Fuelwood and Land Use in West Africa: Understanding the Past To Prepare for the Future

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Executive Summary

Using historical models of fuelwood supply and demand, researchers concluded that there would be a widespread “fuelwood crisis” or “fuelwood gap” in West Africa by 2000. Although there currently is increased scarcity, evidenced by long travel distances for fuelwood collection, there is no widespread shortage.

The models that anticipated a shortage suffer from two deficiencies: underestimates of supply and fixed per-capita estimates of fuelwood demand. Fuelwood supplies in natural woodlands are 2–5 times greater than the estimates of the 1960s and 1970s, and the demand for fuelwood varies with its scarcity and other factors. Alternative fuels, more efficient woodstoves, and a decrease in cooking all reduce demand for fuelwood. In addition, there are new supplies of fuelwood from individual or community-managed forests.

Efforts to reduce demand through distribution of more efficient stoves have had limited success, and fuel savings under experimental conditions tend to be greater than actual savings. An increase in income can increase fuelwood use as people cook more, or it can reduce fuelwood use as they switch to higher-quality fuels, such as kerosene or natural gas.

In early donor-supported community forestry projects, management has tended to disintegrate after donor support ends—a common problem facing even projects that are technically successful. The disintegration can be traced to corruption, high costs, and a lack of management skills.

Devolving authority to communities and individuals generally increases land and resource tenure and has facilitated investment in privately managed forests and in-field trees. Simple and inexpensive, these private ventures have often been more successful than community forestry ventures.

Land tenure and private property rights result in more efficient use of land for agricultural production. Scarcity of fuelwood, browse, or other competing resources under open-access conditions leads to a need for privatization. However, for the very poor, open access is a hedge against absolute poverty. Because privatization leads to a less equitable distribution of resources, resistance to privatization leads to greater scarcity.

Patterns of deforestation are driven by expansion of agriculture and demand for fuelwood. Cutting fuelwood near cities makes agricultural expansion easier, and forests cut for this purpose are commonly consumed as fuelwood. Thus there is a relationship between agricultural expansion and the current supply of fuelwood: forests liquidated for agriculture increase current fuelwood supply, even while the process as a whole reduces stocks of biomass in otherwise forested areas.

Land in humid areas near cities is more valuable for fuelwood and agriculture than dry, distant areas. Development of tenure progresses faster on more valuable lands, although central authorities are reluctant to relinquish authority over them.

Development of private rights in particular, and institutions in general, proceeds faster in areas where there has been a history of experience with similar institutions. The Akamba people of the Machakos District in Kenya used individual farm plots long before government authorities recorded property rights. This history created favorable conditions for investment in land and agricultural technology.

There is a difference between predictions drawn from models on future scenarios and on possible future conditions. Each future scenario is only one of many possibilities for future conditions. User-friendly simulation modeling methods can demonstrate possible future scenarios for fuelwood use, fuelwood supply, and relationships among the variables and conditions described in this paper. Experiments with this method show how anticipated future shortages or other conditions related to fuelwood are sensitive to the data used in the analysis and the basic understanding of the person performing the analysis.

The finding that anticipated shortages of fuelwood have not occurred leaves open the question of future supply and forest health in the face of a growing human population. Data from the UN Food and Agriculture Organization (FAO) on area of certain forest types do not indicate density of biomass or regeneration rates of biomass in forested areas. Declines in density of biomass within forested areas are not fully reflected in these summary statistics.

It is important to avoid making unwarranted warnings on impending crises that do not arrive. It is also important to anticipate the degree to which current decisions or policies have bearing on long-term or future problems. Experiments with simple simulation models show that there can be long delays between the time a harvesting policy is established and the ultimate effects of that policy. Setting a harvest limit, illustrated with information from Burkina Faso, may result in the sustainable use of the natural forests or the continuing decline and accelerating collapse of open-access forests many decades from now. The uncertainty in knowledge of biomass density and regeneration rates may allow this process to continue unchecked, and it leaves a great deal of uncertainty for the future of West African forests and their potential for supplying fuelwood and other services.

1. Introduction

1.1 Purpose

Early hypotheses stated that there would be widespread ecological degradation in West Africa by 2000, driven largely by demand for fuelwood. This review assesses those estimates, incorporating technical information from fuelwood models and broader information on changes in land use from the USAID Africa Bureau's surveys of development experts and the surveys' cited literature.

Concerns over consumption of fuelwood around the world, and in Africa in particular, came to public attention with the 1975 publication of Erik Eckholm's paper, "The Other Energy Crisis." The paper called attention to the growing use of wood for fuel in less-developed countries and the commensurate concerns of deforestation, soil erosion, loss of soil nutrients, and loss of biodiversity. It also noted a connection between poverty and unsustainable fuelwood harvesting—and the difficulty in breaking the cycle of unsustainable harvest, resource depletion, and deepening poverty.

Eckholm's short piece arrived at a teachable moment; with the Arab oil embargo on everyone's mind, it caught people's attention. For better or for worse, the paper has been repeatedly cited in a continuing discussion about fuelwood use and its ramifications for forests, agriculture, and, more broadly, the human condition in ecological systems around the world.

Several authors have researched and written in more depth and detail about the challenge of meeting the need for fuelwood in less-developed countries. Recorded concern over the status of West African forests and the effect of fuelwood cutting on those forests goes back to the early 1900s. Models and hypotheses developed 20–30 years ago anticipate a fuelwood and ecological crisis in West Africa to occur right about now.

However, there is a common view among foresters and development professionals that the increasing scarcity around growing urban centers does not constitute the widespread crisis that was anticipated. This paper is intended to help explain why a crisis did not develop as broadly or acutely as expected. It also demonstrates an analytical tool that others may use to develop their own hypotheses about the basic relationships between forests, agriculture, and people in West Africa.

The first part of this report incorporates a review of the models that anticipated a shortage, including an examination of the data available at the time and how uncertainty in those data is easily compounded to produce more uncertainty in forecasts of fuelwood availability. It also includes a review of the structure of the models used to forecast supply and demand for fuelwood and how certain assumptions about fixed ratios between forest area and supply of fuelwood, and population and demand for fuelwood, were appropriate for short-term forecasts, but have become less realistic over time.

The second part incorporates a broader review of issues surrounding fuelwood supply and demand, including factors that have mitigated shortages, notably changes in land use that have increased the supply of fuelwood in places. These changes in land use are driven in part by development of land tenure and resource tenure and include intensification of agriculture and development of individual woodlots and in-field planting of trees. These investments in agriculture and agro-forestry have been made possible in part by a devolution in authority to communities and individuals.[1]

The third part introduces a modeling environment and includes simple simulation models for reviewing future scenarios for the harvest of wood from West Africa's forests. These scenarios are not predictions, but they illustrate a range of possible outcomes for stocks of forest biomass and growth given certain levels of harvest over time.

1.2 A History of Concern

Eckholm was hardly the first to raise concerns over the effects of woodcutting on West Africa's forests. Ribot (1999) translated from their original French three early accounts by the Gouvernement Générale de l'Afrique Occidentale Française, Mangin, and Aubreville. As early as 1916 the director of the West African Colonial Service of Agriculture and Forestry noted a lack of organization among woodcutters in Senegal. The director noted, "The lack of surveillance of woodcutting has promoted a waste of the country's forest resources, which will prove to make sustaining her energy needs more and more difficult. A better organized exploitation would permit, on the contrary, to easily place at the disposition of her relatively sparse population all the wood and charcoal necessary…. It is, however, of utmost urgency to protect from destruction the forests that still exist, of which the disappearance will not fail in a short time to have disastrous consequences for the future of the country."

The director's comments were targeted mainly toward reducing waste in wood collection, and did not directly suggest an imminent shortage. Regardless, the secretary general of the colony noted, "It is to be foreseen that the rigorous application of these regulations will create difficulties for supplying the principal centers of the colony with wood and charcoal" (GGAOF 1916).

Mangin, a colonial forester also in Senegal, in 1924 lamented deforestation along the railroads and commented on forests in the Senegal River basin: "Instead of afforestation (in rows for example) or creating methodically exploited reserves, one has cut at random and progressively, it is in this manner that the Gonakie (*Acacia nilotica*) forests of the Senegal River are disappearing, it is in this manner that the production of charcoal threatens to destroy completely the forest stands of the region to Tivaouane along the Dakar–Saint-Louis [railroad], etc."

Aubreville (1954), chief of the colonial forest service, noted: "In the countries with dry climates, one lacks timber and firewood to supply the large centers of population and local industries, for

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[1] The information for this review is drawn in part from the results of a survey, and a summary of the results of the survey by Denise Mortimer and Jon Anderson of the USAID Africa Bureau (2002). The survey includes questions about major trends in development hypotheses and approaches in West Africa over the past 40 years, responses from 31 experts, and references to published literature.

whom wood is the only combustible." Chevalier in 1950 echoed Aubreville's sentiments, and both noted rapid degradation of soils and vegetation in West Africa, and called for measures to avoid further degradation (Mortimer and Anderson 2002).

Concerns continued into the 1980s, with USAID's Hradsky (1981) attributing deforestation "to fuelwood collection in the Sahelo-Sudanian Zone and to slash-and-burn agricultural techniques in the Coastal Zone." Hradsky notes a 1979 report arguing, "In Senegal, a recent USAID study has indicated that hypothetical consumption of fuelwood alone may exhaust that country's total forest reserves by the year 2000." He also refers to a French-financed study "that flatly notes in relatively well-endowed Guinea Bissau, the Guinean forest resources will begin to disappear in less than 20 years unless remedial actions are begun immediately." Hradsky concludes that "West African nations will need to act quickly to either a) reduce fuelwood demand through improved utilization methods (improved charcoal conversion, improved wood and charcoal stoves), or b) increase supply through improved production and forest protection (reforestation, fire protection, etc.), or both."

