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THE EVOLUTION OF WOODFUEL DEMAND IN MALI

An Outline Case Study

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Earthscan Energy Information Programme

EARTHSCAN - INTERNATIONAL INSTITUTE FOR ENVIRONMENT AND DEVELOPMENT

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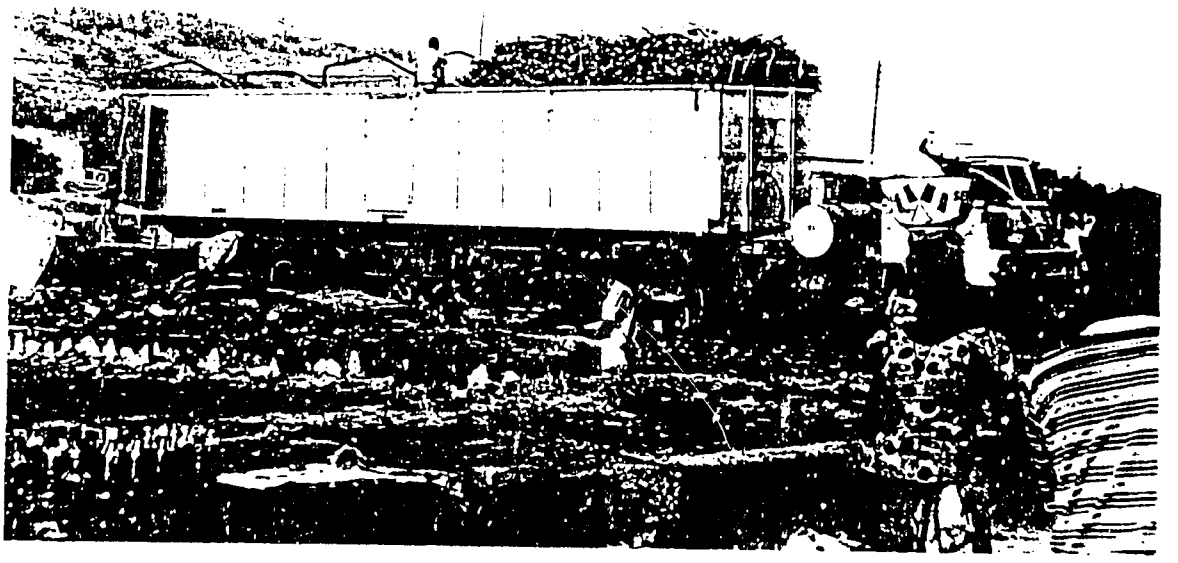

Figure 1: A large trailer of woodfuel being unloaded in Bamako

FOREWORD

This study examines the evolution of urban and rural woodfuel supply and demand patterns in Mali. But it is not intended as a formal energy planning study of the country. Its purpose, rather, is to raise and discuss a number of questions with general relevance to woodfuel and energy policy in Mali and similar arid or semi-arid areas where woodfuel resources are being depleted.

The first part, the General Appraisal, gives an overview of the study and outlines its main findings. The subsequent chapters amplify and discuss the arguments and principal issues in greater detail.

The second part deals with the Malian context. Chapters 2 and 3 provide a general description of Mali and its rural production systems. Chapter 4 looks at conventional fuels and the work which has been done on new and renewable energy sources and improved cooking stoves.

The third part deals with woodfuel. The present position is described in Chapter 5. Future woodfuel supply and demand projections are covered in Chapters 6 and 7. Chapter 8 draws some broad policy conclusions and suggests a minimum agenda of the most urgently needed next steps.

The research for the study was carried out in early 1986. A draft was circulated for criticism and comment. This final report has been rewritten to take the results of these consultations and further research into account.

Many people have helped with the study. A major debt of gratitude is owed to Chun Lai and Mamadou Mana Diakité in the USAID mission in Bamako. Particular thanks are also due to Greg Duly, Project Coordinator, of CARE/Mali.

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None of the above individuals or organisations bears any responsibility for the ideas expressed in this paper.

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Currency

The currency unit in Mali is the Franc CFA (FCFA). This is the common currency unit of the Communauté francaise d'Afrique (CFA). It is tied to the French Franc (FF) at a fixed rate of 50 FCFA = 1 FF.

The former currency unit was the Malian Franc (FM). This was converted to the FCFA in 1984 at the rate 2 FM = 1 FCFA.

At the time of this study, in early 1986, the exchange rate with the US dollar was $1.00 = 340 FCFA.

Firewood Measurements

Firewood measurement conventions vary widely between sources and are subject to frequent ambiguities and contradictions. The following have been used in this report:

1 cubic metre = 1 cubic metre of solid wood = 700 kg air dry wood.
1 stère = 1 cubic metre stack of wood = 230 kg air dry wood.

Energy Equivalents

1 kg wood	= 15 MJ	(air dry)
1 kg millet stalks	= 15 MJ	" "
1 kg dung	= 11 MJ	" "
1 kg butane	= 45 MJ	
1 litre kerosene	= 0.8 kg = 34.4 MJ	

PART I

GENERAL APPRAISAL

1.0 GENERAL APPRAISAL

Any study of the woodfuel supply position in a Sahelian country, or indeed in most of the other arid and semi-arid countries of the developing world, reveals a profound paradox.

On the one hand, it seems evident that the woodfuel resources of these areas are being consumed far more rapidly than they are being renewed naturally or by plantations. There is no disputing that vast areas which were formerly forest or woodland are now virtually treeless. On the other hand, despite the apparent urgency and magnitude of the problem, the people most deeply involved appear unwilling to make the effort to grow trees to assure their future woodfuel needs.

International agencies and governments cannot be accused of lack of interest and practical support. Considerable efforts have been made to involve local people and promote tree growing at a farm or community level in Mali and other Sahelian countries. But in most cases little of enduring significance has been achieved. Nor have the majority of rural people shown any great interest in adopting the more energy efficient cooking stoves which would help them economise in their use of woodfuels.

Why is this so? Are the people concerned really unaware of the worsening woodfuel problems about them? Are they indifferent to their own future? Is the answer to be found in improving the technical quality of programmes and providing better extension programmes?

1.1 A Controversial Hypothesis

The analysis carried out in this study suggests that such questions miss the central point and that there is a need for a radical reassessment of the diagnosis of the 'woodfuel crisis' itself. In the case of Mali, and by inference elsewhere, it seems probable that the conventional analysis seriously underestimates the availability of domestic fuel resources in the rural areas. As a result, there is an exaggerated view of the fuel problems experienced by rural people.

The rural population is therefore right to be unconcerned about woodfuel. In the harsh context of their daily existence, there are many more urgent and important matters than growing trees for firewood.

As for the cities, it looks as if current demand projections seriously over-estimate future woodfuel demands. It also appears as if resources are adequate to meet these demands for at least the next three decades. If these conclusions are correct, the advent of a 'critical' woodfuel supply position will be considerably further into the future than is commonly thought.

The hypothesis that, in effect, there is not a domestic woodfuel crisis in Mali, or similar Sahelian countries, is highly controversial. It is at first sight blatantly inapplicable to the beleaguered countries concerned. It runs counter to what has been almost universally accepted for the past fifteen years. But it deserves investigation since, at least, it has the merit of accounting for the available facts rather better than the "crisis theory" which has held sway up to the present.

1.2 The Malian Context

Mali is one of the largest African countries. It lies to the west of the Sahelian zone and is completely land-locked. Measured by income per head, it is one of the poorest countries in the world.

The climate is hot and dry. There is a single rainy season in the year, lasting about three months in the mid latitudes, longer in the south and shorter in the north. Most of the centre and north of the country was badly hit by the droughts of the 1970s and early 1980s.

The rainfall dictates the patterns of rural existence over most of the country. In the south, where the rainfall is highest, there is settled farming. Millet and sorghum are the staple crops; yams, manioc and sweet potatoes are also grown. Moving northwards, the rainfall lessens, crop yields are lower and sorghum gives way to millet. Cattle play an increasingly important role in the rural economy. North of the limit of settled cultivation, the land is inhabited only by nomadic pastoralists.

Life for a large number people is also heavily influenced by the River Niger. This flows more or less diagonally across the southern half of the country. As its rainy season peak flow declines, cultivation is carried out on the rich alluvial soils exposed by the retreating waters. The most spectacular example of this is in the inland delta of the Niger, where an area of up to 100 km wide stretching along 300 km of the river can be covered with water under peak flood conditions.

1.3 Rural Woodfuel Consumption

At present, woodfuel is universally used in the rural area to meet domestic energy needs.

There is little commercial dealing in the woodfuel used by rural families. Supplies are gathered from village surroundings without any cash payments. The main sources are the natural woodlands or bush and the fallow lands. The responsibility for woodfuel supplies rests generally with women who collect it and carry it back to the home. In some places, men are also involved, particularly when the wood collection area is a long way from the home and a donkey cart has to be used to transport it.

There are virtually no reliable statistics on rural woodfuel consumption in Mali. Few surveys have been carried out and doubt has been cast on the results of several of these. The available evidence suggests an average figure of around 11 kg per day per family. But it is clear that consumption varies widely over the country and, indeed, between different households in the same village. In some areas, dung and millet or sorghum stalks are used as supplementary fuels or alternatives to wood.

1.4 Urban Woodfuel Consumption

Firewood is also the main urban domestic fuel. Unlike, for example, its neighbour Senegal, the consumption of charcoal in Mali is relatively low. It is mainly used for making tea and ironing. It accounts for less than 10% of the total domestic woodfuel consumption.

Bamako accounts for the bulk of urban woodfuel consumption. Little is known in detail about the actual levels or patterns of woodfuel use at a family level. Only one major survey of fuel use in Bamako has been carried out. This showed a two-fold discrepancy between its highest and lowest estimates of consumption. If the average is taken, woodfuel consumption was about 1.5 kg per head per day.

About 75% of the woodfuel supply to Bamako is carried by motorised road vehicles, most of it in large trailers and lorries. Donkey carts, bicycles, and pedestrians carry a further 16%; and a small proportion also comes by rail and river.

In real terms, the price of woodfuel in Bamako appears to have remained more or less constant over the past decade. In the period 1978-1983, the market price was increasing at about 13% per year, but as this was the same as the overall rate of inflation in the country during that time, no increase in real terms was taking place.

One of the most important features of the woodfuel supply system is that virtually all the wood is obtained from natural forest or brush land. It is collected by rural people as a means of earning a living or supplementing farm incomes. Given the lack of other opportunities for earning money in the rural areas - particularly outside the harvest season - the cash return for which rural people are prepared to work on woodfuel collection is minimal. In other words, the "production" costs of this wood are very low.

1.5 Lack of Control of Woodfuel Exploitation

The Malian forestry service, Direction Nationale des Eaux et Forêts (DNEF) is legally responsible for controlling the country's woodfuel resources.

Collection or limited cutting of firewood for people's family use outside the protected forest areas are exempted from taxation or regulation. But when someone wants to cut or gather woodfuel for sale they are supposed to obtain a cutting permit from the DNEF. This specifies the quantity of wood which may be cut and the location from which it may be taken.

The DNEF, however, is singularly badly equipped for the massive regulatory task imposed on it. Its total budget does little more than cover its wages and salaries. In 1984, only 8% was available for expenditure on all other expenses. The result is that officers are largely office-bound. There is consequently little effective control over the exploitation of the country's wood resources.

Nor is there any serious possibility that this position will change substantially in the near to medium term future. The resources required for effective control over the vast expanses of Mali's natural woodlands are far beyond the reach of the Government which has many other pressing calls on its limited resources. The outlook for woodfuel collection is that rural people will continue to collect and cut what they need for their own use, or for sale to the cities, from where they can most easily obtain it.

1.6 Population Trends

The total estimated population of the country in 1984 was 7.3 million, about 80% of whom live in the rural areas. Most of these people live in small farming villages with an average size of about 500 people. Population densities are generally low, below 10 people per square km in most of the drier farming areas, though reaching 20-30 people per square km in the more fertile parts.

At present, the population growth rate is estimated to be about 2.5% per year. If this continues, the total number of people in the country will be about 12 million in the year 2006.

The capital, Bamako, is by far the largest city. Its population in 1984 was estimated to be 600 000. This was about ten times greater than the next largest towns.

Bamako is currently estimated to be growing at about 7% per year. This means it is doubling in size every 10 years. Urban researchers are now beginning to question whether such extremely high growth rates are likely to persist in the future; and urban size projections are generally being revised downwards in other parts of the developing world.

If Bamako were to grow at 7% per year for the next twenty years it would have a population of 2.3 million in the year 2006. This may be implausible; it is difficult to see the infrastructure which would provide the bare minimum of conditions for human survival being provided in time. But even if the growth rate is 5%, the total population will be 1.6 million, more than two and a half times its present size.

1.7 Projecting Woodfuel "Deficits" in the Rural Areas

Most energy studies project rural woodfuel consumption rising in line with population growth. Since virtually no tree planting to supply future woodfuel needs is being carried out, the rising consumption inevitably reaches a point where it exceeds the rate of natural regeneration of the available woodland resources. This means that woodfuel consumption levels can only be maintained by cutting into the stock of trees; this is sometimes termed a woodfuel "deficit."

According to this theory, once the stock of trees starts being cut, the "deficit" begins to increase. When this is associated with rising consumption, as a result of population growth, the position deteriorates at an accelerating pace. Calculations can show the complete exhaustion of wood resources within a period of 15-20 years.

Yet today in many areas which such calculations show to be heading for catastrophe, the surface of events is calm and there is no sense of crisis. No one has the slightest interest in growing trees for fuel. The frequent response by outsiders contemplating this indifference on the part of the local population is to talk of their lack of a sufficiently long time perspective, or an unawareness of the true implications of an exponentially worsening position.

1.8 An Alternative View

A key feature of many of these "deficit" projections is that they are based solely on estimates of the woodfuel resources available in natural and reserved forest areas. They take no account of the large amounts of woodfuel obtained, in practice, from fallow lands.

Taking the fallow land woodfuel resources into account in the depletion calculations dramatically alters the picture. The rate of natural woodland depletion is very much slower, and even when population is increasing, people are able to meet their household energy needs for a very much longer period into the future. The critical issue is not woodfuel: it is the agricultural system. As long as this remains functional, domestic energy supplies are unlikely to be a problem.

The crisis calculations also tend to leave out the reactions of intelligent human beings to increasing shortage. In areas where woodfuel is becoming scarce, or where the natural wood resource endowment is poor, people do not continue consuming wood at the same rate until the last tree has been cut. As woodfuel becomes scarcer, it becomes harder to find. Women start to make the trade-off between the extra time and effort required in searching for wood and that involved in using it more economically. As a result, fires are made smaller, are tended more carefully, and are kept lighting for shorter periods.

Other sources of fuel also come into use. Women collect small wood and branches from trees and bushes which they would previously have rejected. They also supplement woodfuel by burning millet stalks, dung, and other agricultural residues. The total quantities of these supplementary fuels required to maintain the balance between supply and consumption are relatively small. Their use as fuel would make little, if any, difference to the agricultural system.

The calculations carried out in this study take the availability of wood from fallow lands and the use of supplementary fuels into account. They strongly suggest that the conventional analysis grossly exaggerates the gravity of the woodfuel problems facing people in the rural areas. Even when wood begins to become scarce, the supplements and alternatives are readily to hand. In such circumstances, the difficult, uncertain, and time consuming task of growing trees to meet future fuel needs makes no sense to hard pressed local people.

1.9 Changing Patterns of Urban Woodfuel Demand

There is a similar tendency to overstate the problems in the urban areas. Usually, the future level of urban woodfuel consumption is assumed to increase in line with population growth. This fails to take into account the many complex social and economic changes which take place as a city grows.

One of the most important developments is an increasingly marked stratification of social and income classes. Neither the upper nor the lower continue to conform to the norm of woodfuel consumption established when the city was smaller and more closely related to its rural hinterland.

The upper income groups almost everywhere move away from woodfuel as cities grow larger. The use of conventional fuels is cleaner and more convenient than woodfuels. This switch in fuel use by the better off section of the population progressively lowers the average urban woodfuel consumption.

The growth in numbers of the very poor has the same effect of lowering the average woodfuel consumption. These people are not able to pay for substantial amounts of woodfuel. Nor do they have the space or time to do more than maintain the minimum standards of food preparation and cooking. They scavenge, beg, go hungry, and manage as they can. Their woodfuel consumption is small.

There are also changes in general dietary habits as a city grows. The rural routines of pounding millet and long hours of stirring traditional stews and porridges gradually give way to cooking and eating habits more typical of towns. Many workers take at least some of their meals at kiosks or restaurants. Packaged or processed foods come into increasing use.

These shifts in behaviour do not occur overnight. There is often considerable resistance by many people to alterations in their traditional ways. But experience of urban growth over the rest of the developing world shows that the changes usually come.

Thus, while there is no doubt that woodfuel consumption will continue to increase in the future, allowance must be made for the factors which slow the growth in consumption. Twenty years from now, Bamako is likely to be more than twice its present size, but it is extremely improbable that it will be using twice as much woodfuel as it does today. The tentative calculation made in this study indicates an increase of perhaps 50%.

