

Questions examined in this study are related to the possible spatial reorganization of urban fuelwood supply systems.[2] For example, where, in terms of the agricultural space economy, could fuelwood be profitably produced as a 'crop' in competition with other types of land use were it no longer considered to be a 'free' good? In addition, what would be the economic impact, ecological ramifications, social constraints and opportunities, and policy problems associated with a different spatial pattern of fuelwood production?

For the purposes of this study, the term 'fuelwood' will be used to denote firewood (cut logs, trunks, branches, etc.) and charcoal. In the literature, the terms 'fuelwood' and 'woodfuel' are for the most part used interchangeably.

[2] Spatial reorganization refers here to a pattern of fuelwood production other than the current practice of 'mining', without subsequent reforestation, of rural forested lands located at increasing distances from urban market centers.

CHAPTER II

REVIEW OF LITERATURE

This chapter serves as an introduction to the study area and as a review of recent studies relevant to the exploitation of forest resources for the production of fuelwood energy. The first section gives an overview of the study area, outlining its political composition and ecological characteristics. In the second section, linkages between politico-economic and ecological factors related to present environmental conditions in the Sahel are discussed in the context of a conceptual framework for analyzing problems of economic development and environmental protection. The third section discusses the levels of production and consumption of fuelwood energy resources in the countries of the study area. Following this, the fourth section examines the specifics of fuelwood use in the urban context. As the problem of supplying fuelwood energy to urban areas becomes evident, the fifth section discusses several strategies commonly cited to address this problem.

Overview of the Study Area

The term 'Sahel' comes from the Arabic word for coast or border, which, in the geographic context, refers to this region's location along the southern extent of the Sahara desert. Based on its political composition, the West African Sahel is comprised of the following seven states: Burkina Faso, Chad, The Gambia, Mali, Mauritania, Niger, and Senegal (see Figure 2.1). In 1985, the total population of these seven countries was approximately 35 million inhabitants. Of this total, about 22 percent is considered to live in urban areas (World Bank 1988).

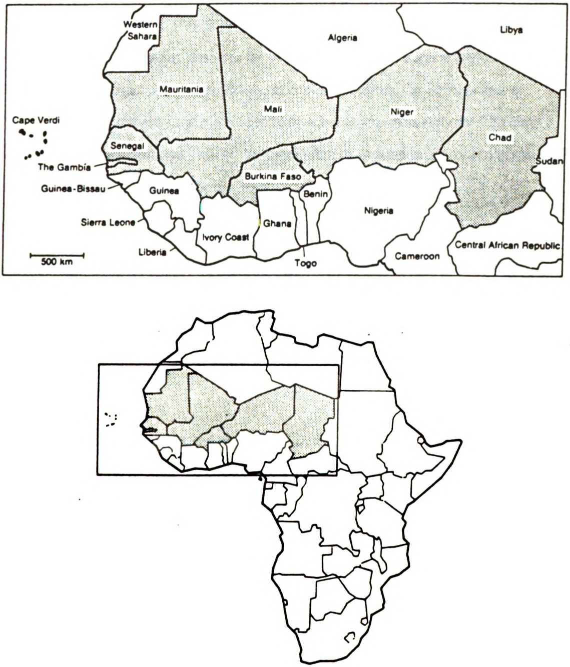

Figure 2.1 Principal Countries of the West African Sahel
Source: Jayne, Day and Dregne 1989

The Sahel extends across West Africa defined primarily by its semi-arid climatic characteristics and is subdivided into different zones based on precipitation (World Bank 1985, p. 2). The Sahel is generally considered to extend from the southern limit of the Sahara desert to the northern limit of the tropical savannah of West Africa's coastal zone. More specifically, in ecological terms, the Sahel proper is bounded by the northern limit of rain-fed cultivation at approximately the 250 mm/yr isohyet, and by the northern limit of the Sahelo-Sudanian zone at approximately the 400 mm/yr isohyet (see Figure 2.2).

Sinclair and Fryzell (1985) identify important physical characteristics of the Sahel that are related to the region's relatively poor biomass productivity. In the Sahelian region, soils are generally of low fertility due to low mineral and organic content, as well as poor water retention capacity. Vegetation consists mostly of open *Acacia* scrub and short grasses, which become increasingly scarce in the northern reaches of the region.

Annual cycles of wet and dry seasons in the Sahel are the result of the seasonal migration of the Intertropical Convergence Zone. This discontinuity between dry continental and moist tropical air masses is the primary driving force controlling precipitation in the Sahelian region. Since the beginning of the meteorological record in the Sahel recurrent drought has been a predominant feature of the region, presumably common in earlier times as well (Nicholson 1982). Oscillating periods of dry and humid conditions spanning several thousands of years have been discerned through archaeological research (National Academy of Science 1983a). Research on contemporary conditions in the Sahel indicates that cycles of severe drought occur at intervals of approximately thirty years; however, some suggest that human agency is currently contributing to more frequent drought conditions (Rasmusson 1987).

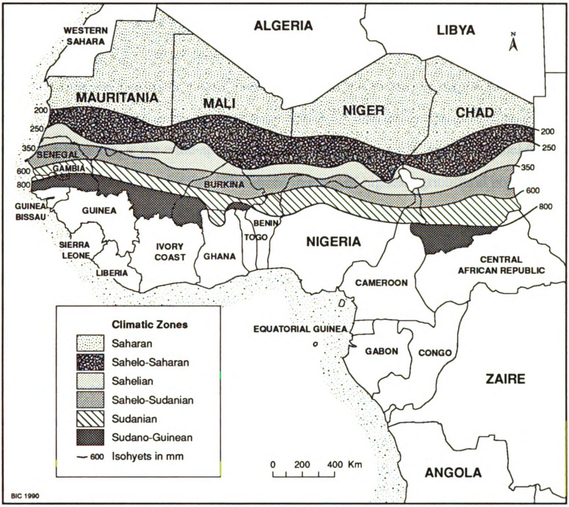

Figure 2.2 Ecological Zones of the West African Sahel.
After: World Bank 1985

Agricultural activity in the Sahel is restricted mostly to the cultivation of drought tolerant crops such as millet and sorghum, which are main staples in the drier parts of the region. Other important crops grown in the Sahel include groundnuts, irrigated rice, and, to a lesser degree, maize (Jayne et al. 1989). Sugar cane - in irrigated areas such as the Senegal River valley - and cotton are two significant cash crops produced in the region. Perhaps more important than cultivation, in terms of extensive land use, is the wide-spread nomadic pastoralism practiced in the Sahel (Swift 1977). Whereas crop production is localized in areas of highest agricultural potential, cattle and other livestock are herded over a much larger spatial range. Competition between farmers and herders for land and water resources is intense, particularly in areas where population pressures begin to exceed local carrying capacities, resulting in the exploitation of increasingly marginal areas.

As the work of Gritzner (1988) has detailed, these three factors - recurrent drought, crop cultivation on marginal lands, and the demands of extensive pastoralism - have contributed significantly to the environmental degradation apparent in the Sahel today. Due to the fact that the natural resource base of the Sahel is inherently limited, and that population pressures continue to rise while levels of agricultural technology remain relatively static, the increasing demands for food, forage, and water contribute to the deterioration of local ecological equilibrium. Under these conditions, it is argued that many areas within the Sahel are losing their productive capacity to the insidious process of desertification (Gorse and Steeds 1985; Grainger 1982).

In light of the scenario described above, one must also consider the contribution of fuelwood demand toward greater environmental degradation. It is important to realize that in addition to the demands for food, forage, and water, the limited Sahelian resource base must also provide the overwhelming majority of the population's energy supply. Whereas most rural inhabitants satisfy their fuelwood requirements by selectively culling wood from locally available resources, urban fuelwood demand is usually met by the intensive cutting of remaining forested stands in remote rural areas. Hence, energy requirements, and particularly those of rapidly expanding urban populations, contribute significantly to overall environmental degradation.

The discussion in the next section indicates how the demand for fuelwood goes beyond the specific issue of energy supply to touch upon broader concerns of overall economic development. It is argued that fuelwood production, environmental degradation, and the productive capacity of the natural resource base (hence the economic development potential) are interconnected in an environment-economy-energy nexus.

A Theoretical Framework for Natural Resource Management

Threatened by the specter of continued environmental degradation, the countries of the Sahel must begin to devise improved strategies and implement effective plans of action designed to stabilize and reverse the deterioration of their productive natural resources. This remains difficult, however, for as Redclift (1987) has pointed out, most theories of regional growth, decline, or development fail to incorporate environmental considerations. He insists that those concerned with planning development must adapt existing theories to take into account the variability of natural resources over space and through time.

In attempting to provide a conceptual framework for incorporating natural resource management issues into overarching theories of regional development, Blaikie and Brookfield (1987) seek to combine economic and ecological considerations. Their main ideas are put forward within the context of what they term 'regional political ecology'.

Regional political ecology seeks to link specific natural resource management issues with broader issues of political economy. The 'regional' in this concept refers to the spatial variations in capability, resilience, and sensitivity of land resources. The term 'political ecology' seeks to encompass concerns of ecology and political economy. It attempts to examine the dialectic between society and land-based resources (Blaikie and Brookfield 1987, p. 17). Regional political ecology also recognizes the importance of the role played by the state in natural resource management. It explores the dynamics of the allocation of public resources to land users, as well as the effects such allocations have on natural resource use.

Kostrowicki (1986) complements the ideas put forth by Blaikie and Brookfield when he discusses the notion of moving from a "technico-economic" approach, to an "ecologico-economic" approach in reconciling environmental concerns with issues of economic development. Kostrowicki acknowledges, as do Blaikie and Brookfield, that problems of environmental degradation are, in effect, societal problems as much as they are problems of physical circumstances of the biosphere. He sees the need to bring together two diametrically opposed viewpoints on ways of seeking solutions to problems of environment and development; he suggests that a solution may be more effectively sought through the "ecologization of economics and other social sciences, [together with] the economization and humanization of the natural sciences" (Kostrowicki 1986, pp. 5-6).

In addition to regional political ecology, Blaikie and Brookfield offer another concept - that of 'landesque capital' - which attempts to bring together the two concerns of environment and development. The idea of landesque capital basically represents the production and/or safeguarding of capital in the form of natural resources for future productive use. It is essentially an investment in land with an anticipated life beyond that of the present crop cycle, or rotation period when dealing with forest resources (Blaikie and Brookfield 1987, p.9). Landesque capital investments are considered as any purposive land management intervention which has the specific intent to create capital for future maintenance of land capability. Examples of such investment would include soil stabilizing wind breaks or live fences, terracing on steep slopes, or the design of proper field drainage systems.

These interventions necessitate a long-term perspective on the use of productive natural resources. Unfortunately, many natural resource management decisions in developing countries seek to maximize short-term gains. This is understandable in environments where risks are high and production is plagued by many uncertainties. However, long-term productive capacity is frequently placed in jeopardy due to the short time horizon of such resource management decisions.

In the case of fuelwood resource exploitation in the Sahel, the regional political ecology framework offers a useful context for examining how political decision making affects the status of the natural resource base, the population living in rural collection areas, and the urban consumer of fuelwood energy. For example, policies that allow fuelwood mining in rural areas to continue unabated contribute not only to environmental degradation, but also to the economic marginalization of farmers whose land-based capital is adversely affected by increased soil erosion and the loss of other service functions provided by trees (e.g., nitrogen fixation by leguminous species). It follows that the marginalization of rural-based agricultural systems affects the status of the overall national economy.

One could also argue that the lack of an effective resource management policy regarding fuelwood production basically amounts to a government subsidy to urban consumers on the price of fuelwood at the expense of rural farmers. This is especially the case when there is little or no subsequent reforestation following fuelwood collection. Hence, in the absence of effective management policies, the allocation of natural resources for fuelwood production in many developing countries leads to an inequitable distribution of the benefits and costs attributable to exploiting such resources.

Without effective measures in place to conserve fuelwood energy, more realistic prices for wood-based fuels, and better management of remaining tree stocks, Sahelian countries will find it difficult to reverse the stress placed on natural productive resources by current fuelwood exploitation practices. The lack of investment in future land productivity presents a serious threat to the prospects of economic growth in resource-poor Sahelian nations.

Within the regional political ecology framework, the interdependent variables of economics, politics, and ecology can be brought together in order to seek more effective solutions to problems facing the future prospects of development in the Sahel. The current situation regarding fuelwood exploitation in this region is an example of the type of issue that can be addressed by this holistic concept. This approach is consistent with the suggestion that the societal goal of economic development, which includes meeting energy requirements for domestic and industrial purposes, be met in an environmentally sound and sustainable manner (Matthews and Siddiqi 1981). Thus, the complexity of the fuelwood issue in developing countries must be seen in terms of its interconnected environment, economy, and energy components.

Fuelwood Production and Consumption

The developing world's dependence on wood-based fuels to meet domestic energy requirements was not a major concern of environmental researchers or development assistance organizations until fairly recently. In the wake of the tumultuous repercussions of the 1973 oil crisis in the industrial nations, there was an increase in research attention given to the "other energy crisis," namely that of fuelwood (Eckholm 1975; Arnold and Jongma 1977).

Whereas industrial nations rely almost exclusively on conventional fuels such as petroleum, coal, natural gas, hydroelectricity, and nuclear power generation, approximately 90 percent of the people in most developing countries depend on fuelwood as their chief source of energy (Eckholm 1984).

To illustrate the dependence of developing nations on fuelwood energy, the following statistics contrast world production of fuelwood with that of the developing world. In 1985, total world roundwood production was estimated at 3.2 billion cubic meters, with fuelwood accounting for 53 percent of this figure (FAO 1986). Eighty-five percent of the fuelwood production for the same year took place in developing countries (see Table 2.1).

Table 2.1 World Fuelwood Production - 1985

	(Thousand m^3)
Developed countries	254,587
Developing countries	1,408,384
Total	1,662,971

Source: UNFAO, Yearbook of Forest Products, 1986.

Fuelwood use represents approximately 5.4 percent of total world energy consumption. Although this may appear to be a relatively small amount on a global scale, estimates for total energy requirements met by fuelwood in developing countries range from 50 to 80 percent (de Montalembert and Clement 1983, p. 16). Some countries, such as Burkina Faso and Nepal, are even more dependent on wood-based fuels. In these two countries figures for wood as a percentage of total energy consumption reach 94 and 98 percent respectively (Eckholm 1984, p. 11). This dependence is most pronounced in the rural areas of developing countries, particularly those of sub-Saharan Africa, where in many cases 100 percent of the domestic energy requirement is met by fuelwood (de Montalembert and Clement 1983, p. 28).

The figures mentioned in the preceding paragraphs are to be interpreted with caution. Quantifying the amount of fuelwood consumed in thousands of small, remote villages around the globe is a difficult, if not impossible task. However, the point to be stressed is that without viable alternative sources of energy to satisfy domestic needs, most people in the developing world are highly dependent on fuelwood.

What is probably one of the most comprehensive attempts made to assess the fuelwood supply situation in developing countries was reported by the United Nations Food and Agriculture Organization (FAO) in a 1983 study (de Montalembert and Clement 1983). The report gives a systematic overview of fuelwood production vis-a-vis consumption requirements on a region by region basis for all developing countries. Data were gathered on a country by country basis, and then analyzed and aggregated in order to develop a global picture of the fuelwood situation. The results culminated in an important update to an earlier FAO study which produced a map of the fuelwood situation for developing countries (see Figure 2.3).