Ribot (1999) noted two studies in 1985: "a donor conference report from Senegal claimed that seven of Senegal's ten regions were already in deficit; 'the situation is cause for concern and the trend is unacceptable'" (République du Senegal 1985), and a World Bank forester who argued that "large urban centers '…are responsible for much of the disappearance and deterioration of the forest cover because of their nearly exponential growth'" (Gorse 1985). Leach and Mearns also note Anderson's 1984 and 1986 work for the World Bank in the Sudan, and Nkonoki and Sorensen's work in Tanzania. Those works anticipate a growing "fuelwood gap" and virtual elimination of forests in those areas in the 1990s or early 2000s (Leach and Mearns 1988).

The United Nations Development Program and World Bank, reporting the results of their 1986 work in Niger, described "rapidly widening fuelwood deficits in the catchment areas of Niamey and Zinder by the year 2000," with forecasted deficits growing through 2030 (Foley, Floor et al. 1997). These reported figures assume a 100-km radius for fuelwood supply, so the potential for closing the gap by collecting from afar is not expressed by the numbers. In contrast, work in Kano indicates that fuelwood and charcoal used there are transported from as far as 600 km (Cline-Cole, Falola et al. 1987).

1.3 Current Status and Anticipated Trends

Additional recent work by the World Bank suggests that demand for fuelwood in 2020 will exceed sustainable supply in Gambia, Niger, and Senegal and just meet sustainable supply in Burkina Faso. A surplus in Mali will result in a slight surplus for those countries as a whole (Utria, Wilton et al. 1996). Perhaps because of uncertainties in past estimates, the authors caution that the results "deliberately are not called an energy balance" (although they do look like one) and that "only demand-supply differences over 30 percent are statistically meaningful." The authors also do not call the supply-demand differences a "fuelwood gap," so the meaning of the figures is not clear. The historical use of supply and demand estimates to anticipate fuelwood gaps 20 years distant raises concerns about the ambiguous meaning of the figures. Whether we should infer an absolute shortage in 2020 is unclear.

Utria et al. have not, for example, incorporated the possibility of increasing yields of fuelwood on private land to alleviate this anticipated imbalance. There are cases where farmers in Niger, facing increasing costs for fuelwood (in either monetary terms or financial terms), have converted millet fields to private forestry plots for fuelwood by relying on natural regeneration, an approach that has spread across Niger to Burkina Faso. These private forestry initiatives in turn tend to alleviate fuelwood scarcity and drive down prices or collection times. People in Niger's Majjia valley have recognized this principle, but from a different perspective. They complained during the 1980s that annual trimming of the windbreaks left a glut of wood—this in an area where there were shortages during the 1970s (McGahuey 2002).

The fact that in the past others have inferred future widespread shortages that have not come to pass raises doubts about anticipated future widespread shortages for the same reasons. However, Nordhaus (1992) notes that just because people have cried wolf in the past when there was no wolf does not mean that the woods are safe. Further insights into the role of fuelwood harvesting on fuelwood supplies, and the nature of the domestic energy challenge, will require a more intricate understanding of related issues of land use and management.

Utria et al. (1996) argue that the national totals are based on more detailed analysis of local areas, but they also acknowledge that results suffer from the classic problem of aggregation, which tends to obscure local problems. Similarly, the aggregate data in the analysis do not show the effects of fuelwood movement across national boundaries, as between Gambia and Senegal.

This study is distinctive, however, in that it explicitly distinguishes between sustainable yield and stock reduction. Continued stock reduction is not sustainable and ultimately leads to deforestation; understanding the difference and determining what part of the total fuelwood harvest is due to stock reduction is key to understanding fuelwood's role in deforestation. Earlier studies mostly did not articulate the difference. In this five-country aggregate study, the estimated stock reduction from 1990 to 2020 totals 62 million tons—about twice the anticipated annual demand in 2020. Stated otherwise, the study suggests that between 1990 and 2020, two years' worth of fuelwood in these countries will be attributed to deforestation.

Another notable aspect of the Utria et al. study is the anticipated shift in demand over time from rural fuelwood use to urban use. The historical trend is toward urban use, as people in rural areas move into cities, and the authors anticipate that within the five countries studied, the urban share of consumption will rise from a quarter in 1990 to more than half by 2020 (Utria, Wilton et al. 1996). Considering migration into cities and population growth overall the authors anticipate a quadrupling of urban fuelwood use, and a 50 percent increase in rural fuelwood use. These estimates reflect anticipated migration decades into the future and should be regarded as rough. Regardless of the raw numbers for fuelwood use, and regardless of the final percentages for the future rural-urban split, the continuing migration toward urban areas does indicate that urban fuelwood use and fuelwood collection methods will increasingly dominate over rural trends.

The UN Food and Agriculture Organization (FAO) reports that fuelwood constitutes about 85 percent of total energy consumption in West Africa and accounts for 89 percent of the wood harvest. While rural communities run into circumstances where fuelwood is in short supply (and therefore takes more time to collect), the problem of scarcity is generally perceived to be more acute around urban areas, where networks of collectors, procurers, transporters, and distributors bring in fuelwood from lands increasingly distant from cities. Estimates are rough and sometimes contradictory, but harvesting for the Dakar and Lagos markets is as far away as 400 km, and Ougadougou currently obtains fuelwood from a distance of about 150 km (FAO 2002).

However, opinions are divided on the nature of the scarcity around urban areas. Although there tends to be little fuelwood free for the taking around urban areas, Cline-Cole et al. (1987) point out that from the consumer’s point of view, there is virtually always firewood or charcoal to be bought at some price, and so it can be said that the collection and distribution system works well, even if transportation distances are large. It is also generally competitive among woodcutters. So long as there is no collusion among woodcutters and among distributors, fuelwood or charcoal can be bought in urban areas at competitive rates.

2. Formal Models of Fuelwood Use

2.1 Data for Supply

There is general agreement that early estimates of supplies of available fuelwood were low, sometimes tremendously. The standing crop of biomass above ground and annual productivity are largely determined by the amount of rainfall and availability of soil nutrients (Kowal and Kassam 1978; Utria, Wilton et al. 1996). There is considerable uncertainty, but estimates range widely from 4 to 30 m^3 per hectare for biomass density, and 0.1 to 1.5 m^3 per hectare per year (70 to 1,000 kg per hectare per year) for productivity from the northern Sahelo-Saharan zones to the Sudano-Guinean areas in the far south (Utria, Wilton et al. 1996). The World Bank has compiled statistics on area, growing stock, and sustainable yield for each of 87 land cover classes of vegetation, although the authors caution that the data are of variable quality and include extrapolations of studies from other continents. Data for mangrove forests, for example, are borrowed from Costa Rica and Thailand (Millington, Critchley et al. 1994). Regardless of the true figures, there is a growing view that historical predictions of net primary productivity in general, and potential supplies of fuelwood in particular, have been underestimated (Fairhead and Leach 1996; Utria, Wilton et al. 1996; Foley, Floor et al. 1997; Openshaw 2001; Mortimer and Anderson 2002).

Openshaw has interesting insights on how early estimates of woody biomass were systematically understated. The early formal studies, such as the Openshaw FAO Tanzania study (FAO 1971), employed methods that tended to underestimate the total stock of wood. To calculate available wood, a forester would estimate the diameter of the trunk at the base, estimate the diameter near the top, and calculate the volume of the tapered cylinder between those two disks. Biomass beyond the main stem was considered negligible, of no interest to foresters. This method miscalculated biomass in several ways: overestimating the taper resulted in underestimated volume, woody biomass beyond the trunk is generally equal to the volume of the trunk, and woody biomass suitable for burning from lighter vegetation such as shrubs was not considered.

In a recent inventory in Benin where total aboveground biomass was estimated, the taper of the trunks was measured as 0.48 of the base diameter, whereas the forest service was using an estimated taper of 0.33. This discrepancy alone understates the volume of the stem by 45 percent (Openshaw 2000). A further multiplier of 0.8–1.2 is commonly appropriate to estimate the additional wood beyond the main stem. In the same inventory, only 60 percent of the woody biomass was in stems, with 32 percent in branches and twigs and 8 percent in shrubs and small trees. Of the total, 10 percent was dead wood.

The minimum size for measurement historically used by foresters also causes standing stock of fuelwood to be underestimated. In the Tanzania study, trunk diameters were measured down to 10 cm. Higher minimum trunk diameters of 30 cm have also been used, leaving the possibility of significantly underestimating the standing stock available for fuelwood collection. The true stock available was frequently 2 to 4 times the early estimates; current estimates may also be too low (Openshaw 2001).

In addition to low estimates of standing stock, largely overlooked is the continuing supply of fallen deadwood, collected more or less continuously. Both subsistence collectors and commercial collectors prefer dead wood for its lighter weight and ease of collection. Commercial collectors tend to prefer larger, denser stems, but still prefer dry dead wood over live trees. Therefore, in a woodland where 10 percent of the wood is dead (as in the Benin case), the amount of collected wood that is dead is higher than 10 percent. The supply of deadwood, when it is preferentially collected over live wood, does not so easily enter into calculations of sustainable yield from forests. That is, sustainable yield, when based on of tree growth estimates over a multi-year rotation, comes out as an underestimate when deadwood is collected continuously and not counted as part of the rotation. A recent study in Malawi revealed that deadwood makes up 40 percent of commercially collected fuelwood (Openshaw 1997).