1.10 Meeting Future Woodfuel Demand in Bamako

The present woodfuel supply for Bamako is brought in along the six major routes leading to the city. It is cut in the woodlands on either sides of these roads and brought to the roadside where it is picked up by the transporters. Most of the cutting is within 3-5 km of the roads. Pick-up points can be found from within a few kilometres of the city up to a distance of 175 km away.

This system seems adequate to meet the city's woodfuel needs for at least the next three decades. The necessary supplies of wood can be obtained by extending the distance travelled from the city and widening the collection distance on either side of the roads. The additional distances are not great enough to to bring about a substantial increase in the costs of woodfuel.

This means that the economic case for woodfuel plantations will remain extremely poor for a considerable time to come. Increasing the taxes on woodfuel being carried into the city has no effect on the basic "production" cost of the wood. Higher taxes will provide additional revenue for the Government but in the absence of effective control over the exploitation of the natural woodlands they will not improve the competitive position of woodfuel plantations.

The widespread fears of "desertification" if alternative sources of woodfuel are not provided also appear to be unjustified. The bush will undoubtedly be heavily cut over but it will not be completely cleared to provide woodfuel. The urban area does not provide a ready market for the small wood and twigs which are all that can be obtained when the saleable woodfuel has been cut. If desertification occurs, it is as the result of over-grazing or poor agricultural practices rather than exploitation of the land for woodfuel.

1.11 Policy Implications and Next Steps

This study of the woodfuel position in Mali has revealed that it is possible to interpret the available information in a radically different manner from that conventionally done. The evidence presented here is that in the rural areas there is neither an existing energy problem nor any serious prospect of one over the next couple of decades. The level of woodfuel resources available to supply Bamako also appears to be adequate to meet demands over the next twenty years and well beyond.

The point is not merely intellectual or polemical. If the problems are not properly defined, then the solutions will not be appropriate. There is no question that the Sahelian countries need all the help that can be given to them. Their plight is such that the very best efforts must be made to ensure that any programmes which are launched must be based on a proper understanding of the problems they are meant to solve.

It cannot, therefore, be over-emphasized that this study is not advocating complacency about either the rural or urban areas of Mali or the Sahelian countries in general. They are quite obviously deficient in the basic necessities of food, water, health, education, and most of the goods and services that the industrial world takes completely for granted. All the present study is suggesting is that those who are able to grow or buy enough food to feed themselves will not be without the fuel to cook it.

This has serious implications for policy. There is no point in using scarce resources to solve energy problems which do not exist, or are being solved quite adequately by local people. When external help is being offered, it has to be related to the real needs and priorities of the people and countries concerned. If the supply of domestic energy is not now an urgent issue, there are plenty of others to take its place.

There is therefore an urgent need for new and more broadly based studies of the woodfuel position in Mali and countries in a similar position. In the rural areas, these studies need to examine the total context in which families go about meeting their woodfuel needs and how they respond to changing circumstances. In the cities, they need to tackle the issue of woodfuel demand within the complex pattern of change which accompanies urban growth.

At present, energy policy making in the woodfuel area is taking place without an adequate factual or analytic basis. The current conceptual models and paradigms have clearly served their purpose. They need to be replaced with others which more adequately reflect the reality with which people have to deal, if woodfuel programmes are to become an area for fruitful technical assistance and collaboration with the developing world.

PART II

CONTEXT

2.0 MALI: THE COUNTRY

The total area of Mali is 1.24 million square kilometres, more than twice the size of France. It is completely landlocked, bounded by Algeria, Niger, Burkina Faso, Cote d'Ivoire, Guinea, Senegal, and Mauritania. It was formerly part of the French colonial empire and became an independent republic in 1960.

For the most part, the landscape is flat or slightly undulating. The altitude is generally between 200 and 350 metres above sea level. In a number of areas, however, there are abrupt changes of level. The Dogon plateau, to the west of Mopti, is bounded on its east by a spectacular cliff 500-600 metres high.

The basin of the river Niger forms the geographical axis of the southern half of the country. It enters Mali in the extreme south, flows in a northeasterly direction for a distance of about 1000 km and then loops southward into Niger. The west of the country forms a separate watershed drained in a westerly direction by the river Senegal and its tributaries.

There are three main seasons in Mali. From March to July there is a very hot dry period. The rainy season is between July and September in the mid-latitudes of the country; it is longer in the south and shorter in the north. There is a cooler period from about October to March. The dry months can be extremely dusty, particularly when the north east wind, the Harmattan, is blowing. Wind can be a particularly potent agent of erosion when the vegetation cover is reduced.

By any standards, Mali is a poor country. The World Bank lists it as the third poorest in the world, with an annual GNP per head of $140 in 1984. The life expectancy at birth is 46 years and the literacy rate is 5%. There is little large scale manufacturing industry; agriculture and services each account for about 45% of the total GNP. In the period 1973-84 the average rate of growth in the economy was 4.1% per annum (World Bank, 1986).

There are serious disease problems over large areas of the country. Malaria is endemic over the whole populated area. There is tsetse fly infestation over most of the Sudanian zone. Schistosomiasis, or bilharzia, is found along the whole length of the Niger basin and the southern part of the country. Onchocerciasis, or river blindness, is also widespread in the south. Recently, AIDS has been added to this grim catalogue, though no statistics on its incidence are yet available (Sabatier, 1986).

The country was badly hit by the Sahelian drought of the early 1980s. There was a widespread failure of crops and natural forage in the drier farming and pastoralist areas. In some of the drier parts, people were reduced to digging in the sand to find grain buried by ants, or boiling the skin of dead animals to obtain some nutrition.

Many pastoralists lost their entire flocks and had to migrate southwards looking for work. Food relief was distributed in the worst hit areas. But conditions generally did not reach the state of widespread famine and death found in some of the other Sahelian countries.

2.1 Ethnic Groups and Cultural Traditions

There are over twenty different ethnic groups in the population, of which the Bambara are the most numerous. Other well known groups are the Tuareg, the Fulani, and the Dogon whose traditional art is among the most striking in Africa. The official language of the country is French, but Bambara is the most widely spoken tongue.

Malian social structures are extremely complex and deeply rooted in the country's long, rich and often violent history. People's occupations are largely determined by the ethnic group to which they belong. Thus the Tuareg are nomadic pastoralists who range over the northern part of the country. The pastoralists of the Sahelian zone are mainly Maures and Peul. The fishermen along the Niger are principally from the Bozo group. The farmers include the Dogon, the Malinke in the west, and the Bambara.

There are also clear distinctions in the social ranking of groups relative to each other. These are rooted in historical relations between conquerors and conquered (Hill, 1985). Slavery persisted into the present century, and its traces are still discernible in certain aspects of Malian social life, especially in the remoter villages.

Each ethnic group is also organised in accordance with its own systems of hierarchy; in some there is a rigid division between nobles and people of lower caste. Some functions, such as iron forging or shoemaking are allocated on a hereditary basis to certain groups or castes. The Dogon, who are extremely skilled at prizing a living out of the difficult soils of their region, for example, claim no expertise in looking after animals and frequently employ Peul to do this for them.

These traditional distinctions and social structures are being blurred by modernisation, urbanisation, and the increasing movement of people within the country. But they are still an important factor in Malian life. They have to be taken into account when woodfuel and other programmes are being planned at a detailed level.

2.2 Climatic and Ecological Zones

Mali lies between latitudes 10° and 25° north of the equator. The main variations in the climate and ecology occur from north to south and are principally related to the annual rainfall level. The country can be divided into five broad zones as shown in Figure 1.

Caution, however, is needed when considering the rainfall levels shown in Figure 2. These are based on data accumulated up to the mid 1970s. The average since then has been lower, which means that the present position of the isohyets is further south than shown. Whether this is a permanent or long term change in the climate of the country is still unknown.

2.21 Saharan Zone

The Saharan zone occupies the northern portion of the country down to about latitude 20°. It covers about 25% of the country. This is a true desert area with little or no rainfall.

Figure 2: Climatic zones and rainfall levels.

The few human inhabitants, mostly Tuareg, live a completely nomadic life. They travel between points where water can be found, transporting their possessions on camels.

The vegetation is extremely sparse or non-existent.

2.22 Sahelo-Saharan Zone

The Sahelo-Saharan zone lies roughly between latitudes 20° and 16°. Its southern boundary is approximately marked by the 300 mm isohyet. Within the zone, the rainfall tends to be patchy and unreliable and often falls in violent storms.

The natural vegetation consists of a light scattering of low thorny shrubs and bushes. When rain falls, a rapid growth of grasses and other herbaceous vegetation occurs within a period of a few days. Water also accumulates in large shallow lakes. These areas of grass and water are used by nomads during their annual migration away from the farming areas during the growing season.

Because of the low and unreliable rainfall, settled farming is not possible in this area. There is, however, a certain amount of cultivation along the banks of the river Niger.

Tombouctou and Gao lie on the southern edge of this zone. Although, historically, both these towns were extremely important trade centres, they have now greatly declined.

This zone, together with the Saharan, accounts for about 60% of the area of Mali. But the population is only about 5% of the national total.

The standing stock of woody material and the annual yield are generally very low. Both depend heavily on the rainfall; in dry years the vegetation does little more than survive. In some areas, there are substantial standing stocks of dead wood, trees which were killed off in the droughts of the 1970s and 1980s.

2.23 Sahelian Zone

The Sahelian zone stretches across the whole width of the country roughly between latitudes 16° and 14°. The rainfall varies from about 300 mm per year in the north to 700 mm in the south.

The natural vegetation is brush or open woodland. In the northern drier areas this is relatively sparse and low in height, but it becomes denser and taller towards the south as the annual rainfall increases. During the rainy season there is a profuse and rapid growth of grasses and herbaceous plants.

In the north of this zone, where agriculture is difficult and risky, pastoralism is the predominant means of livelihood. Moving southward, farming increases in importance as the rainfall becomes higher. Much of the area is traversed by pastoralist flocks of animals in their seasonal treks in search of fodder and water.

The droughts of the 1970s and 1980s are causing a variety of land use changes to take place. In some of the more northerly areas the balance is shifting towards pastoralism as a result of the difficulty of farming under increasingly dry conditions. In other areas, pastoralists unable to find sufficient grazing areas to sustain their flocks through the year, are taking up farming.

2.24 Sudanian Zone

The Sudanian zone occupies the southern portion of the country below about latitude 14°. The rainfall ranges from 700 mm at the northern edge up to 1500 mm in the extreme south. In the north, the natural vegetation is an open woodland. This becomes gradually denser and richer towards the south.

This is an area of settled farming. The capital, Bamako, on the Niger, is positioned at its centre. Segou, the second largest city, is to its north; Sikasso, near the border with Burkina-Faso is in the south; and Kayes on the river Senegal lies to the west.

It is also the area in which the tsetse fly is found. Trypanosomiasis, sleeping sickness, is endemic over most of the zone. There is a rapid increase in the numbers of tsetse fly in the beginning of the rainy season, though they disappear when the dry weather returns. The northern part of the zone is used for dry season grazing by pastoralists. The cattle owned by sedentary farmers are restricted to the trypanosomiasis resistant N'dama type (Ohler, 1985).

2.25 Inland Delta of the Niger

A further climatic and ecological sub-region with its own unique characteristics can also be distinguished in Mali. This is the inland delta of the river Niger. The climate is Sahelian, but much of the ecology of the area is determined by the annual ebb and flow of the Niger floods.

The delta stretches from near Segou up to Tombouctou. This is an extremely flat plain within which the river divides and braids into a variety of different channels and forms a number of permanent or semi-permanent lakes. Its largest tributary within Mali, the Bani, joins the Niger near the southern end of the delta.

During the dry season, the river flow declines greatly; most of the channels in the delta have no water, and the Niger itself is only navigable by small boats. The mean low season flow measured at Koulikoro, near Bamako, is just 70 cubic metres per second, with a recorded minimum of 18 cubic metres per second.

During the flood period, however, the water flow increases dramatically. The mean flood flow at Koulikoro is 5290 cubic metres per second, some 75 times greater than the mean low period flow. The maximum recorded flood was 9700 cubic metres per second and happened in 1925.

When the flood reaches the inland delta, the river channels and lakes are filled and the waters spread across the land. Under maximum flood conditions the delta has a length of about 300 km and a width of 100 km

at its widest point. On average about 2 000 000 ha are flooded each year.

The vegetational patterns vary widely in this area, with a great deal depending on the regularity and depth of flooding. In the heavily flooded areas, only those tree species such as Acacia nilotica which can stand prolonged immersion can flourish. There are also islands of natural woodland raised above the general flood level where there are substantial standing stocks of trees.

2.3 Population Distribution and Growth

There are few reliable demographic statistics on Mali. Most of the available information is based upon the 1976 census.

Pastoralist transhumance also adds to the difficulty of assembling consistent statistical data. In some of the villages of the north and east, only 25% of the total population may remain permanently at home throughout the year. The large scale movements forced on people during the recent drought years add to the already high level of uncertainty about population numbers and distribution. All figures must therefore be treated with considerable caution.

The total estimated population in 1982 was 7.3 million people. About 80% of this population was living in the rural areas (Anon, 1985). According to the 1976 census, only 42 settlements had a population greater than 5000 people. The rest of the population live in a host of small villages with an average size of about 500 people.

Bamako, the capital, is by far the largest city. Its estimated size in 1984 was about 600 000 people. This gave it a population around ten times greater than Segou and Mopti, the next largest towns. Recent data are not available for other towns but Table 2.2 lists the populations of the principal towns according to the 1976 census.

Table 2.2 Population of Principal Towns in 1976

Bamako	404 000	Mopti	53 000
Kayes	49 000	Tombouctou	19 000
Koulikoro	16 000	Gao	31 000
Sikasso	46 000	Segou	65 000

Source: 1976 census data quoted in (Pringle, 1984)

In the rural areas, there is a large range of variation in population densities, but in general, they are low. In the desert and near desert areas the population density is in the range 0-0.5 person per sq km. Throughout most of the Sahelian zone, the density is less than 7 persons per sq km.

Even in the farming areas, a high proportion of the land has a population density of less than 20 persons per sq km. It is only in the region of the larger towns and villages that average densities in

the range 20-30 persons per sq km are found. In a few areas, such as the irrigated rice growing zones of the inland delta, the density reaches 40 persons or more per sq km.

2.31 Population Growth Projections

At present, the national population rate is estimated to be about 2.5%, per year. About 20% of this growth is currently taken up by emigration (Pringle, 1984). But this may not continue; events in some of the neighbouring countries and France indicate an increasing reluctance on their part to accept foreign workers.

Over most of Mali, there is also a flow of people from the rural areas towards the towns. Some of this is on a permanent basis. But there is also a considerable amount of temporary migration. Young people, in particular, come into the towns during the dry season and take up jobs in small scale manufacturing, the services sector or selling goods in the streets. They return to their homes for the farming season.

Permanent migration from the rural areas has, however, increased as a result of the drought. Many farming and pastoralist families who can no longer gain a living from the land have taken refuge with relatives living in the towns.

The overall rate of growth of the urban population is estimated to be 5.6% per annum (Pringle, 1984). But this is spread unevenly around the different urban centres. Bamako is undoubtedly the major attraction and its growth rate is estimated to be about 7% per year at present.

If the growth rate of 7% per annum were to continue in Bamako it would result in a doubling of population every 10 years. This would lead to a city of 2.4 million people by the year 2006. Although such projections of very rapid urban growth were widely accepted in the past, they are now being treated with more caution. Many of the alarmingly high projections made for cities in other parts of the developing world during the 1970s are being revised downwards (Hardoy and Satterthwaite, 1986).

Nevertheless, a continued and rapid growth in the size of Bamako is almost certain. Even if the rate falls to, say, 5% over the next 20 years, this will result in a population of about 1.6 million by the year 2006. This can be taken as a reasonable assumption for the purpose of the present discussion.

Growth in the other urban centres in the country has tended to be lower than Bamako. But this may well change in the future. Towns such as Segou and Mopti, which are well placed as far as communications are concerned, may well grow rapidly if there is a sustained period of even moderate economic growth in the country. But given their relatively small size at present, this is not likely to affect the national population distribution picture to any great extent.

Given the more rapid urban growth rate, the rural population increase will be somewhat less than the estimated national average rate of 2.5% per year. An average rate of increase of 2.3% can be taken as a working figure for the present discussion, but the actual figure is likely to vary considerably between different parts of the country.

3.0 RURAL PRODUCTION SYSTEMS

Rural life is difficult over most of Mali. The work is hard and heavy and relies almost entirely on traditional methods. Tools and implements are simple and hand operated.

Incomes are low, with the bulk of production going for family subsistence. For most farmers there is little, if any, cash surplus for capital investment or development of their production capabilities.

3.1 Agriculture

Farming is carried out wherever the soil and climatic conditions permit. There are remarkable feats of cultivation in some areas. The farmers of the rocky Dogon plateau are particular skilful in building small terraces to retain the minute amounts of available soil from which they manage to obtain a living. Cultivation conditions improve gradually towards the south as the rainfall increases and becomes more reliable.

