ENERGY WING

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PAKISTAN HOUSEHOLD ENERGY STRATEGY STUDY (HESS)

FOREST ENERGY IN PAKISTAN:

THE EVIDENCE FOR SUSTAINABILITY

RICHARD H. HOSIER

BIOMASS USER'S NETWORK

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EXECUTIVE SUMMARY

This report addresses the sustainability of Pakistan's wood-energy system. Despite the fact the Pakistan's households are currently consuming approximately 10 million tonnes more woodfuel than can be sustainably produced, woodfuel can continue to supply the largest share of the nation's energy for the foreseeable future. However, some efforts are required to ensure that the transition from reliance upon old-growth trees to trees planted and managed deliberately for timber and fuelwood production will be completed.

The evidence indicating where fuelwood is most scarce is complicated by the many different possible definitions of fuelwood scarcity: absolute physical scarcity, relative physical scarcity, and and economic scarcity. Throughout most of Pakistan, woodfuel is only scarce at the level of relative physical scarcity. Because of these definitional problems and the many possible conflicting indicators of woodfuel scarcity, it is impossible to say definitively where it is most scarce at present. Different regions are at different stages in the transition to woodfuel sustainability. Woodfuel prices have not demonstrated depletion effects, indicating that it is not increasing in scarcity terms. In general, woodfuel markets in Pakistan have worked efficiently to ensure that those wanting to utilize woodfuel are supplied with it.

However, households have responded to gradually increasing woodfuel scarcity by making increasing use of lower quality biomass fuels, such as twigs, straw, crop residues, and dung. Although this helps avert the local crisis of availability, it eventually leads to a gradual deterioration in environmental quality, as soil nutrients are not replaced. In general, however, this reliance on woodfuel leads to little deterioration in environmental quality.

Scenarios of future wood supplies reveal five lessons about the woodfuel supply system. First, for woodfuel supplies to continue as the most important energy supplies in the country, there must be a transition from existing trees to trees planted for timber and fuel. Fuel supplies cannot continue to come from old-growth forest supplies. Second, as a result, it is important that tree planting on farms continues at a high and increasing level. The maintenance of a sustainable woodfuel system demands that a high throughput system be maintained. Third, the management of trees on agricultural land must be improved. Both the survival rate of planted trees and the production from existing trees should be increased. Fourth, although the gains to be expected from improved efficiency can be easily overestimated, they cannot be ignored. Pakistan needs to begin improving the efficiency of wood use. Finally, unbridled population growth without increases in income to provide for interfuel substitution can lead to the eventual destruction of the fuelwood supply system.

From a policy perspective, the Energy Wing should support efforts at afforestation. Such approaches cannot be dictated from above, but can only be supported and encouraged, for the farmers themselves are the only ones who can plant trees. They will plant trees to supply the lucrative timber market. This should be encouraged, as increasing timber supplies and fuelwood supplies are not inconsistent goals. Next, the Energy Wing can begin to focus on efforts to increase the efficiency of fuelwood use. In this pursuit, serious attention must be paid to draw from the considerable experience which has already been accumulated in the field of fuel-efficient stoves in other countries. Thirdly, the Energy Wing should ensure that households that have the resources to utilize modern fuels should have access to them. This will mean relying upon the market to increase supplies and prices when necessary, and undertaking grid and network extensions when it is cost-beneficial to do so. Finally, effort needs to be devoted to monitoring the household energy situation with respect to fuelwood use, alternative fuel use, tree planting, fuel prices, and other related topics. The HESS energy data base provides an excellent foundation for this, and some cost-effective techniques for monitoring changes and trends in the field should be investigated further.

CHAPTER I

Introduction

Economic development entails a process of energy intensification. As new industries emerge and transportation needs grow, a nation's demand for fossil fuels and electricity will increase dramatically. Energy planners often struggle to ensure that supplies of modern fuels keep pace with the rapid increase in demand necessary to fuel the development transition. In their haste to attend to the energy needs of economic growth, energy planners have paid little attention to what remains the single largest energy consuming sector in the economy: the household sector. Until recently, little was known about the dynamic energy-use patterns of the household sector, largely because little attention was paid to them. As more attention has been given to energy use in the household sector, energy planners have become aware that it is in this sector that energy plays its most critical role as a pillar for subsistence, contributing directly to improving standards of living. Clearly, the energy needs of households cannot be ignored.

The realization of the importance of the household energy sector led the Energy Wing of the Government of Pakistan to initiate the Household Energy Strategy Study (HESS). With the support of the United Nations Development Program (UNDP), the HESS project set out to estimate, analyze, and understand the role of the household energy sector in Pakistan. The project will serve to lay the foundation for more substantial and focused future work in the household energy field. Using a unified sampling frame for both demand and supply-side assessments, the HESS project has assembled a heretofore unrivalled data base focusing on the supply and demand for household energy. While this information improves our understanding of the household energy sector, it also raises some difficult questions. This report is intended to address some of these questions.