In addition to fallen deadwood, other sources of fuel for personal use include dung, crop residues, and light woody biomass from shrubs and other roadside sources. These sources may be highly variable from region to region, between individuals, and from season to season. For crop residues and dung in particular, there may be competing uses, including maintenance of soil organic matter. Regardless, these diffuse sources may collectively provide a substantial part of a family's total fuel consumption.

There are, therefore, three major aspects of fuelwood supply estimates that have been substantially underestimated in the past. First, the methods and assumptions employed by foresters concerning volumes of tree stems resulted in the standing crop of woody biomass available for fuelwood in forests being underestimated by 50–75 percent (Openshaw 2001). Second, the dead and other light wood taken from forests continuously, and not as part of a periodic harvest every so many years, is not counted in measurements of standing crops of woody biomass. Third, there are other sources of woody biomass outside forests that serve as fuelwood supplies, and there are other sources of fuel, including crops residues and dung. These alternative fuels are in addition to other higher quality alternative fuels, including gas and kerosene. Collectively, these additional sources, not counted in early models of fuelwood supply and demand, may constitute a fuel supply underestimation of 200–500 percent. Given the approximate doubling of population in the 25 years since the early formal anticipations of a fuelwood gap, lack of a widespread shortfall in fuelwood can be explained by these underestimates of supply alone.

2.2 Assumptions about Demand

The basic assumption repeated throughout studies of fuelwood supply and demand is that there is a fixed, or nearly fixed, ratio between population and fuelwood demand. Eckholm (1975) said it explicitly and directly: "The firewood needs of the developing countries cannot be massively reduced. The energy system of the truly poor contains no easily trimmable fat…. The unfortunate truth is that the amount of wood burned in a particular country is almost completely determined by the number of people who need to use it."

Hradsky (1981) echoes those sentiments: "Fuelwood energy demand will continue to grow at rates similar to those of population." However, he is more cautious and recognizes the possibility of changing fuel, of using more efficient stoves, and of converting wood to charcoal more efficiently. For these reasons, he cautions, "Simple linear extrapolations probably do not paint an accurate picture of long-term scenarios." Regardless, in his analyses he uses the figure of 0.5 m^3 of fuelwood consumed per person per year for all of West Africa.

The Forest Resource Analysis and Planning (FRAP) fuelwood model incorporates population growth rates, wood and charcoal stove efficiency, wood and charcoal demand per person by end-use (fixed throughout a model run), aggregate wood and charcoal demand for industry and commerce, percentage of rural and urban households that consume wood and charcoal, price and income factors that influence demand, wood demand for non-energy purposes, and area of land subject to certain uses or conditions (EDI 1986). These detailed input requirements would suggest a degree of sophistication greater than simple extrapolations of past demand. However, this model also uses fixed coefficients to estimate both supply and demand; there is no demand dampening or fuel switching due to increased scarcity, and similarly no increases in supply from agroforestry ventures due to increased scarcity of wood in natural woodlands. In this respect, it is similar in structure to other models, notably Hradsky's, that have been used to anticipate or describe potential future conditions.

FRAP's fixed-proportions assumption, repeated in the other models of fuelwood supply and demand, is useful for short-run prediction or intervention, and for understanding sensitivity to certain variables. In the long run, true relationships will almost certainly differ from the point estimates incorporated into the model, so the model is not very good for long-run predictions. Sarewitz et al. (2000) explore in detail many cases of prediction gone awry, including energy supply forecasts.

Other estimates of fuelwood supply and demand are not fully explained, so they are difficult to critique beyond the general comments concerning fixed coefficients, including per-capita demand (FAO 1967; République du Senegal 1985; Utria, Wilton et al. 1996; FAO 2000; FAO 2002). Hradsky's notable work will receive more attention here because he is unusually candid about the methods and assumptions used in his analysis. He does recognize some flexibility in demand for fuelwood and potential for efficiency improvements in charcoal conversion and improved stoves. For example, Hradsky notes that charcoal conversion efficiency by weight may be 10 percent or less when wood is piled in a hole, covered with dirt, and left to smolder for several weeks. However, in the "Guinean method" (wood is stacked, covered with straw and then dirt, a pole in the center is removed to leave a chimney, and the mound is left to smolder for 1–2 months) conversion efficiencies are around 20 percent. A more efficient variation on this method, using a metal chimney and improved ventilation, may yield 30 percent of dry weight (Hradsky 1981).

Based on historical data through 1977, Hradsky estimated "theoretical evolution of annual fuelwood consumption" in Burkina Faso, Gambia, Mali, Niger, and Senegal combined. For illustrative purposes, he assumed population growth of 2.5 percent per year and wood consumption of 0.5 m^3 per person per year. Using these figures, anticipated annual consumption of fuelwood for 1997 was 20,300,000 m^3, equivalent to the standing crop of a 1,020,000-hectare natural forest (Hradsky 1981). The fuelwood harvest is spread more evenly than that through the forest; it does not all come from clearcutting. However, FAO statistics differ. Current figures from the World Resources Institute, taken from the FAO database, indicate that 26,500,000 m^3 of fuelwood were consumed in 1997 in those countries, and that forest loss in an average year during 1990–2000 equaled 217,000 hectares. Hradsky's rather simple 20-year forecast of fuelwood consumption was off by 23 percent. Actual forest loss, as reported in FAO statistics, was 4.7 times greater than that which Hradsky could attribute to clearcut fuelwood.

Several points bear mentioning. First, the figure for anticipated 20-year demand, off by 23 percent from the reported figure, is remarkably close. Second, although some fuelwood comes from clearcuts, on the whole it is collected more evenly across the landscape. Hradsky's figure for deforestation that might be attributed to fuelwood cutting, at about a fifth of the reported figure for deforestation from all causes, suggests that there may be another major cause, notably agricultural expansion. Third, there is a question of data reliability and interpretation. Closed forest is defined by the FAO as an area where tree foliage and branches cover 20 percent or more of the ground; open woodlands are wooded savannah areas containing less than 20 percent forest cover (Hradsky 1981). In theory, then, a forest with a completely closed forest could be thinned by fuelwood cutting to 20 percent of its original density and still fall under the definition of closed forest. Substantial changes in the density of vegetation are not captured in the FAO's summary statistics of forested area. More recently, the FAO has written new criteria for classification as forest. In the 1990 Forest Resources Assessment, the minimum area requirement for being counted as forested land was 100 hectares. In the 2000 assessment, the minimum area is 0.5 hectares (FAO 2001). This reduction in the area requirement means that fragmented forests that were not previously counted will now be included in FAO statistics. Backdating of 1990 results under the new classification regime increases figures for total forest in West Africa by 1.8 percent, and total forests for all of Africa by 29 percent.

Although most authors assume a fixed per-capita consumption rate for fuelwood, in practice there may be considerable possibility for improving efficiency or reducing fuelwood use. For illustrative purposes (this is not a prediction), modest improvements in the conversion of wood to charcoal might reduce wood consumption in certain areas by 10 percent. Improvements in cooking efficiency through more efficient stoves might reduce fuel use by 20 percent of remaining use. Reducing cooking from three times a day to two, or from two times a day to one might reduce fuel use by 40 percent of remaining use. Total remaining fuel use from these three measures taken together, therefore, is equal to 43 percent of the original demand. In contrast to Hradsky's estimate of 0.5 m^3 per person per year of fuelwood use for West Africa, and the Cline-Cole et al. (1987) figure of 0.52 m^3 per person per year for Kano, corresponding figures for Afghanistan, Nepal, and Papua New Guinea are 0.3, 0.9, and 1.8 m^3, reflecting the scarcity of fuelwood in those regions (Agarwal 1986). Dewees (1989) echoed this reasoning, noting that fuelwood consumption is a function of the cost of obtaining it.

Some of these measures, such as a reduction in cooking, may constitute real hardships for people living in poverty. Also, it would be unusual to adopt all of these measures at once. People living in poverty, for example, may reduce their fuel use by reducing the amount of cooking they do, but the fact that they are in poverty makes it difficult or impossible for them to buy a more efficient cookstove. These figures, therefore, should be considered only to illustrate the weakness of the fixed per-capita demand assumption. Together with the potential fivefold underestimate of fuelwood supply described above, they fully explain why an anticipated widespread fuelwood gap in West Africa has not developed at this time.

3. Broader Issues of Fuelwood Supply, Demand, and Investment

3.1 Attempts To Intervene

Early attempts by colonial authorities to manage forests in West Africa were centered on protection through the establishment of state forest reserves. These reserves were generally created without the participation—or consultation—of local populations. The authorities effectively made attempts to keep people out as a means of protecting the forests from what appeared to be progressive degradation due to fuelwood and roundwood harvesting. These concerns fed into a later and broader understanding of spreading desertification. This hypothesis held that the desert was expanding from the north as a result of forest misuse and was exacerbated by drought, notably during 1968–73. Efforts to keep people from harvesting were not especially successful. As one observer put it, desperately poor people who are getting poorer "will take out every tree and every shrub in the effort to survive, as we would if our children were at risk." Post-colonial governments followed in this vein along conventional lines. This top-down approach toward forest reserves would be accompanied by a plethora of regulations that did not necessarily consider the basic needs of local people, or what local incentives those regulations created (Mortimer and Anderson 2002).