In the farming areas, people live in villages of tightly clustered houses. Many families have small walled vegetable gardens attached to their dwellings. Similar small gardens surrounded by thorn fences may be found in the area immediately around the village. Poultry and goats are reared by most families and wander about the village and its surroundings.

Houses are made of banco. This is a mixture of mud and sand, usually with the addition of straw or dung, which is made into bricks and dried in the sun. The walls of the dwellings are built with these bricks and finished with a banco plaster. The roofs are of straw or banco and are supported on wooden rafters.

Land ownership and inheritance rights vary widely. The combination of traditional customs and modern statutory laws found in many instances can complicate the picture enormously. Often the land is owned by the village, with every family having a right to a certain amount. Whether lands can be transmitted from generation to generation, what the rights are over trees, and how dry season grazing is shared with pastoralists, and between members of the village depends upon local conditions and can only be established by detailed investigation.

3.11 Cultivation Patterns

The farm land close to the village is almost always cultivated on a continual basis and the fields are fertilised each year with animal manure. In some areas, farmers provide food and lodging for pastoralists who corral or tether their flocks in the cultivated areas in order to manure them. Further away from the village, cultivation tends to be based on a fallow system. The area in fallow is normally five to six times that under cultivation. Beyond these farming areas, there are usually extensive areas of brush or open woodland.

Land clearing and preparation for sowing are carried out at the end of the dry season in May and June. The use of animals for ploughing and other agricultural tasks is relatively rare and nearly all the work is done manually.

Fig 3: Cultivated area close to a village near Segou

Families usually cultivate their own areas; though in some parts of Mali a large extended family based on groups of male relatives with their wives and children may cultivate a set of fields and store the crops in a common granary (Martin, 1985). Hoeing is frequently carried out on a collective basis by village groups. The cultivated fields are rarely demarcated with hedges or fences.

Seeds are sown immediately after the first rain; if there is a delay in the following rainfall, the newly germinated seed may die and further sowings must be made. In drought years, perhaps four consecutive failed sowings may be made, heavily depleting the grain stocks on which families depend for food while they are waiting for the harvest.

Weeding is done several times during the growing season. Crops must also be guarded against birds and animals. Many farmers live throughout the growing season in small straw or stone huts built on their crop lands. This time of the year, when the stocks of food from the previous harvest are at their lowest, is the most difficult for most families.

Sowing, weeding and protecting crops, and the harvest make heavy demands on the available labour. In the dry areas, all this work has to be fitted into a season of about 3 months. In the south, the pressure is less and the growing season lasts about 5 months.

Fire is very commonly used by farmers. The trees and vegetation on fallow or brush land are usually burned when the land is being cleared for cultivation; the ash produced is a readily accessible fertiliser for new crops or pasture. Farmers also burn the unwanted stalks of millet or sorghum left over from the previous harvest. The vegetation in grazing areas may also be burned in an effort to clear it of cattle ticks.

In recent years, there has been a tendency for farmers to establish their own small sedentary herds of livestock. This makes them independent of pastoralists for meat and milk. Since grazing areas and straw are reserved for these animals, it also reduces the availability of fodder for the pastoralists (Bertrand and Meyer, 1985).

3.12 Crops and Trees

Millet (petit mil) is the main crop in the drier areas; its northern limit of cultivation is about the 400 mm isohyet. Towards the south, sorghum (gros mil) becomes more important; its northern limit roughly runs along the 700 mm isohyet. Whereas millet is virtually the sole staple food of the northern cultivated areas, millet and sorghum divide this role almost equally between them in the south. Beans and other legumes are also cultivated in association with millet and sorghum in some areas.

Cotton and peanuts are grown as cash crops, mainly for export, and are extremely important in Mali's trade balance, though both have been hit by lower prices in recent years. Cotton accounted for 38% of the country's exports in 1982. Other food crops include yams, sweet potatoes, maize and manioc; these are mainly grown in the south of the country.

When land is being cleared for cultivation some trees are usually preserved; even when fire is used, farmers protect the trees they wish to keep. One of the most common of these is the Acacia albida. In the cultivated expanses of land around many villages large numbers of these trees can be seen growing at distances of 15-50 metres from each other.

The Acacia albida remains in leaf through the dry season and is an important source of fodder for livestock; the seeds are also a nutritious animal feed and are often collected and sold. The value of this tree is widely recognised; in the pre-colonial period in Niger, anyone cutting an Acacia albida was liable to the death penalty (Bertrand and Meyer, 1985). The karite tree (Butyrospermum parkii) is also widely cultivated for its nuts which are a source of vegetable oil. Mango trees are grown in many areas and the baobab tree, which provides a multitude of products useful to rural families, is also common.

3.13 Flood Plain Cultivation

Flood plain, or recessional, agriculture is carried out in the inland delta of the Niger; it is also practiced on a smaller scale in other areas along the Niger and its tributaries and in the basin of the river Senegal. The principal grain crop in these areas is rice. A certain amount of maize is also grown, often in small patches near people's homes.

Rice yields tend to be poor, usually in the range 500-700 kilograms per hectare. Large crop losses are caused by rice-eating fish during the growing period. Birds are another major source of crop destruction. In particular, the Quela-quela, a type of weaver finch, can cause massive damage. These birds nest in closely packed colonies in thorn bushes; flocks numbering millions assemble in cultivated areas (Serle et al, 1977).

One of the greatest difficulties faced by flood plain farmers is that they are completely at the mercy of the variations in the river floods. In most areas there is little, if any, tradition of irrigation or flood control. Large areas therefore cannot be cultivated when the flood level is low. This makes planning virtually impossible and helps explain why some of the worst hardship and food scarcities during the drought occurred in this area.

Close to Segou, there is the Marakala Barrage which was completed in 1947. It was to be the key element in a massive irrigation scheme planned in the late 1920s and the 1930s under the French colonial administration. An organisation called the Office du Niger, which still exists, was set up to implement and run the project. The original plans envisaged the creation of a zone of controlled irrigation covering an area of almost a million hectares of desert land outside the area normally flooded which was referred to as the dead delta (delta mort).

The actual achievements of the Office du Niger have fallen far short of the ambitious intentions of its creators. Nevertheless, some 55 000 hectares are at present irrigated under the scheme. The water is taken from the barrage at Marakala and flows through two major canals from which it is directed through subsidiary irrigation channels into the cultivated fields. The whole system flows by gravity and is regulated by a system of sluices.

Land is allocated to tenant farmers who plant and harvest their plots using seed provided by the Office du Niger. Trees have been more or less completely cleared from the area to permit mechanised ground preparation, and to eliminate roosting and breeding places for seed eating birds.

The flood control works in this area permit agriculture to be carried out on a more predictable basis. But the irrigation system is still vulnerable to shortages of flood water, and the irrigated area was reduced during the recent drought years. Lack of maintenance of the canals, drainage channels and control sluices has also greatly reduced their effectiveness.

In the vicinity of Mopti, there is a also an area of controlled irrigation for rice farming which covers an area of 18 000 ha. It is under the control of a parastatal body with the title Operation Riz Mopti. A similar scheme, Operation Riz Segou, covers about 30 000 ha near Segou. Cultivation under both these projects depends heavily on the flood level in the Niger and was badly affected by the drought.

One of the most interesting aspects of cultivation in the Inland Delta, is that it is completely out of phase with the harvest in other areas of Mali. This is because it depends on the rhythm of the Niger floods rather than the rainy season. At Bamako, the peak in the flood occurs in September-October; it reaches Tombouctou in December; and does not reach Gao until the end of January. As the waters recede, the cultivators spread out across the flood plain and plant their crops; the harvest in the region of Gao may be as late as April.

3.2 Pastoralism

Pastoralism plays a vitally important role in the Malian economy. It is virtually the sole means of subsistence and income for people in the dry northern and eastern areas. Livestock exports to neighbouring countries accounted for 36% of the country's total exports in 1982. But this trade is now being hit by cattle exports to West Africa from Argentina.

North of the 300 mm isohyet, in the Sahelo-Saharan zone, where settled farming is impossible, the pastoralist way of life is almost entirely nomadic. People depend on the meat and milk they obtain from their flocks of cattle, sheep, and goats for practically all of their food needs. Donkeys are used to carry tents and personal possessions. Cash earnings come from the sale of livestock.

The pattern of activity consists of an annual backwards and forwards movement, or transhumance, in search of fodder and water. In the rainy season, this movement is towards the north and east; those in the western part of Mali cross the border into Mauritania. During this part of the year, the pastoralists rely on the rapid growth of grass and vegetation which takes place with the rains; their water comes from the temporary lakes and ponds which are formed during the rainy season.

Contrary to what might be expected, the nutritional quality of grass in the dry season grazing areas is high (Kessler and Ohler,1983). The limiting factor for the pastoralists is water. As one study said:

"...one of the most interesting conclusions to emerge from a study of the pastures of the Sahel in recent years is that, in general, the pastoral resources of the region are not over-used and even in special situations where grazing pressures are intense (e.g. around water sources in the dry season), the grasses are often capable of a full recovery given adequate rainfall and a temporary easing of grazing pressures.." (Hill and Randall, 1985).

As the water supplies dry up in October and November, the pastoralists head southwards towards their dry season water and fodder sources. During this time, when the grass has become scarce, the leaves of trees and bushes are a vital source of fodder for livestock. In many areas, herders badly damage trees by pulling down or cutting branches so that livestock can reach the leaves. Trees which have been heavily cut are particularly vulnerable to the stress caused by drought and many die.

Further south, into the Sahelian zone, where cultivation becomes possible, there is usually a combination of pastoralism and agriculture. With the approach of the planting season, the majority of the livestock flocks, under the care of herders, are sent away from the cultivated areas. In some cases, pastoralists divide their flocks of animals into three groups in order to obtain the maximum benefit, while also making the best use of the available grazing resources.

Under this system, one group of animals, composed of cows in milk and their calves, is kept close to the village all year round. These are kept in straw covered shelters and fed with dry forage collected from the family pasture land. When the main flocks return from their rainy season grazing areas, the better quality animals are kept close to the village for as long as there is fodder available. The poorest quality animals are, however, taken straight to the dry season grazing areas.

The majority of these transhumance movements take place along well defined routes. One of the principal locations for dry season water and fodder is the inland delta of the Niger. Pastoralists follow the receding flood waters, taking advantage of the rapid growth of grasses which takes place as the land is exposed. Well over a million head of cattle are brought into this area every year. There are other major transhumance routes in the west of the country. Many of the regulations by which pasturage is shared and transhumance routes are defined were established by the Emperor Sekou Ahmadou in the early 19th century.

In recent years, many pastoralists who found themselves in financial difficulties have had to sell their flocks. This provided an investment opportunity for town dwellers. The result is that some pastoralists are now simply paid shepherds rather than the independent stock owners they were previously.

3.3 Fishing

Fishing is an extremely important activity along the Niger, and other rivers in Mali. The total annual fish catch varies greatly depending on flood conditions but the average on the Niger is estimated to be in the region of 100 000 tonnes.

The stocks of fish migrate along the Niger and the main fishing season occurs when the flood waters are receding. The fishermen follow the movement of the fish along the river. This gives fishing a semi-nomadic character as the flood peak takes almost six months to move along the length of the river.

About [illegible] of the catch is dried or smoked by traditional methods using wood as fuel. The continued depletion of the wood resources from which supplies have been obtained for this purpose is leading to increases in the costs of smoking fish. The use of refrigerated storage by merchants in Bamako and Mopti, and even by some fishing cooperatives, has begun to ease this problem (Thomson, 1985).

4.0 CONVENTIONAL FUELS, RENEWABLE ENERGY SOURCES, AND IMPROVED STOVES

Conventional commercial energy sources supply only a small proportion of Mali's total energy consumption at present. But they are vital to the industrial and commercial life of the country. As the Malian economy modernises and grows, the use of these fuels will inevitably increase.

Petroleum products make up the vast bulk of conventional energy consumption. Electricity supplies come mainly from hydro power, but the total production is small and is consumed almost exclusively in the urban areas. The country's large untapped hydroelectric resources have the potential to make a major contribution to its future energy needs.

Under the pressure of oil price rises, new and renewable energy sources received a considerable amount of attention during the late 1970s and early 1980s. Solar energy, wind, and biogas have been the subject of research programmes in Mali in recent years. Progress in all these technologies has been slow.

Research and development work on improved cooking stoves has also been carried out. A modest degree of success has been achieved in the dissemination of a metal stove in the urban areas; efforts have also been made to promote the use of a simple banco stove among rural dwellers.

4.1 Petroleum Fuels

Total petroleum consumption in Mali grew from about 60 000 tonnes in 1968 to a peak of 167 000 tonnes in 1980, a growth rate of about 10% per annum. Under the impact of economic recession in the country, consumption then declined to a level of 134 000 tonnes in 1982.

Road transport accounted for 62% of the 1982 consumption; aviation consumed a further 8.5%. The domestic sector consumed 14%, mainly in the form of kerosene for lighting. Industry used about 12% and the Malian national electricity utility, Energie du Mali (EDM) used about 2.5% for electricity generation (Trans Energ, 1984).

A small amount of bottled butane gas is also imported. This is used for domestic cooking and lighting, mainly in Bamako. The total consumption in 1982 was only 226 tonnes. The price of butane in 1983 was 380 FCFA per kg, equivalent to 8.4 FCFA/MJ (Trans Energ, 1984).

Petroleum accounted for about 10% of Mali's total imports in 1982; this was roughly the same proportion occupied by imported foodstuffs. The cost of oil imports was about 20% of the revenue obtained from merchandise exports (Trans Energ, 1984).

The price of kerosene in Bamako in August 1983 was 175 FCFA per litre. Roughly 25% of this was accounted for by government taxes. In energy terms, the price was about 5 FCFA/MJ.

Since 1982, the price of crude oil on the international market has fallen from around $35 per barrel to $15-20. This fall of about 50% will obviously not be fully reflected in the costs of petroleum imports

to Mali. These include the refinery mark-up in Dakar or Abidjan, as well as the costs of transport into Mali. But there is little doubt that a substantial reduction in petroleum product prices is in prospect. A corresponding fall in the price of butane, which is in competition with liquid petroleum products over a range of uses in the international market, can also be expected.

4.2 Electricity

The amount of electricity supplied by Energie du Mali (EDM), grew from 56 GWh per annum in 1974 to 113 GWh in 1982. Of the 1982 total production, 105 GWh were obtained from hydroelectric sources and the remainder from diesel or gas-oil generation. Private generation of electricity by industrial users was estimated to be about 36 GWh in 1982, all of which was generated by diesel or gas-oil (Trans Energ, 1984).

The total installed hydroelectric capacity is 52 MW. The main installation has a capacity of 45 MW and is at Selingue, 140 km from Bamako on the Sanakari river, a tributary of the Niger. A further 5.4 MW are provided by the Sotuba installation on the Niger near Bamako.

Just over 90% of the total production in 1982 was consumed in the Bamako region where 38% of dwellings are connected to the electricity supply. The poorer domestic consumers obtain their supplies on a 'social tariff' under which the price paid in 1982 was 43.5 FCFA per kWh, or 12.1 FCFA/MJ (Trans Energ, 1984). The establishment of a national television service is likely to stimulate a further growth in the number of domestic consumers.

The two existing hydroelectric installations can satisfy the Bamako demand throughout the year when river flows are at an average level. In years of low flow, they must be supplemented by diesel generation during the dry season. Further generating capacity will be required in the near future; the same applies in most of the provincial centres where power cuts are already a frequent occurrence.

Mali has ample hydroelectric reserves and a number of projects are being discussed. The most ambitious of these is at Manantali on the river Senegal. A barrage is already under construction there to control the river flow for irrigation and navigation purposes between Kayes and the Atlantic. This barrage is a joint project between Senegal, Mauritania, and Mali. Ultimately, this barrage can be equipped with five 40 MW generators with an annual output of 800 GWh.

Two very much smaller projects have also been under discussion for some years. One is a 5 MW extension of the Sotuba installation; the other is a 3 MW installation at Markala on the Niger close to Segou. Either of these would be capable of providing the extra capacity needed to meet the projected medium term needs of the Bamako region.

At present, domestic consumers, particularly those on the social tariff, use electricity almost exclusively for lighting. Although there does not appear to be any significant use of electricity for domestic cooking, at present, this could well begin to change in the near future. In other African countries at a roughly similar economic level, such as Tanzania, Malawi, and Uganda, cooking by electricity is widespread among the richer urban families.

4.3 New and Renewable Energy Sources

In Mali, as elsewhere, the rise in oil prices and doubts about security of supplies during the 1970s stimulated considerable interest in the search for alternative energy sources. Over the past five years, the Laboratoire de l'Energie Solaire (LESO) in Bamako has carried out a programme of research into the potential applications of new and renewable energy sources in the country.

Promising theoretical and practical results have been obtained in the use of solar photovoltaic systems to power drinking water pumps. About 60 of these have been installed in different parts of the country. The costs remain extremely high, $10 000 - 14 000 per installation. This is well beyond the reach of individual farmers or small cooperatives. But a number of villages have shown themselves willing to make substantial financial contributions to the costs of such pumps in areas where it is possible to recover the investment by the sale of water to pastoralists and villagers.