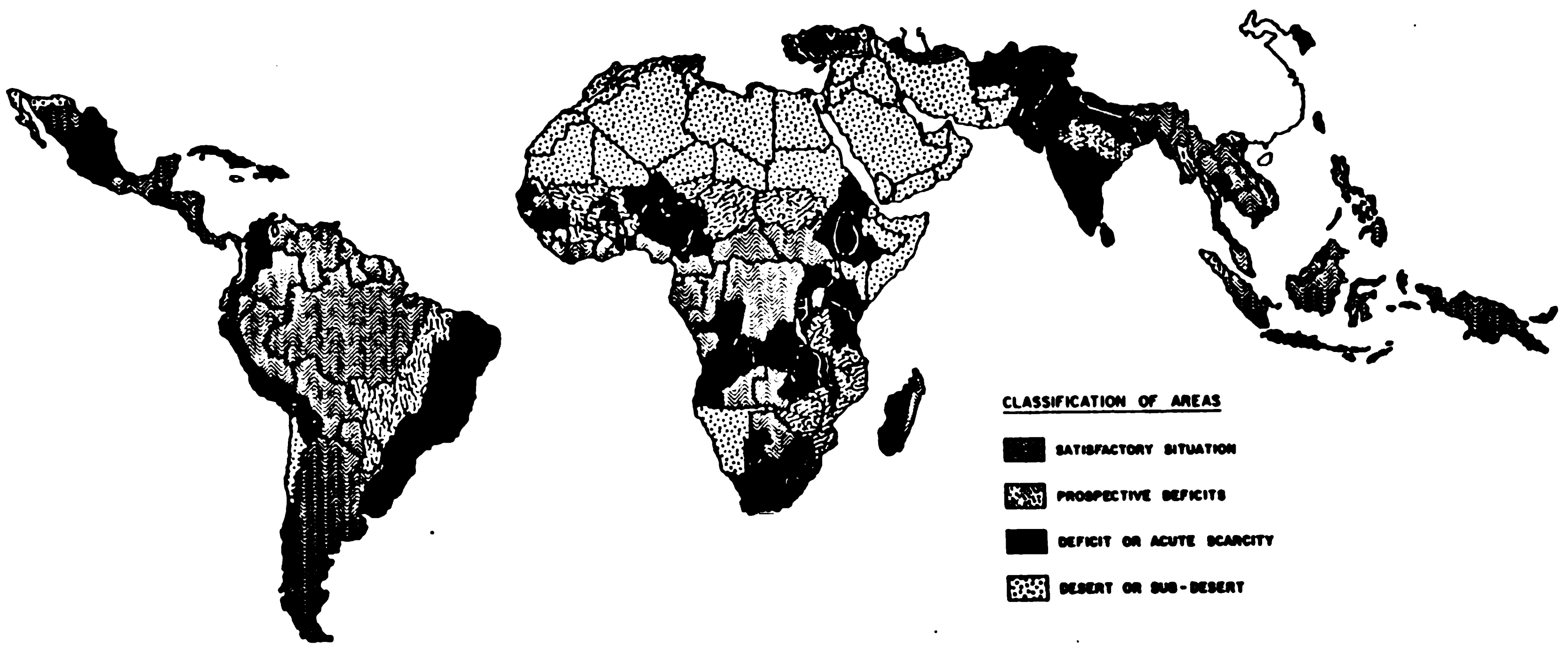

Figure 2.3 Fuelwood Situation in Developing Countries
Source: UNFAO 1981

In the study by de Montalembert and Clement, categories of varying severity were developed in order to indicate the status of the fuelwood situation in a given region. The categories and their definitions are given as follows:

Acute scarcity situations: zones or countries with a negative balance where the fuelwood supply level is so notoriously inadequate that even overcutting of the resource does not provide a sufficient supply and fuelwood consumption is, therefore, clearly below minimum requirements.

Deficit situations: present level of supplies is insufficient to ensure provisioning on a sustained basis, and overcutting leads to degradation or progressive destruction of the resources.

Prospective deficit situations: zones or countries in which supplies still exceeded demand in 1980, but which in 2000 will be in a deficit situation if present trends continue.

Satisfactory situations: zones which on the whole will still have sufficient supplies by the year 2000.

As indicated on the map in Figure 2.3, most of the territory in the West African Sahel is classified as zones of acute scarcity/deficit (western Senegal, southwestern Niger, and central Burkina Faso), or prospective deficit (southwestern Mali). According to the map, a small area classified as satisfactory is located in southeastern Senegal, a region in which the population is relatively sparse and rainfall relatively good.

In their consideration of why many areas are experiencing expanding fuelwood deficits, de Montalembert and Clement cite the combined effects of 1) rapid population growth, 2) deterioration of natural forest resources, and 3) the absence of viable alternative energy sources. These points will be addressed in greater detail later in this chapter.

Reports by Floor and Gorse (1988), and Bouttoud (1988), concentrate more specifically on the fuelwood problem in countries of the West African Sahel. In addition, Keita (1982) employs a similar approach to that of de Montalembert and Clement in classifying the fuelwood situation for the seven countries of the Sahel region. However, rather than reporting his findings on a country by country basis, Keita divides the region into four ecological sub-divisions according to rainfall parameters. These divisions are given as follows: 1) Saharan zone - less than 100 mm/yr, 2) Sahelian zone - 100-400 mm/yr, 3) Soudanian zone - 400-1200 mm/yr, and 4) Soudano-Guinean zone - 1200-1600 mm/yr.

Keita notes that of the sub-divisions defined above, the Soudanian zone (with 17 percent of the total land area and 60 percent of the total population of the region) is experiencing the greatest degree of deforestation and land degradation. Unfortunately, no attempt is made to estimate the proportion of this degradation due to fuelwood consumption.

In his study, Keita describes the different spatial patterns of fuelwood supply for various sized settlements in the Sahel. For rural villages, he notes a 'fuelshed' proscribed by a circle with an average radius of 10 km, within which firewood is collected mostly by women and children. For small-town settlements, the average fuelshed radius is within a range of 10-50 km. In these areas, fuelwood is usually brought to the settlement by animal carts, or, in some instances, small vehicles. Major urban centers are shown to have a minimum fuelshed radius of 50-60 km and a maximum radius ranging from 200-400 km. Most of the fuelwood consumed in these centers is in the form of charcoal and is transported from the collection site by large-capacity trucks.

From the general conclusions of Keita's study, the future fuelwood situation for the Sahel is regarded as a crisis looming on the horizon. In light of projections comparing future energy supply from natural tree growth with expanded fuelwood consumption (see Table 2.2), it appears that Keita's conclusions warrant serious attention. The author notes that due to problems of substituting conventional fuel sources such as oil, coal, or natural gas, "no other source of energy will be able, in the near future, to replace fuelwood products under appropriate technical and economic conditions on a large scale" (Keita 1982, p. 51, my translation). In light of projected supply and consumption, however, it is evident that dependence on fuelwood will require innovative interventions in order to satisfy future energy demand.

Table 2.2 - Fuelwood Consumption Compared with the Mean Annual Increment of Tree Stocks in the Sahel

Year	Accessible Supply from Tree Growth 000m^3/yr	Fuelwood Consumption 000m^3/yr	Excess of Consumption over Accessible Supply 000m^3/yr	%
1980	17,000	22,000	5,000	30
2000	15,000	34,000	19,000	127

Source: Anderson and Fishwick 1984, p. 15.

Finally, in the 1980s, researchers and development assistance agencies began to pay greater attention to the problem of meeting increasing demands for fuelwood, and to mitigating the environmental degradation ensuing from the 'mining' of forested lands. Several writers examined the relationship between fuelwood consumption, clearing of land for agriculture, and increasing rates of deforestation in Africa and other developing regions (Allen and Barnes 1985; Anderson 1986; Anderson and Fishwick 1984; Bowonder 1985/86; French 1986; Gritzner 1982; Hosier 1988; and Pimentel et al. 1986). In-depth studies and analyses of the situation began to examine the varied and interrelated effects of unsustainable fuelwood exploitation on both physical and human environments at the local level in urban and rural areas, as well as on an overall national level (Moss and Morgan 1981; Eckholm et al. 1984; Bogach 1985; Timberlake 1985; Agarwal 1986; Leach and Mearns 1988; and Munslow et al. 1988). These effects range from soil erosion and watershed deterioration, to poorer human health and declining rural incomes, to reduced agricultural productivity and gross domestic product.

The broad range of interrelationships between fuelwood resource exploitation and the condition of natural and human environments spans several contextual and scalar levels of analysis. The problems of meeting fuelwood energy requirements can thus be examined from ecological, political, social, and economic perspectives. In addition, analyses can be performed at scales ranging from the local to the national level.

Fuelwood Situation Around Sahelian Urban Areas

As in most of sub-Saharan Africa, wood-based energy makes up the majority of primary energy supply in the Sahelian region. On average, the amount of energy produced from fuelwood accounts for two-thirds of the national energy budget in most sub-Saharan countries (World Bank 1989, pp. 128-130). This section examines more closely the important characteristics of fuelwood use at the urban level within the Sahelian region.

Major distinctions exist between energy consumption in urban and rural areas. First, the majority of fossil fuel energy consumed on a national basis takes place in the urban areas. It is here that the majority of industry is located, where fuel needs for transportation are most concentrated, and where the vast majority of electricity is consumed. For example, in Dakar, Senegal, one-sixth of the country's population comprises 90 percent of the nation's electricity consumers, who purchase 55 percent of the total national electricity output (Di-Meo et al. 1985, pp. 1-2). In addition, 75 percent of imported petroleum products are destined to meet the local demand of the greater Dakar area.

Second, fuelwood meets almost all rural energy requirements for domestic purposes, e.g., cooking, heating, and myriad other uses. In urban areas, fuelwood meets approximately 90 percent of domestic energy requirements. However, there is a significant difference between rural and urban areas in terms of the form in which wood-based energy is consumed. In rural areas, fuelwood is almost always consumed in the form of firewood - mostly dead, lopped-off branches of trees collected from around villagers' homesteads.[1] On the other hand, almost all of the fuelwood consumed in major urban areas (e.g., 98 percent in Dakar) is in the form of charcoal (Floor and Gorse 1988, p. 72).

This is significant due to the nature of the carbonization process. Although charcoal is more efficient than firewood in terms of calorific energy per unit weight, approximately 55 percent of the heat energy in firewood is lost in the conversion process to charcoal (Earl 1975, pp. 26-28). The net effect of this energy loss is that in order to obtain an equal amount of useful energy, an urban inhabitant utilizing charcoal consumes twice as much wood as a villager who obtains the energy in the form of firewood (Goodman 1987, p. 114). Thus, it is apparent that urban domestic energy consumption (in the form of charcoal) has a more deleterious effect on the natural resource base than firewood consumed in rural areas.

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[1] This situation is beginning to change, however, in countries suffering from almost complete deforestation. It appears that rural charcoal markets begin to appear in some areas when local forest resources are depleted (see Whitney 1987).

The differential in fuelwood consumption between rural and urban areas is even more important in light of the rapid population growth rate of Sahelian cities. Table 2.3 indicates that urban population growth rates in the Sahel are approximately twice those of overall national growth rates.

Table 2.3* - Population Growth in the Sahel

	Urban Population				National Population	
	Total Pop %		Avg An Growth %		Avg An Growth %	
Country	1965	1985	1965-80	80-85	1965-80	80-86
Burkina Faso	6	8	3.4	5.3	2.0	2.5
Chad	9	27	9.2	3.9	2.0	2.3
Mali	13	20	4.9	4.5	2.1	2.3
Mauritania	7	31	12.4	3.4	2.3	2.6
Niger	7	15	6.9	7.0	2.7	3.0
Senegal	27	36	4.1	4.0	2.5	2.9

Source: World Bank 1988, pp. 274 & 284.
*Data for the Gambia not available.

The population growth rate of urban areas is an important indicator of demand for fuelwood in cities and towns. It is argued that this will remain the case as long as the substitution of more conventional fuels, i.e., fossil fuels, remains an unlikely option for urban dwellers due to prohibitive costs, irregular supply, and poor distribution networks.

Few studies have examined the specific problems of fuelwood supply and consumption in and around urban centers of the Sahel. However, some attempts have been made to document the situation pertaining to a small number of cities and towns.

One of the earliest studies undertaken regarding fuelwood production for a Sahelian urban center was reported on Niamey, the capital of the Republic of Niger (Delwaulle and Roederer 1973). Although this information is now dated, what was reported at the time were the first signals of a deteriorating fuelwood situation. The authors observed a 15-20 km radius of deforested land surrounding Niamey. No natural regeneration was taking place, as most of the land was kept in cultivation to supply food for a growing urban population. Because of the growing need for agricultural land, drastically reduced fallow periods were contributing further to the process of environmental degradation. Thus, the authors predicted a radius of complete 'desertification' of 40-50 km around Niamey. In addition, due to the poor rate of natural forest regeneration, it was noted that fuelwood was already being collected from remaining savannah-forested zones more than 60 km from the city.

Another note of interest from this study relates to the transportation infrastructure available to bring fuelwood to the Niamey market. Delwaulle and Roederer discuss the geographic distribution of collection areas as being a function of the quality of the transportation infrastructure. To the north of Niamey, the road was unpaved; hence, the distance transporters were willing to travel 'off-road' was less than that which they would travel to the east or west on paved surfaces. Situated on the north bank of the Niger River, Niamey had been poorly served by deliveries coming from the south until the construction of a bridge facilitated the transportation of fuelwood. The authors envisioned greater traffic via the southern route due to this improvement. It should also be noted that fuelwood was being transported to the Niamey market by boat along the Niger River. Unfortunately, the authors did not provide information regarding the significance of this mode of transportation.

In another study related to the problem of urban fuelwood supply in the Sahel, Chauvin (1981) examined the potential of bringing fuelwood from surplus areas in the Ivory Coast to the critical fuelwood deficit city of Ouagadougou, Burkina Faso (formerly Upper Volta).

At the time of his study, Chauvin determined the average distance from Ouagadougou to existing wooded savannah areas to be 70-100 km along the main roads. With natural regeneration rates of forested lands, i.e., the mean annual increment of growth, lagging behind urban fuelwood demand (due to a reported 8 percent per annum urban population growth rate), the author suggested a three-pronged approach to relieve the pressure on natural forests to supply Ouagadougou. This entailed 1) a program to conserve fuelwood, 2) the creation of plantation forests, and 3) the import of charcoal from distant resources, i.e., the abundant forests of the Ivory Coast.

Overall, Chauvin concluded that the cost of producing charcoal in the Ivory Coast and transporting it to Ouagadougou would, considering the local retail price and marketing costs, be economically viable. He examined alternative transportation modes (road and road/rail combination), and determined that the margin between the delivered cost and retail price would be greatest for charcoal produced in the central region of the Ivory Coast and shipped via a road/rail combination to Ouagadougou. To date, the degree to which fuelwood may be entering the Ouagadougou market via Chauvin's proposed channel has not been documented.

In a study of a region with similar ecological and socio-economic characteristics, Digernes (1977, 1979) examined the contribution of fuelwood use to the overall degradative process of desertification around the town of Bara, Sudan.[2] The

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[2] Although this case study comes from outside the present study area, the conditions surrounding Bara are quite similar to those found in many West African Sahelian

study noted changes in wood/charcoal consumption which indicated a trend from individual household collection of a 'free' firewood resource, to the commercialization of the domestic energy supply. This was due primarily to the expanding distance between the site of collection and the town. Fuel that was formerly collected and returned to the town by the end-users themselves was now brought to the market for urban consumers by rural villagers. The villagers converted firewood into charcoal since the latter is less bulky and easier to transport over longer distances.

For the purposes of the present study, it is interesting to note the spatial aspects of the fuel supply system for towns such as Bara (see Figure 2.4). Although schematic in nature, Digernes' graphic model illustrates the process of fuelwood 'mining' and the resultant deforestation around urban centers.