In response to rising concerns about a coming fuelwood crisis, in the 1970s and 1980s donors began many forestry projects and technical efforts to reduce demand for fuelwood. These forestry projects ranged from village- or community-managed forests to the establishment of larger-scale managed markets (Mortimer and Anderson 2002). The UN Development Program (UNDP)–World Bank Niger Household Energy Project is instructive as an illustration of the possibilities and problems encountered by these medium- to larger-scale fuelwood projects (Foley, Floor et al. 1997), although the Guesselbodi project was perhaps the most famous early project (Christophersen, Hawkins et al. 1993).

The Guesselbodi National Forest was chosen partly because of its proximity to Niamey, partly because it had become severely degraded. It involved 5,000 hectares of land divided into ten 500-hectare community plots. The idea was to increasingly involve the local population in the planting, restoration, and management of the plots in return for the right to harvest fuelwood and fodder. Technically and ecologically, initial results were positive, with substantially increased regeneration of trees and growth of grass. There were logistical problems, including transportation difficulties where communities that had a right to harvest wood lost interest because of the distance involved. There were also institutional problems and conflicts between the project and local people who had traditionally grazed their animals in the forest, but were subsequently excluded (Foley, Floor et al. 1997).

Donor support for the project ended in 1990. Three years later, Christophersen et al. reported, "At Guesselbodi, USAID support has ended, and the activities carried out with project support are now largely discontinued—the systems and institutions created are not functioning as intended. The cooperative no longer has the means to pay guards, nor to pay for soil and water conservation activities, largely because disciplined management of funds was not applied and the cooperative members did not have sufficient managerial or technical skills" (Christophersen, Hawkins et al. 1993). The sheer size of the Guesselbodi project, and subsequent projects on a similar scale, created many management problems.

Costs were also a major problem. Initial investment costs of rehabilitating woodlands, coupled with continuing management spending, including the cost of hiring guards, meant that fuelwood from the Guesselbodi project cost about twice that of conventionally collected fuelwood from less intensively managed natural woodlands. To increase demand for the project wood, the government would stop issuing cutting permits in natural woodlands from time to time to eliminate competition from the less expensive, conventionally collected wood (Foley, Floor et al. 1997).

The problems with the Guesselbodi project were primarily managerial and organizational, not technical or biological. The system of village cooperatives, together with paid guards, was evidently too elaborate or complicated to hold together after donor managerial support ended. In addition, management costs, correctly reflected in the final price of fuelwood from the project, were high enough above the cost of wood from unmanaged lands that the project could not sustain itself. It should be noted, however, that despite the management problems of the Guesselbodi project, many of the lessons learned have been applied in subsequent projects. The architects of the UNDP–World Bank Niger work were thoroughly aware of the successes and pitfalls experienced at Guesselbodi, and sought to simplify their project and keep costs low.

Even so, similar managerial and cost problems have challenged the UNDP–World Bank Niger Household Energy Project. The project included supply components primarily directed at management of natural woodlands and demand components primarily directed at introduction of alternative fuels and more efficient stoves. Recognizing the management and cost problems of the Guesselbodi project, the UNDP–World Bank approach around Niamey emphasized low cost and provisions to steer fuelwood cutting and consumption into sustainably managed woodlands. Community fuelwood markets were not only to be self-sustaining financially, but also self-sustaining biologically. The supply strategy was to modify existing law to create a new set of rights for villages, so that they could control the use of woodlands in their area, reorganize the fuelwood trade into a more regulated environment, and use taxes and cutting fees to direct cutting toward managed areas and away from heavily degraded areas (Foley, Floor et al. 1997).

By limiting cutting and limiting the number of people who can cut, woodcutters working within managed areas became more wealthy. However, anticipated tax revenue did not materialize, partly because taxes on fuelwood cut outside the village forests were set well below what the project managers had anticipated, and partly because the taxes were not uniformly collected or fraudulently diverted. Some managers of cooperatives lacked the skills necessary for basic bookkeeping, and the donors still raise concerns that the markets will not be maintained without their continuing technical and financial support (Foley, Floor et al. 1997). Kerkhof et al. (2001) note that there are ongoing problems, including abuse by forest brigades who fine or arrest and essentially hold hostage village leaders who have broken no rules. They also note continuing corruption within the fuelwood markets. The long-term viability of these community forests and fuelwood markets remains to be seen. The donors' continued involvement raises the possibility that the level of management and cooperation necessary to hold the cooperatives together, and the related financial costs, may be high enough that the cooperatives will require long-term donor support. Kerkhof et al. said it well: "The greater the expense incurred in forest management, the less effective and the less sustainable it will be." There is general agreement among development experts that early community-managed forests have required continued donor support (Mortimer and Anderson 2002).

Technical approaches to reducing the demand for fuelwood included efforts to promote commercially alternative fuels, such as kerosene, and more efficient fuelwood stoves. Comparisons with a traditional three-stone method suggest that 40-percent improvements in technical efficiency of fuel use are possible, although in practice efficiency may vary substantially, as may total fuel use. In the Niger program, natural gas stoves and fuelwood stoves were subsidized and promoted. The program estimates that the distribution of stoves has reduced fuelwood use in Niamey by about 2 percent of total consumption (Foley, Floor et al. 1997). Keeping energy prices low by subsidizing fuels tends to dampen development of new or alternative supplies. The subsidization of alternative fuels in the UNDP–World Bank Niger case begs the question of how high the price of fuelwood would have gone and what new fuelwood supplies would have come from private plots, had alternatives not been subsidized.

Reducing fuel use by improving stove efficiency is an interesting challenge. Observed reductions in fuelwood use attributed to more efficient stoves varies tremendously, even within the same village. Foley and Moss (1983) found changes in fuel use that varied between a 50 percent reduction and a 16 percent increase as a result of changing stoves.

The higher the technical efficiency of a given stove, the less fuel it will burn cooking—and therefore the less expensive it will be to operate. Because the more efficient stoves are less expensive to operate (whether the cost is measured in monetary terms or in time spent collecting wood), people tend to cook more when they are using a more efficient stove. Therefore, anticipated savings in fuelwood use calculated on the basis of technological improvement in efficiency will almost always exceed the actual savings in practice. This finding runs directly contrary to the fixed per-capita use assumption of historical models of fuelwood use, but is supported by empirical evidence. Jones (1988) found that when woodstove efficiency is improved by 25–50 percent, roughly half of the technical fuel savings from stove efficiency improvements are lost through increased cooking. Zein-Elabdin (1997) puts the figure at 42 percent. That is, 42 percent of fuel savings due to technical improvements in efficiency of the stoves are lost due to increased use of the stoves. This finding helps explain why donor efforts to reduce fuelwood use by promoting the distribution of woodstoves has produced reductions in fuelwood use, but not substantial reductions.

There appear to be few analyses of data linking price of fuelwood to demand for fuelwood in Africa. However, Zein-Elabdin did find that in Sudan increasing the price of charcoal by 10 percent will cause a 5.5 percent reduction in use of charcoal. Hradsky (1981) reported that a 10 percent increase in price in Abidjan would cause 4.5 percent reduction in fuelwood use, though he did not say how the figure was calculated. Data from Ethiopia suggest a 3.7 percent reduction. The data also indicate that a 10 percent price increase in Ethiopia will cause a 3.7 percent reduction in demand (Kidane 1991).

It is generally true that demand for energy is not very responsive to changes in the price of energy. These data are consistent with that finding. Moreover, they suggest that use of fuelwood and charcoal is even less responsive to changes in price than is demand for other fuels in other parts of the world. In short, although consumption of fuelwood does indeed vary with changes in price, it does not vary much. This finding is consistent with low incomes, where most consumption is essential, or nearly essential. Even though these price-induced changes in fuel use are low, these findings should put the final nail in the coffin of the fixed per-capita demand assumption of early fuelwood supply and demand models.

A common view holds that wealthier individuals often elect to use kerosene or natural gas stoves instead of wood or charcoal stoves, especially in urban areas. There are a few data that shed light on this relationship. Zein-Elabdin (1997) found that a 10 percent increase in income will increase use of charcoal by 8.7 percent in Sudan. This suggests that people will use more charcoal as incomes rise. In contrast, other authors found that the same 10 percent increase in income will reduce charcoal use by 25 percent in Ethiopia, 23 percent in Kenya, and 59 percent in Sudan. This suggests that people shift from charcoal to other, more desirable fuels as their incomes rise.

Although the data are spotty, possibly inconsistent, and incomplete, the relationships they describe have important implications for development. Increasing incomes may increase overall fuelwood use or reduce it. One explanation for these data suggests that people burning fuelwood tend to shift to cleaner-burning but more expensive charcoal as their incomes rise. Similarly, people burning charcoal tend to shift to still cleaner kerosene and natural gas as their incomes rise further. Because of the energy loss during the conversion of wood to charcoal, the first shift from fuelwood to charcoal increases wood use overall. The second shift from charcoal to kerosene or natural gas reduces wood use overall. Therefore, the effect of increased wealth on wood use depends on one’s starting point—increases in incomes of the poorest people lead to an increase in fuelwood use overall (including use of wood converted to charcoal) and increases in income of wealthier people leads to reductions in fuelwood use.

Another uncertainty in these findings is how changes in the price of fuelwood affect the relationship between income and demand for fuelwood. As the price of fuelwood rises, higher quality fuels (such as kerosene and natural gas) become more cost-competitive. Under those conditions, fuel-switching will be more sensitive to income. Therefore, to achieve the highest impact on people’s choice of fuels, increases in income should be accompanied by increases in the price of fuelwood and charcoal. The UNDP–World Bank project in Niger, by promoting alternative fuels and by seeking to tax wood harvest from the hinterlands, is consistent with these principles. The level of management and skill necessary to maintain the tax system and community-managed forests remains a problem.