Windmills have been studied as a potential source of power for pumping. The prospects for wind power, as far as a suitable wind regime is concerned, are best in the northern and eastern regions such as Tombouctou, Nioro and Gao. The difficulty in serving these areas with conventional fuels makes the use of wind power particularly attractive. But a considerable amount of work remains to be done before suitable windmill models become available at a price which is within the range of local farmers.

The potential for the use of biogas has also been studied and a number of test digesters have been built. But this is a difficult technology to introduce to most areas of Mali because, even though supplies of dung are widely available, the substantial water needs of biogas digesters are difficult to meet in many areas. The costs and technical problems associated with building and running biogas digesters also place heavy burdens on local families or communities. For most rural families seeking an alternative to woodfuel it is much simpler to burn dung directly rather than go through the complications of turning it into gas.

In short, a great deal remains to be done before a new and renewable technologies make the necessary breakthrough and begin to come into common use in Mali. It is also clear that their primary potential is in applications such as pumping and small scale electricity generation. They are unlikely to have a significant impact on the domestic cooking needs currently met by woodfuel.

4.31 Rice Husk Gasification

Rice husk gasification, however, is a notable exception to the generally limited achievements with other alternative energy technologies. The use of rice husks to make a combustible gas to drive an internal combustion engine is difficult. Despite a considerable amount of research in the early 1970s, many researchers had more or less given up hope of developing a reliable and economic rice husk gasifier (Foley and Barnard, 1983).

Progress in rice husk gasification was, however, made in China. In 1972, a Chinese team installed a rice husk gasifier at a rice mill at Dogofiori in the Inland Delta region. It operated for over 70 000 hours and was overhauled by Chinese engineers in 1985.

Little was known about this project outside Mali until quite recently. But once it was realised what was happening, outside experts were quick to pay attention. A detailed technical evaluation of the project was carried out by a team from Twente University in the Netherlands; it has also been included in the UNDP/World Bank Gasifier Monitoring Program.

A further unit was installed at another rice mill in 1985 and an evaluation was due to be carried out in 1986. There are plans for another installation (Mahin, 1986).

A breakthrough in rice husk gasification, such as appears to have happened, would be welcome news indeed. Rice husks are available in large quantities and have few uses; in fact disposing of them can often be a problem. If they can be used instead to provide economic and reliable power for remote rice mills, gasifier technology has the potential to make a significant contribution to Mali's energy needs.

4.4 Improved Cooking Stoves

Work on the design and dissemination of a variety of improved stoves has been carried out in the country since the late 1970s. At a conference held in Bamako in 1984, it was decided to rationalise and concentrate these various efforts on two basic types of stove.

In the rural areas, a small single-pot stove made of banco is being promoted. This is usually referred to as the Louga stove; but sometimes it is described as the 'improved three-stone fire.' It is designed to be used with a single pot. It is built on the ground in the form of a thick banco ring about 25 cm high. The pot sits inside this, and is supported on three stones embedded in the banco. Fuel is pushed horizontally in under the pot through a hole in the ring.

The stove shelters the fire from wind and draughts. Because there is only a narrow gap between the pot and the inside of the stove, the transfer of heat from the combustion gases to the pot is improved. The size of this gap is critical to the efficient working of the stove; this means that a separate stove is required for each size of pot used by the cook.

These stoves are being promoted in the villages. Volunteers and government agents carry out training programmes in which women are taught how to make the stoves. In areas where there is a concerted dissemination campaign, the stoves appear to be readily adopted by local women. But the numbers in use are still relatively small, and there does not yet seem to be any evidence that they are being spontaneously taken up on significant scale by villagers themselves in the absence of promotion agents.

In the urban areas, the focus is on improved types of metal stoves. These are also based on the principle of providing a shield around the pot so that the transfer of heat from the combustion gases is improved. As in the case of the Louga, a separate stove is required for each size

of pot used. A number of traditional metal stove makers have started making these stoves and they are now to be seen on sale among the wide variety of metal stoves available to customers in the markets in Bamako.

If properly used, both these types of improved stove are clearly more energy-efficient than a comparable open fire, but it is difficult to predict the amounts of energy likely to be saved in practical use. The actual household savings of woodfuel will depend on how correctly the stove is used, its state of repair, and the proportion of the total household fuel used in it. To date, there has been little monitoring of the stoves under practical conditions.

The only comprehensive set of field tests is that carried out by the Laboratoire de l'Energie Solaire (LESO) in late 1984 and early 1985. Four villages were studied. In each, the consumption of ten families using traditional open fires and a different group of ten families using improved stoves were measured.

The improved stoves were of different types, including both mud and metal. They had been distributed to the families during an earlier exercise to test the acceptability of different stove designs to village women. Data were collected on the consumption of wood per meal in each family. In all, the wood consumption for ten meals per family, that is 100 meals for each group in each of the four villages, was measured.

There were considerable variations in the patterns of consumption and a wide overlapping of results. The quantities of wood per meal, in fact, varied by a factor of 14, from 0.5 kg up to 7.0 kg. The average consumption of wood per meal among families using an open fire in the village of Forgho, near Gao, for example, was substantially lower than that on improved stoves in all the other villages.

But the consumption figures inside each village showed a substantial saving by stove users in each case. Over the four villages, the average consumption of wood per meal using an open fire was 2.7 kg and using an improved stove was 1.9 kg. This was a saving of 29%.

A careful statistical analysis was carried out in order to assess the reliability of the results and try to disentangle the savings attributable to the stoves from such distorting factors as different family sizes, different pot sizes, different diets, and whether the cooking pot had a lid. The fact that different types of stoves were being used was a further complication. Nevertheless, it was clear that fuel savings were being made wherever the stoves were in use. The savings were in the range 17-39%: but given the small sample and the number of variables, it was impossible to be more precise (Hart, 1985).

It is difficult to establish an accurate figure for the numbers of improved stoves in use. The number disseminated in the rural areas is probably in the range 1000-2000; the number of improved metal stoves in use is probably about 1500. The rate of dissemination of both types is perhaps 1000 or so per year.

Any assessment of the overall impact of improved stoves on future woodfuel demands in Mali can only be speculative. As a working hypothesis, it might be assumed that the use of an improved stove would bring a saving in total family fuel use of 25%. If every family had a stove, the total national saving would be somewhat less, say 20%, to

allow for non-domestic woodfuel uses.

The arithmetic of what is required to achieve this, however, is quite startling. To equip the country's present 1 million families with an improved stove over, say, a 20 year period would require a rate of dissemination of 50 000 stoves per year; a further 25 000 would be required to keep pace with population growth. In addition, a steady replacement of stoves at the end of their three year life would have to be maintained. In 10 years from now, this would require that the total production of improved stoves should rise to about 325 000 per year.

This is most unlikely to happen if stove programmes remain dependent on external funding and the efforts of paid promoters. But it is by no means impossible if improved stove dissemination truly takes off and is carried out spontaneously by people themselves. Pending evidence of such a transformation in the dissemination of stoves, it is right to be cautious about the anticipated woodfuel savings at a national level.

This is not to say that improved stove programmes are not worthwhile. Even a 10% national saving of woodfuel consumption would represent an extremely large quantity of wood. The economic case for improved stoves, at a national level, is strong (Shaikh, 1985). And at the level of individual families they can provide substantial benefits (Foley, 1985). Any effective dissemination of properly designed improved stoves can only improve the domestic fuel supply position at both a national and individual family level.

PART III

WOODFUEL

5.0 WOODFUEL: PRESENT SUPPLY AND CONSUMPTION PATTERNS

Woodfuel is the predominant fuel in the country. Firewood is used almost everywhere in the rural and urban areas to meet domestic cooking and heating needs. Small scale businesses and commercial enterprises also meetmost of their fuel needs with firewood or charcoal. Some estimates place the contribution of wood to the national energy balance at about 95%.

But despite its evident importance, there is very little detailed or quantitative information on woodfuel use in either the rural or urban areas. The available survey data show wide variations and are frequently contradictory or inconsistent.

Nor is there a great deal of information on the level of woodfuel resources available. A certain amount of work has been done on the productivity of natural forests and the grasslands of the Sahel. But there has been little systematic analysis of the actual resources available to rural families for use as fuel.

5.1 Woodland Productivity

Woodland productivity depends on a variety of factors. The primary determinants in any given locality are the rainfall and soil characteristics. Human intervention can also have a major influence. Limited exploitation, in fact, may stimulate the productivity of woodlands; over-exploitation reduces or destroys it.

Most of the published estimates on woodland productivity are imprecise about what exactly is being measured. Those coming from forestry sources tend to be biased towards what foresters regard as wood. This does not usually include the fallen dead wood, small branches, bushes, and other woody biomass which people collect for fuel. The actual sustainable yield of woodfuel from an area of woodland can therefore be several times greater than conventional methods of estimating forest yields would suggest.

Table 5.1 Wood Stocks and Annual Production related to Rainfall in the Sahelian and Sudanian Zones

Annual Rainfall mm	Standing stock cu m/ha (tonne/ha)*	Annual production cu m/ha (kg/ha)*
400-600 mm	3.9 (2.7)	0.13 (91)
600-800 mm	5.4 (3.8)	0.18 (126)
800-1000 mm	7.2 (5.0)	0.24 (168)
1000-1200 mm	8.7 (6.1)	0.29 (203)
1200-1500 mm	10.5 (7.4)	0.35 (245)

* Converted at the rate 1 cu m = 700 kg
Source: (Club du Sahel, 1982)

Table 5.1 gives figures which have been suggested for the average standing stock and yield for different rainfall ranges in the Sahelian and Sudanian Zones of Mali. They are distinctly pessimistic in their specification of the annual production of woodfuel. But, emanating from the Club du Sahel, they are widely quoted and are used as a basis for discussion in this paper.

5.2 Rural Woodfuel Consumption

Throughout the rural areas, woodfuel is gathered from the village surroundings without any cash payment. A certain amount is obtained from the trees in the permanently cultivated areas through pruning, or when a tree dies. But the main supply sources are the bush and fallow areas. The wood is brought back to the house where a stockpile is usually kept so that daily trips do not have to be made. Prior to the rainy season, the stockpile is usually increased.

Women are generally responsible for domestic fuel supplies but in some areas it is the young boys who do the collecting. For distances of up to a few kilometres, the wood is usually carried home in headloads. Beyond this, donkey carts (charettes) are often used. In some cases, women gather and stack the wood in the bush and it is loaded and brought back in the cart by men. Some of the collected wood may be sold or bartered in the village.

Charcoal is used for ironing and making tea. Usually it is obtained from the embers of wood fires. But sometimes whole trees are burned down and left to smoulder for a few days in order to make the charcoal.

The most comprehensive survey, so far, on rural woodfuel consumption in Mali was carried out under the auspices of the Laboratoire de l'Energie Solaire (LESO) in four different regions of the country during 1981. Data on fuel use and other activities in a total of 20 villages were collected over a period of about a year (Koenig, 1981; Koenig, 1984).

One set of villages was in the relatively high rainfall area of Bougouni, about 175 km south of Bamako. Much of the cooking in this region is done for large extended family groups; sometimes the meals are prepared for 30 or more people. Cooking is done almost entirely with wood.

The average family use of wood per day was found to be 10.6 kg. This gave an overall average of 1.4 kg per head per day for the 5 villages. The most striking feature of the data was the extremely small variation in consumption between the different family sizes; the average daily consumption of a 6-person family was 10.36 kg and that of a 33-person family was only 11.68 kg. This implies a range in per head consumption of 0.36-1.7 kg per head per day.

In this area, dung is not used for domestic fuel. But dung and agricultural residues are used as fuel in making karite butter and soap, and other non-domestic activities.

Another set of villages was in the area of San which is on the Bani river about 150 km east of Segou. The climatic conditions are broadly similar to those in Bougouni. Here, the average family use of woodfuel was 11.3 kg per day or 2.6 kg per person. Dung was not used as a fuel.

Fig 4: Bush land beside the road to Segou about 150 km from Bamako

A third set of villages was in the Nioro area, in the north-west of the country, where the climate is arid and the vegetation is much more sparse. Wood consumption in the villages surveyed here was nevertheless found to be an average of about 14 kg per family per day, or 2.25 kg per person. Dung was widely used as a fuel. Millet and sorghum stalks were also used.

Enormous practical difficulties were found in the survey in the Gao area, where the climate and vegetation are similar to those in Nioro. There were also major problems in establishing meaningful average consumption figures over the year because of the high level of mobility of people. Survey work in a number of villages had to be abandoned because a sizable proportion of the population left during the survey period.

An average figure of 10.6 kg per family per day was found; but the average family size was recorded as just 3 people. This gives a figure of 3.6 kg per person per day, but little reliance can be placed upon it. The general indication, however, was that despite the dryness of the area and the sparseness of vegetation, wood could be obtained relatively easily. Dung was widely used for domestic cooking and other village fuel using activities.

A certain measure of doubt, however, hangs over the whole of this study. Random site visits by LESO personnel to some of the villages revealed the absence of the study monitors. It was said that some of the results were filled in at home by the monitors rather than being measured on site (Hart, 1985). Caution therefore needs to be used when attempting to interpret the detailed survey figures.

A small number of other village studies have been carried out during the past decade. Two villages in the south of Mali were surveyed in 1976. Another survey was carried out in two villages near Nara, close to the border with Mauritania, in 1980. In all four villages, the average consumption for domestic use was in the range 1.3-1.4 kg per head per day (Trans Energ, 1985).

An estimate has also been made of average per head consumption on a regional basis, taking into account the available survey results, as well as data from comparable areas in other Sahelian countries. These figures suggest a consumption of 0.7-0.9 kg per person per day in the arid parts of the country and 1.7-2.4 kg per head per day in the higher rainfall areas (Trans Energ, 1984). A recent survey of 90 rural families in Niger found an average of 0.84 kg per head per day (Deschambre, 1986).

The huge range in per head consumption found in the LESO study, however, vividly illustrates the problem of obtaining consistent statistical data on rural woodfuel consumption. The use of per head figures is particularly subject to uncertainty. The LESO study showed a five-fold variation in per head consumption inside just one village. Estimates based on per head consumption therefore run the risk of being very far indeed from the truth.

The available data appear to be somewhat more consistent when the consumption per family is taken. This also accords with common sense. Fuel consumption does not vary in exact proportion with the number of people for whom a meal is prepared; cooking for a family of twelve may

require little more fuel than for a family of half that size. For the purposes of the present discussion, the average family consumption is taken as 11.5 kg per day or 4.2 tonnes per year.

5.3 Urban Woodfuel Consumption

Only one major study of urban woodfuel consumption has been carried out in Mali. This was in Bamako in 1978 (Sankaré, 1979).

In this survey, three separate approaches were used. The first was a week-long, day and night, census of all the fuelwood and charcoal being brought into the city by road, rail and river. The second was a sample survey of consumption by householders over a period of 14 days. The third was a survey of wood and charcoal purchases at various market outlets.

The traffic survey figures showed that total wood consumption was equivalent to 159 000 tonnes per year, while charcoal was just 7400 tonnes. Given the population level of about 400 000 at that time, this represented an average wood consumption of 1 kg per head per day.

In the household survey, the consumption of 450 families was measured. These were divided uniformly among the city's 37 districts. Around 12% of the families practiced some form of artisinal activity such as metal working, laundry, or food preparation. The average consumption of wood was found to be 1.8 kg per head per day and that of charcoal 23 kg per head per year.

Applying these average consumption figures to the whole population gave an annual total of 280 000 tonnes of wood. An additional 18 000 tonnes of woodfuel was estimated to be consumed by industries. This gave a total consumption in Bamako of 298 000 tonnes.

No details are given in the report on how the survey of market purchases was carried out. A total annual consumption of 277 000 tonnes of wood was, however, estimated for Bamako based on the results obtained.

There is almost a two-fold discrepancy between the highest and lowest estimates of consumption obtained in the survey. One possible explanation is that the traffic survey underestimated the total. This could be because a great deal of the wood entering the city came by routes other than those being surveyed, or in vehicles which were missed by the enumerators; another possibility is that the weights of wood carried by trucks and lorries were seriously underestimated.

An alternative explanation is that the estimate based on the household survey figures is too high. This could be because large numbers of people in the city do not live "typical" family lives. Many, for example, eat some of their meals in small cafes, or buy their food from kiosks or street vendors. Their average fuel consumption is likely to be lower than those relying entirely on family meals.

There are also many poor families living in makeshift huts and other accomodation. They almost certainly consume, and cook, less food than permanently settled families and much of the fuel they burn is likely to be scavenged rubbish. Their woodfuel consumption will therefore tend to be less than that of the better off. Applying the family consumption

average to the whole urban population is thus likely to over-estimate the total consumption figure.

The survey lists about 20 different models of gas and kerosene stoves which were found to be on sale in the city. This clearly indicates that a certain amount of cooking was done on butane gas and kerosene, but no consumption figures were obtained for these fuels.

There was also a surprisingly widespread use of other biomass fuels besides wood. The survey mentions the use of millet stalks (67% of families), peanut shells (57% of families) and cow dung (54% of families). But no quantities are given for any of these.