Stage A in the model relates to the collection of fuelwood by endusers themselves, requiring no monetary or other exchange in order to obtain the necessary supply. This is the 'free good' stage, not accounting for the opportunity cost of time and labor. In stage B, the expanding zone of resource depletion becomes evident. Stage C is perhaps the most representative of existing conditions in the Sahel, where fuelwood resources are being collected at great distances from cities and towns. One note of caution is necessary regarding stage D in this model: the amount of alternative energy originating from external (5) or internal (6) sources is usually highly dependent on access to these alternatives. In the case of conventional energy sources, i.e., imported petroleum products, such access is restricted in many developing countries due to lack of foreign exchange, efficient distribution networks, appropriate cooking devices and/or sufficient income to purchase alternative forms of energy. Most likely, greater amounts

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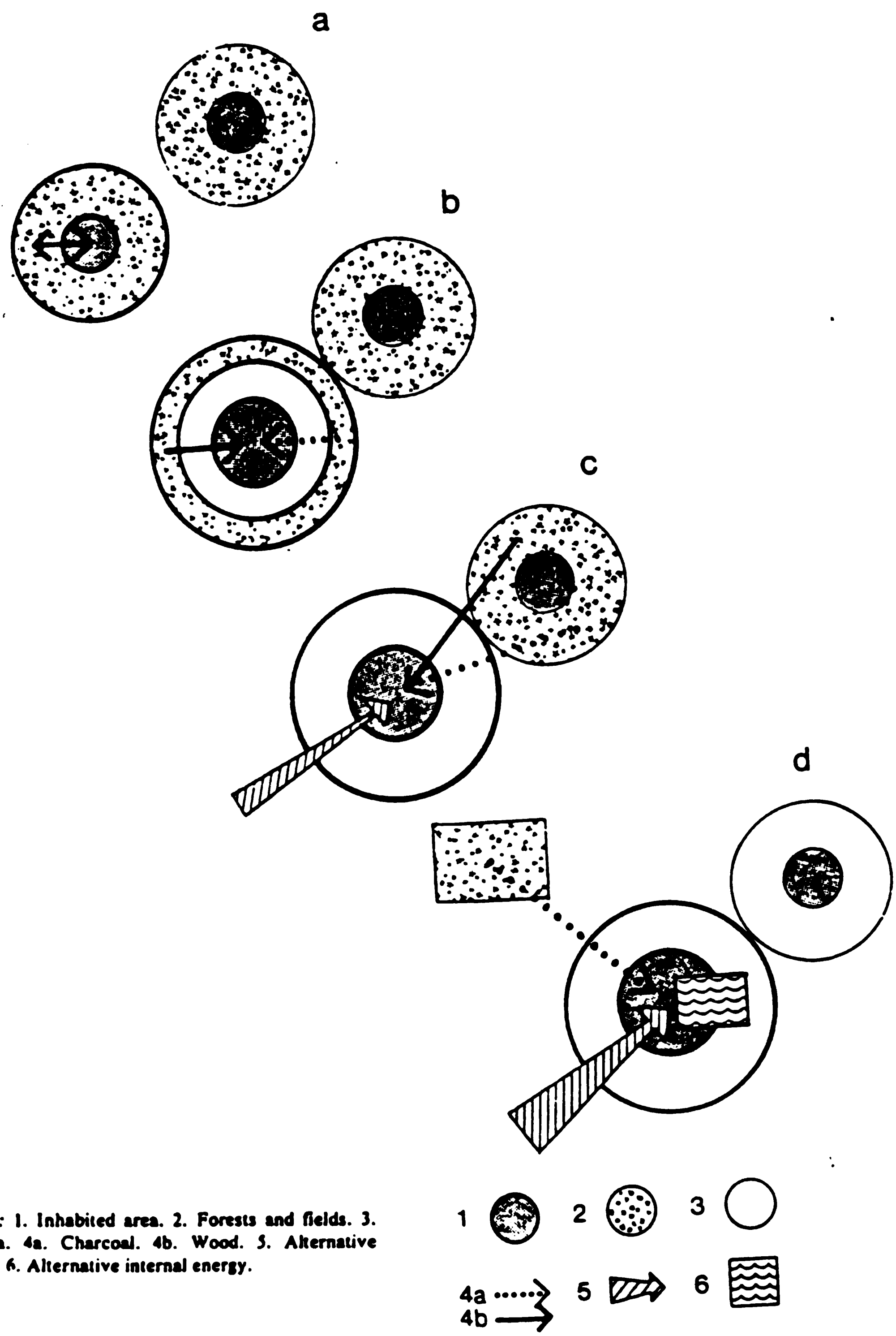
countries. Therefore, the conclusions drawn by Digernes are relevant to the present discussion.

of energy are being supplied from the far-removed forested areas as indicated in the diagram.

According to the major findings from the review of studies related to Sahelian urban centers, it is evident that urban fuelwood consumption is an important factor in land degradation in peri-urban environments and in rural hinterland areas. The progression of fuelwood collection sites into increasingly distant rural areas has the combined effect of raising the price of fuelwood paid by urban consumers, and accelerating the rate at which deforestation and environmental degradation take place. This is particularly worrisome in light of the effect that the change from firewood to charcoal use has on the rate of forest clearance, as distance increases between collection and consumption points. Thus, as related to the present study, the findings from the work examined so far indicate that exploring the establishment of peri-urban fuelwood plantations could possibly lead to a more environmentally sustainable and less costly urban energy supply system.



Legend: 1. Inhabited area. 2. Forests and fields. 3. Desertified area. 4a. Charcoal. 4b. Wood. 5. Alternative external energy. 6. Alternative internal energy.

Figure 2.4 Fuelwood Supply Model for Dryland Population Centers
Source: Digernes 1979

Strategies to Address Fuelwood Deficits

In light of the growing difficulties of supplying affordable fuelwood energy to urban areas, and doing so without destroying the ecological balance in rural areas, research attention has focused on a variety of strategies to ameliorate current deficit situations. Generally recommended policy options to redress fuelwood deficits fall into three main categories: 1) the use of substitute fuels (sometimes referred to as 'fuelswitching'), 2) conservation in the use of existing fuel resources, and 3) enhancing the supply of fuelwood energy (Anderson and Fishwick 1984, p. 3). Each strategy is addressed in turn.

Replacing fuelwood energy with conventional fuels (kerosene, bottled gas (LPG), coal, electricity, etc.) has been the focus of several recent studies in the developing world (Elkan 1988; Hosier et al 1982; Foley 1986; Whitney et al. 1987). However, in many instances the implementation of the substitution option has faced numerous obstacles.

The quantity of fossil fuel energy required to meet the domestic needs of the entire population of the developing world currently using fuelwood is relatively small, equivalent to approximately 2 percent of current global oil consumption (Goodman 1987, p. 116). However, foreign exchange expenditures for petroleum imports in many developing countries already exceed 50 percent of export earnings. In a recent study in the Sudan, Whitney and colleagues (1987, p. 320) state that given the high cost of importing fossil fuels, forest 'mining' appears, in the short term, to be an economically rational policy decision. Reducing fuelwood consumption to prevent deforestation through the use of fossil fuels would require an increase of over 100 percent in Sudan's annual petroleum imports. The added foreign exchange expenditure that fossil fuel substitution would require is a fiscal burden that Sahelian countries, among the poorest in the world, can hardly afford.

In addition to concerns about foreign exchange availability, there are several other issues that make switching to more conventional fuels problematic. One of these is the problem of assuring delivery of imported fuel resources (Leach and Mearns 1988, p. 244). Given that most Sahelian countries are landlocked, the delivery of imported fuel resources to interior urban centers is particularly difficult. Long distances from port locations, along with the poor state of transportation infrastructure, pose serious obstacles to making fossil fuel products accessible to these resource poor countries.

Assuming that a viable supply system existed to deliver alternative fuels to Sahelian consumers, another problem to be overcome is that of the additional costs associated with the use of fossil fuels. For example, the use of such fuels would require modern cooking and heating devices. Since incomes in Sahelian countries are generally low, most households cannot afford the large lump-sum investment in an expensive kerosene or gas cooker. In addition, due to the day-to-day functioning of most family budgets, higher occasional payments for utility bills or replacement gas bottles are more difficult to make than smaller, more frequent payments made to cover daily fuelwood needs.[3]

Fuelswitching strategies involving the use of renewable sources of energy have also been examined for potential application in the Sahelian region. A significant amount of research into solar, aeolian, and bio-gas digestion techniques has been carried out (Harrison 1987b). Although feasible in some cases (particularly small-scale applications), these renewable energy strategies have proven difficult to apply on a

[3] These budget problems, along with cultural preferences for firewood or charcoal to prepare local dishes, have been examined in Dakar, Senegal, by Tibesar and White (1985).

large-scale basis. In some instances (windmills for example), the initial costs of applying this technology have been prohibitive. Other difficulties have been encountered in terms of adapting renewable energy systems for use under local circumstances. Experiments with solar cooking devices in the Sahel have demonstrated that they are not particularly well-suited for meeting the requirements of preparing local foods (nor can they be used in sheltered areas or at night).

The success of fuelswitching interventions will be determined by the level of economic development in a given country as measured by national foreign currency reserves and consumer purchasing power. Unfortunately, the slow pace of economic development in the Sahelian region does not augur well for reducing fuelwood dependence through the substitution option.

The second strategy for addressing fuelwood deficiencies is that of energy conservation. In the Sahel, conservation of existing fuelwood resources is a somewhat foreign concept. Although most Sahelian fuel use is fairly judicious, no extraordinary attempts are currently being carried out to conserve what is considered by many outsiders to be a dwindling resource base. For the most part, this situation is due to indigenous perceptions of fuelwood scarcity. In contrast to estimates made by outside observers, the indigenous population does not necessarily view this resource scarcity to be as severe or critical (author's personal observations).

Nevertheless, programs have been initiated in Sahelian countries with the objective of conserving, or making more efficient use of fuelwood resources. These programs may be categorized under two basic types: the first deals with the dissemination of improved cooking devices (i.e., more efficient wood-burning stoves), and the second is concerned with the design of more efficient charcoal kilns (Gill 1987; Harrison 1987a; Krugmann 1988; and Meier and Munasinghe 1987).

The dissemination of improved cookstoves has been carried out through two types of programs. In the first case, stoves have been designed and constructed for the use of firewood in rural villages. These are made from local materials (usually a mixture of sand and clay) and built by the villagers themselves. The stoves are designed so that more heat energy is applied to cooking the meal, thus reducing the amount that is dissipated into the surrounding air. The construction of these cookstoves requires little or no cost to the builder/user, except for the opportunity cost of labor and time required to make the stove. The benefit of building an improved cookstove is expected to result in less time spent collecting firewood, and thus less wood consumed.

The second design is a metal cookstove intended for use by urban (mostly charcoal) consumers. The urban version of the improved cookstove is produced by local blacksmiths and sold in neighborhood markets. Through the use of the metal cookstove, charcoal consumers in urban areas are expected to realize a monetary savings per unit time in the amount of fuel required to meet their needs. The production of these stoves also provides a small degree of employment opportunity to local artisans, most of whom work in the so-called informal sector of the economy.

The specific design of improved charcoal kilns, unlike cookstoves, is as varied as the locations in which they are used (see Harrison 1987b). Improved kilns are expected to reduce the energy loss inherent in the carbonization process, thereby contributing to a reduction in deforestation rates. The use of these devices is marginal in most Sahelian countries, especially where materials for their construction must be imported. Currently, more research is required into the development of effective improved kilns made from less costly materials such as recycled metal products.

Evaluating the performance of the conservation intervention has proven to be quite difficult. No one knows for certain how many stoves have been built or sold, nor how much firewood or charcoal (or money) may have been saved by their use. Generally, the urban metal cookstoves have experienced greater popularity and success because they are relatively fuel efficient and, more importantly, show a tangible benefit to their user through reduced cash expenditure on fuel. On the other hand, the improved stove intended for use in villages has experienced several problems. Among the difficulties are 1) poor acceptance/usage rates, 2) poor fuel efficiency performance, 3) short life spans, and 4) less widely perceived benefit in terms of reducing amount of labor and time required to collect fuelwood.

Due to the difficulties in assessing the contribution that conservation measures have made to reducing fuelwood consumption, tentative conclusions indicate only that these measures are at best rather marginal. However, conservation measures should continue to be promoted as a corollary activity to other fuelwood-deficit reduction efforts.

The third strategy for reducing fuelwood deficits, and the one most germane to the present study, is the enhancement of the fuelwood supply. This approach addresses the problem of meeting urban fuelwood requirements through the establishment of plantations in the periphery of urban centers. There exists a wide range of studies on this topic (Anderson and Fishwick 1984; Floor and Gorse 1988; Anderson 1986; El-Hinnawi 1982; Tanticharoen and Gururaja 1982; Leach and Mearns 1988; Munslow et al., 1988; and Goor and Barney 1976).

There has been much debate concerning the advantages and disadvantages of promoting plantations for the express purpose of growing fuelwood. Among the benefits, the idea of reclaiming deforested lands in the urban periphery in order to meet an important need for urban energy supply would seem eminently sensible. Anderson (1986, p. 857) argues that due to rising scarcity prices of fuelwood, peri-urban plantations show potential for good financial and economic returns. Additional benefits that he cites include: 1) lower transport costs due to shorter distances between points of production and consumption, 2) regeneration and stabilization of biomass productivity in degraded areas, and 3) the potential for employment and income generation.

The disadvantages of fuelwood plantation development arise primarily from competition for other uses of land close to urban areas, large initial establishment costs, and competition from other sources of 'free' fuelwood, i.e., fuelwood for which the market price reflects little more than collection and transport costs (Anderson and Fishwick 1984; Elkan 1988). Other studies have noted problems related to improper species selection and climatic constraints such as rainfall variability in dryland environments (Catterson et al. 1984; Freeman and Resch 1985/86).

Despite these disadvantages, Anderson and Fishwick (1984) state that plantations for fuelwood, if appropriately located, have the potential to be economically viable. The task of the present study is to examine a method for determining where, and under what conditions, peri-urban fuelwood plantations could compete effectively with other agricultural land uses in order to satisfy the demand for energy in Sahelian urban centers.

Need for Present Study

It is evident from the literature that dependence on fuelwood energy in regions such as the West African Sahel is unlikely to diminish in the near future. However, research has also indicated that, under current conditions of resource exploitation, fuelwood dependence will exacerbate the problems of environmental degradation in rural areas while contributing to economic impoverishment in both rural and urban population sectors.

The review of strategies to redress the fuelwood deficit situation has indicated that: 1) the 'fuelswitching' option is unlikely to prove successful due to financial difficulties, and 2) conservation measures can be expected to have only a marginal effect on reducing fuelwood consumption. In contrast, the establishment of peri-urban plantations for the purpose of growing trees to meet urban energy needs may prove to be an economically viable solution. Although much work has been undertaken to detail the advantages and disadvantages of establishing peri-urban fuelwood plantations, little attention has been paid to the important question of where, in terms of the space economy, such plantations should be located.

There are two general issues involved in determining the best site for locating peri-urban fuelwood plantations. The first deals with the problem of site specificity related to the physical requirements of a selected tree species (soil type, rainfall, etc.), and the second relates to the competitiveness of a specific site for tree production with other potential land uses. This study will demonstrate one way in which the second issue may be addressed.

The literature has also indicated that the increasing distances between fuelwood collection and consumption sites is a major factor contributing to higher fuelwood prices and accelerated rates of deforestation and environmental degradation. It is suggested that the peri-urban plantation strategy can help to resolve this problem by investing in the rehabilitation of degraded lands on the periphery of urban areas. Such an intervention would follow in the spirit of Blaikie and Brookfield's idea of 'landesque capital', and represent an attempt at solving natural resource management issues within the framework of the regional political ecology concept.

The investment in a renewable resource, energy-producing forestry system would be consistent with the maintenance of land capability for future production. At the same time, this type of energy production system would present an opportunity to meet urban demand without sacrificing rural (and national) productive resources.

A spatial reorganization of the present system of fuelwood exploitation in the West African Sahel will have inevitable repercussions on the region's economic and ecological systems. It will also generate a set of social opportunities and constraints based on the dynamics of the land use decisions that will have to be implemented. This last issue will present new challenges to those responsible for determining natural resource management policy. This study will address these issues as well, attempting to describe some of the changes that can be expected in association with a shift in the location of fuelwood production.

CHAPTER III

METHODS AND DATA COLLECTION

While set within the theoretical framework of regional political ecology, this study approaches the more specific locational question of where peri-urban fuelwood plantations could be established. This is accomplished through the application of Johann H. von Thunen's model of agricultural land use as a method of analysis. Thunen is credited by many geographers as being the first to put forward a comprehensive theoretical model of agricultural land use. His original work, *The Isolated State*, was published in 1826. Thunen's work laid the foundation for numerous subsequent studies by economic geographers.[1] The first section of this chapter is devoted to a discussion of the Thunen model of agricultural land use and the rationale behind its application to this study as a method of analysis.