In addition to management challenges, there is the question of equitable distribution of benefits. Raising the price of fuelwood through regulations and harvest taxes makes for more efficient and sustainable use of forests. However, some people are priced out or regulated out, and for people already in poverty, it can make a difficult situation worse. Lopez (1997) observed that scarcity leads to a need for privatization of natural resources. Privatization leads to a worse income distribution, so resistance to privatization leads to greater scarcity. This adverse feedback is again seen in the Niger fuelwood projects, where those who traditionally grazed animals on open-access lands vigorously objected to what amounted to privatization of the Guesselbodi forest. Open access may be equitable, and may help hedge against absolute poverty, but it is still inefficient.

Another interesting relationship is the one between price of charcoal and supply of charcoal. Working in the Sudan, Zein-Elabdin (1997) found that a 10 percent increase in the price of charcoal will cause a 2.5 percent increase in supply of charcoal. This figure should be treated with a degree of caution, as supply of charcoal depends on many factors, including the status of relevant woodlands and availability of wood, capacity to make charcoal, and political control over harvesting of wood.

3.2 Evolving Views

Respondents to the USAID survey offered a range of views on fuelwood harvesting and its effect on the environment, its role in deforestation, and factors that bear on the issue. Several broad themes come out of the responses. Devolution of authority, starting with highly centralized colonial powers and working downward toward communities and individuals over time, is generally regarded as a positive development. Efforts to develop civil society and effective governance, while not always successful, are regarded as very important. One product of this devolution of authority and development of effective governance at local levels is advancement in land tenure and resource tenure, which is regarded as necessary for investment in agricultural intensification and other investments in land. Also, in addition to being a human tragedy, poverty is a serious threat to natural resources. The relationship between poverty and natural resource degradation is seen as mutually reinforcing, complicated, dynamic, and interactive. Alleviating poverty is very important to effective management of natural resources (Mortimer and Anderson 2002).

Technical interventions to address the fuelwood problem—introduction of renewable energy technologies and promotion and distribution of woodstoves—are generally regarded by respondents as unsuccessful at making major changes in patterns of fuelwood collection and use. Likewise, village or community projects have suffered from financial and management problems and are not regarded as particularly successful, although in wetter areas above 500–600 mm of rainfall, they do better. The limits to the success of these purely technological approaches, and mixed results in community fuelwood projects, fed into a broader understanding during the 1980s of an approach that recognizes relationships among the environment and resources, agriculture, land tenure, economics, governance, and sustainability. It also emphasizes community governance more than the historical emphasis on higher levels of government. One respondent said, “The core understanding is that protecting the environment is central to protecting rural production systems and livelihoods.” Similarly, “clear self-interest can be tapped to conserve the environment…. The weakness of the whole system seems to lie in the planning process, which usually doesn’t pay credit to the opinion of beneficiaries (peasants and African partners in general).” Efforts by donors to improve management of resources have turned toward local populations and individuals including farms (Mortimer and Anderson 2002).

Respondents reported that impacts from donor-assisted projects have primarily been local, with very few successful interventions on a large scale; often people act as households or individuals, rather than as communities, and many of the most productive investments have been at the individual or household level. These effects have resulted in the intensification of agricultural production through greater management and increased inputs, including non-commercial inputs of animal dung and crop residues; diversification of production, including integrated livestock, gardening, and agriculture, particularly within range of urban centers; and diversification of rural economic activity, including non-agricultural production and commerce (Mortimer and Anderson 2002).

From the 1990s to the present, donors have also emphasized improvements in the enabling conditions for local initiatives. These conditions include land tenure, devolution and decentralization of power, improved governance, revision of forestry codes, and better definition of community and individual management rights. NGOs have played an important role here, supporting innovative models for natural resource management and agricultural intensification (Mortimer and Anderson 2002).

3.3 Land Tenure and Investment

Land tenure repeatedly appeared among survey respondents as a necessary condition for investment in agricultural intensification (Mortimer and Anderson 2002). The empirical evidence supports this conclusion. In the Rwandan highlands, Clay et al. (1998) note that households are far less likely to grow perennials on land they rent than on land they own, recognizing that long-term investments in leased land may be lost to the owner if the lease is not renewed. By the same reasoning, when landlords see that tenant farmers have made substantial improvements to their land, they may be likely to raise the rent or not renew the lease so they can benefit further from the tenant's investments. This relationship can be a powerful deterrent to investment.

An important related theme that arose among the respondents is the appearance of investment in local agriculture, especially agro-forestry. One aspect of this investment is the systematic shift since colonization in levels of authority over resources. This devolution of authority increases the possibilities for an individual to recoup his or her investment in the land. While distant, sparsely populated areas are effectively open-access, areas nearer to urban centers tend to be privately held and available for investment and intensification in agriculture, including agro-forestry. Partly for this reason, opinions are divided on whether areas near urban centers are threatened most seriously by efforts to collect fuelwood (and wood for other purposes) than are more distant lands.

Private rights to land may be formal and legally codified, or they may flow from traditional rights similar to freehold rights. Whether maintained through tribal customs or by agents of the government, rights to land are maintained through institutions, and a community's past experience with these institutions has bearing on the security of tenure.

The Akamba people of the Machakos District of Kenya offer an interesting case study of land tenure and agricultural development (English, Tiffen et al. 1994; Tiffen, Mortimore et al. 1994). In the 1930s, the Akamba people, effectively hemmed in by Crown Lands and lands reserved for European settlement, grazed and cultivated their available lands intensively, in a way that yielded rampant soil erosion and a bare subsistence living. In the Machakos District, the Akamba had a longstanding concept of an individual's use of a certain parcel of land. Before the 1930s, rights similar to freehold were recognized and respected. These historically traditional rights made it possible for individuals to reap the benefits of investment in agriculture even before formal land registration. As a result, over the decades, as crops replaced livestock, the Akamba adopted terracing, diversified their crops, and developed farm equipment and methods. Other innovations included ox-drawn plows, early-maturing varieties of maize, use of crop residues for forage, and use of animal manure in soil. The authors identified 45 new technologies that had been adopted over the 60-year period (English, Tiffen et al. 1994).

The authors of the case study note that the new market orientation of agriculture has increased its perceived value, and provides an incentive to maintain systems that permit continued intensive use of the land. It is that understanding—maintenance of the natural capital stock is necessary to maintain agricultural output—that leads people to reinvest in natural capital and technology to increase productivity.

This market orientation, strong land tenure, and an understanding of the desirability of expanding the capital stock, drives agricultural investments in the Opération Haute Vallée du Niger (OHVN) region. Kelly reports that within the OHVN significant numbers of producers are moving from subsistence farming to more diversified market-based farms where yields are increasing and degradation rates are falling. These results follow heavy farmer investments in agricultural equipment, animals for traction, and livestock. Although some farmers are increasing yields through intensification, on the whole, production for most crops has been realized through expansion of the area farmed (Kelly 2000).

Several donor countries and 20–30 NGOs have been working in the area for 20 years, and the efforts appear to be paying off. Kelly attributes the investment activities to good identification of appropriate technologies; expansion of cash crops, especially cotton; a community approach to implementation; a focus on youth; a focus on villages and farmers most likely to benefit from donor support; incremental training; and a demonstration effect, where farmers see and emulate others' successes. This last factor suggests the possibility of a critical mass, where the spread of improved practices, and commensurate increases in yield lead to further spread and further increases.

The Machakos experience, where land and resource tenure has been relatively secure for a long time, and where the benefits of investment flow directly to the investor, may be compared with experience in the fuelwood projects in Niger. In the Niger experience, revenues from the community projects would be funneled up through newly created institutions that strained the capacities of their managers. When revenues are concentrated in managers and held in their trust, there will be an incentive to steal or cheat, and these managers or village leaders make good targets for forest brigades who see an opportunity to tap into the wealth. Even when communities as a whole are able to secure control over their community forest, resource tenure over the trees—and the wealth they represent—is eroded when there are incentives to steal and cheat. Shaikh et al. (1988) note that for smallholders living close to the margin of subsistence, an important concern is risk minimization. Instead of managing resources for maximum long-term yields, the objective of those with little surplus income for investment is to guard against immediate losses. Under these circumstances of poverty-induced risk aversion and corruption-induced risk to community forests, it is difficult to envision how the community projects can possibly compete favorably with individually held woodlots.

The difficulty that donors have had in maintaining cooperative fuelwood projects, as in Niger, is characteristic of communities that have not had long exposure to institutional development. Chapra and Gulati (1996), working in India, show that only communities that have had a long exposure to institutions cooperate well to maintain common resources. This finding suggests that elaborate management approaches, such as those necessary to maintain community fuelwood projects, will require long-term support by donors for the development of institutions. Conversely, where there is a history or familiarity with institutions, it should be easier to develop new ones, or amend the old as necessary for cooperative resource management. The traditional freehold rights demonstrated by the Akamba made it relatively easy to take the step of registering privately held plots.

Increases in demand for fuelwood, coupled with secure tenure over land, has led to expanded interest in private agro-forestry projects. Agricultural development projects that have promoted clearing trees to make way for traction animals historically discouraged the maintenance of trees in agricultural fields. However, farmers who have secure tenure and who understand a potential for using or selling wood from their fields have a clear reason to maintain trees. As forest area decreases, trees outside forests are becoming an increasingly important source of fuelwood for both rural and urban use (FAO 2002).