According to demand estimates developed as part of the HESS project, Pakistan's household sector consumed about 20.75 million tons of oil equivalent (mtoe) in 1991, or about 57% of total national energy use (Ouerghi, 1993). Thus, the household sector is the single largest energy-using sector of the economy. Within the household sector, biomass fuels comprise the largest share of total energy consumption, accounting for nearly 89% of household energy use (17.85 mtoe) or 49% of total national consumption. In total, traditional fuel use accounts for 55.3% of total national energy consumption for 1991 (20 mtoe), of which, 53% of the total is made up of fuelwood. Thus, household energy consumption in Pakistan is an extremely important component of the national energy balance, and as of 1991, this energy is largely supplied through firewood.

In addition to these demand estimates, the HESS project has also undertaken an extremely thorough national-level assessment of biomass fuel supplies. The supply assessment estimates that the current level of standing wood-stocks by itself is insufficient to provide adquate fuelwood supplies on a sustainable basis. That is to say, the sustainable offtake from existing wood supplies is less than estimated current consumption of firewood and timber. In this assessment, the results of the HESS program resemble those of many past and present analyses of Pakistan's forest resource base. Most recently, the conclusion reached by the assessment embodied in the Forestry Sector Master Plan (FSMP) is that "Consumption is approximately twice the sustainable growth. As things stand, the entire forest resource could be wiped out in the next 20-25 years" (Forestry Department, Brief for Donor's Conference, p. 7). The widely-held opinion expressed in the FSMP documents and similar environmental reports is that Pakistan's forest resources are *en route* to oblivion due to excessive cutting for fuelwood, forest products, and agricultural intensification.

However, such dire conclusions are not supported by the findings of the HESS project for two sets of reasons. The first lies in the fallacious reasoning inherent in the wood-gap theory used to paint the gloomy picture of future forest resources. Not only has this reasoning been demonstrated to be false and misleading in other contexts, but also it constitutes another embodiment of Malthusian scarcity which have been demonstrated to be logically incorrect for nearly 200 years. The second reason revolves around the finding that rural Pakistanis are already engaging actively in planting trees. In 1991, the HESS survey estimates that over 120 million trees were planted on farmland in rural Pakistan (Leach, 1993). This is a substantial effort brought about, no doubt, by farmers' perception of market conditions, opportunities, and felt needs. These afforestation efforts can be strengthened and improved upon, but they represent an important feedback response. Clearly, they hold the long-term solution to the question of Pakistan's wood energy availability.

This paper addresses the sustainability of Pakistan's wood-energy system based upon the findings of the HESS project. It begins not from a concern for the national forest resource base *per se*, but rather from the perspective of national household energy policy. From this perspective, the question becomes not so much whether or not national forest resources are being depleted, but rather what are the best policies to ensure that the nation's energy needs for both subsistence and development are met. Therefore, the sustainability or non-sustainability of wood-energy resources has important ramifications for economic development, environmental management, and social equity. If the situation of other wood-scarce countries can serve as a guide, wood depletion will have profound negative economic implications; it will accelerate land degradation; and its burden will fall disproportionately on the poor. All of these important concerns for national energy planners will be addressed in the following pages.

This paper contains five chapters. This introduction represents the first. Chapter II presents the HESS-estimated wood balance for 1991. This balance is contrasted with estimates obtained from other sources before the shortcomings of the "wood-gap" are discussed. Then, a discussion of forest trends in Pakistan demonstrates that a wood gap may have existed for a long time in Pakistan, even though forest resources have not been depleted according to past forecasts. This also raises questions about the utility of a wood-gap approach to fuelwood planning.

Chapter III focuses on different facets of wood availability in an attempt to get behind the wood balance. It first examines spatial availability of wood resources. The discussion addresses the drain placed on rural resources by urban demand as well as the market forces and trends in the prices of woodfuel. The section then assesses the feedback responses induced by supposed woodfuel scarcity. Although interfuel substitution to poorer quality fuels appears to take place partially as a response to wood scarcity, shifts to more sophisticated energy carriers still appear to result primarily from increased incomes. The primary response of the population to the woodfuel supply situation is the planting of trees by small-scale farmers. These trends all have broader ramifications with respect to social equity, environmental management, and economic development.

Chapter IV utilizes scenarios of future energy development to shed light on the question of future fuelwood sustainability. In particular, it develops four scenarios which demonstrate the degree to which tree planting, wood conservation and the promotion of wood-using industries can be used make wood resources sustainable over the medium term.

The final chapter, Chapter V, summarizes the conclusions of the preceding section, addressing the question about the role of energy policy in managing future fuelwood availability. The evidence from the HESS project would indicate that far from being in a crisis of woodfuel scarcity, Pakistan appears to be turning the corner into long-term fuelwood sustainability through the continued efforts at tree planting on farmland. The role of the Energy Wing should be to monitor and evaluate these activities, supplementing efforts where necessary. It should also support the efforts of the Forestry Department. The Energy Wing should focus its efforts not on duplicating the work of the Forestry Department, but rather on ensuring that the efficiency of traditional fuel use is improved. An accelerated program of interfuel substitution is not called for on the basis of the present and likely future woodfuel supply situation. However, the Energy Wing should work to ensure that modern fuels pose viable alternatives to traditional fuels throughout Pakistan for those households willing and able to pay for them. Thus, the household energy transition can take place in a natural process driven by rising incomes which lead to increased demand for higher quality energy carriers.