The second section of this chapter discusses the selection of data used in the analysis. Limitations inherent in the data due to secondary collection methods and applied assumptions are also mentioned. These assumptions have a critical bearing on the outcome of the data analysis, and therefore must be well understood in advance. Finally, the last section of this chapter explains the calculations that will be performed in the data analysis.

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[1] For a description of the Thunen model see: de Souza 1990; Conkling and Yeates 1976; Chisholm 1979; Dunn 1954; and Barlowe 1978. For a translation of Thunen's original work, *The Isolated State*, published in 1826, see Hall 1966. Examples of works applying Thunen's model include: Horvath 1969; Griffin 1973; Moran 1979; Peet 1969; Sinclair 1967; and Stevens and Lee 1979.

The Thunen Model as a Method of Analysis

By maintaining meticulously detailed records of his farming operations in the northern German state of Mecklenburg, Thunen formulated a model of the patterns of agricultural activity around a single market center. His idealized agricultural region is represented as a flat, featureless plain upon which a single mode of transport (horse-drawn cart) is used to bring crops to a central market from any and all directions. Land is deemed to be uniformly fertile, and all farmers are assumed to act in such as manner as to maximize their profits.

Departing from the Ricardian concept of 'economic rent', i.e., the difference in the net profits attributable to parcels of land inherently different in terms of fertility, Thunen developed an alternative view of this concept known as 'location rent'. Thunen considered location rent to represent the net revenue produced at a given site compared with the return generated by cultivation at the margin of production, i.e., where land is capable of yielding a return just sufficient to cover production expenses. The equation for determining location rent is given as follows:

$$R = E\,(p\text{-}c) - (E\,f\,k)$$

where R = location rent per unit of land
E = crop yield per unit of land
p = market price per unit of output
c = production cost per unit of output
f = transport rate per unit of distance per unit of output
k = distance to market.

This concept of location rent demonstrates how 'rent' is a function of distance from a market center. Essentially, rents decline with increasing distance from the market center until there is 'negative rent', i.e., beyond the spatial margin of profitability. In cases where more than one agricultural activity competes for the same parcel of land, the one that commands the highest rent will be deemed the best suited to occupy that location (see Figure 3.1).

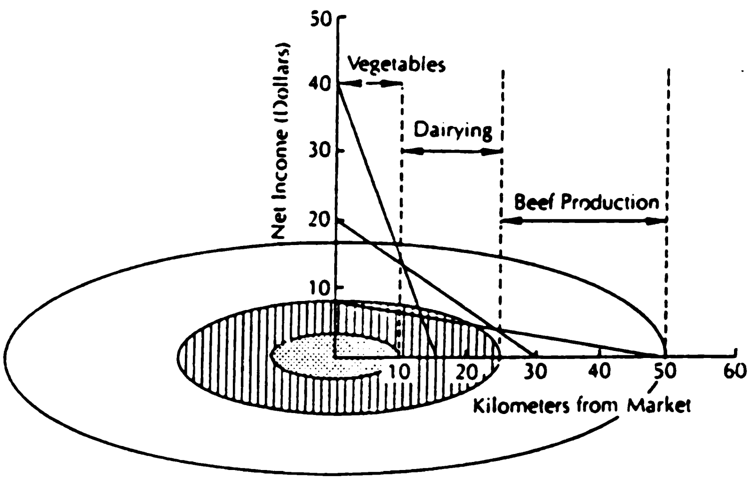

Figure 3.1 Location Rent Gradients for Competing Crops. Source: de Souza 1990

In Thunen's isolated state, the idealized pattern of land use is represented by a series of concentric circles around the market center (see Figure 3.2). The innermost zones include products that are perishable (e.g., fresh vegetables) or heavy and costly to transport in relation to their value (e.g., fuelwood and building lumber). Immediately beyond these inner zones, field crops are produced which employ less intensive methods of farming as distance from the market increases. Finally, forms of agricultural production that require extensive land, use such as livestock grazing, are located in the zone most distant from the market center.

This idealized pattern of agricultural land use is of course modified by real world situations. Thunen recognized that the concentric circles zonation would be

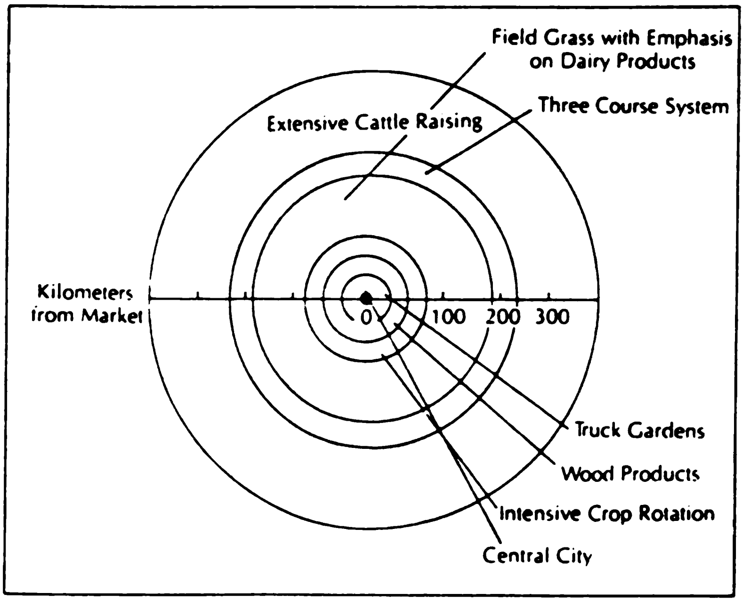

Figure 3.2 Land Use Zones in Thunen's Isolated State
Source: de Souza 1990

altered by many different factors. Among these he discussed the effects of competing secondary market centers, as well as improved transportation systems, e.g., navigable rivers, which reduce shipment costs compared to overland carts.

Given present-day industrial economies, the land use zones of Thunen's Isolated State are not necessarily reflected in modern agricultural land use patterns. In particular, Thunen's location of a forest products zone might seem somewhat anomalous as modern societies have acquired new sources of energy. However, for the towns of early nineteenth-century Germany, nearby forests were an important source of building materials and fuel. Today, in industrial economies with improved transportation systems, higher transportation costs to move forest products over longer distances have been compensated for through economies of scale and regional comparative advantages in modern production processes. Hence, a forested zone surrounding a major urban settlement in today's industrial nation would more likely be attributed to aesthetic reforestation than to a source area for fuel and building supplies. It is argued, however, that the current status of economic development in most developing countries may explain certain resemblances to nineteenth century Europe in terms of the patterns of agricultural activity surrounding urban centers (Sinclair 1967, p. 73).

In a study by Horvath (1969), the author describes agricultural land use patterns found around the capital city of Addis Ababa, Ethiopia. The results of his study suggest an interesting parallel between the pattern of agricultural zonation in the Addis Ababa area and that of the idealized Thunen model. Among his findings, Horvath noted a forested zone of *Eucalyptus* surrounding the city which served to meet the needs for fuelwood and building materials. In addition, the study described the elongated shape of this forested land as it extends along the areas surrounding an improved transportation artery. Although Horvath had to adapt some of the basic assumptions of the Thunen model to fit the situation found in the Addis Ababa study area (e.g., lack of the flat featureless plain around the city), his work is a good example of how this model can be applied in the context of an urban area in the developing world.

Despite the many studies undertaken which have built upon Thunen's work, there is still a certain degree of debate as to whether his model is basically descriptive or normative in nature (Harvey 1966, p. 363). Chisholm (1979, p. 14) has discussed how Thunen's model can be seen as an analytical method of general applicability, one that is essentially a normative statement on the form of the agricultural landscape, according to certain assumptions. Sinclair (1967) would concur, arguing especially for the validity of applying the Thunen model to agricultural zones around urban centers in less developed countries. It is in such cases, Sinclair states, that Thunen's assumptions and driving forces, i.e., transport costs as a function of distance, continue to operate as primary factors in shaping the patterns of agricultural land use.

From the preceding discussion it is argued that Thunen's model can be adapted to help determine viable locations for peri-urban plantations in present-day Sahelian countries. Where the cost of fuelwood in urban markets is directly influenced by distance-related transport costs, Thunen's model should be able to provide some useful insight into answering the question of where fuelwood plantations could be located.

Data Collection

The determination of the best location for a peri-urban fuelwood plantation, according to the Thunen location rent equation, requires data for agricultural land uses surrounding a selected market center. In this study, data are examined for a set of agricultural crops from an agro-ecological zone typical of the West African Sahel. In addition, hypothetical data based on estimates for plantation forestry under similar conditions are presented.

Data on agricultural products are given for the Fifth Administrative Region of Mali, which has as its main market and administrative center the town of Mopti, located on the Niger River (see Figure 3.3). The selection of this agricultural market center for the current study is based on the availability of recently collected (secondary) farm-level data, and the fact that ecological conditions and fuelwood dependence in the Mopti region are representative of the Sahelian agro-ecological zone.

The Mopti region covers a total land area of approximately 77,800 km^2, and is situated between 14 and 16 degrees north latitude, and 4 and 6 degrees west longitude (Henry de Frahan et al. 1989). The climate is representative of the Sahelian and the

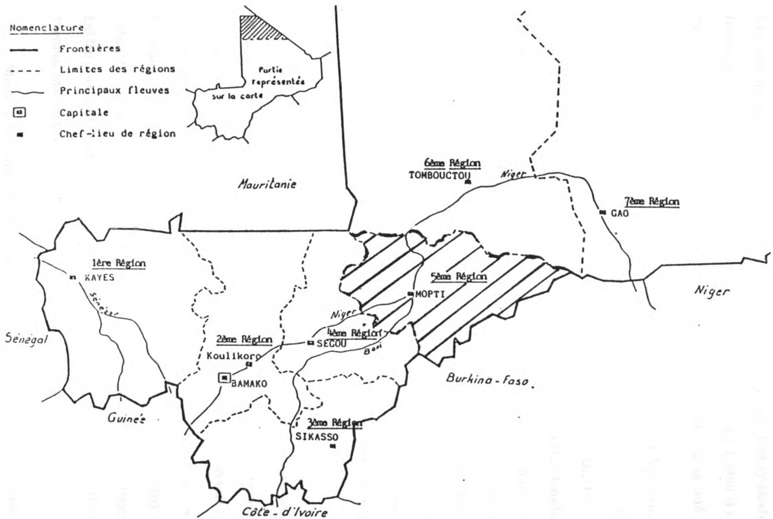

Figure 3.3 Administrative Map of Mali
Source: Henry de Frahan et al. 1989

Sudano-Sahelian ecological zones, with annual rainfall ranging from 200 to 600 mm. Clay soils predominate in the inland delta area of the Niger, with mostly sandy soils found throughout the remainder of the region. The economy of the region is based essentially on the primary activities of crop production, livestock raising, and fishing.

Crop data used in this study are from the Malian Ministry of Agriculture (Republique du Mali 1989), and two other sources (Henry de Frahan et al. 1989; Stryker et al. 1987). In order to calculate rent gradients according to the Thunen equation, figures are given for the following variables: 1) crop yield in tons/hectare, 2) market price per ton of crop, 3) total production costs per ton of crop, and 4) an estimated freight rate for transporting crops to market. The crops for which data are available in the aforementioned sources include rice, millet, maize, groundnuts, and cotton. Production of most crops involves techniques such as the use of improved seed varieties, some use of chemical fertilizers, and the rotation of crops from one growing season to the next. In some cases, particularly flooded rice cultivation, animal traction is used.

Data for yields and production costs of plantation-produced fuelwood are highly variable depending on the source of data. In most instances, data are generalized and reported in terms of cost per hectare of production, or unit weight or volume of product, without reference to the yield realized or species grown - factors which vary widely from one location to another. Wardle and Palmieri (1981), and Foley (1986), have indicated that there is a dearth of reliable data regarding the true value of fuelwood, its hidden costs (related to the free good notion), and the numerous factors that influence eventual market prices.

Many factors must be taken into account in order to arrive at a reliable estimation of the expected costs of production and potential yields. These include physical conditions such as soil properties, irrigation versus rain-fed production, and fertilizer use. Other important factors relate to species selection, stocking rate, the degree of mechanization used versus manual labor employed, and whether or not multiple products (such as building materials, fruits, gums, resins, etc.) are expected to accrue from the production system.

In light of the lack of reliable data for plantation costs of fuelwood in the Sahelian region, hypothetical data are developed for this study based on a range of figures generally cited in the literature. Extreme caution must be used in any attempt to interpret the results generated by the analysis of such data. The data for the hypothetical fuelwood plantation do not necessarily represent site-specific conditions of the agro-ecological zone of the Mopti region; they are at best general approximations. In addition, the range of production cost figures is rather wide (from US$ 500 to US$ 1,300 per hectare). Although the reliability of the data is questionable, the analysis of such a wide range of values may generate some important information regarding the conditions under which fuelwood plantations would be feasible.

For the purposes of this study, the data for the cost of plantation-produced fuelwood reflect a range of figures cited by Floor and Gorse (1988), and Anderson and Fishwick (1984). This range varies from US$ 500 to US$ 1,300 per hectare for plantation-produced *Eucalyptus* species that are widely promoted in dryland environments such as the Sahel. Over this range, three production cost scenarios are devised based on arbitrarily selected values of US$ 500, US$ 1,000, and US$ 1,300 per hectare, representing 'low', 'medium' and 'high' cost situations respectively. The dollar amounts are converted into local currency (the Franc CFA) in order to allow for comparison with the data on agricultural crops.

Furthermore, it is assumed in this study that fuelwood production takes place in a *taungya*[2] agroforestry system. Earl (1975, pp. 52 & 71) states that the implementation of the *taungya* method is an effective, indeed almost essential, means by which the high establishment costs of fuelwood plantations can be compensated for. The production of agricultural crops interspersed between trees during the early stages of plantation development results in a substantially reduced final cost per unit of fuelwood. For example, Weinstabel (1984) describes how a similar intervention in Burkina Faso turned a net loss fuelwood-only plantation scheme into a net gain agroforesty system. Earl has estimated that by using the *taungya* method, plantation fuelwood costs per ton of wood can be as low as 50 percent of the costs of producing fuelwood alone. Hence, the production costs given for the three plantation scenarios in this study are recalculated to adjust for fuelwood produced in an agroforestry system affording maximum financial benefit from associated crop production according to Earl. It must be pointed out that this assumption may not necessarily hold for present conditions in the Sahelian region, despite Weinstabel's supporting evidence. Much would depend on the specific crop components, prevailing local market prices, and site-specific physical conditions of the particular agroforestry system.

Yield estimates for *Eucalyptus* plantations in the Sahelian ecological zone used in this study reflect the median to lower values of the expected range for this environment, according to data from the National Academy of Sciences (1980), and Anderson and Fishwick (1984). The use of moderate yield estimates in the analysis should more closely represent actual conditions. The best estimate available for a fuelwood freight rate is given by Shaikh (1985), and assumes the use of large-capacity

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2 *Taungya*, a form of intercropping, refers to a system of establishing forest plantations whereby agricultural crops, e.g., groundnuts, cowpeas, etc., are grown between the newly planted trees until the canopy is closed.

vehicles on paved surfaces. Again, caution is required in the use of this information. Transportation in the Sahel is very difficult and variable according to seasonal conditions. Shaikh's estimate may very well underestimate actual transport costs.

The determination of an estimated market price for plantation-produced fuelwood presents another type of problem. Under the current fuelwood exploitation and marketing structure in most Sahelian countries, market prices for fuelwood are, relatively speaking, so low that peri-urban plantations would be infeasible. However, if it is assumed that wood energy is perfectly substitutable for kerosene, then a shadow price for fuelwood can be derived by equalizing the costs of these energy sources in terms of delivered energy content (see Christophersen and Karch 1988, pp. 31-32). Shadow pricing is frequently used as a means of determining the intrinsic value of wood energy. The derived increase in the fuelwood price has the effect of rendering plantation production systems economically feasible.