Some interesting aspects of the devolution of authority and development of land tenure involve the value of land. The incentive to develop land tenure is strongest where land is most valuable, notably near urban centers and in wetter, more productive areas. While the demand for tenure is greatest in these high-value areas, in areas where resources are valuable, government officials are generally reluctant to devolve authority to local officials. Thus the pressure from individuals and communities on government officials to hand over land for private ownership is greatest in wetter areas, where land is most productive—the same areas with which government officials are most reluctant to part. Customary control of pastoral lands by communities will probably continue in dryer areas, where the development of individual rights proceeds more slowly (FAO 2002).

Survey respondents report expansion of agriculture as a major causes of deforestation in West Africa (Mortimer and Anderson 2002). Commercial collection of fuelwood for urban use ranks as an additional important cause of degradation of forests and loss of forest cover, and rural subsistence collection comes in third. The empirical evidence suggests that this relationship, at least as it pertains to expansion of agriculture, is correct. Openshaw (2002) estimated that expansion of cropland in West Africa accounts for 87 percent of forest loss between 1980 and 1990. Other less widely accepted views hold that deforestation as a result of fuelwood cutting is temporary, and that some areas that are described as deforested by abusive practices were never forested to begin with (Fairhead and Leach 1996; McCann 1997; Ribot 1999).

For rural subsistence consumption of fuelwood, collection is generally done on foot within a radius of a few kilometers, usually taking in small-size deadwood. In these rural areas, there is generally some factor other than the availability of fuelwood that limits population density, so although there are some shortages in rural areas as evidenced by long walking distances, there is no widespread general shortage (Openshaw 2001). Cutting for urban markets is a different process. Woodcutters prefer deadwood, so when they first enter an area to cut, they will avoid populated areas and collect only deadwood. As deadwood is depleted, they will move on to live trees and may substantially clear an area. Moving outward from the urban centers in a growing circle, they may commonly deliver wood or charcoal from 100 km away or more back into the urban centers (Cline-Cole, Falola et al. 1987; Foley, Floor et al. 1997).

The land around urban centers is more valuable for agriculture and woodcutting than is more distant land. Whether land cleared by fuelwood cutting makes the land available for agriculture, or whether agricultural expansion into woodlands causes the cutting wood for fuel, the two processes are related, making it difficult to assign one or the other as a sole cause of deforestation. The process is one of population growth, growth of urban areas, and an outwardly expanding change in land use from woodland or fallow to permanent cultivation.

However, as the circle of exploited woodland widens around an urban center, the demand for closer supplies grows. Given tenure security and other conditions for investment, forestry initiatives near urban areas have a role to play. Increases in agricultural productivity through intensification and in-field planting of trees tend to take pressure off neighboring lands, and, coupled with broader private forestry initiatives, this relief in pressure on open-access forests also tends to ease the fuelwood problem. None of these relationships are in the early models of fuelwood supply and demand.

Cline-Cole et al. (1987) researched conditions around Kano and found that private woodlots and in-field trees were successful. In contrast to the larger community projects such as the UNDP–World Bank projects in Niger, small-scale private agro-forestry initiatives do not have the high maintenance costs of dedicated guards and managers, nor do they have the continuing challenge of maintaining the institutions that employ those managers.

In the Kano case, the authors note that density of biomass on privately managed woodlands is about twice that of nearby unmanaged lands. In commercial firewood production on private lots, the decision of what to cut is made by the owner, who has reason to consider how today's cutting will affect future cuts (Cline-Cole, Falola et al. 1987). Open access to unmanaged lands in urban areas virtually guarantees that any wood on them will be harvested for fuel, so these results concerning stand density are not surprising. For comparison, Foley et al. describe how periodic cutting of about 10 percent of the trees in the Niger projects, rather than cutting all available wood, maintains the yield of the woodlands. Similarly, pruning trees rather than cutting them outright helps to maintain the integrity of the woodland and spur growth (Foley, Floor et al. 1997).

All of this discussion on fuelwood, agriculture, and forests has bypassed an entire set of issues of great importance to Africans, and to the world. Biological diversity is declining globally. Increased pressure on natural areas, led by growth in the human population and commensurate increases in population density, and expansion of the area of land inhabited by people continue. Natural areas and the ecosystems they contain have great value to people, and preserving those natural areas as natural areas carries tremendous benefits to people (Ehrlich and Ehrlich 1981; Wilson 1992; Daily 1997; Novacek 2001). However, these benefits are long-term and diffuse, and the poor of West Africa need immediate, direct benefits.

While devolution of authority and development of individual property rights is an important condition for private investment in land, those private investments are primarily for the sole benefit of the investor. The preservation of large natural areas and ecosystems requires the concerted efforts of both national governments and local authorities. In the face of growing population and pressing immediate human needs, maintaining natural areas will be a continuing, growing challenge for development professionals.

3.4 Simulation Modeling as a Tool for Developing Future Scenarios

Fuelwood models that try to match supply with demand all have common features that ensure that any long-term forecast made by the models will be off by at least a little bit—and sometimes off by a lot. User-friendly simulation methods can accommodate simple relationships, or more sophisticated understandings about supply and demand for fuelwood, and other ecological and economic variables that have bearing on forests, agriculture, and investment.

There is a difference between predictions of future conditions drawn from models and possible future scenarios drawn from models. Each future scenario is only one of many possibilities for future conditions. User-friendly simulation modeling methods can demonstrate possible future scenarios for fuelwood use, fuelwood supply, and relationships among the variables and conditions described in this paper. Experiments with this method show how anticipated future shortages or other conditions related to fuelwood are sensitive to the basic understanding of the person performing the analysis and the data used in the analysis. Woodwell (2000) demonstrated the potential for expressing a broad range of development hypotheses in simulation models. Once these hypotheses are incorporated into a simulation model, running the model can demonstrate the implications of the hypotheses.

The finding that anticipated shortages of fuelwood have not occurred leaves open the question of future supply and forest health in the face of a growing human population. Data from the FAO on the area of certain types of forests do not indicate regeneration rates or density of biomass in forested areas. Declines in density of biomass within forested areas are not fully reflected in these summary statistics. In light of this uncertainty, it is important to avoid making unwarranted warnings on impending crises that do not arrive. It is also important to anticipate the degree to which current decisions or policies have bearing on long-term or future problems.

Simple simulation models show that there can be long lag times or delays between the time a harvesting limit is set, and the ultimate effects of that limit. The effect of setting a harvest limit, illustrated with the available information for Burkina Faso, may be a sustainable use of the natural forests, or may be continuing decline and accelerating collapse of open-access forests many decades from now. Furthermore, uncertainty of biomass density and regeneration rates may allow this process to continue unnoticed, leaving a great deal of ambiguity for the future of West African forests and their potential for supplying fuelwood and other services.

The simple models discussed at the Ouagadougou workshop incorporate growth of natural forests, and an adjustable rate of harvest. The growth of forests and stocks of biomass are related according to the logistic curve, $dN/dt = rN(1-N/K)$, where dN/dt is the change in biomass per year, r is the annual growth rate as a percentage, N is the total stock of biomass in thousands of metric tons, and K is the maximum stock of biomass of a natural forest. Rough data for Burkina Faso for stocks of biomass and regeneration rates are derived from World Bank data (Millington, Critchley et al. 1994). Data for harvest in the year 2000 is from FAO (2002).

The models are written in the Stella modeling environment where stocks of forest biomass are represented as boxes, flows (changes in the stocks) as straight arrows, auxiliary variables or parameters as circles, and connections as thin arrows. Figure 1 shows a simple model of forest growth, with an adjustable harvest determined by the user. Figure 2 shows a model run with a harvest set at the World Bank's estimate of the maximum sustainable yield for Burkina Faso of 14.7 million metric tons per year. Note that stocks of forest biomass fall to about half the original over time, then stabilize. Yield grows as the forest is thinned, and then it stabilizes as well. Figure 3 shows the effect of increasing the harvest slightly, to 15.3 million tons per year. The first third of the model runs looks remarkably similar to the sustainable yield case, but instead of stabilizing, stocks continue to decline. As stocks decline in the second half of the model run, density of the forests fall enough that regeneration rates start to fall. Falling regeneration rates lead to more rapid decline of the stocks of biomass, and the downward spiral accelerates toward complete deforestation. For comparison, current harvest of wood (roundwood and fuelwood) in Burkina Faso totals about 7 million tons per year (FAO 2002), slightly less than half the World Bank's estimate of maximum sustainable yield.