A number of other limited woodfuel consumption studies have been carried out the towns of Kayes, Mopti, Segou, and Tombouctou. The consumption levels found varied between 1.4 and 2.1 kg per person per day, giving total consumption figures of 20 000 - 30 000 tonnes per year for each of these towns (Trans Energ, 1985).

For the purposes of the present discussion, an average of 1.5 kg per head per day is assumed for urban woodfuel consumption. Allowing an extra 10% for industrial and commercial use, gives a total consumption for the city of 240 000 tonnes in 1978.

5.4 The Urban Woodfuel Supply System

About three quarters of the wood brought into Bamako comes by road. The 1978 survey (Sankaré, 1979) showed that 58% of the total was carried by large trailers, and lorries; the trailers have a capacity of up to 30 tonnes while the lorries are usually in the range 7-10 tonnes. A further 17% was carried by pick-up trucks and other small vehicles. Donkey carts, bicycles and pedestrians carried a further 16%; rail accounted for 7%, and river transport 2.5%.

The wood brought in by the small scale supplier using a donkey cart will probably be collected by himself or his family. His only other costs will be for a cutting permit - if he pays it - and the upkeep of his donkey and cart. Often, this wood will be sold directly to the consumer rather than through a retailer or wholesaler. But despite the lack of payment to any intermediaries, the competitive position of these small suppliers is poor because of the very small turnover they can manage.

The wood brought to the city in large trailer loads, on the other hand, passes through perhaps half a dozen steps. It is collected in the brush and brought by head load or donkey cart to the road, where it is unloaded. A team of labourers load it into the trailer and it is brought to the city. There, it is unloaded at a major wholesale depot from which it may be passed to a semi-wholesaler, then on to a retailer and finally to the customer.

Some of the wood sold in Bamako is supplied by the Operation Amenagement et Production Forestiere (OAPF). This is an organisation under the aegis of the Direction National des Eaux et Forêts (DNEF). It supplies wood at a reduced price to industrial consumers. This wood is obtained from forest clearing carried out as part of the replanting and forest management operations of the OAPF. This low price wood is intended to have a role in influencing the price of wood on the market, but this is

likely to be minor since the OAPF sales are only about 3% of the total consumption in Bamako.

The charcoal trade is on a much smaller scale than that of woodfuel but follows roughly the same lines. The charcoal is made in a number of areas along the main transport routes from the city and collected by transporters. Small charcoal depots are found in the main markets and in various parts of the city. The charcoal is usually sold by volume; small piles are laid out on a piece of sacking spread on the ground by the trader.

5.41 Woodfuel Supply Sources for Bamako

The present supply of woodfuel for Bamako is obtained from the woodlands along the half dozen or so main supply routes leading into the city. Between these principal radial routes, there is a fine network of dirt roads which interconnect the hundreds of villages in the area and provide their access to the roads into Bamako.

The majority of the wood is obtained within 3-5 km of the main roads. Some of it is carried to the collection point in headloads or on bicycles. Donkey carts carrying 1-2 cubic metres of stacked or bundled wood are also used. Stacks of wood waiting for collection can be seen close to villages and where paths through the brush and woodland join the main roads. There are also more extensive collection points where trailers and large lorries are loaded.

The wood is usually made up into bundles of sticks or split pieces. These, in turn, are stacked horizontally in neat rectangular piles. The wood is dry, either fallen dead wood which has been gathered, or live wood which has been cut and allowed to dry. In some cases, however, the wood is not split. Logs of 15-20 cm diameter are shipped directly to the city for preparation and bundling at the fuelwood depots.

There is ample evidence of cutting in the woodlands close to the main roads. This is also the case in the classified forest of La Faya close to Bamako. But the cutting is far from total in most cases and there are substantial quantities of wood still remaining.

There is no particularly obvious pattern in the distribution of collection points. Piles of wood can be seen waiting for collection from within a few kilometres of the city up a distance of 175 km. In most cases the quantities are relatively small, consisting of no more than a few stacked cubic metres, but in some areas, particularly the more distant, there is sufficient to load a large trailer. Figure 5 shows one of these larger collection points.

5.42 Woodfuel Prices and Costs

Retail prices vary widely, depending on the market in which the wood is bought and the time of year. The retail selling price also depends on the size of bundle sold and whether it consists of small branches or has been split from larger pieces. In a survey in October-November 1983, the range of woodfuel prices in Bamako was 9.3-16 FCFA per kg, with an average of 12.5 FCFA per kg (Trans Energ, 1985).

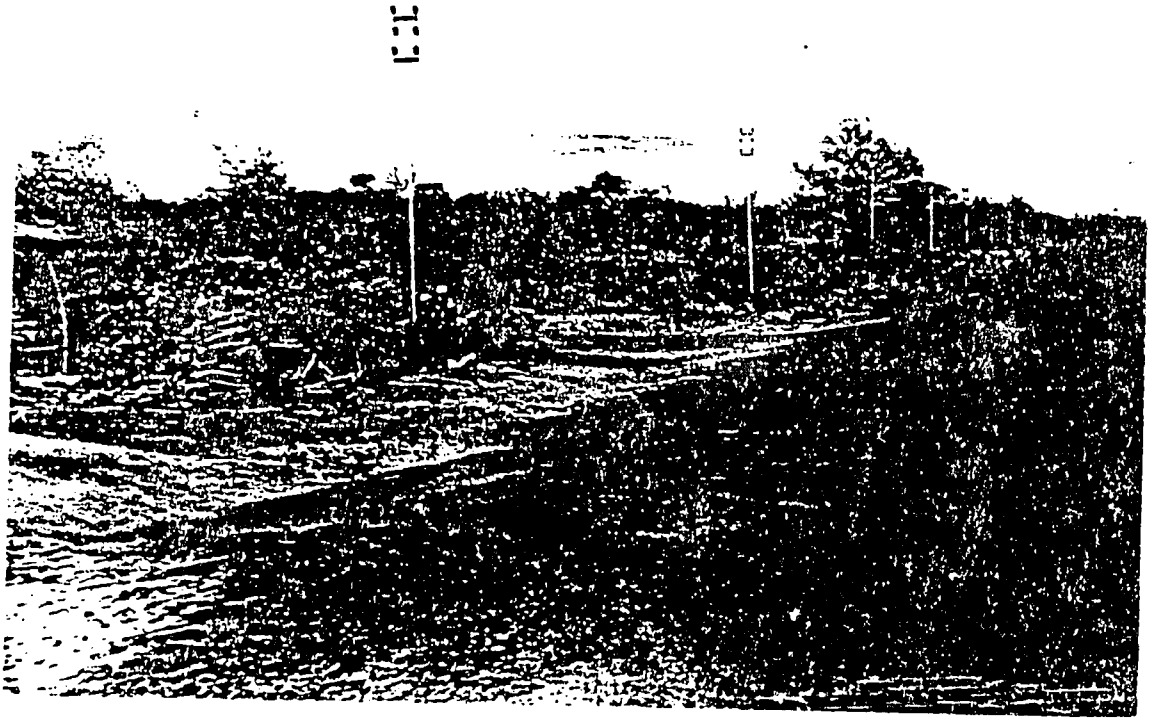

Fig 5: A woodfuel collection point on one of the roads to Bamako.

There was a steady rise in the market price of woodfuel in Bamako of about 13% per year in the period 1978-1983. This was the same as the rate of general inflation in the country. The price of wood therefore remained constant in real terms. Official food prices rose more slowly than inflation during this period; this was mainly as a result of the widely criticised low price policy of the government's food marketing office (OPAM). This has now been reversed because of the damage it was doing to rural incomes.

At each step of the distribution chain from the woodfuel collector through to the final consumer there is an additional cost. The buildup of these costs obviously varies according the particular distribution chain considered.

In principle, it is possible to establish the costs incurred at each step. But there are considerable practical difficulties in obtaining the necessary information; dealers are unwillingwilling to reveal anything to outsiders which the tax or regulatory authorities would like to know. Establishing meaningful cost figures is rendered even more difficult by the fact that a high proportion of the transport used, particularly the large lorries and trailers, is carrying woodfuel as a return load.

This is because Bamako is the centre from which most of the country's imports and manufactured goods are distributed. Lorries and trailers carry a wide variety of loads to the provincial centres and distribution points. On the return journey, when they would otherwise be empty, they carry wood back to Bamako and the marginal transport cost is small.

There is, nevertheless, a tendency for the price of wood by the roadside to decrease with distance from Bamako. Very broadly, the roadside prices in 1983 varied from about 5-7.5 FCFA per kg within 20 km of Bamako down to less than 2.5 FCFA per kg in the more distant areas (Trans Energ, 1985). But the pattern is by no means uniform and there are many exceptions. The actual price in any particular place depends on the buyer, the quantity and type of wood being sold, and the financial need of the seller.

The most important single factor which all the different supply channels have in common is that the wood is obtained from natural forest or brush land. It is collected by rural people as a means of earning a living or supplementing farm incomes. Much of the work is carried out by women and children.

Given the lack of other opportunities for earning money in the rural areas, the cash return for which rural people are prepared to work on woodfuel collection is very low indeed. Under present day conditions in rural Mali, it appears to be about 300 FCFA (about $0.85) per day.

The productivity of such labour will vary depending upon the availability of wood and the distance it has to be carried to a pick-up point. Near the city where the most accessible resources have been depleted, the amount of time spent to 'produce' a given quantity of wood at the roadside will be higher than in the more distant areas where there are plentiful supplies of wood close to the road. But, everywhere, the 'production cost' will be very low.

Suppose, for example, a worker can gather, bring to the roadside and bundle 200 kg of wood per day, the basic 'production cost' is 1.5 FCFA per kg ($4.4 per tonne). This is formidable competition for anyone, be it an individual farmer, community group or the forest service, considering growing trees to sell in the urban market.

5.5 Lack of Effective Control over Woodfuel Exploitation

Legally, the government has total control over the exploitation of woodfuel resources in Mali. Under the law, farmers do not have the right to cut any trees, even those they have planted themselves on their own land. If they wish to do so they must obtain a cutting permit from the forestry service, Direction National des Eaux et Forêts (DNEF). People's collection or limited cutting of wood for their own use is, however, permitted and is exempt from taxation or regulation.

When someone wants to cut or gather wood for sale, they are supposed to obtain a cutting permit (permis de coupe). This is purchased from the DNEF and specifies the quantity of wood which may be cut and the area from which it can be taken. The permit lasts for 3 months. A corresponding free transport licence is issued with each cutting permit. The cutting permit cost 100 FCFA per stère of wood in 1983. This is about 0.3 FCFA per kg of wood, or about 2.5% of the retail selling price of the wood.

In practice, the cutting permit is obtained by the transporter and is produced if his load is checked. The degree of control over the location from which the wood has been obtained is therefore negligible. Effective monitoring of the cutting would, in fact, require a legion of inspectors throughout the countryside and is far beyond the financial and manpower resources of the Government.

Unauthorised cutting is punished by a fine imposed by the forestry agent who detects it. There is a contentious dividing line between permissible cutting and the offence of mutilating a tree. Given the vast extent of the country and the lack of resources in the DNEF, the detection of offences is on a more or less random basis. The fines are frequently regarded as an annual tax imposed by the forestry service. Once a fine has been paid, the woodfuel collector feels free to cut as much as he wants for the rest of the year.

Evasion and disregard of the cutting and transport regulations is widespread. Only about 25% of the total estimated woodfuel consumption in Bamako is covered by cutting permits. The remainder comes from illegal cutting, multiple use of permits, or the fraudulent issue of permits from which agents have not declared the revenue. At a national level, the woodfuel consumption covered by cutting permits amounted to about 3.5% of the country's total consumption in 1984.

5.51 Direction National des Eaux et Forêts

The national body charged with controlling exploitation of the country's wood resources is the forestry service, Direction National des Eaux et Forêts (DNEF). This body is also responsible for the management and renewal of the country's classified forests, as well as control of fishing and hunting.

The DNEF is faced with enormous difficulties in fulfilling its mandated tasks. Its most fundamental problem is lack of adequate finance. The budgetary resources of the Malian government are extremely limited and the DNEF is in competition with all the other important and pressing claims on the nation's finances.

At present, only a small proportion of the DNEF funding comes from general government revenue. The total 1984 budget for the DNEF was about 240 million FCFA ($700 000). The government grant covered 17% of this. The remainder came in roughly equal amounts from receipts from cutting permits and fines for violation of the various regulations laid down in the national Forestry Code.

The most frequent fines are for unauthorised cutting of wood and setting bush fires. When a fine is imposed, 10% goes to the reporter of the offence (usually the forestry officer himself), 5% to the officer who prepares the indictment, and 10% is distributed at various management levels in the regional forestry office.

The total budget of the DNEF does little more than cover salaries and wages. In 1984, only 8% was available for expenditure on fuel, equipment, buildings, and other materials. During the year, none of the regions received its full budgetary allowance (DNEF, 1984). Salaries and wages are frequently up to several months in arrears.

The total staff of the DNEF, excluding administration, drivers and labourers, in 1984 was 750. According to its own Annual Report, the organisation is very centralised and top heavy. It has some 513 engineers and senior technicians and just 210 forestry agents and guards. In general, the staff is young, insufficiently trained, lacking experience, and poorly motivated. In many areas, fines and cutting permits are simply kept by the agents concerned and forged or fraudulent documents are frequently used (DNEF, 1984).

The level of equipment maintenance is very poor. In Koulikoro and Kayes, the forestry posts are said to resemble 'vehicle cemeteries,' and in Tombouctou the life of Land Rover is rarely more than 2 years. Supplies of diesel and petrol are frequently unavailable.

According to the statutes under which it is established, the DNEF is a para-military organisation. Military training is obligatory for all officials of the service and they are obliged to wear the regulation uniform in the exercise of their duties. Arms are carried in the course of official duties and all forest posts have a stock of rifles and ammunition.

The traditional orientation of the service has been towards policing and this has created an atmosphere of distrust between the service and rural people. The fact that a major proportion of the funding for the DNEF has to be obtained from fines adds to the difficulties in changing attitudes. Major efforts to inform and train personnel in new attitudes have been made in recent years. But a great deal remains to done before the present barriers between the DNEF and the rural population are broken down and effective collaboration in the management of the country's wood resources is established.

It is important to recognise the severe limitations which circumstances place upon the DNEF. Discussions about the woodfuel future and what might be done about it, frequently allocate a totally unrealistic role to the DNEF in controlling wood resource exploitation. It is far better to recognise that for the foreseeable future, the major proportion of the woodfuel consumed in the country will come, as it does today, from the unregulated exploitation of natural woodlands and poorly guarded forest reserves.

6.0 FUTURE WOODFUEL SUPPLY AND DEMAND: RURAL AREAS

The data required for confident and detailed projections of future woodfuel supply and demand in the rural areas do not yet exist. The almost universal assumption, however, is that there is a rapidly worsening position requiring immediate remedial action.

But the available evidence is open to a variety of interpretations. Starting with the same basic data, it is possible to show that, rather than moving rapidly into crisis, the position is relatively stable. People undoubtedly have problems, but the supply of domestic energy is far from being the worst of them.

6.1 The Woodfuel Future in the Sahelian Zone

Not just in Mali, but across the whole Sahel, it is the Sahelian Zone which tends to receive the most attention when the woodfuel issue is raised. Most analyses stress the gravity and urgency of its woodfuel problems.

In Mali, the Sahelian Zone zone has perhaps 1.75 million inhabitants, about a quarter of the total rural population. In the drier, predominantly pastoralist, northern parts, the population density is usually below 10 people per sq km. Towards the south, where it merges into the Sudanian zone, densities of 10-15 people per square km are found in the more fertile areas.

The basic problem, of course, is rainfall; no one knows whether the droughts of the 1970s and 1980s represent a permanent deterioration of the climate. Assuming that the zone remains habitable, the primary requirement, if population growth is to take place, is an increase in food production. In principle, this might be achieved by improved cultivation techniques and intensification use of the existing land. Given the lack of financial resources of the rural population, this is unlikely to happen to a significant extent in the near future. The only realistic means of increasing food production is by extending the areas under cultivation.

Increased land for food production means a reduction in the natural woodlands. Given that the food can be produced to feed an increasing population, the question to be considered here is whether their fuel needs can also be met.

6.11 Flaws in the Conventional Analysis

The conventional analysis of the energy position is usually based on the assumption that the woodfuel consumption in a particular area will increase in line with population growth. Sooner or later, the level of consumption will exceed that of the sustainable yield of the available wood resources. The area is then said to be in a woodfuel "deficit". Current needs can only be only be met by depleting the wood stock on which future supplies depend. Once this happens, the position rapidly degenerates into a runaway process of increasing deficits and an accelerating decline in woodfuel stocks.

The approach appears to be logical; the conclusion is inevitable. The danger of taking the analysis literally, and assuming that this is what actually happens, can be illustrated by taking a numerical example.

Consider an area where the population density is at present 10 persons per sq km and the rainfall is around 600 mm per year. The location is one of average productivity typical of the Sahelian zone in Mali. Villages are surrounded by a stretch of permanently cultivated land; beyond this, there is a zone of fallow cultivation; this in turn is surrounded by an area of bush and open woodland which is used for grazing livestock and woodfuel collection.