Given the assumptions made in the preceding paragraph, a shadow market price for fuelwood is used in the present analysis. The calculation of this price, detailed in the next chapter, is based on an assumed retail price for the kerosene energy substitute, calorific energy conversions between kerosene and wood, and estimated thermal efficiencies of both kerosene and wood cooking devices.

Calculations Used in the Analysis of Data

There are two calculations performed in the next chapter in order to determine locational characteristics of the hypothetical fuelwood plantation. The first is based on Thunen's location rent equation (p. 42). Subject to this equation, rent gradients for the various agricultural and tree products are derived in order to determine the resultant patterns of land uses generated by the model. This procedure will help to ascertain the best location for fuelwood production relative to the location of the market and other agricultural land uses in the urban periphery.

A second calculation is performed in order to determine the location of the 'firewood/charcoal calorific threshold'. Poulsen (1978, p. 15) has noted that in a wood-based urban energy production system a decisive point will be reached, in terms of transportation costs, where an equal amount of energy (in calorific terms) can be delivered to the market less expensively in the form of charcoal as opposed to firewood. This is due mainly to the fact that per unit weight, charcoal provides approximately twice as much useful energy (Earl 1975). This point can be considered as a 'firewood/charcoal calorific threshold'. The location of this threshold is important in that it determines the form in which fuelwood should ultimately be marketed based on transportation costs and distance to market. Furthermore, knowledge of where this threshold is located can provide useful information for resource management strategies. This is particularly important due to the larger area of forested land cleared to produce charcoal versus firewood.

To summarize, the procedures followed in this study entail the analysis of data on agricultural crops produced in the Fifth Region of Mali, along with estimated data for a hypothetical peri-urban fuelwood plantation. Rent gradients are calculated for all crops and fuelwood using the equation for location rent derived from the Thunen model of agricultural land use. The analysis of the resultant crop patterns will help to answer the question of where to locate fuelwood production in an economically viable fashion. The determination of this location will provide some insight into answering other questions, referred to in the previous chapters, related to the economic, ecological, and social ramifications of an altered spatial pattern of fuelwood production.

CHAPTER IV

ANALYSIS OF DATA

This chapter first presents data for agricultural crops produced in the Fifth Region of Mali, as well as data for fuelwood production in the hypothetical peri-urban plantation. An explanation is given detailing how production costs and market price for the fuelwood 'crop' were estimated. Second, rent gradients are calculated and presented for each crop, including plantation-produced fuelwood. The rent gradients, calculated according to the Thunen model, are used to display the theoretical zonation pattern of these crops. Third, based on the calculated rent gradients, the best location for plantation fuelwood production is then determined. Fourth, the location of the firewood/charcoal calorific threshold is determined through an analysis of fuelwood production and transportation costs. Locating this threshold provides further insight into the ecological ramifications of the peri-urban fuelwood plantation system based on the form in which fuelwood should be produced. Finally, a preliminary interpretation of the results of the data analysis is offered.

Agricultural Crop Data

In Table 4.1, figures for yield, market price, production cost, and freight rate are listed for five crops cultivated in the Mopti region. The data, collected during the 1986-87 agricultural campaign, are based on estimates for production using improved manual techniques and the sale of produce in the Mopti market. The freight rate estimate is given for transportation costs via paved surfaces, and therefore should be considered an underestimate since many farms are not located near modern transport arteries.[1]

[1] The equal freight rates for all crops is not explained by the data source. In reality, these rates can be expected to vary according to factors such as the bulkiness of product, season, road conditions, and the demand for transportation.

Table 4.1 - Agricultural Crop Data

Crop	Yield (ton/ha)	Mkt. Price[1] (thousand CFA/ton)	Prod. Cost[1] (thousand CFA/ton)	Frt. Rate (CFA/ton/km)
Cotton	1.2	330	318	25
Groundnuts	1.0	115	104	25
Maize	1.6	66	65	25
Millet	0.8	64	60	25
Rice	0.7	143	126	25

[1] Market prices and production costs are given in local currency, Franc CFA (Communaute Financiere Africaine), $1 U.S. = 270 F CFA approx. (1986).

Sources: Republique du Mali 1989, Henry de Frahan et al. 1989, and Stryker et al. 1987.

Fuelwood Data

As mentioned in chapter three, the determination of production costs for fuelwood grown in a plantation setting depends on many factors, e.g., species planted, soils, rainfall, and local labor costs. Plantation establishment in a semi-arid location such as the Sahel is very tenuous, particularly in light of environmental uncertainties such as highly variable rainfall. Thus, production costs may vary widely depending on local conditions within the Sahel. The figures used here for fuelwood production costs represent a range of possible scenarios for a plantation system in the Sahelian environment.

Floor and Gorse (1988) have suggested that plantation costs in the semi-arid environment of the Sahel can range between US$500-1,000 per hectare. Anderson and Fishwick (1984) have stated that this cost may reach as high as US$1,300 per hectare. These are the assumed total costs per hectare over the entire initial rotation period (approximately 8-10 years) for a typical dryland tree species such as *Eucalyptus* *camuldalensis*. Included in the total for the initial rotation are the costs of tree seedlings, ground preparation, planting, maintenance, and interest on capital.

In Table 4.2, the total costs of fuelwood production (per ton of product) are presented for several hypothetical *Eucalyptus* plantations based on three arbitrary levels of assumed cost per hectare: US$ 1,300, 1,000, and 500 respectively. These figures represent 'high', 'medium' and 'low' cost scenarios. The total cost per ton of fuelwood is given for production both with and without using a *Taungya* system. The two yield figures provided represent more modest harvest estimates expected from *Eucalyptus* plantations in semi-arid regions, reflecting the lower end of a commonly-cited range of between 2.0 and 11.0 tons/ha (National Academy of Sciences 1980; Anderson and Fishwick 1984). The transportation cost (freight rate) given in the table is an estimate from Shaikh (1985), and assumes the use of large-capacity vehicles on paved surfaces. Again, estimates for yield and freight rate are used with caution as actual figures may be quite different.

Table 4.2 - Estimated Fuelwood Plantation Costs

Scenario #1 - High cost: assuming US$1,300/ha (US$1 = 270 F CFA)

Expected yield	3.0 tons/ha
Total production costs without *Taungya*	117,000 F CFA/ton
Total production costs with *Taungya*	58,500 F CFA/ton
Freight rate	40 CFA/ton/km
Expected yield	5.0 tons/ha
Total production costs without *Taungya*	70,200 F CFA/ton
Total production costs with *Taungya*	35,100 F CFA/ton
Freight rate	40 CFA/ton/km

Scenario #2 - Med. cost: assuming US$1,000/ha (US$1 = 270 F CFA)

Expected yield	3.0 tons/ha
Total production costs without *Taungya*	90,000 F CFA/ton
Total production costs with *Taungya*	45,000 F CFA/ton
Freight rate	40 CFA/ton/km
Expected yield	5.0 tons/ha
Total production costs without *Taungya*	54,000 F CFA/ton
Total production costs with *Taungya*	27,000 F CFA/ton
Freight rate	40 CFA/ton/km

Scenario #3 - Low cost: assuming US$500/ha (US$1 = 270 F CFA)

Expected yield	3.0 tons/ha
Total production costs without *Taungya*	45,000 F CFA/ton
Total production costs with *Taungya*	22,500 F CFA/ton
Freight rate	40 CFA/ton/km
Expected yield	5.0 tons/ha
Total production costs without *Taungya*	27,000 F CFA/ton
Total production costs with *Taungya*	13,500 F CFA/ton
Freight rate	40 CFA/ton/km

Sources: According to estimates from Floor & Gorse 1988, Anderson & Fishwick 1984, Earl 1975, and Shaikh 1985.

Determining the market price of fuelwood for this analysis poses a difficult problem. Since fuelwood sold in Sahelian urban markets does not reflect the replacement cost of wood, i.e., the cost of growing a tree to replace one cut down, it is not possible to empirically determine a market price for plantation-produced fuelwood. Currently, fuelwood prices cited for Sahelian cities vary widely. For example, prices range from approximately 4,600 F CFA/ton in Mopti (Christophersen & Karch 1988), to 15,400 F CFA/ton in Dakar (Leach & Mearns 1988), to as much as 27,000 F CFA/ton in Ouagadougou (Bertrand 1985/86). Based on these prices, and the costs of producing fuelwood in plantations as shown in Table 4.2, it would appear that, in most cases, growing wood for fuel in plantations would not be economically viable.

However, it is possible to determine a market price for fuelwood based on an alternative method. Since energy used for domestic purposes is considered as a basic human need, demand for fuelwood can be considered fairly price inelastic (Meier & Munasinghe 1987, p. 127). Theoretically, plantation-produced fuelwood sales would be viable as long as the price is lower than that of the next best energy substitute, e.g., kerosene.

The estimated market price for plantation-produced fuelwood may be deemed more competitive if wood energy is assumed to be perfectly substitutable for imported kerosene.[2] Christophersen and Karch (1988) point out that a "shadow price" can be derived for fuelwood, vis-a-vis kerosene, by equalizing the cost of the two energy sources in terms of energy content delivered. It is argued that the shadow price of fuelwood more accurately reflects its replacement cost and intrinsic value as a source of

[2] In most cases, kerosene is considered to be the next fuel up the "energy ladder" following fuelwood. Households with a regular, sufficient income are expected to switch to using kerosene, assuming supply is regularly maintained.

energy in comparison to imported energy products that require foreign exchange expenditures.

Table 4.3 indicates the shadow price of fuelwood based on two different estimates for the price of imported kerosene. To perform the calculation, one must determine the relative cost of producing an equal amount of useful energy from kerosene vis-a-vis fuelwood. One litre of kerosene contains approximately 10,500 kilocalories of energy (Christophersen and Karch 1988). One ton of dry wood contains approximately 4.7 million kilocalories (Earl 1975). It is assumed that kerosene used for cooking has a thermal efficiency of approximately 50%, i.e., half of the energy produced actually cooks the food, and half is dissipated. It is also assumed that the thermal efficiency of a typical improved wood-burning stove is approximately 25%. Hence, the kerosene stove is considered to be twice as efficient as the wood-burning stove.

Table 4.3 - Shadow Price for Fuelwood Based on Kerosene Substitute

Assume:	Kerosene	Fuelwood
Retail price (FCFA/litre)	120	n.a.
Calorific value (kcal)	10,500/litre	$4.7 * 10^6$/ton
Kerosene equivalent/ton fuelwood (litres)	448	n.a.
Kerosene equivalent price (FCFA)	53,760	n.a.
Shadow price (FCFA/ton)		26,880*
Shadow price assuming kerosene retailing @ FCFA 150/litre		33,600*

* n.b.: Since the kerosene stove efficiency is twice that of the wood-burning stove, it is necessary to divide the kerosene equivalent price by two to determine the fuelwood shadow price.

Sources: Christophersen & Karch 1988, and Earl 1975.

The increased estimated market price for fuelwood reflected in its shadow price (Table 4.3) should make peri-urban plantation production more economically attractive with respect to the production cost figures in Table 4.2.

Calculation of Rent Gradients

Using the location rent equation outlined in chapter three, ($R = E(p-c) - Efd$), rent gradients for the five agricultural crops are calculated. Table 4.4 gives the maximum R values (maximum net revenue when distance equals zero), and the maximum distances from the market at which profitable production takes place (maximum distance when R = 0, i.e., the margin of profitable production).

Table 4.4 - Maximum Rent and Distance for Crops

Crop	Max. Rent (CFA/ha)	Max. Dist. (km)
Cotton	14,400	480
Groundnuts	11,000	440
Maize	1,600	40
Millet	3,200	160
Rice	11,900	680

The results obtained in Table 4.4 are used in constructing the rent gradients in Figure 4.1. When the rent gradients are examined for these crops in competition with each other, it is noted that only two of the five crops (cotton and rice) would actually be cultivated according to the Thunen principle of highest and best use. Groundnuts, millet, and maize are all effectively 'outbid' by either cotton or rice.[3] In this particular case, cotton would be the most profitable land use of all crops up to a distance of 200

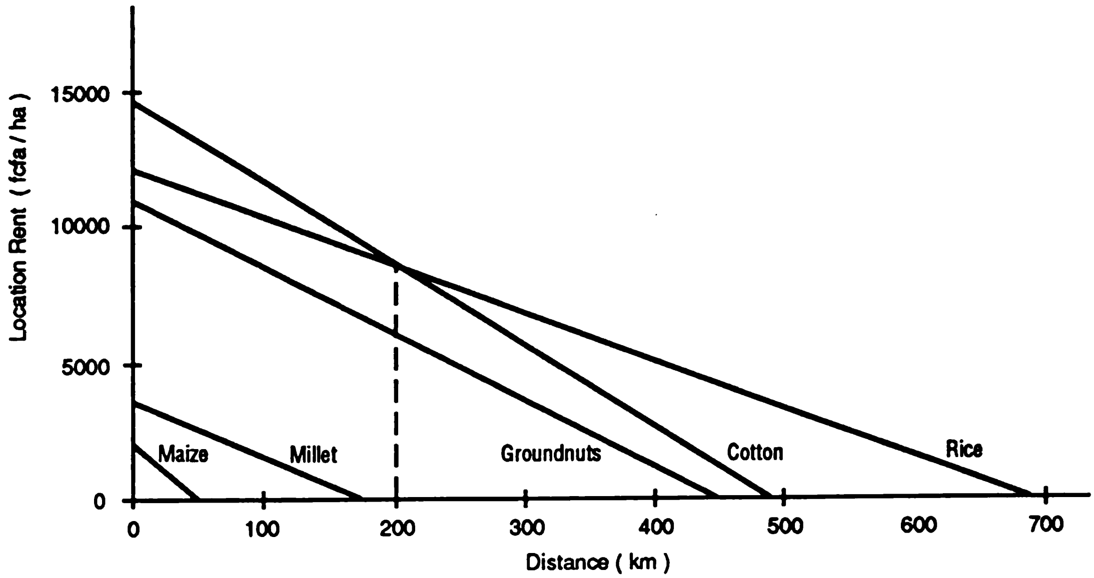

Figure 4.1 Rent Gradients for Agricultural Crops

km from the market. At this point, the 'break-even' point (or margin of transference) between cotton and rice is reached and the location rent for the two crops is exactly the same. Beyond 200 km from the market, rice would become the most profitable crop to cultivate, able to outbid all other crops up to a maximum distance of 680 km from the market.

The crop zonation pattern suggested by Figure 4.1 does not accurately reflect that of current agricultural production in the Mopti administrative region. Cotton and rice are not, of course, the only crops produced. Groundnuts, millet, and maize are also produced, the former as an important cash crop and the latter two as significant food crops.

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[3] Rent gradients are sometimes referred to as 'bid-rent' curves.

There are many factors that influence the spatial pattern of crop production in the Mopti region (Thom & Wells 1987, pp. 333-338). For example, rice cultivation takes place predominantly in the inland delta area of the Niger River, where production depends highly on seasonal flooding of the river valley. The cultivation of groundnuts, millet, and maize is dependant for the most part on rain-fed production systems, and is marked by extensive agricultural practices at the margins of the inland delta. Thus, the spatial variability of production factors, e.g., soils, drainage, relief, etc., have a major impact on the actual patterns of agricultural activity in the Mopti region.

In addition to the physical factors affecting crop production patterns, certain aspects of the Malian agricultural economy can also influence the outcome of which crops are ultimately produced. For example, the predominant position of cotton in the modeled agricultural space economy (Figure 4.1) is explained in part by its high market price relative to the other commodities (cotton is Mali's most important agricultural export). The fact that rice figures as an important staple food in cities and towns in Mali helps to explain its relatively important position as the next most competitive crop after cotton in the zone less than 200 km from the market.

Although the modeled spatial zonation of crop production does not match that of the actual patterns observed in the Mopti region, the theoretical rent gradients are still useful in the process of determining the best location for fuelwood production in the agricultural space economy. Although based on assumptions of the Thunen model which do not hold in the Mopti region, e.g., equal soil fertility in all areas, the rent gradients provide useful information regarding how these crops would compete economically with fuelwood. The analysis now turns to examining the rent gradients for several fuelwood plantation scenarios.