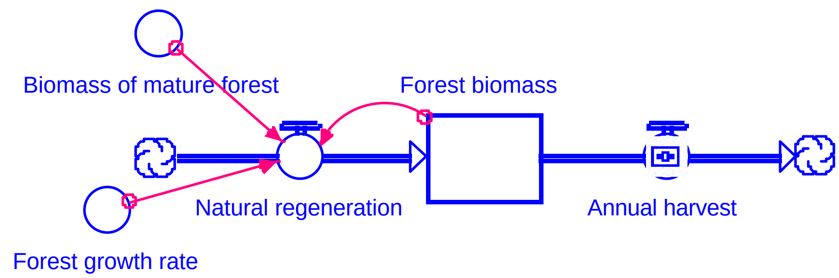

Figure 1. A simple model of forest growth, with an adjustable annual harvest

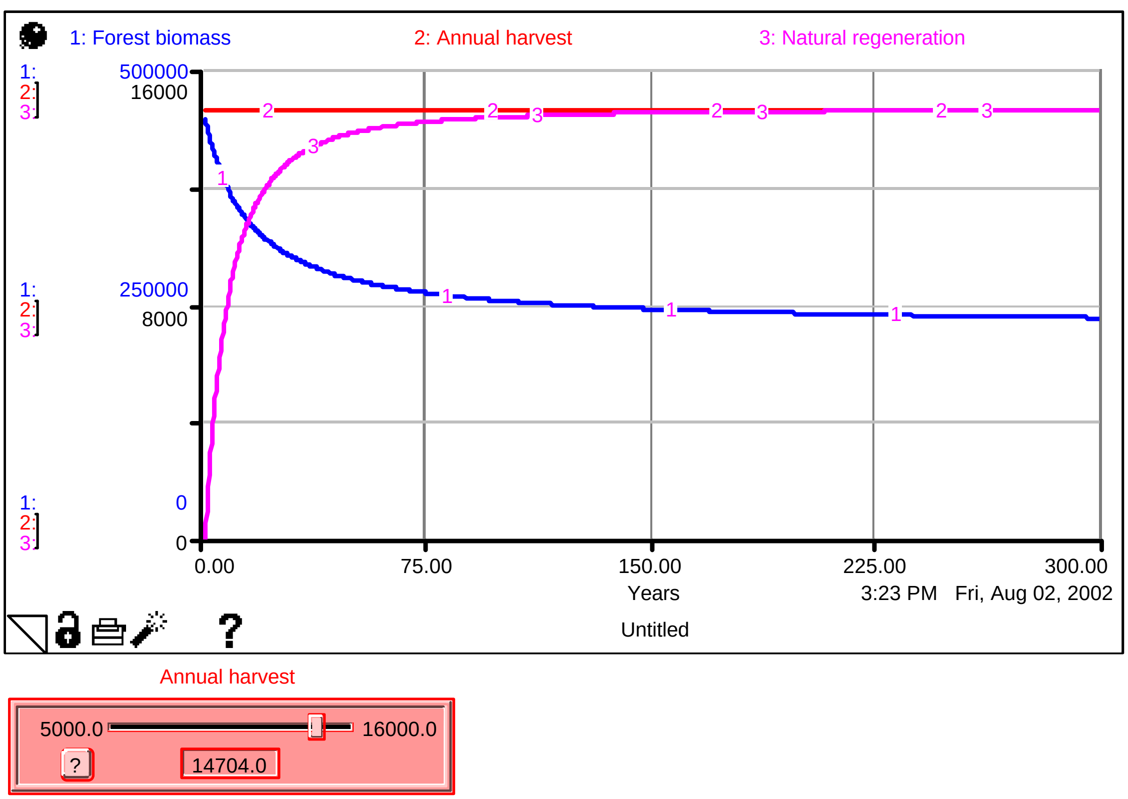

Figure 2. A potential scenario for the future of forests in Burkina Faso

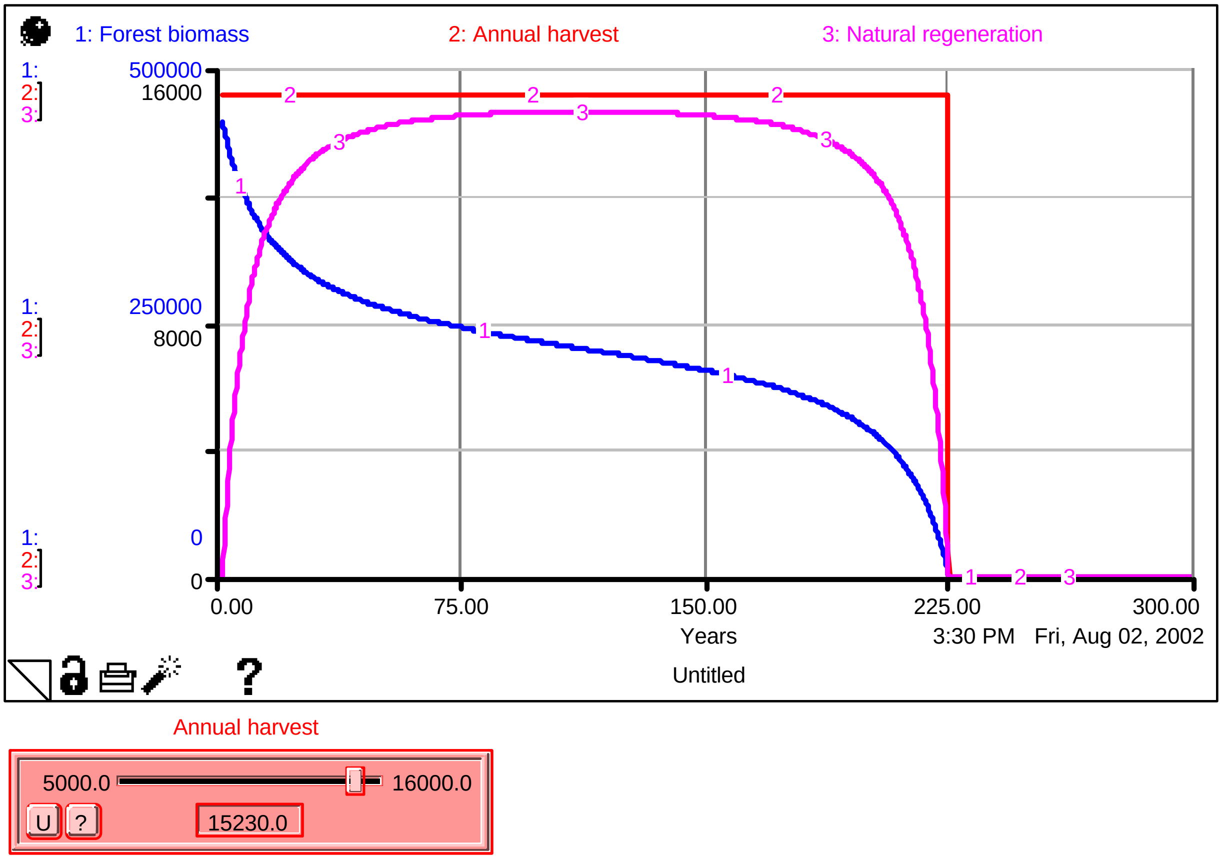

Figure 3. Another potential scenario for the future of the forests, where harvest exceeds maximum sustainable yield

In these two scenarios, harvest is constant throughout the model run. The harvest can be adjusted by the user during the model run, but to reflect an increase in harvest with an increase in population, the model in figure 4 is modified to allow continuing increases in harvest. The model run in figure 5 starts with the current harvest for Burkina Faso, and increases the harvest at 1.2 percent per year, slightly less than half the rate of population growth.

The notable features of the model run include the speed with which the increasing harvest overtakes regeneration and the shape of the regeneration curve. Regeneration increases steadily, then makes an abrupt turn downwards as the stock of trees is thinned further while harvest grows.

Another important feature in all of the cases is that these simple models are constructed with a basic understanding that the forests are open-access and will remain so. However, as discussed earlier, there have been many changes in the use and management of open-access forests. The expansion of agriculture and related consumption of natural forests for fuel has led to a reduction of forest biomass overall in those areas, although the process of devolution of authority and development of community and individual property rights allows for reinvestment in land, private forestry ventures in particular. This privatization, or community control and reinvestment, does not necessarily increase the maximum sustainable yield when compared with natural forest. However, as long as institutions are strong enough to ensure land tenure, then effective control of the harvest does open the possibility that some forests will not be harvested beyond a maximum sustainable yield. Therefore, rather than tending toward extinction on the whole as in figures 3 and 5, even with increasing demand for wood, they might tend toward a sustained yield, although not a maximum sustained yield on the whole.