Consider a "typical" village of 500 people. Given the average population density of 10 persons per sq km, the total amount of land associated with the village will be 50 sq km. It can be represented as a circle of radius 4 km around the village. It is from this area that the village will draw its food and fuel.

Assume that the average family size in the village is 7 people and that the rate of population growth is 2.3% per year. Assume also that the area of land under cultivation is 2.5 hectares per family and a further 15 hectares are in various stages of fallow. The total area of farm land is therefore 1250 hectares. The remainder is bush or open woodland, of which say 20% is barren scrub and waste land.

Take the woodfuel consumption as 11.5 kg per family per day or 4.2 tonnes per family per year. Assume that all the woodfuel is collected from the bush and woodland. It is relatively low quality brush (see Table 5.1) with a standing wood stock of 2.5 tonnes per hectare and a sustainable annual yield of 90 kg per hectare.

The village details are summarised in Table 6.1 below.

Table 6.1: Village Characteristics: Average Productivity Area

Population Density:	10 persons/sq km
Village size:	500 people
Average family size	7 people
Rate of population growth	2.3% per year
Crop land/family	2.5 ha
Fallow land/family	15.0 ha
Total land area:	5000 ha
Crop land:	179 ha
Fallow land:	1071 ha
Total farm land	1250 ha
Bush and open woodland:	3000 ha
Scrub and waste land	750 ha
Woodfuel consumption:	4.2 t/family/year
Total woodfuel consumption	270 t/year
Average standing wood stock in bush	2.5 t/ha
Stock of wood on 6 year fallow land	1.25 t/ha
Yield of woodfuel from bush	90 kg/ha/year (3.6% of standing stock)

Under the above conditions, woodfuel consumption is 300 tonnes per year, whereas the sustainable yield from the bush is 270 tonnes per year. The village is therefore in "deficit" with its hinterland. The excess of consumption is 10% of the annual yield; which means that consumption can only be met by reducing the standing stock. Moreover, the population is growing. This increases woodfuel consumption while the extension of farming simultaneously reduces the area of bush land from which wood can be obtained.

Table 6.2 shows how the position evolves with time, assuming that the trends continue unchanged. The "deficit" steadily mounts; in year 13 it exceeds the sustainable yield. Meanwhile, the standing stock of wood is declining with ever-increasing rapidity. In 20 years it is only 40% of today's value; in 27 years it has completely disappeared.

Table 6.2: Projected Woodfuel Supply and Demand: Trends Continued Scenario

Year	Village pop.	Crop land ha	Fallow land ha	Total farm land ha	Woodfuel cons t	Woodfuel yield t	Woodfuel "deficit" t	Standing stock t
1	500	179	1071	1250	300	270	30	7500
2	512	183	1096	1279	307	266	41	7398
3	523	187	1121	1308	314	262	52	7284
4	535	191	1147	1338	321	258	63	7158
5	548	196	1173	1369	329	253	76	7019
6	560	200	1200	1401	336	247	89	6866
7	573	205	1228	1433	344	241	103	6700
8	586	209	1256	1466	352	235	117	6519
9	600	214	1285	1499	360	228	132	6323
10	614	219	1315	1534	368	220	148	6111
11	628	224	1345	1569	377	212	165	5884
12	642	229	1376	1605	385	203	182	5640
13	657	235	1408	1642	394	194	200	5379
14	672	240	1440	1680	403	184	219	5101
15	687	246	1473	1719	412	173	239	4805
16	703	251	1507	1758	422	162	260	4490
17	719	257	1542	1799	432	150	282	4157
18	736	263	1577	1840	442	137	304	3806
19	753	269	1613	1882	452	124	328	3434
20	770	275	1650	1926	462	110	352	3044
21	788	281	1688	1970	473	95	378	2633
22	806	288	1727	2015	484	80	404	2203
23	825	294	1767	2061	495	64	431	1754
24	844	301	1808	2109	506	47	459	1285
25	863	308	1849	2157	518	29	489	796
26	883	315	1892	2207	530	11	519	289
27	903	323	1935	2258	542	-	550	-

Many such calamitous projections of the woodfuel future in different parts of the Sahel have been made. When the initial position is studied at a local level it looks stable and unthreatening; the "deficit" is just 0.4% of the remaining standing stock. No one in the village has any worries about woodfuel supplies or an interest in growing trees to

meet future woodfuel needs. But according to the projections, in fifteen years from now the situation is irredeemable.

Sometimes the local people are blamed for their lack of foresight or their inability to understand exponential growth. Table 6.3 provides an alternative view and suggests they are probably right not to worry unduly about woodfuel.

Table 6.3: Projected Woodfuel Supply and Demand: Taking Wood from Fallow Land into Account

Year	Village pop.	Fallow land ha	Fallow wood yield t	Bush wood yield t	Total wood available t	Woodfuel cons t	"Surplus" t	Standing stock t
1	500	1071	223	270	493	300	193	7500
2	512	1096	228	267	496	307	189	7428
3	523	1121	234	265	498	314	184	7355
4	535	1147	239	262	501	321	180	7279
5	548	1173	244	259	504	329	175	7202
6	560	1200	250	256	507	336	170	7124
7	573	1228	256	254	509	344	166	7043
8	586	1256	262	251	512	352	161	6961
9	600	1285	268	248	515	360	155	6877
10	614	1315	274	244	518	368	150	6790
11	628	1345	280	241	521	377	145	6702
12	642	1376	287	238	525	385	139	6612
13	657	1408	293	235	528	394	134	6520
14	672	1440	300	231	531	403	128	6425
15	687	1473	307	228	535	412	122	6329
16	703	1507	314	224	538	422	116	6230
17	719	1542	321	221	542	432	110	6129
18	736	1577	329	217	545	442	104	6025
19	753	1613	336	213	549	452	97	5919
20	770	1650	344	209	553	462	91	5811
21	788	1688	352	205	557	473	84	5700
22	806	1727	360	201	561	484	77	5587
23	825	1767	368	197	565	495	70	5471
24	844	1808	377	193	569	506	63	5353
25	863	1849	385	188	574	518	56	5232
26	883	1892	394	184	578	530	48	5108
27	903	1935	403	179	582	542	41	4981
28	924	1980	412	175	587	554	33	4851
29	945	2025	422	170	592	567	25	4718
30	967	2072	432	165	597	580	16	4582

The point is that it is not just the bush which is used to provide woodfuel. Fallow land can be a far more important source of woodfuel for the rural family than the bush or forest (Bongkoungou and Catinot, 1986; Ohler, 1985). In Table 6.3, all the other characteristics of the village are the same as in previous Table, but account is taken of the wood obtained when fallow lands are cleared.

Roughly one sixth of the fallow land is being brought back into cultivation every year. At the end of its six year fallow, this land

has a substantial wood cover. It is assumed that this amounts to 1.25 tonnes per hectare, half that of bush land.

Table 6.3 shows that, instead of an initial woodfuel "deficit" there is a "surplus" of woodfuel available. This remains true throughout the whole period; even in year 30 there is still a woodfuel "surplus". The supply of wood from the fallow land actually increases with time; taking it into account transforms the woodfuel supply outlook.

Nevertheless, there is a significant reduction of the standing stock of wood in the bush land as a result of land clearing. As the years pass, woodfuel will have disappeared from an increasing number of areas from which it was previously obtained. To get their supplies from the bush, women and children will have to travel further. But the overall availability of wood is still sufficient to meet the village's requirements. The key factor is the agricultural system and its 6 year rotation of fallow land. As long as this remains operational, the supply of the bulk woodfuel needs is assured.

6.12 Future Woodfuel Supplies in an Area of Low Productivity

The scenario illustrated in Table 6.3 applies to an area which is reasonably productive. There are obviously less productive areas where the stock and yield of woodfuel are lower. This may be a result of poorer soils, drier climate, shorter fallow periods or a higher proportion of barren land. In such cases the pressure on wood resources is greater. Table 6.4 sets out the characteristics of a village in such an area.

Table 6.4: Village Characteristics: Low Productivity Area

Population Density:	10 persons/sq km
Village size:	500 people
Average family size	7 people
Rate of population growth	2.3% per year
Crop land/family	2.5 ha
Fallow land/family	15.0 ha
Total land area:	5000 ha
Crop land:	179 ha
Fallow land:	1071 ha
Bush and open woodland:	3000 ha
Scrub and waste land	750 ha
Woodfuel consumption:	4.2 t/family/year
Total woodfuel consumption:	270 t/yr
Average standing wood stock in bush	1.25 t/ha
Stock of wood on 6 year fallow land	0.6 t/ha
Yield of woodfuel from bush	45 kg/ha/year (3.6% of standing stock)

The population and land allocation figures remain the same but the stocks and yields of wood are all reduced by 50%. The yield of wood when fallow land is brought into cultivation is now only 0.6 tonnes per

hectare. The stock of wood on bush land is 1.25 tonnes per hectare and its annual sustainable yield is 45 kg per hectare.

Under these conditions, the village has a woodfuel "deficit" even when the wood from clearing fallow land is taken into account. Table 6.5 shows the results when the trends are projected forward. The position rapidly worsens in the initial years. By year 22 it reaches disaster with the complete disappearance of the standing stock of woodfuel.

Table 6.5: Projected Woodfuel Supply and Demand: Low Productivity Area

Year	Village pop	Fallow wood t	Bush wood t	Total woodfuel yield t	Woodfuel cons t	Woodfuel "deficit" t	Standing stock t
1	500	107	135	242	300	58	3750
2	512	110	132	241	307	66	3656
3	523	112	128	240	314	74	3554
4	535	115	124	239	321	82	3444
5	548	117	120	237	329	91	3325
6	560	120	115	235	336	101	3197
7	573	123	110	233	344	111	3060
8	586	126	105	231	352	121	2914
9	600	129	99	228	360	132	2757
10	614	131	93	225	368	143	2591
11	628	134	87	221	377	155	2414
12	642	138	80	218	385	167	2226
13	657	141	73	214	394	180	2028
14	672	144	66	210	403	194	1818
15	687	147	58	205	412	208	1597
16	703	151	49	200	422	222	1364
17	719	154	40	195	432	237	1120
18	736	158	31	189	442	253	864
19	753	161	22	183	452	269	597
20	770	165	12	177	462	285	317
21	788	169	1	170	473	303	25
22	806	173	-	173	484	311	-

The evidence from Mali and elsewhere, however, suggests that this is not the way things happen in reality. As woodfuel becomes more scarce, women begin to make a choice between the extra time and effort required in searching for wood and that involved in using it more economically. Scarce woodfuel can be saved by making the fire smaller or keeping it lighting for shorter periods. As wood becomes scarcer, greater economy is forced on people whether they want it or not.

Other sources of fuel also come into use. Because of the increased difficulty in obtaining traditional quality wood from the bush, people begin to collect small wood and branches from bushes that they would previously have rejected; these can be obtained from the scrub and fallow land, as well as the bush itself, thus widening the basis of supply.

The increasing difficulty in obtaining woodfuel also makes dung and agricultural residues more attractive. The further the depletion of woodfuel resources proceeds, the more all these responses are brought into action. Table 6.6 examines the effect of such changes.

The woodfuel yields and stock are the same as in Table 6.4. But there is a gradual adoption of supplementary fuels in the form of dung, agricultural residues, twigs and other burnable biomass. The proportion of the total supplied by these rises from 5% of family fuel consumption up to 35% at the end of the period. In addition, the total fuel use per family falls slowly from 11.5 kg per day to 8.0 kg (wood equivalent) per day. This is equivalent to 1.1 kg per head per day and still remains well above the average woodfuel consumption estimated for the drier parts of the country (see p. 40).

Table 6.6: Projected Woodfuel Supply and Demand: Effects of Conservation and Supplementary Fuel Use

Year	Village pop	Fallow wood t	Bush wood yield t	Total woodfuel t	Woodfuel consumpt t	Dung ag. res etc t	Woodfuel "deficit" t	Standing stock t
1	500	107	135	242	300	15	43	3750
2	512	110	132	242	303	18	44	3671
3	523	112	129	241	307	21	45	3591
4	535	115	126	241	311	25	45	3510
5	548	117	123	241	315	28	46	3428
6	560	120	120	240	318	31	46	3344
7	573	123	117	240	322	35	47	3260
8	586	126	114	240	326	39	47	3175
9	600	129	111	240	329	42	47	3090
10	614	131	108	240	333	46	47	3003
11	628	134	105	240	337	50	47	2917
12	642	138	102	240	341	54	47	2830
13	657	141	99	240	344	58	47	2744
14	672	144	96	240	348	62	46	2657
15	687	147	93	240	352	66	46	2571
16	703	151	89	240	355	70	45	2485
17	719	154	86	241	359	75	44	2400
18	736	158	83	241	363	79	43	2316
19	753	161	80	242	366	83	41	2233
20	770	165	77	242	370	88	39	2151
21	788	169	75	243	373	92	37	2070
22	806	173	72	244	377	97	35	1992
23	825	177	69	246	380	102	33	1915
24	844	181	66	247	384	106	30	1841
25	863	185	64	249	387	111	27	1769
26	883	189	61	250	390	116	24	1700
27	903	194	59	252	394	121	20	1634
28	924	198	57	255	397	126	16	1571
29	945	203	54	257	400	131	12	1511
30	967	207	52	260	403	136	8	1455

Table 6.6 shows that the woodfuel "deficit", rather than racing out of control, gradually decreases and has virtually disappeared at the end of the period. The clearing of fallow land still provides the bulk of

the woodfuel. There is a major decline in the stocks of woodfuel on the bush land almost entirely as a consequence of clearing land for agriculture. But this does not result in any pressure on domestic fuel supplies which remain adequate at all times.

6.13 Using Dung and Agricultural Residues as Fuel

Perhaps the most obvious substitutes for woodfuel in the dry farming areas are millet stalks. These have an air dry calorific value of about 15 MJ/kg which is about the same as that of wood. They are already commonly used as fuel in some areas in Mali and in other countries in the developing world they play a major role in domestic fuel supply. The stalk to grain ratio for millet varies widely. A ratio of 3:1 can be assumed for present purposes.

Cow dung is also available to farming families. The amount produced by an animal depends on its size, its state of health, and the amount of food it eats. The total amount of dung produced by a cow in Mali can be assumed to be 0.75 tonnes per year (Barnard and Kristopherson, 1985). The calorific value of dung varies according to its moisture content. When fully air dry, it should be about 75% that of wood.

The effects on the overall agricultural system of substituting dung and agricultural residues for woodfuel have given rise to a considerable amount of concern. It is widely taken for granted that any substantial use of supplementary fuels will lead to a major deterioration in crop yields. It is therefore necessary to examine the likely impact of the switch to dung and agricultural residues postulated in Table 6.5.

The maximum annual use of supplementary fuels shown is 136 tonnes (equivalent woodfuel) in year 30. Making allowance for the lower calorific value of dung, the total weight of supplementary fuels can be taken as about 150 tonnes.

Assuming that each family plants an average of 2 hectares of millet with a yield of 500 kg per hectare, the total harvest in year 30 is 138 tonnes. With a stalk to crop ratio of 3:1, the total quantity of millet stalks available is 414 tonnes.

The total number of cattle in the village area will vary greatly depending on the time of the year. There will probably be a limited number of stall-fed cattle throughout the year; in addition, there will be a very much larger number of animals in the grazing areas for a portion of the year. Assume that each family has an "annual equivalent" of ten cattle. The dung production of these will be about 0.75 tonne per head per year, giving 1035 tonnes for the village total.

The production of twigs and bushes is considerably greater than that of wood. It occurs throughout the whole of the fallow areas as well as the bush. If this is taken as an average of 100 kg per hectare of burnable material per year, then the total production (excluding the areas actually under cultivation in any given year) is 465 tonnes.

In all, there are over 1900 tonnes of supplementary fuel available. Different families will permutate their supplementary fuel requirements in different ways. Assuming that they are divided equally between millet stalks, dung, and small twigs and wood, the impact on the supply

of each is relatively slight.

The stalks of millet and sorghum are not a particularly rich source of soil nutrients. Some 70-80% of the nitrogen, phosphorous and potassium are contained in the grain of these crops. Thus even if the stalks are fully recycled, their contribution to the vitally important process of maintaining soil fertility will be relatively slight.

Moreover, it is difficult to recycle these materials under practical Malian farming conditions. Ploughing the stalks back into the soil using hand hoeing is extremely arduous; they are also slow to decompose in the very dry climate. In general, they are either burned - which causes the loss of the nitrogen; left in place as animal fodder; or removed and used for fodder or other purposes. They do, however, provide food for termites whose burrowing actions help aerate and loosen the soil, making it easier to prepare for planting. But it is difficult to see how abstracting 10-15% of the stalks for domestic fuel can have any serious for the agricultural system.

Similar remarks can be made about dung. A considerable proportion of dung produced within the lands around the village is deposited in the grazing areas. Provided the dung which is burned is not taken from the cultivated areas, burning it for fuel will have no effect on agricultural productivity. Alternatively, some of the dung produced by the stall fed cattle could be used, as is done in other countries. In all, the quantity involved is just 5% of the total annual production.