Based on the data for estimated fuelwood plantation costs in a *Taungya* production system (Table 4.2) and fuelwood shadow prices (Table 4.3), there are five possible conditions under which plantation production would be profitable.. Whether or not production is viable is determined by various combinations of yield, market price, and production cost factors. The five cases in which production is economically feasible are summarized below in Table 4.5.

Table 4.5 - Conditions for Profitable Plantation Production

Case No.	Yield (ton/ha)	Price (CFA/ton)	Cost (CFA/ton)
1	3.0	26,880	22,500
2	3.0	33,600	22,500
3	5.0	26,880	13,500
4	5.0	33,600	27,000
5	5.0	33,600	13,500

In Table 4.5, cases one and two are based on the lower expected fuelwood yield (3.0 tons/ha) and the low production cost (scenario #3 @ 22,500 FCFA/ton) from the range noted in Table 4.2 above. The first two cases differ in the market price for fuelwood, i.e., the shadow price. Case one is based on an assumed retail price for kerosene of 120 CFA/litre (26,880 FCFA/ton) - consider this the 'base shadow price', whereas in case two the retail price is based on 150 CFA/litre (33,600 FCFA/ton), representing a 25 percent increase. Case three is based on the higher fuelwood yield (5.0 tons/ha), the base shadow price of 26,880 FCFA/ton, and low production cost (scenario #3 in Table 4.2). Finally, cases four and five are similar in terms of yield (5.0 tons/ha) and fuelwood price (33,600 FCFA/ton). However, the last two cases differ in terms of plantation costs. Case four is based on the medium plantation cost, whereas case five reflects the low plantation cost (scenarios #2 and #3 respectively from Table 4.2).

Based on the various factors of yield, price, and costs summarized in Table 4.5, maximum rent and distance figures are calculated and listed in Table 4.6 below. The results are used to construct rent gradients for each fuelwood plantation scenario. The rent gradients are plotted in Figure 4.2.

Table 4.6 - Maximum Rent and Distance for Fuelwood Plantations

Case No.	Max. Rent (CFA/ha)	Max. Dist. (km)
1	13,140	110
2	33,300	278
3	66,900	335
4	33,000	165
5	100,500	503

According to the rent gradients in Figure 4.2, the fuelwood plantation cases with the highest net revenues and most extensive production 'cones' (rings circumscribed around the market center by the rent curves) are, in decreasing order, numbers five, three, two, four, and one. Higher expected yield (5.0 tons/ha) and associated low production costs explain the positions of the margin of production for cases five and three, at 503 and 335 km from the market respectively. Case number five also displays the effect of the higher fuelwood shadow price. Despite the low yield figure for case two (3.0 tons/ha), a higher shadow price and low production cost effectively extend the margin of production for this case to 278 km from the market. Due to a higher production cost, case number four has a smaller production cone, profitable up to 165 km from the market. Finally, although case number one reflects a low production cost, the lower expected yield and base shadow price restrict profitable production to a distance of only 110 km from the market.

The next step of the analysis entails the determination of the best location for the siting of the peri-urban fuelwood plantation according to the results obtained to this point. In order to do this, the rent gradients for agricultural crops and fuelwood are plotted onto the same graph (see Figure 4.3).

It is apparent from the results of combining the two sets of rent gradients that, with the exception of case one, all fuelwood plantation scenarios would be able to

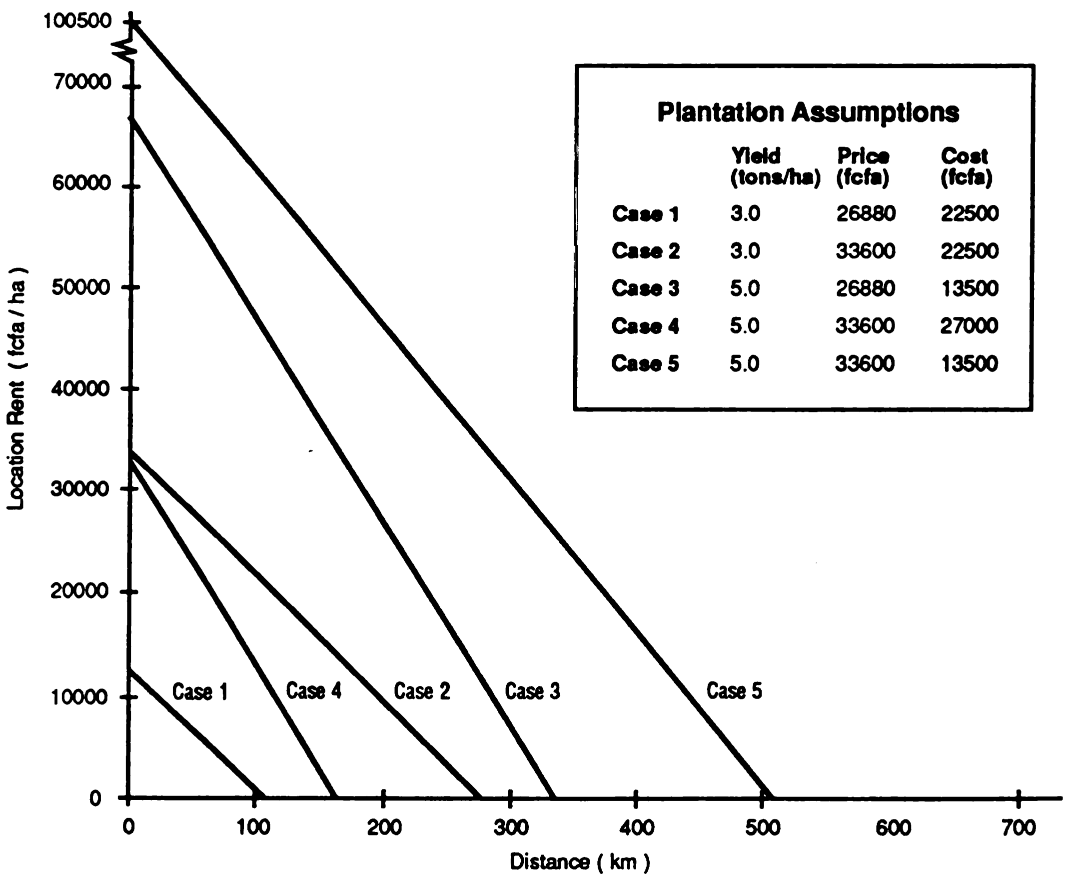

Figure 4.2 Rent Gradients for Fuelwood Plantations

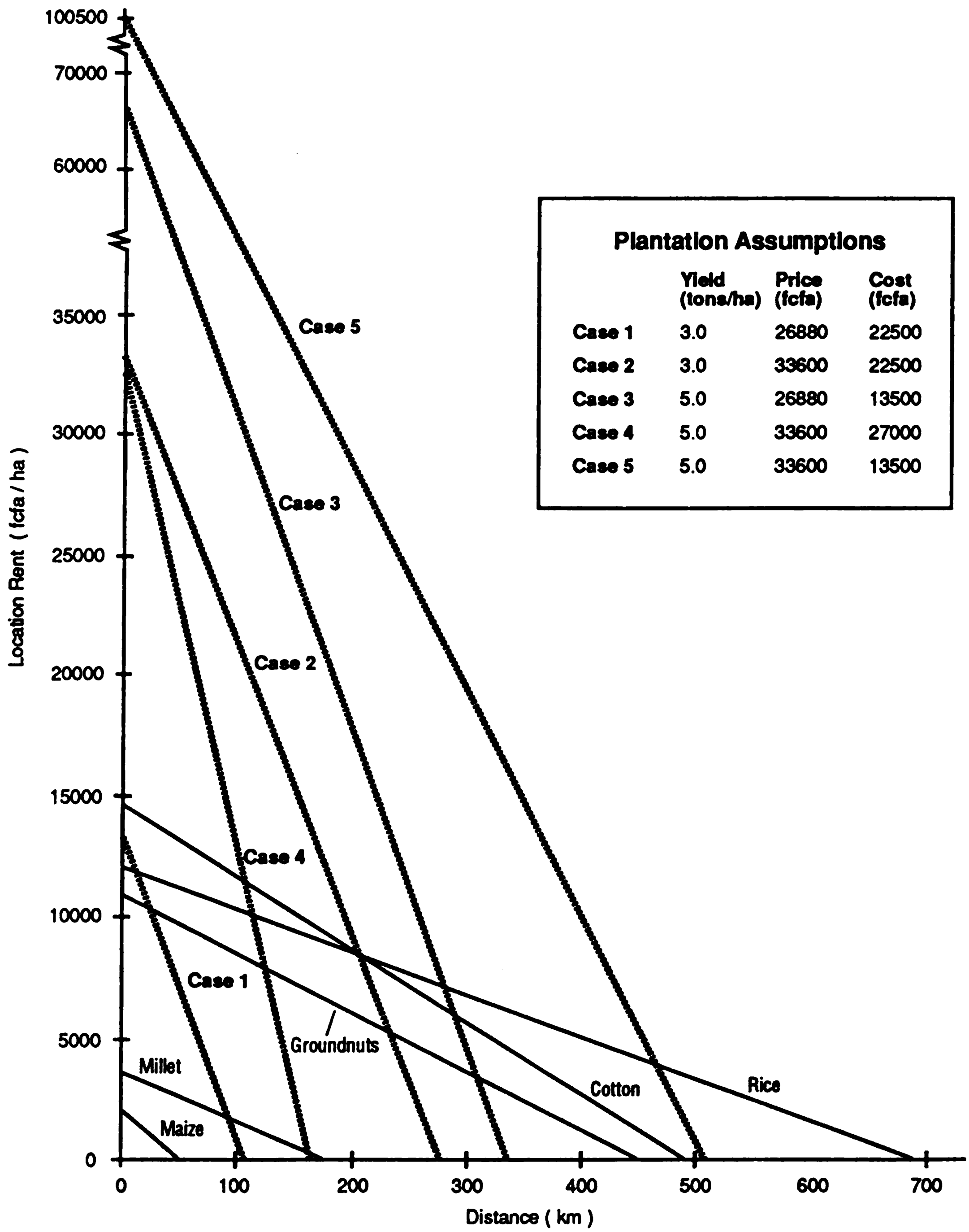

Figure 4.3 Combined Rent Gradients

compete effectively with all other agricultural land uses presented in this market area. Case one would not be able to compete with cotton production at any location, but could outbid rice, groundnuts, and millet for distances of up to approximately 12, 23, and 100 km from the market respectively.

Among the plantation scenarios that compete successfully with the other agricultural crops, it can be argued that either case four or case one would be the most plausible outcome. Cases two, three, and five are all predicated on the lowest possible production costs, in addition to either a higher yield (case #3), market price (case #2), or both (case #5). For these reasons it can be assumed that cases two, three, and five are all unrealistic outcomes considering Sahelian conditions.

Although case four is based on both higher yield and price, it may be more realistic to assume this outcome due to the higher production cost figure (scenario #2 from Table 4.2). Calculations also show that case four could compete at a lower shadow price of at least 29,880 CFA/ton (approximately 11 percent increase over the assumed base price), albeit over a smaller area. Despite the fact that case one (as in cases 2, 3, & 5) is also based on a low production cost assumption, it may be even more realistic to expect this outcome over that of case four based on lower yield and price factors. However, in order for case one to be able to outbid cotton, and rice for more that just the area within the closest proximity to the market (approximately 0-12 km), its rent gradient calculation would require an increase in the shadow price to a minimum level of 27,300 CFA/ton, an increase of approximately 1.6 percent above the assumed base shadow price (see gradient 1' in Figure 4.4). Nevertheless, based on these assumptions cases one and four appear to be more likely outcomes than the remaining cases.

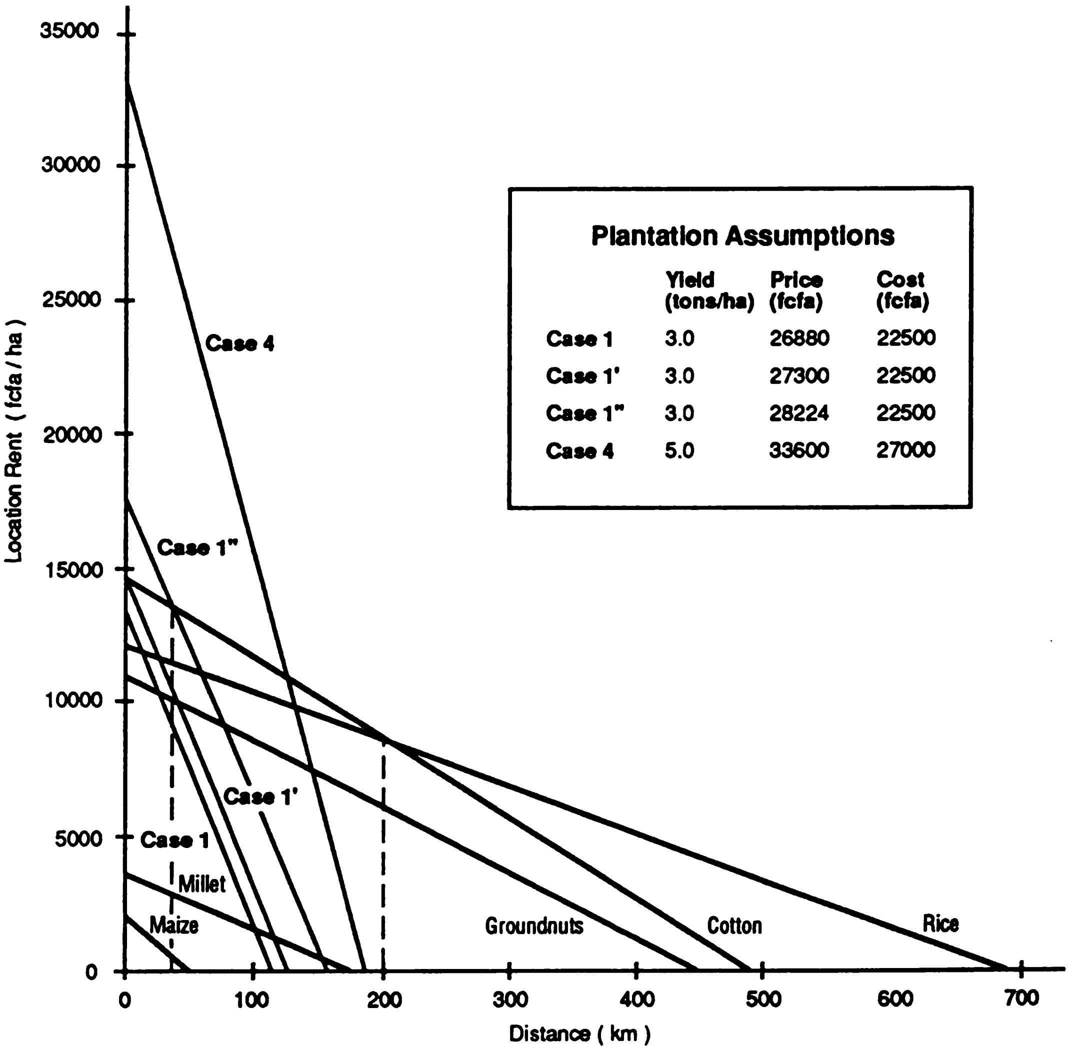

Figure 4.4 Optimal Fuelwood Plantation Rent Gradients

Assuming that case one, if modified by an increase of 5 percent above the base shadow price to 28,224 CFA/ton (in order that it might compete more effectively with cotton - see rent gradient 1"), is the most likely fuelwood plantation to succeed, it can be concluded that plantation-produced fuelwood, in this particular space economy, would be the optimal land use in the annulus located between 0 and approximately 31 km from the market.[4] In the remaining zones of this modeled market area cotton and rice would be produced. Cotton production would be the best land use in the annulus located between 31 and 200 km from the market. Following cotton, rice would be the best suited crop for production in the annulus located between 200 and 680 km from the market.