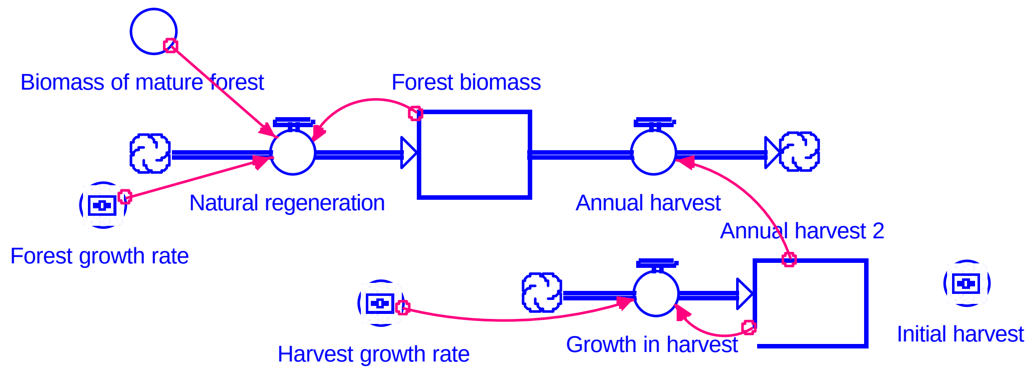

Figure 4. A simple forest model with continuing growth in harvest

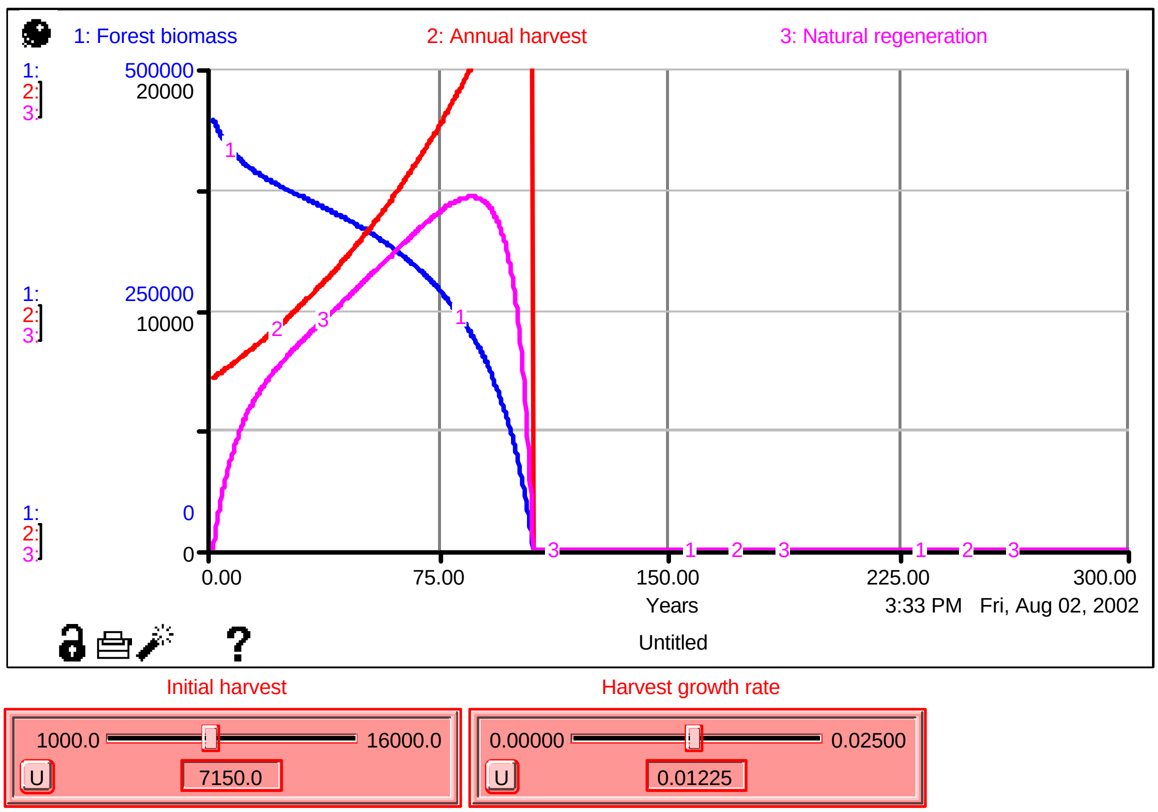

Figure 5. Model output with a continuing growth in harvest

Other relationships also warrant mention. Increasing demand for wood and increased scarcity of wood tend to spur technological development that increases the efficiency of wood use. Similarly, the availability of substitutes tends to reduce demand for wood, as do basic conservation measures. Effective governance is related to wealth, tending to erode with growing poverty, so effective management of the forests is a self-reinforcing component of well-being. Similarly, eroding governance is self-reinforcing feedback to poverty. These feedbacks and others could be incorporated into these models, and the outcome of the models runs would vary accordingly. The net effect of these relationships is an open question, and models that reflect these relationships can offer insights into the range of potential future scenarios for these forests.

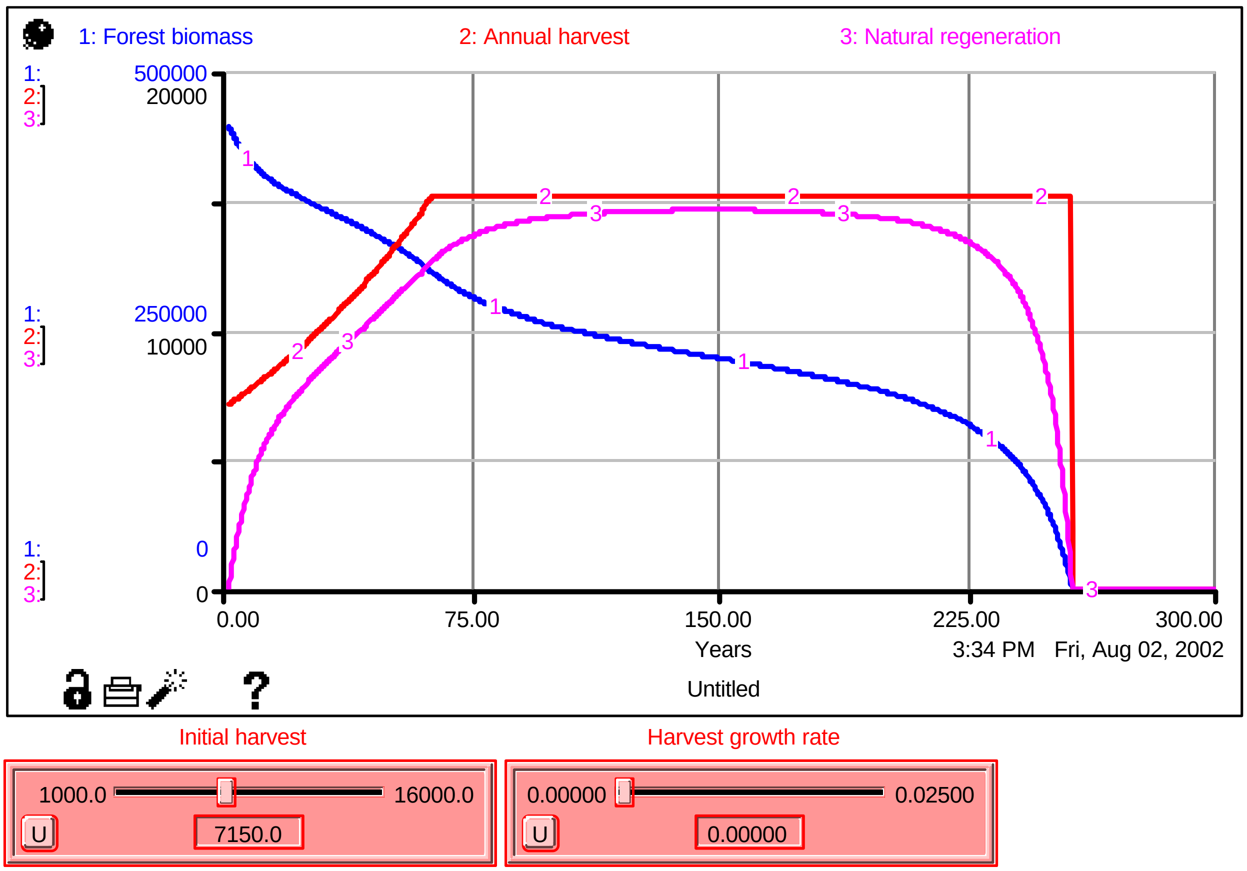

Figure 6. Harvest limited to 16 million tons per year

Figure 6 brings some insight to anticipating trends well into the future without sounding unwarranted alarms. The model run includes increasing harvest of wood, but caps total harvest at 16 million tons per year. Given the imprecision of FAO data and the uncertainty in regeneration rates a slow reduction in stocks of forest biomass is hard to notice. Even today, although there is general agreement that deforestation is occurring throughout much of West Africa, some authors disagree with this conclusion. For the model run in figure 6, there is reasonably good data for the harvest of wood, but there is not good data (almost none) for the other two series of forest biomass and regeneration. For this reason, the slow deforestation illustrated in the middle of figure 6 would be hard to detect and would not necessarily be noticed for the 150-year period of slow deforestation.

After 150 years of a constant harvest, it might be easy to conclude that the harvest is sustainable. However, the reductions in stocks do lead to a reduction in regeneration in the second half of the model run, which in turn leads to accelerated forest loss, even with the harvest limit in place. Given our difficulty today in observing changes in biomass density in West Africa’s forests, and if we are on this curve, the question remains open as to when on this curve we would notice definitively that our use of forests is not sustainable. To be sustainable, the harvest curve must be at or below the regeneration curve, so at year 150, the correction would need to be small; less than a 10 percent reduction in harvest would bring harvest below regeneration. As time goes on the distance between those two curves grows. If the reduction in harvest is delayed until year 225, the reduction has to be 20 percent to bring the annual harvest below the annual regeneration. If it is delayed until year 250, the reduction has to be more than 50 percent.

Fuelwood models of the 1970s and 1980s that anticipated widespread crises 20 or 30 years in the future have been discredited in part because those crises did not occur. These modeling exercises suggest that the time delay between the establishment of a policy to manage forests and the ultimate effect of that policy may be substantially longer than even that two- or three- decade timeframe. Furthermore, early intervention to avoid unsustainable forests uses is much easier than last-minute efforts to reverse a stock-depletion problem.

4. Conclusions

The challenge of meeting energy needs in West Africa is far more intricate than simple problem of fuelwood supply. Inaccurate assumptions in models of fuelwood availability and demand are easy enough to change to address a short-term issue of cooking fuel for the immediate future. However, the broader long-term issues include expansion of agriculture into natural lands and commensurate loss of woodlands or their replacement by private forestry initiatives; development of institutions that allow for land tenure and a broader concept of resource tenure; development of institutions that allow for effective management of common lands; and elevation from poverty.

Domestic energy in West Africa is part of a even larger and more intricate development challenge. Problems that develop slowly and gain momentum over a long time must be dealt with early if they are going to be dealt with effectively. Those who anticipated a fuelwood crisis recognized and acted on that principle. Efforts to meet the challenge, however, were carried out in the context of many other problems and relationships that both confounded their efforts, and eased the immediate fuelwood problem. An understanding of basic biological relationships and human behavior in light of needs, risks, and opportunities may be the lesson to learn from this experience.

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