6.2 The Woodfuel Future in Other Zones

Treatment of the remaining zones in the country can be more cursory. In general, their woodfuel position is less critical than that in the Sahelian zone. Little would be added by detailed numerical examples similar to those above.

6.21 Sudanian Zone

This zone covers about 20% of the total area of the country. The rural population density varies from around 10-15 people per sq km over most of the western portion of the zone to 20-30 in the centre, east and south.

The woodfuel resources of this zone and the annual yields are proportionally higher than than the population densities (See Table 5.1). From an overall viewpoint, therefore, the woodfuel position is generally less critical than in the Sahelian zone. This is particularly true in the more southerly areas where the natural forest becomes increasingly rich and more productive.

Supplementary cooking fuel is also available from millet and sorghum stalks, maize cobs and other agricultural residues. Cattle and livestock are also kept, which means that dung is also available as a domestic fuel. Although projections based purely on woodfuel consumption can reveal 'deficits' in the woodfuel supply, it seems reasonable to assume that, as in the Sahelian zone, alternative fuels can be found to meet any shortfall which occurs in reality.

6.22 Inland Delta Region

The total population in this zone is perhaps 600 000 people. The density varies widely even over short distances. Controlled irrigation schemes permit densities of up to 40 people per sq km. But only a few kilometres outside the perimeters of such areas, densities may fall to below 10 persons per sq km.

Millet is grown in the dry areas so that its stalks are available to make up a deficiency in wood supplies. Rice straw and husks are produced in large quantities in the regularly irrigated areas and can be used as a supplementary fuel. There is also a large amount of cow dung available in this zone.

In its broad outlines, the domestic fuel position is therefore similar to that in the Sahelian zone. Wood is undoubtedly the preferred fuel at present and will continue to be used as long as it is reasonably easy to obtain. But with increasing scarcity, the other biomass alternatives will become more attractive and come into more common use. In the area of Djenne on the edge of the delta south west of Mopti, for example, dung is already widely used.

The depletion of the wood resources from which fishermen obtain their fuel for smoking their catch may, however, constitute a case of special hardship. A detailed analysis of where supplies of wood are presently obtained and how quickly resources are being depleted is obviously required.

6.23 Saharan and Sahelo-Saharan Zones

The population density in these vast areas is very low. Pastoralism is the main form of livelihood, with a small amount of recessional agriculture along the Niger. The total number of inhabitants is probably 300 000-400 000; though many of these spend a substantial part of the year away from their home villages.

There is very little reliable quantitative information on any aspect of domestic fuel consumption in this zone. But it is clear that people use wood as the preferred fuel wherever it is available. Cow dung and millet stalks are also used.

There is an equal shortage of information on the supply side. Little is known in detail about the standing stock, annual growth, and rate of depletion of wood resources. In some areas, there are substantial stocks of dead wood as result of the number of trees which were killed by drought during the 1970s and 1980s.

The key issue in these zones is rainfall. Pastoralists can only survive in areas where their flocks are able to obtain the necessary fodder. In the areas where this proves to be possible, the pastoralist herders will automatically have a supply of burnable material in the form of dried cow dung and wood from shrubs and bushes. It is therefore difficult to see how domestic fuel availability can be a limiting factor on the survival of people in this area.

6.3 No Overall Domestic Fuel Shortage?

The calculations in this chapter are not presented as literal models of how villages actually obtain their woodfuel supplies. There is a great deal more variation and flexibility of response than is suggested by the simple assumptions used in the different examples. Their main purpose is to demonstrate show that the available data can be re-worked in a way which convincingly shows that, as far as domestic woodfuel supplies are concerned, the position in Mali is far less serious than is usually assumed.

The reason for this is twofold. Firstly, the conventional analysis tends to be based solely on the woodfuel resources available in the bush and open woodland areas. This greatly underestimates the amounts of wood available to families from fallow lands. Once this is taken into account, the woodfuel position becomes much less serious.

Secondly, people do not continue using woodfuel at the same rate, irrespective of its availability. Once it begins to become scarce, they start to economise and switch to alternative fuels. There are precedents in Mali itself and in other African countries for such fuel switches.

The calculations show how these kind of changes can dramatically alter the domestic fuel supply picture. A mixture, probably varying from season to season, of millet stalks, dung, and wood can adequately cover family fuel needs without endangering the agricultural system on which they depend.

7.0 PROJECTING FUTURE WOODFUEL SUPPLY AND DEMAND: URBAN AREAS

Urban domestic fuel consumers have to pay for their domestic fuel. Projections of future fuel supply and demand in the urban areas need to take this crucial point into account. It is not simply the availability of resources which determines consumption patterns. The preferences and economic circumstances of consumers will also influence their choice of fuels and the quantities they consume.

7.1 Urban Growth and Change

A population of 1.6 million people in the year 2006 has been assumed for Bamako. If the estimated 1978 woodfuel consumption of 240 000 tonnes (See p 42) were to increase in direct proportion to population growth, this would give a consumption of 950 000 tonnes in the year 2006. But such an assumption takes no account of the complex changes which take place as a city increases in size.

As a city grows, the total activity in business, commerce and government also increases and becomes more complex. This takes place at all income levels. Even the poorest have to buy most of their living requirements; they earn the money to do so providing goods and services for cash in a myriad of small scale activities. Markets offer a huge range of cheap domestic wares and appliances. The range of choice is immensely wider than in the rural areas.

There is also an increasing number of administrators, professional people, wholesale and retailer traders, and providers of a continually widening and more sophisticated range of services. The number of middle and upper managers, as well as white collar workers rises. The provision of roads, office buildings, commercial buildings, and urban infrastructural requirements provides a large amount of work for the construction industry.

The social structure also reflects such change, becoming increasingly stratified according to income. The poor are crammed together in small run down accomodation in the older parts of the city; new arrivals from the country tend to go to shanty towns on the outskirts. The middle and upper income classes adopt a distinctive style of life; they live in their own areas of the city. They employ a considerable number of servants, many of whom eat and sleep in the accommodation provided by their employers.

As the city becomes larger, the wholesale provision of meals becomes more important. Many working people begin to eat their midday meals in cafes, or buy food from kiosks and street vendors. Breakfasts are often bought on the way to work instead of being cooked in the home.

Domestic cooking patterns vary greatly between the social classes. The rich, and their servants, make increasing use of bottled gas and electricity for cooking. Young new arrivals from the countryside living in cramped single accomodation may do little cooking of their own. The very poor have to beg and scavenge for what will keep them alive.

Increasing city size is also brings about changes in the food supply system. The provision of fresh foods becomes more difficult and

expensive because of the growing complexity and cost of storage and distribution. There is an increasing use of processed and packaged cereal and milk products and canned foods. The economies of scale brought about by the increasing market, together with their easier distribution and storage, make these more economical for consumers than traditional foods.

The fact that both food and fuel have to be bought is a particularly important factor in bringing about change in cooking habits at all economic levels. It means that the housewife can make a trade-off between paying a higher price for pre-prepared foods and obtaining a saving in fuel costs. The question of time is also important. Women with opportunities for paid employment cannot afford the long routines of traditional food preparation and cooking.

The use of foods which are quicker and easier to cook also makes the substitution of woodfuel by conventional fuels easier and more likely. Using a gas or kerosene stove for a stew which requires two hours stirring and simmering is likely to be impractical; but this is not so if it is a case of quickly making a porridge from pre-processed cereals or dried milk products. The use of conventional fuels usually starts with the preparation of snacks and hot drinks; in time, it spreads to the preparation of other meals.

There are very few quantitative data anywhere in the world on how these social and domestic changes affect urban woodfuel consumption levels. But it is clear that the majority reduce both the numbers of woodfuel consumers and their average consumption. The changes do not take place overnight, but from the evidence of other countries, it is clear that their impact can be substantial.

The Indian city of Bangalore, for example, is set in an area in which the vast majority of local people use woodfuel for their cooking needs. Yet 65% of the urban population rely solely on conventional fuels and do not use any woodfuel whatsoever. It is only among the poorest urban families that there is an exclusive use of woodfuel for cooking and water heating. Among these people, the average consumption is 0.52 kg per head per day, compared with 1.42 kg per head per day in a number of villages in the surrounding area (Reddy and Reddy, 1983).

7.2 Feasibility and Implications of a Shift to Conventional Fuels

It is frequently assumed that a shift to conventional fuels is not feasible in a poor country like Mali because it would place an impossible burden both on individual families and national finances. It is worth considering these in turn.

It is quite misleading to base estimates of conventional fuel consumption on the quantities of woodfuel currently consumed. It is not simply a question of taking the energy content of the woodfuel used by a family and assuming that an equivalent amount will be supplied in the form of conventional fuels. This grossly overstates the conventional fuel requirements if a switch is made from woodfuels.

The first reason for this is the difference in efficiency of fuel use. A gas or kerosene pressure stove is likely to be anything from three to five times as efficient as a wood fire or stove. Preparing the same

meal using conventional fuels will therefore use correspondingly less fuel.

More importantly, the switch to conventional fuels needs to be seen as part of a more general change in the economic and cooking habits of the household. The foods cooked in a household using conventional fuels will tend to require less cooking time and less fuel than those in a household relying on woodfuels. It is highly unlikely that the family which now relies on a millet stew which simmers over a wood fire for three or four hours would attempt the same cooking task on a gas stove. If they have made the switch to conventional fuels, they would choose something considerably quicker and easier to cook.

There is thus no basis in the present woodfuel data from Bamako for any estimate of the likely future consumption of conventional fuels. The only way an estimate can be made is by taking what appears to be a reasonably plausible pattern of fuel use for a family and examining its implications.

Suppose, therefore, that a family of six has a bottled gas burner or a kerosene pressure cookers on which they rely for their cooking and hot water needs. Assume that the total use is 1.5 hours at full power and a further 3 hours simmering each day.

A recent study sponsored by the World Bank examined a wide range of wick and pressure kerosene stoves and gas burners available in the developing world (World Bank, 1985). Their fuel-using characteristics fit within a surprisingly narrow range. The average minimum power output, with the flame turned down as far as possible, was about 0.4kW; their average maximum output was about 1.5 kW. Their efficiencies generally lay in the range 40-60%.

Taking an average stove, with an efficiency of 50%, the total daily energy consumption for the family is 24.8 MJ/day. This is equivalent to a family consumption of 200 kg of bottled gas or 263 litres of kerosene per year.

The price of butane in Bamako in 1983 was 340 FCFA per kg; that of kerosene was 173 FCFA per litre (Trans Energ 1985). This would mean that the total annual family expenditure on butane would be 68 000 FCFA, or on kerosene would be 46 000 FCFA.

This can be compared with present expenditure on woodfuel. In the woodfuel survey carried out in Bamako in 1978, the average consumption was 1.8 kg per person per day among the 450 families surveyed (Sankaré, 1979). With woodfuel at 12.5 FCFA per kg, this would imply an annual expenditure of 49 000 FCFA for a family of six.

The calculation shows that cooking with conventional fuels is, in principle, within the reach of today's woodfuel consumers. It does not mean that a major switch to the use of conventional fuels is likely to take place in the immediate future. But as urban growth continues, the attractions of conventional fuels will continue to exert their influence on people. In the Bamako of ten to twenty years from now, it is likely that a large number of households will have either totally or partly abandoned the use of woodfuels for cooking.

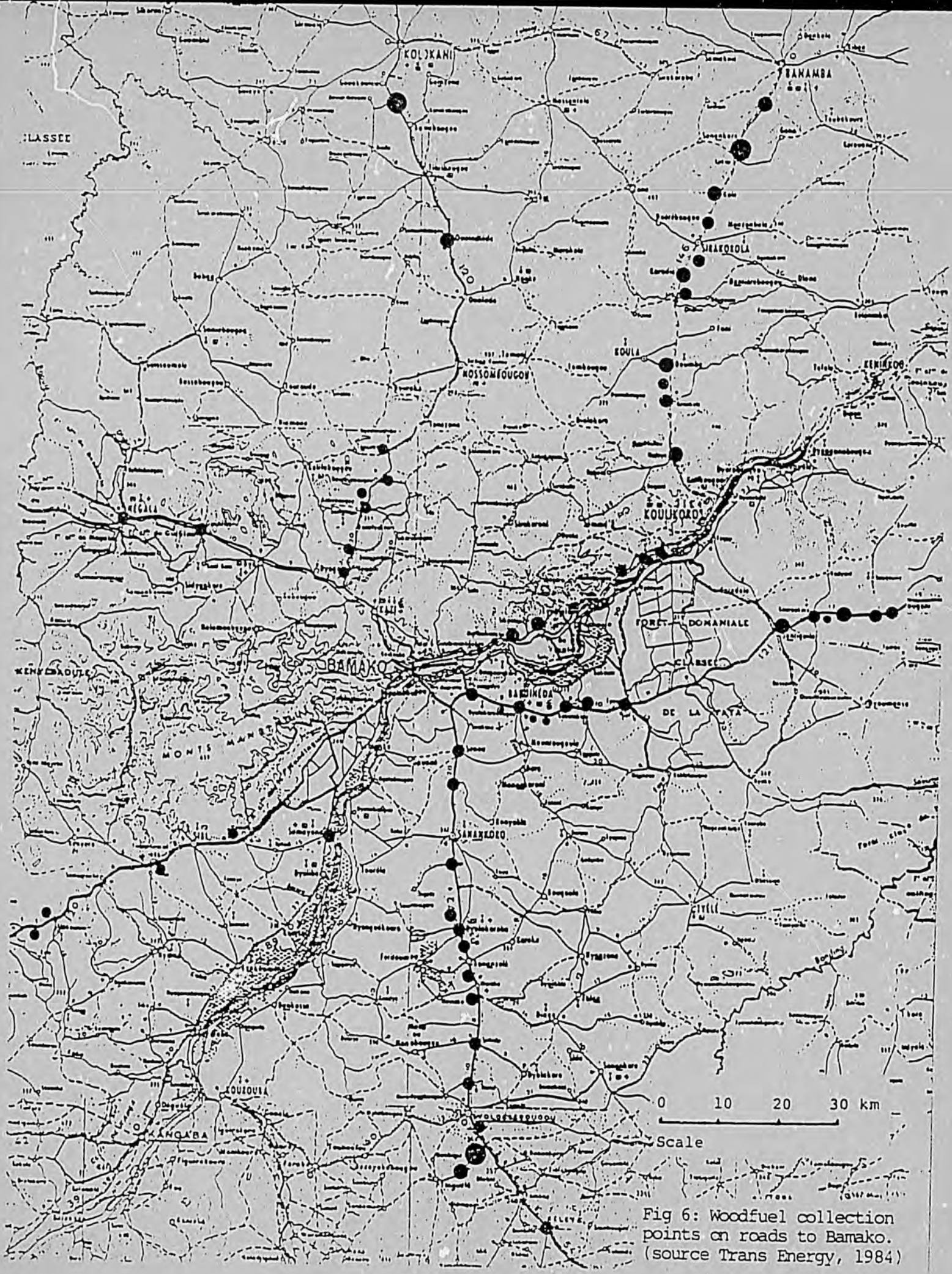

Fig 6: Woodfuel collection points on roads to Bamako. (source Trans Energy, 1984)

At a national level, a major switch to petroleum fuels by woodfuel users in Bamako would have a relatively minor effect. If, for example, a quarter of the projected population of Bamako in the year 2006, some 400 000 consumers, were to use bottled gas or kerosene at the above rate, the total imports would be about 13 000 tonnes per year. This is about 10% of the total petroleum imports in 1982. At 1982 prices, it would increase the country's total import bill by about 2%.

During the 1970s, the annual rate of increase in consumption in petroleum products was around 10% per annum, with imports reaching a peak level of 167 000 tonnes in 1979. There is, thus, nothing inherently improbable about a 10% increase in total imports spread over the next 20 years to enable a major shift to butane or kerosene by domestic consumers to take place in Bamako.

Such an expansion in petroleum fuel use would require substantial investment in transport and distribution facilities. One of the largest of these is the pressure bottles in which butane is sold. But evidence from elsewhere in the developing world clearly shows that given an expanding market and an introduction period of two decades, the necessary investments are well within the capacities of the petroleum companies supplying the fuels.

7.3 Future Woodfuel Demand in Bamako

The absence of any reliable data on the rate at which fuel consumption patterns are changing in Bamako means that there is a great deal of uncertainty about any projections of future demand. Nevertheless, reasonable assumption can be made about the likely course of events.

Assume that the population will rise to 1.6 million people by the year 2006 and that 25% of these will, by then, be meeting all their domestic cooking needs with conventional fuels. Assume also that the average level of woodfuel consumption falls from 1.5 kg per head per day (see p. 42) falls to 1.0 kg per head per day among those still using woodfuel.

Combining these assumptions gives a projected annual consumption of 438 000 tonnes by the year 2006. The level of uncertainty in this is considerable because of the number of unknowns. But it is likely to be closer to the truth than the very much higher figures obtained when consumption is projected to increase exactly in line with population growth.