In light of this hypothetical analysis, it should be recalled that the actual locations of crop production under real-world conditions will be greatly influenced by physical and socio-economic factors not accounted for by the basic model conditions. As has been noted for the case of agricultural production in the Mopti region, different crops tend to be produced in their own specific 'spatial niches'. Therefore, the optimal location for fuelwood production as determined by this analysis may vary substantially depending upon prevailing local conditions.

Locating the Firewood/Charcoal Threshold

As mentioned earlier in this study, determining the location of an economically viable peri-urban fuelwood plantation is only one element in the analysis of this type of urban energy production system. A second element that needs to be addressed is the

[4] The 31 km limit of fuelwood production is determined by calculating the "break-even point" between fuelwood production and the next most profitable land use, which in this case is cotton. The break-even point represents the distance from the market at which adjacent land uses generate equal location rents.

form in which fuelwood will ultimately be produced, i.e., firewood or charcoal. This entails determination of the firewood/charcoal calorific threshold.

This location is important in that, due to energy loss in the carbonization process and the wood-to-charcoal conversion factor, charcoal production can contribute significantly to increased rates of deforestation in the source area (or increased rates of harvested acreage in plantations). It should be pointed out, however, that locating the firewood/charcoal threshold is of greater importance when dealing with traditional methods of forest clearance for fuelwood production. For example, in cases where the cost of wood does not reflect its intrinsic value, the transportation costs of bringing fuelwood to market constitute a major percentage of final market price - up to 50 percent in some instances (Leach and Mearns 1988). In plantation situations, the fact that wood bears a higher, more realistic production cost reduces the percentage of the final retail price attributable to transport costs. Nevertheless, in situations where transport costs are relatively high, it is important to determine the location of the firewood/charcoal threshold and attempt to plan for the production of wood within this limit.

To determine the location of the firewood/charcoal threshold, data are required on the costs of producing firewood and charcoal in terms of equal amounts of energy content. In addition, a freight rate for transporting the fuelwood to market must be known. Using the data for production cost and freight rate from plantation case number one from the previous section, the firewood/charcoal threshold for this best-case scenario is determined below.

The first step in determining the firewood/charcoal threshold is to calculate the production costs of both firewood and charcoal in terms of a common energy equivalent. Table 4.7 gives these costs per ton of coal equivalent (CE), based on a conversion factor of three tons dry wood to one ton of charcoal (Earl (1975) estimates this ratio at 4:1; Poulsen (1978) at from 2:1 to 4:1, depending on tree species and moisture content).

Table 4.7 - Production Cost of Firewood and Charcoal Per Ton CE Energy*

Production Costs	Firewood	Charcoal
CFA/ton (raw wood)	22,500	67,500
CFA/ton CE	33,075	65,475

* Based on the following energy equivalents:

1 ton CE = $6.9 * 10^6$ kcal
1 ton dry wood = $4.7 * 10^6$ kcal
1 ton charcoal = $7.1 * 10^6$ kcal

note: 1.47 ton firewood/ton CE and .97 ton charcoal/ton CE

Based on the costs of firewood and charcoal per ton CE, and using the freight rate of 40 CFA/ton/km (from Table 4.2), the firewood/charcoal calorific threshold would be located at a distance of 1620 km from the market.[5] To demonstrate how this threshold point is sensitive to changes in transport costs, a second threshold value is calculated based on a doubling of the freight rate. In this case, a freight rate of 80 CFA/ton/km would result in a firewood/charcoal threshold located approximately 810 km from the point of consumption. Hence, a doubling of the freight rate results in halving the distance between the market and the firewood/charcoal threshold.

[5] The equation for determining the firewood/charcoal threshold is as follows: PROD. COST WOOD/TON CE + (1.47 TON WOOD/TON CE * 40 CFA/TON WOOD/KM * KM) = PROD. COST CHAR./TON CE + (.97 TON CHAR./TON CE * 40 CFA/TON CHAR./KM * KM). Solving for KM (distance) will determine the location of the threshold.

According to these results, it is abundantly clear that fuelwood produced under the scenario presented by case number one would be more economical to supply in the form of firewood rather than charcoal. This would be true at any location within the zone of profitable production. The location of this firewood/charcoal threshold is significant in that under this particular set of conditions for production and transportation costs, the harvesting of fuelwood should take place in a sustainable fashion without adverse effects on the surrounding environment. However, in some circumstances consumer preference for charcoal over firewood, particularly in crowded, enclosed urban conditions, can influence the form in which the fuel is actually marketed.

Preliminary Interpretation of Results

The primary question posed in this study relates to the determination of where, in terms of the agricultural space economy, peri-urban fuelwood plantations could be successfully located. According to the Thunen analysis for agricultural crop data and the hypothetical fuelwood plantation considered for the Fifth Region of Mali, the results demonstrate that, under certain assumed conditions, plantation-produced fuelwood can compete with other agricultural land uses and be cultivated in an area proximate to the consuming market. This suggests that it may be possible to alter the production system from the current practice of fuelwood mining in remaining forested areas distant from the market, to one in which fuelwood is produced on a competitive, sustainable yield basis in the urban periphery.

Before any definitive conclusions are reached, however, it is imperative to point out two critical sets of issues. First, the Thunen analysis in this case study is capable only of providing a general sense of where, in terms of location rent, fuelwood could be produced competitively in the area around the market center. There is no accounting for site-specific factors, e.g., soil quality, water availability, etc., related to the production of a given selected tree species. In addition, there are other competing uses of land on the urban periphery which have not been dealt with in this analysis. The potential for truck gardening, housing development, and other commercial uses of land must be assessed in addition to the agricultural land uses discussed in this study.

A second set of issues, closely related to the first, concerns the assumptions used for the fuelwood data in this analysis (as well as the agricultural crop data). The success of any given fuelwood plantation scenario will ultimately depend on the reliability and accuracy of the corresponding data. The data used for the hypothetical *Eucalyptus* plantation are at best rough estimates, and may not adequately reflect the local conditions of this study area. For example, the low production cost figure used for plantation case one would most likely require that optimal site-specific physical requirements for tree growth be met. In addition, favorable labor and capital costs would be necessary in order to attain such low total production costs. The rate of compensation provided by the implementation of a *Taungya* system is also a point of concern. Although considered a valid and tested procedure, the benefit from this type of agroforestry intervention is highly dependent on site-specific conditions. Whether these requirements and assumptions are realistic for the difficult conditions extant in the Sahelian environment must be carefully scrutinized.

Another assumption made in the analysis of plantation case number one (i.e., rent gradient 1" in Figure 4.4) regarding the estimated market price must be considered. The value used in the location rent equation for case 1" is based on a value 5 percent above the estimated base shadow price of fuelwood.[6] Depending on the price stability of kerosene, it is by no means certain that fuelwood priced at this level would still be competitive. Although the fuelwood price figure used is 5 percent above the shadow price, plantation case number one could still compete with cotton production (although over a much smaller area) at a market price of just over 1.56 percent above the base shadow price (see gradient 1'). In addition, any incremental increase in the production cost and/or reduction in price figures would effectively decrease the competitiveness of the fuelwood crop in this scenario. The low yield in the rent equation is probably the most reliable of the figures used; however, this too depends on the site-specific characteristics of the production system. Because of imperfections in available fuelwood data, an attempt has been made to maintain as conservative an approach as possible in selecting price, cost, and yield criteria upon which the decision of the best plantation scenario is made. Avoiding the selection of plantation parameters that would be unlikely to obtain in the Sahelian environment provides for as realistic an outcome as possible.

Noting these provisos and caveats, one could cautiously state that there is potential for the establishment of a peri-urban fuelwood plantation at some location in close proximity (0-31 km) to the urban market. This would be considered a desirable improvement over a fuelwood production system represented by the collection of 'free' resources at greater distances from the point of consumption. However, the benefits obtained from reduced environmental degradation in rural forested areas (coupled with any downstream benefits to the national economy through improved agricultural production) would need to be estimated and compared to the increased costs to consumers of plantation-produced fuelwood (coupled with any other costs, e.g., benefits

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[6] Whether or not this price for fuelwood would engender a switch to kerosene would still depend on other factors, such as the regular supply of this alternative fuel and the users' ability to purchase the appropriate cooking devices.

foregone from alternative land uses) in order to arrive at some reasonable societal-level benefit-cost analysis of such as spatial reorganization of the fuelwood production system. An attempt must be made to establish some quantitative valuation of these externalities and incorporate them into the overarching social benefit-cost analysis. It should be understood, however, that the data collection task thus required would be extraordinary in most developing-country situations.

The results of the data analysis given in this chapter have shown that establishing fuelwood plantations in proximity to urban centers, rather than mining forested rural areas to meet urban demand for energy could, under certain circumstances, be economically feasible. The next chapter will proceed to evaluate the use of the Thunen model in this particular application. In addition, Chapter V will elaborate on the brief interpretation of the results discussed up to this point, emphasizing the secondary questions of this study concerned with the economic impact, ecological ramifications, and social constraints and opportunities of a different spatial pattern of fuelwood production.

CHAPTER V

DISCUSSION

The first section of this chapter evaluates the use of the Thunen model as a method of analysis for determining the possible location of peri-urban fuelwood plantations. Following this, the evaluation of the results obtained in the previous chapter is elaborated upon in terms of the secondary questions raised by this study. The discussion explores in greater detail the economic impact, ecological ramifications, and social constraints and opportunities that could be expected to follow from a potential spatial reorganization of fuelwood production. Finally, policy problems associated with such a change in the location of fuelwood production are briefly examined. These issues are discussed in the context of the 'regional political ecology' framework mentioned earlier in the study (see page 7).

Evaluation of the Thunen Model Application

In evaluating the use of the Thunen model as a method of analysis for determining the location of peri-urban fuelwood plantations, it is important to realize certain key limitations imposed by the model's assumptions.

First, as was demonstrated by the analysis of crop data for the Mopti region of Mali, factors related to the natural environment have a major impact on the spatial pattern of agricultural land use. Whereas the Thunen model assumes uniform fertility of the land, the actual pattern observed in the Mopti case is determined in greater part by variability in land suitability rather than comparative location rent values. In the same way that rice, millet, and maize occupy certain locations due to physical factors, the siting of a given tree species in a plantation situation will also depend on specific natural conditions. Obviously, the Thunen model, as it is commonly applied, does not take into consideration the important effects on land use imposed by the physical characteristics of land resources. It is only when assumptions of the model are relaxed that influences of real-world conditions can be examined.

Second, the crop zonation patterns observed in Thunen's base model result from the interaction of a single market center with its complementary agricultural region. The possibilities, however, for trade and exchange outside the "isolated state" may strongly influence actual crop production patterns. In the case of the Mopti region, linkages with the greater Malian and West African markets would appear to have an affect on the type and extent to which certain crops are produced within the region. In the case of fuelwood, it would be necessary to attempt to determine the degree to which production might be influenced by these external linkages.

Third, Thunen's model is based on land use around a static urban market center with relatively stable boundaries. However, with urban expansion as a dynamic process occurring over space and through time, the spread of non-agricultural land uses around the urban fringe influences the uses to which such land will be put. Hence, land in peri-urban environs has an opportunity cost associated with it that is not taken into account when determining its best agricultural use based on Thunen's model.

This is an important factor to consider when attempting to determine the best location for peri-urban fuelwood plantations. Plantation development requires a long-term investment in land, which is subject to various other non-agricultural uses as urban centers continue to expand rapidly as is the case in the Sahel today. However, Earl offers some thoughts regarding the decision making process involved in weighing the opportunity cost of land against the consideration of plantation establishment. He states that if the provision of fuelwood is regarded as a

> social function of the state (through the medium of the forest service), an expected financial return from plantations approaching the marginal cost of capital should be sufficient justification for the establishment of fuelwood plantation schemes....[since] the economic or social rate of return would be normally expected to be much higher (Earl 1975, p. 91).

This outlook on the role of the state is consistent with the regional political ecology concept as it relates to the allocation of land-based resources for societal benefit.

Despite the limitations noted above, applying Thunen's model to the locational analysis of peri-urban plantations does provide useful information for establishing fuelwood as a crop in the agricultural space economy. This is particularly the case with regard to determining the parameters under which fuelwood plantations could compete with other agricultural land uses. Based on the analysis of the data for the Mopti region, the results give a fairly clear indication of the plantation yield, market price, and production cost conditions that must be met in order for plantations to be viable and occupy a location in proximity to the urban center.

In addition to the information provided on yield, cost, and price factors, the Thunen model is particularly well-adapted to explain patterns of agricultural land use based on transportation costs. Indeed, Thunen's arguments for the agricultural zonation patterns he observed in his time were based on transportation costs, as a function of distance from the market, as the primary force determining such patterns.

The importance of transportation costs as a factor in fuelwood exploitation is clearly stated in this study. Under the present conditions of fuelwood collection in remote forested areas, transportation costs bear directly on increasing market prices for energy in the urban centers of the Sahel. In addition, it has been demonstrated how transportation costs as a function of distance affect the form in which fuelwood is marketed. Greater distances from market and higher transportation costs eventually result in crossing the firewood/charcoal threshold, which in turn results in accelerated rates of deforestation and environmental degradation.

As Sinclair (1967, p. 76) has noted, where the condition of transportation infrastructure in the developing world today resembles that of Europe and North America in the last century, it is likely that the Thunen principles of agricultural land use are still applicable. Therefore, where transportation costs are essentially proportional to distance and a factor of bulk, as they are for fuelwood, one could expect to discover zones of forest products in relative proximity to the urban market. This pattern is evident in Thunen's observations as reported in the *Isolated State* (Hall 1966), as well as in Horvath's (1968) contemporary study of the zonation of agricultural land use around Addis Ababa, Ethiopia. According to the steeper rent gradients obtained in this study for fuelwood plantations vis-a-vis other crops (see Figure 4.3), it is evident that higher transportation costs for fuelwood would restrict this land use to areas closer to the market.

It is important, however, to note that factors associated with the dynamics of urban land use may reduce the attractiveness of establishing peri-urban plantations. Although siting plantations close to urban markets is expected to reduce the transport costs of fuelwood, plantations may lose their economic feasibility as urban areas continue to grow. Rising land values, wage rates, and the profitability of alternative uses of land can quickly erode the feasibility of peri-urban plantations. The opportunity costs of other non-agricultural land uses also need to be considered for the zone determined best-suited for fuelwood production.

Finally, in much the same way that Thunen himself proceeded, it would be interesting to attempt to determine how relaxing the model's assumptions would affect the location of peri-urban plantations in the Sahel. For example, in Thunen's consideration of a navigable river (or other transportation improvement) traversing the flat plain, he concluded that the concentric ring pattern would be altered to the effect that land use zones would be elongated roughly parallel to the direction of the transportation artery. In many instances, Sahelian cities are located such that they are positioned along rivers (e.g., Bamako, St. Louis (Senegal), Mopti, Niamey) or at various points along the region's rail lines (e.g., Dakar, Bamako, Ouagadougou).

Economic Impacts of Fuelwood Plantations

Economic analysis of the establishment of peri-urban fuelwood plantations should attempt to take into consideration the cost and benefit flows attributable to this type of energy production and resource management intervention.

In terms of the economic impact resulting from the establishment of a peri-urban fuelwood plantation, the most obvious statement that can be made is that fuelwood prices in the urban market must rise in order for plantations to be viable.[1] Changing from a system of depletive resource 'mining' to more sustainable, regenerative production practices will require that the price paid for this renewable energy resource reflects more accurately the cost of its replacement. The ability of urban fuelwood consumers to pay more for their energy needs is, of course, related to the broader issue of increased economic development in a given country. It is beyond the scope of this study to investigate the dynamics of national economic growth in developing countries. However, the spatial reorganization of fuelwood production systems in such countries will likely impose additional economic (and perhaps political) difficulties on the urban populace.

[1] Prices should be expected to rise with or without plantations, as distance to the market increases. However, overall societal costs due to degradative 'mining' could be much higher than the cost of adjusting to higher-priced, plantation-produced fuelwood.

In considering the energy needs of the Sahelian population, fuelwood should be thought of as a locally available renewable energy for these resource-poor countries which lack the financial means to make the switch to fossil fuels. Although rural populations may satisfy their energy requirements from their immediate surroundings, urban dwellers must acquire their fuel needs from the land-based capital stocks of forest resources in rural areas. However, energy derived from these natural resources obviates the need to depend upon imported petroleum products, which are acquired only at great expense to the national treasury. Therefore, the development of sustainable supplies of wood-based fuels could form the basis for meeting the short-to-medium term energy requirements of Sahelian countries. Despite the image of fuelwood use in developing countries as representing a "bondage to a past that is unacceptable" (Goodman 1987, p. 112), such use may be ultimately easier to secure than fossil fuels which require substantial expenditures of foreign exchange. Hence, developing systems of fuelwood production in the urban periphery could be a cost effective means of securing necessary energy supplies.

If the above statements are considered from the perspective of the regional political ecology concept, then one can observe the linkages that exist between the political economy of energy supply and the issue of effective natural resource management. Unable to increase their consumption of fossil fuels due to economic constraints, Sahelian countries continue to rely on fuelwood. As tree stocks are depleted in the areas closest to growing urban centers, the increasing demand for fuel must be met by harvesting the extant supply of energy in the forests of the hinterland. Rather than making an investment in 'landesque capital', i.e., reforestation, the remaining resources are mined with little consideration for the effects this has on the ecological destruction of productive agricultural lands, increasing energy costs to urban consumers, or the overall stability of the national economy.

As an alternative to depletive resource use, peri-urban plantations, where feasible, should be encouraged as a means of meeting energy demand. Situated in a suitable location proximate to urban markets, such plantations would have the potential to 1) correct the inequities of supplying urban areas with energy at the expense of rural populations, 2) stabilize the processes of environmental degradation, 3) improve the potential productivity of predominantly rural-based economies, and 4) reduce dependence on prohibitively expensive petroleum imports. It would appear that such an alternative system distributes its benefits in an equitable fashion.

As a final note on the economic impact of peri-urban fuelwood plantations, it should be pointed out that it remains unclear as to exactly who will be able, or willing, to make the required investment in this type of energy production system. One might consider it to be the role of the state to assure the establishment of such landesque capital through forestry interventions. However, much remains to be investigated regarding this point. Questions on issues such as subsidies to potential plantation investors, taxation policy, and what, if any, pricing mechanisms should be considered will need to be explored. To date, the public and parastatal sectors in Africa have not performed very well. Nevertheless, due to the natural resource and planning policy decisions required in order to establish peri-urban plantations, there will inevitably be a role for the state to play in such undertakings.

Ecological Considerations

The establishment of fuelwood plantations in areas surrounding Sahelian urban centers has the potential to produce a dual response in environmental rehabilitation. A shift in the spatial pattern of production for urban supply from a primarily rural-based operation to a peri-urban one could generate ecologically beneficial results for both environments. This change would represent a major improvement over the currently expanding limits of degraded lands surrounding urban centers, and the increasingly vulnerable resources of rural areas.

Assuming that plantations can be developed in areas of the urban periphery previously devoid of forest cover, their establishment should produce some regenerative benefits. Erosion control, soil stabilization, and microclimate improvement are some of the secondary benefits that can be expected to accompany plantation development. While such benefits accrue to the areas in proximity to the peri-urban plantations, concurrent ecological improvements could be realized in the previously exploited rural areas. Assuming that the amount of fuelwood produced in plantations is sufficient to meet most of the urban demand, forested zones in rural areas should benefit from lower rates of deforestation than are currently experienced. A situation in which the M.A.I. (mean annual increment) of forest growth approaches the annual harvested cut required to meet rural needs would be a positive sign of moving toward achieving an ecologically stable situation. Under current conditions, according to Anderson (1987, p.7), demand exceeds M.A.I. of growth by approximately 30 percent in most Sahelian countries; however, severe levels of off-take are evident in Niger where demand exceeds M.A.I. by 200 percent!

Experiments with greenbelt projects around Ouagadougou, Burkina Faso (Weinstabel 1984), demonstrate that increasing the amount of woody biomass around the city contributes to soil erosion control and the reduction of wind-blown sand and silt pollution in the built-up areas. The reestablishing of vegetation cover on degraded land is aided by the development of a humus layer resulting from tree litter. The root systems of trees and shrubs also contribute to better water retention in the surface layers of the soil.

Additional ecological benefits would most likely accrue from the application of agroforestry techniques in peri-urban plantations. Agroforestry systems seek to optimize the positive interactions between the various components (e.g., crops, trees, animals) in order to achieve a more productive and protective, i.e. sustainable, output from the land than would be achieved through conventional agricultural practices. As already mentioned in this study, agroforestry techniques are virtually an *a priori* requirement for achieving economic feasibility in this type of land use investment. Several studies support this position (Arnold 1983; Harou 1983; and Hoekstra 1983a, 1983b). In addition, the contributions of an agroforestry approach to ecologically sustainable land use and fuelwood energy production have been the focus of numerous studies (NAS 1983b; Winterbottom & Hazlewood 1987; Repetto 1987; Cook & Grut 1989; and Weinstabel 1982, 1984).

An example of the ecological benefits of an agroforestry intervention in the Sahel is the intentional planting of *Acacia senegal*, more commonly known as gum arabic, within a traditional farming system (Pearce 1988). This leguminous species is well-adapted to the semi-arid ecological Sahelian zone, and provides a range of products and services. For instance, fodder is provided for domestic animals, fuelwood for cooking, and gum arabic as a marketable commodity. In addition, soil stabilization and nitrogen fixation help to improve field conditions and yields for the crop component of the system.

Social Constraints and Opportunities

Relocating the production of fuelwood energy for urban areas from distant rural locations to plantation schemes surrounding towns and cities will impose certain social opportunities and constraints on the nations of the Sahel. The composition of groups currently involved in fuelwood exploitation may change considerably with a shift in the focus of activity from rural to peri-urban zones. These changes would most likely have the greatest effect on employment and investment patterns in the fuelwood business. The focus of activity would of necessity shift from rural forest collection areas to more formally controlled peri-urban production sites. As it currently stands in many Sahelian countries, much of the fuelwood industry is considered to belong to the informal or 'dual' sector of the economy. As a part of the informal sector, there are large numbers of people employed as occasional, seasonal workers in this activity. This is significant for Sahelian countries in which unemployment and underemployment are relatively high. A change in the location of fuelwood production (with its opportunities and constraints) must take into consideration the impact such a change will have on the status of the employment picture.

The changes that take place when the provision of fuelwood energy switches from household collection to that of a monetized good were discussed earlier in this study. Formerly a 'free good' (opportunity costs aside), fuelwood becomes a marketable commodity for which city dwellers are required to devote a portion of their cash expenditures. As this transformation takes place, a complex production and marketing apparatus forms to supply growing urban centers. The stages in the process include the production (felling of trees and conversion to charcoal), transportation to market, and distribution of product from fuelwood wholesalers to retailers throughout the neighborhoods of Sahelian cities and towns.

Studies related to urban fuelwood markets in the Sahel have looked at the nature and composition of the marketing and distribution channels which have developed to supply urban centers (Ribot 1989; Republique du Burkina Faso 1987). Ribot's study of the charcoal market in Senegal indicates that a significant number of people in rural areas are employed (mostly seasonally) in the fuelwood production stage, while large numbers in urban areas are involved in the wholesale and retail stages.

Shifting fuelwood production activities to peri-urban locations will obviously reduce off-farm employment possibilities for rural villagers. Whether this change should be looked upon as depriving the villager of opportunity is debatable. Involvement in fuelwood production does represent an occasion for earning cash to supplement farm incomes. However, wages paid to rural workers are comparatively low, and the fuelwood merchant is not particularly concerned with reforestation activities once all the harvestable wood has been collected. In effect, rural farmers are cutting down trees for a relatively small profit, while contributing to environmental degradation and their own impoverishment in the process. Low rural wages and the frequent evasion or non-payment of stumpage fees[2] result, in effect, in a subsidy on the price of fuelwood to urban consumers made at the expense of the rural population.

According to the regional political ecology framework, this exploitation of the rural environment for the benefit of providing energy to urban areas is a good example of an urban bias in the dialectic between society and land-based resources. The allocation of forest resources to meet urban needs, without compensatory action, i.e., reforestation, results in the reduction of the productive capacity of rural populations. The service functions of forested land which benefit rural agriculture, e.g., erosion control and nitrogen fixation, are foregone when there is no effective management policy in place (or enforced) to protect the land-based capital of rural populations.

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[2] Stumpage fees are intended as a 'clearance fee' or tax, payable by those involved in the exploitation of fuelwood resources. The official government agency responsible for regulating forestry-related activities is usually charged with collecting the stumpage fee. However, payment of this tax is frequently circumvented (see Ribot 1989).

Peri-urban fuelwood plantations would indirectly serve to correct some of the urban bias in resource allocation mentioned above. The establishment of a sustainable production system closer to urban markets could result in a stage of environmental recuperation in degraded rural areas, while at the same time contribute to the restoration of previously degraded areas surrounding urban centers. Peri-urban plantations would also generate employment opportunities for some of the unemployed now crowding into the already saturated urban job market.

Policy Problems

In proposing an alternative to fuelwood mining in rural areas, this study has shown that any new system must be economically viable, technically feasible, and socially acceptable. In addition, the alternative system must be institutionally supported. The neglect of this last factor can easily lead to the failure of the proposed alternative. Bromley, as cited in Southgate and Hitzhusen (1987, p. 77), states that

> the disappointing performance of many Third World environmental projects is explained by the fact that those projects usually do little to alter the incentives existing under prevailing institutional regimes to manage resources in a depletive fashion.

It can be argued that Bromley's point has been proven correct in projects related to the forestry sector in the Sahel, as well as in other parts of Africa, particularly at the village level. Village-level woodlots have been promoted in Sahelian countries as a means of securing adequate fuel supplies as well as the ecological benefits accruing from trees. However, these projects frequently fail to achieve their expected results (Brokensha & Castro 1984; Fortmann 1985; and Skutch 1983). Many projects fail because the intended beneficiaries, i.e. the rural population, are not convinced that the investment required of them (financial or in-kind) is worthy of the risk. Under the severe conditions of the Sahel, it is understandable that rural peasants would be risk averse. In addition, factors such as the lack of institutionally secured land tenure rights (Thomson 1981), and the relatively poor relationship between rural farmers and the police-like structure of many African forestry departments (Shaikh 1985/86, pp. 51-3) contribute to project failure.

The issue of institutional support (i.e. political sanction) for peri-urban fuelwood plantations will be as important here as in the case of the village-level situation mentioned above. It is clear that in order to develop a sustainable energy supply system based on fuelwood, the unpleasant political reality of higher prices will have to be defended. In addition, stricter enforcement of measures designed to protect the remaining stocks of forested land will be required. An increase in market price for fuelwood is likely to encourage more tree cutting outside formal plantation channels. The control of untaxed fuelwood transiting into Sahelian cities is already a major problem. The potential for corruption and mismanagement will present difficult challenges to the political structures in the Sahel.

The discussion in this chapter points out that, despite some of its limiting assumptions, the Thunen model of agricultural land use can provide useful information when applied as a method of analysis to determine the best location for peri-urban fuelwood plantations. Its application assists in determining the economic parameters under which fuelwood production could compete with other agricultural crops, and it gives some indication as to the location of such land use. Although the model does not effectively consider the important physical requirements of plantation establishment, nor the dynamic processes of urban expansion and their effect on peri-urban land use, it does demonstrate how transportation costs would effect the location of various agricultural land uses including fuelwood production.

This chapter has also considered the economic, ecological, social, and policy implications of a locational shift in fuelwood production. Despite the high financial cost involved in producing fuelwood in a plantation scheme, and the fact that these costs would have to be borne ultimately by urban energy consumers, it would appear that a spatial reorganization of wood-based energy production might result in greater economic benefit to society at large. Provided that sustainable production systems of this renewable energy resource can be established, with the requisite political support such an endeavor would demand, a return on investment to the national economies of Sahelian countries should be realized in the form of higher agricultural productivity and a more stable ecological balance.

CHAPTER VI

SUMMARY AND CONCLUSIONS

According to the literature reviewed at the outset of this study it is clear that Sahelian countries will continue to depend on wood-based energy for some time to come. The fuelswitching strategy discussed in chapter two can only begin to take effect when higher levels of economic growth are reached. The prospects for this taking place in the debt ridden, resource poor countries of West Africa in the near future are dismal at best. In addition, the implementation of energy conservation measures such as the dissemination of improved cookstoves, while a positive step in the right direction, can only be expected to contribute in an complementary fashion to reducing the rapidly growing deficit between fuelwood production and consumption.

In contrast to fuelswitching and conservation measures, fuelwood supply enhancement strategies may be able to effectively respond to meeting the energy requirements of Sahelian cities and towns. Under certain conditions, such strategies may also be able to contribute to stabilizing the degradative processes currently afflicting the fragile ecological balance of the Sahel. The establishment of peri-urban fuelwood plantations may be one option capable of producing wood-based energy in the quantity that will be required to meet growing urban demands.

The actual establishment of peri-urban fuelwood plantations will depend on meeting an array of prerequisite conditions. First, a consensus must be reached on the part of political decision makers that such an approach should be carried out for reasons that it is in the long-term best interests of society. The imperative of reversing the pattern of depletive resource exploitation, and in turn investing in productive and protective land uses must be a set precondition by which resource allocation decisions can be guided. The idea of landesque capital investment, which seeks to safeguard the productive capacity of land-based resources for future social and economic benefit, provides a useful framework from within which these land use decisions can be made. From this perspective, plantation development must be seen as an investment geared not only toward assuring a supply of energy, but also as an effective means of securing future agricultural productivity and hence economic development.

Second, a decision to proceed with a peri-urban fuelwood plantation strategy must be subjected to a method of locational analysis in order to determine where this type of land use could be established under economically viable conditions. This study has endeavored to demonstrate how the principles of the Thunen model of agricultural land use could be employed to determine the best location for this use.

Third, a technical feasibility study will be required that is capable of combining the information obtained from the economic-locational analysis with site-specific physical requirements for plantation establishment. Although this point seems blatantly obvious, there have been previous instances in which such feasibility studies failed to generate a satisfactory physical data base (Freeman and Resch 1985/86). The results of such poor project planning can be disastrous in terms of wasting scarce financial resources.

The location analysis undertaken in this study has generated some potentially useful information regarding the siting of peri-urban fuelwood plantations. Although the data used were for the most part hypothetical, and thus must be interpreted with extreme caution, the results of the location rent analysis indicate fairly clearly the conditions under which plantations would most likely be able to compete in the peri-urban space economy. In light of the poor natural resource base and difficult prevailing economic situation in the Sahel, the scope for viable peri-urban plantation development may be very limited.

From the analysis it can be concluded that the economic feasibility of any particular fuelwood plantation scheme will be subject to 1) future prices obtained for fuelwood as well as alternative fuels such as kerosene, 2) attainable fuelwood yields, 3) level of returns from associated agroforestry crop components (e.g., from a *Taungya* intercropping system) which affect total production costs, and 4) potential competition from other uses of land in the peri-urban environment. It is also apparent from the analysis that, even under favorable price conditions, fuelwood production is likely to be restricted to land relatively close to the market center. This may prove to be problematic under conditions of dynamic urban growth, particularly in light of the long-term investment required for establishing plantations.

Having established the important economic parameters associated with the production of fuelwood in peri-urban plantations, this study proceeded to consider several additional factors related to potential changes in the Sahelian urban energy supply system. The present discussion has illustrated that fuelwood resource exploitation is not restricted simply to an energy supply issue. It is a complex, interrelated phenomenon that is best examined in the context of an energy-economy-environment nexus incorporating societal and political factors of natural resource management. Regional political ecology theory enables the complexity of the fuelwood problem to be addressed in a systematic, integrated fashion because it provides an holistic framework from within which analysis of the related social, political, ecological and technical factors of fuelwood production can be undertaken.

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