7.31 Meeting Future Demands

As far as the supply of woodfuel is concerned, a simplified model can be used for illustrative purposes. As shown in Fig 7.1, the wood supplies for the city are drawn from the lands on either side of the six main radial routes leading to it. The collection distance on either side is 3-5 km, say an average of 4 km, to give a collection strip about 8 km wide. Assume that the urban supplies are drawn from a third of this and the remainder is farm and bush land from which the rural population obtains its food and woodfuel supplies. In reality, there were will be no such physical distinction, but the assumption allows the effect of the urban demands to be assessed on their own.

Woodfuel collectors will take whatever suitable wood is readily available close to the roads; in area where the bush has already been cut over, the wood will consist of branches and regenerated shoots which have grown to a suitable size. The remainder of the city's supplies will be obtained by moving further away from the roads and cutting wood in areas which have not yet been cut over. In neither case will this involve the complete clearing of bush land since there is no urban market for the very small low grade wood which is left after the saleable firewood has been cut.

For calculation purposes this can be simplified by saying there is an area of cut over bush close to the road which is harvested on the basis of its annual yield. Beyond this, there is bush land into which collection is encroaching and reducing the wood stock. The total woodfuel collection area is thus expanding every year.

Rough figures can be put upon these assumptions. The area around Bamako is in the Sudanian Zone of Mali. The standing stock of wood in the bush can be taken as 7.5 tonnes per hectare (See Table 5.1); assume that cutting over this reduces the stock to 2.5 tonnes per hectare with an annual yield of 150 kg per hectare.

The year 1978, in which the woodfuel survey was carried out in Bamako, can be taken as the starting year. The details are summarised in Table 7.1 below.

Table 7.1 Schematic Description of the Woodfuel Supply Sources for Bamako in 1978

No. of radial strips:	6
Length of each:	175 km
Width of each:	8 km
Total area:	8400 sq km
Proportion from which woodfuel obtained	30%
Total collection area serving Bamako	2520 sq km
Standing stock in uncut bush	7.5 t/ha
Standing stock in cut over bush	2.5 t/ha
Yield from cut over bush	150 kg/ha/yr
Woodfuel consumption in Bamako	240 000 t/yr

The progression of events over a 30 year period from 1978 to 2008 is illustrated in Table 7.2. Woodfuel consumption is shown rising to 450 000 tonnes in the final year. In each year, a proportion of the city's needs is met by the sustainable yield from the existing collection area. The remainder is obtained by extending the collection area and reducing the stock in this new area from 7.5 tonnes per hectare to 5 tonnes per hectare.

At the end of the thirty years, the total area from which woodfuel is collected has expanded slightly more than five fold. The collection distance, for example, might have extended to 250 kms from the city, with wood being drawn from up to 15 km on either side of the road. The

balance between the wood obtained by harvesting on a sustainable basis and that from cutting into new woodlands has also shifted markedly. About half is being drawn from the already cut over area and would tend to be of lower quality than that obtained from the uncut bush.

Table 7.2 **Evolution of Bamako Woodfuel Collection Area: 1978-2008**

Year	Woodfuel consumpt Bamako '000 t	Collect'n area sq km	Yield '000 t	"Deficit" '000 t	Additional cutting area sq km
1	240	2772	42	198	397
2	245	3169	48	198	395
3	251	3564	53	197	394
4	256	3959	59	197	393
5	262	4352	65	196	393
6	267	4745	71	196	393
7	273	5137	77	196	392
8	279	5530	83	196	393
9	285	5922	89	197	393
10	292	6316	95	197	394
11	298	6709	101	197	395
12	305	7104	107	198	396
13	311	7500	112	199	397
14	318	7897	118	200	399
15	325	8296	124	200	401
16	332	8697	130	202	403
17	339	9101	137	203	406
18	347	9506	143	204	408
19	354	9914	149	206	411
20	362	10326	155	207	414
21	370	10740	161	209	418
22	378	11158	167	211	421
23	386	11579	174	213	425
24	395	12005	180	215	430
25	403	12434	187	217	434
26	412	12868	193	219	439
27	421	13307	200	222	443
28	431	13750	206	224	449
29	440	14199	213	227	454
30	450	14653	220	230	460

7.3 Not a Crisis Position

The projection shows that a large additional area of bush land has been cut over, but the position is very far from crisis. There is no widespread "desertification" as a result of supplying the city's woodfuel needs. The bush in the collection area has, of course, been heavily degraded but there is no point in woodfuel collectors gathering twigs and bushes for the urban market when there are readily accessible resources of more saleable fuel. The vegetational cover left will be capable of providing a substantial supply of small wood for fuel on a sustainable basis.

Moreover, the total collection area is only 7.4% of the land within a 250 km radius of the city. This leaves considerable room for further expansion of woodfuel collection for at least a further couple of decades.

This is low cost wood taken from natural woodlands. It is readily accessible and can be obtained and delivered by the same methods being used at present. The increased distance from the road will add to the labour required to bring wood to the collection points. But the labour costs at this end of the supply chain are extremely low. No major change in the supply system or its costs therefore appears likely to be forced on suppliers as a result of woodfuel scarcities within the next few decades.

8.0 POLICY IMPLICATIONS AND NEXT STEPS

This paper raises a number of extremely important points about the current approach to woodfuel policy making in Mali. It relies on the same data as that used in the conventional analysis of the woodfuel issue. But it arrives at more or less diametrically opposed conclusions.

Many gaps still remain. The examples taken represent "typical" situations. There is little doubt that closer and more detailed investigation would reveal a wide range of different circumstances, but few such studies have been carried out. Until they are, policy making must continue to be based on the presently available broad brush studies and generalised data.

The significance of the analysis presented here is that it casts a large measure of doubt on the conventional interpetation of the available data and the consensus view of the Sahelian woodfuel "crisis." The following sections briefly review the main conclusions and their implications for woodfuel policy.

8.1 Tree Growing to Meet Rural Needs

A great deal of effort has been directed into various programmes to promote tree growing to meet rural needs. Few of the projects have relied on the profit motive to stimulate rural interest. The main focus has been upon promoting voluntary tree growing as a means of resolving certain energy and environmental problems.

If these problems do not exist, or are not seen as serious by local people, then it is obvious that they have little reason to invest time or effort in trying to solve them. If, alternatively, the problems are real but are not linked with energy shortages, it is unlikely they will be solved by trying to persuade people to plant trees to increase their energy supplies.

8.11 Tree Growing to Meet Rural Woodfuel Needs

The main conclusion of this study is that, in the general context of Malian rural life, the supply of domestic fuel is not a serious problem and is unlikely to become one in the next two decades. Where woodfuels are scarce, or likely to become so, there are readily available alternatives. Wherever people are able to grow enough food to feed themselves, it seems as if they will be able to find the fuel with which to cook it without any major difficulty.

Nor does it appear as though the use of supplementary fuels such as dung and millet stalks will impose any particularly serious additional burden on the agricultural and pastoralist systems on which people depend. The quantities required for domestic fuel, in comparison with those being produced, seem well below the level at which their use as fuel is likely to cause damage.

The difficulties of growing trees in arid areas must also be borne in mind. Growing substantial numbers of trees can be an extremely arduous

task, particularly in the drier areas of Mali. The work of planting and weeding has to carried out during the short agricultural season when labour is scarce; the trees also have to be fenced or protected in some other way against animals. Seedlings often need to be watered at least a few times a week throughout the dry season for the first year or two. The task of supplying the family's water needs is difficult enough in itself; there need to very pressing reasons to make the added burden of providing water for tree seem worthwhile.

Given the availability of woodfuel and acceptable substitutes, the onerous, time-consuming, and uncertain business of growing trees to provide fuel does not make sense. Unless, therefore, there are specific local circumstances which indicate otherwise, there does not appear to be any point in trying to persuade local people to take part in programmes to grow trees to meet rural fuel needs.

8.12 Tree Growing for Non-Fuel Purposes

The fact that domestic fuel supply are reasonably adequate does not mean that there are no other problems in the farming areas. People cannot survive if they are unable to produce enough food.

Drought, over-grazing, inappropriate agricultural practices, and a variety of other factors can combine to bring about the collapse of agricultural production. These issues are outside the scope of this study, but many authorities have voiced their concern about them. There is little doubt that further tree growing would be beneficial in many areas.

Many farming families have traditionally grown their own trees; they also protect or transplant seedlings found in the wild. Provided there is a sympathetic understanding of local traditions and effective technical help, it should be possible to build on existing local practices and successfully promote additional tree growing in appropriate areas.

Firewood is obtained from the loppings and thinnings when trees are grown for any of these purposes. It is, no doubt, a welcome bonus to the families concerned. But if domestic fuel is not particularly scarce, its provision is unlikely to be a significant factor in the decision to grow trees or the choice of species planted.

The course most likely to be successful will concentrate on getting trees grown which provide the benefits which local people recognise as worthwhile. Programme promoters should, therefore, be wary of giving too much weight to the woodfuel production aspect of multi-purpose trees. It could lead to the dilution of the aims of programmes and the choice of trees species which are less useful in the agricultural system, less well adapted to the climatic conditions under which they are meant to grow, or less in accord with what rural people see as their real needs.

8.13 Land and Forest Management

One the major problems facing the rural dwellers of Mali, is the lack of control over the land resources from which they obtain their food, wood

and other necessities. Where communal resources are being over-exploited, it is difficult for individuals to make a contribution to their more rational management. The same is true where state forest resources are ineffectually guarded. The logical response by local people is to take what is available before someone else does.

Such unregulated exploitation of natural resources can lead to a complete environmental breakdown with a collapse of the agricultural system. Along the way, woodfuel is likely to become scarce. But is important to see this as part of the broader sequence of events taking place.

The woodfuel shortage is not the major determining factor in the deterioration of conditions. As long as the agricultural system is functioning, domestic fuel supplies remain adequate. The fuel shortage is not a cause; it is a symptom of the breakdown in land management. Tinkering with tree growing programmes to provide fuel will be completely irrelevant if what is really required is a radical change in local land tenure or usufruct systems.

8.2 Urban Woodfuel Supplies

Large amounts of woodfuel are likely to be used in Bamako for a considerable time to come. It appears as if the existing supply system will be able to meet these woodfuel demands for at least the next twenty or thirty years without major cost increases or structural change.

There will, however, be the environmental costs of an expanding area of degraded, though not totally destroyed, woodland to be borne. It is therefore worth examing whether there are alternative methods of supplying woodfuel to the city which would ease the pressure on the natural woodlands.

8.21 Economic Viability of Woodfuel from Forestry Plantations

The crucial question when forestry plantations to supply the urban woodfuel market are being considered is their economic viability. The Malian Government has so many calls on its scarce resources that subsidising woodfuel is not a practical policy option. If forestry plantations are to be justified, they should provide an adequate return on the resources invested in them.

There has been little recent experience of plantation projects. The World Bank's First Forestry Project created 2 700 hectares of semi-industrial forestry plantations at an overall cost apparently approaching $3000 per hectare. The heavy infrastructural and peripheral costs involved in gearing up the forestry service for the project, however, mean that this figure is considerably higher than the actual marginal plantation costs. The estimated cost of similar plantations in the World Bank's Second Forestry Project is about $1400 per hectare.

Even on the most optimistic forecasts of yields it is obvious that woodfuel produced on such a basis cannot compete economically with that collected by extremely low cost labour from natural woodlands. Nor is the position likely to change in the short to medium term future. With no major increases in woodfuel prices in real terms likely over the next

few decades, woodfuel from forestry plantations will remain uncompetitive. It therefore does not look as if such plantations have any significant role to play.

This does not necessarily apply to plantations for poles and timber. Here, the ability of forest plantations to produce straight wood from fast growing species gives them a considerable advantage over wood collected from the bush. Plantation poles will almost certainly sell at a substantial premium over those from the bush. Their production in forestry plantations may well be a profitable exercise.

The wood obtained from the thinnings, lops and tops in pole and timber plantations can be sold for woodfuel in the urban market. This already happens in the case of wood produced in the course of normal forest management. It is one of the economic benefits of such activities and may help justify plantation projects.

But it is pointless selling this wood below its market price in an effort to control the price level as is currently done in Mali. The quantities involved are far too small to affect the market. It simply reduces the revenue which the forestry service or the government would otherwise obtain.

8.22 Increasing Woodfuel Taxes

It is intended that there will be a sharp increase in the level of the cutting permits, as well as stricter control over the woodfuel traffic into Bamako. This has frequently been discussed as a means of bringing the market price of wood closer to its replacement or production costs. It is important to note, however, that it will not make tree growing economically more attractive.

The cutting permit fee is paid by the transporters and is, in effect, a transport tax. In the rural areas, the "value" of wood will remain exactly as it is today, which is the cost of collecting it and bringing it to the pick-up point. The fact that it is taxed further down the distribution chain makes no difference to what it costs the dealer to obtain it in the rural areas. It therefore does not increase the incentive to grow wood for sale in the urban market.

But higher taxes and better collection will obviously increase the revenue to the government and can be justified on these grounds. This extra finance could be used to strengthen the DNEF and widen its scope of action. But any such choice remains entirely the prerogative of the Government.

Higher woodfuel prices in the market will, in principle, also encourage a more economical use of wood, as well as the diffusion of improved cooking stoves, and a higher use of conventional fuels. But such effects are likely to be relatively minor because of the practical political difficulty of raising woodfuel taxes by an amount sufficient to cause major changes in the behaviour of woodfuel users.

At present the permit fee is only 100 FCFA per stère, just over 2% of the retail selling price. Any increase in the permit level will be resisted by the transporters. It is also likely to cause a major public outcry when the increases - quite possibly enhanced - are passed on to

the consumers. If the government succeeds in imposing a five-fold rise, the retail price would only increase by 11%, which is well within the range of normal market fluctuations. Manipulation of tax levels is therefore of very limited utility in modifying consumer behaviour or affecting the the operation of the woodfuel system in the rural areas.

8.23 Small Scale Farm Production of Woodfuel for the Urban Market

The potential of small scale farm production of wood for the urban woodfuel market in Mali has scarcely been examined. But it appears as if it could supply a substantial proportion of future woodfuel demand if it were to become widespread.

Over much of the region around Bamako, tree growing is not the difficult operation it is in the Sahelian zone of the country. Provided the appropriate species are chosen, seedlings can survive without watering. Moreover, there are areas of market gardening and cash crop production close to the city where cultivation is carried out in demarcated fields protected by hedges and fences. The cost and difficulty involved in growing additional trees along these boundaries, around people's dwellings, or in small groves of 50-100 trees are not particularly great.

Such trees, if they are deliberately grown for the urban market would tend to be primarily for poles, since these normally fetch a better market price than firewood. But they can also be trimmed or pollarded for woodfuel. There are no data on what might be the sustainable yield of woodfuel obtainable in such a way from a tree. One suggested figure is 20 kgs per year per tree as a reasonable yield from pruning (Weber, 1986).

Taking this is a starting figure, the remarkable potential of this kind of tree growing - at least in theory - can be illustrated by taking an extreme example. At an average population density of 15 person per sq km, the total number of people within a 200 km radius of Bamako is 1.9 million, say 270 000 families. If each family planted just 4 trees every year, so that they had a total of 80 trees each by the year 2006, pruning these on an annual basis would be sufficient to supply the whole projected woodfuel demand of Bamako at that time.

It is not suggested that this will actually happen, though it is not entirely fantastic. Already, a certain amount of woodfuel is being supplied to the Bamako market by some farmers who trim the trees on their land and bring the wood in with their market produce to sell in the city. Since the labour and land input required to grow trees in this way is negligible, the wood is competitive with that supplied by the professional woodfuel dealers. It is easy to envisage the practice becoming more popular.

Programmes to encourage small scale tree growing in the peri-urban area are far more likely to succeed if they focus primarily on pole production rather than woodfuel (Foley and Barnard, 1984). Nevertheless, it appears they could also make a reasonable contribution to meeting the city's future woodfuel needs. They deserve to be examined closely.

8.3 Immediate Next Steps: A Minimum Agenda

The existing agenda for study and analysis in the Sahel is already long. It is easy to lengthen it indefinitely. But there is little point in adding a large number of additional items when resources are already spread so thinly. The number of immediate next steps recommended here is therefore cut to the following:

1. Carry out a series of surveys of rural energy consumption patterns but on a wider and more comprehensive basis than has been done up to now.

   These need to go beyond simply measuring the quantities of wood used by families. They should take into account the fuel alternatives which are available to people if wood becomes more difficult to obtain. Their aim must be to obtain an understanding of how rural families go about providing their domestic fuel requirements under changing circumstances.

   It is only on the basis of such information that a judgement can be made on where there are real domestic fuel problems and what can be done about it. The present level of knowledge does not provide an adequate basis for analysis or policy making.

2. Carry out a series of surveys of urban domestic energy consumption patterns.

   These surveys should examine the full range of domestic fuels used They should take account of the differences between households according to income groups. The relationship between fuel use and dietary patterns also needs to be probed. The present assumption that woodfuel use increases in line with population growth is obviously inadequate. The aim of these surveys should be to provide a broad understanding of how urban energy use patterns are likely to change with time.

The achievements of woodfuel programmes in the Sahel over the past decade have not been great. The analysis presented here suggests that one of the basic reasons is that the available data have been misinterpreted. If woodfuel policy is to make a significant contribution inthe future, it needs to be based on a much firmer basis than has been the case up to now. The above steps are an essential part of this process.

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