CHAPTER II

Current Wood Resource Adequacy: The Limitations of Information and Knowledge

One of the purposes of this paper is to assess whether or not the current woodfuel consumption and supply situation is sustainable. In order to do this, a materials-balance approach is adopted to verify the sustainability of the current situation. By referring to "sustainability", we are questioning whether current woodfuel supplies are adequate to support present and likely future consumption. If current annual woodfuel production at least equals current annual production, the forest resource situation can be considered sustainable at present, but future growth in consumption (or reduction in supply) may render the situation unsustainable. However, if annual consumption exceeds estimated annual production, then a fuelwood deficit situation can be said to exist at present, and the current situation is not sustainable. In such a case, the future is anticipated to deteriorate to an even less sustainable situation.

The difficulty in what appears to be a straightforward analysis lies in the complexity and level of detail of the data being utilized. While it is a relatively simple task to estimate the sustainability of forest resources on a small plot of land, enormous uncertainties enter in when the same exercise is undertaken at the national level. In assessing present wood resource adequacy at the national level, estimates of national supply and demand derived from random samples are used. While statistically valid methodologies were deployed by the HESS project team, the size of the country still allows for considerable error due to spatial variation. For example, even though the estimate of national biomass supply is considered to be accurate with a ±10% standard error (Archer, 1993, p. 49), it is still possible that the estimates are non-representative at any given point on the earth's surface. Large regional variations can be masked by undertaking the analysis at the national level, and yet the alternative--undertaking a more intensive, spatially restricted study-- will not satisfy the political needs of the analysis for making national policy.

When these national-level data are used to assess future sustainability, the uncertainties are compounded. As a result, any assessment of wood resource availability is fraught with pitfalls and potential errors. For this reason, the following analysis focuses primarily on the estimates of wood supply and demand for the base-year of 1991. The reasoning is that it is impossible to comprehend the future without first understanding the present. For the analysis of both the present and the projected future situation, a great deal of effort is required to understand exactly what the numbers mean. In fact, it is extremely important to understand the reality behind the numbers, for the numbers are but abstract representations of a very complex reality.

A. Estimated Supply-Demand Balance: 1991

The estimated 1991 wood balance for Pakistan is presented in Table 1. The table is broken into agroecological zones, using the zonation developed as part of the supply assessment for the HESS project (Archer, 1993). The wood stock and production figures are categorized by the quality of the wood: timber being the highest quality wood, followed by roundwood, then twigs, and finally shrubs. Total wood stocks were estimated at 210 million tons of woody biomass and total annual yields were estimated at 22 million tons. Wood consumption is broken down by fuelwood use by rural and urban households, and wood used as feedstock and fuel by industries. The total wood consumption for 1991 is estimated at 32 million tons. This gives an estimated national wood deficit of 9.7 million tons. For 1991, Pakistan is estimated to consume about 10 million tons more woody biomass than is sustainable. If these numbers are accepted as being accurate and no changes in the wood consumption and supply situation were to occur in the immediate future, all of Pakistan's wood resources might be anticipated to disappear in the next 20 years. As is explained below, this is **not** the conclusion reached by the HESS project team.

Wood deficits are new neither to Pakistan nor to energy planners in developing countries more generally. As early as 1959, FAO produced a report which, on the basis of extremely suspect consumption figures, estimated that for 1947, the national fuelwood balance was in deficit to the amount of 3.92 million m^3 or about 2.74 million m^3 (FAO, 1959). In 1978, a World Bank mission estimated woodfuel consumption to be approximately $0.2m^3$ per person per year. This figure was accepted as the true figure for many years, not on the strength of the methodology with which it was estimated, but rather on the basis of the reputation of the World Bank. In 1984, the Canadian International Development Authority (CIDA) produced a report which utilized the World Bank consumption figure to estimate that the annual wood deficit was on the order of 13.4 million m^3 or about 9.4 million tons per annum. Whatever the estimation techniques used, past analysts have seemed to arrive at the same conclusion: wood supplies are inadequate to meet estimated consumption. In virtually all cases, forest resources were considered to be under threat of absolute destruction.[1]

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[1] For a discussion of different past consumption and supply estimates, see Crabtree and Khan, 1991.

Table 1 Pakistan Wood Balance, 1991

Measure	Irr high North	Irr high South	Irr low North	Irr low South	Barani	Forest/ Highland	Semi-Arid	Desert	Total Pakistan
Standing Wood Stocks (000 tons)									
Timber	23,054	2,921	10,005	2,320	307	30,152	4,315	252	73,326
Roundwood	23,146	5,961	11,567	3,123	2,816	40,159	5,584	4,037	96,393
Twigs	12,951	1,947	4,079	580	1,282	8,188	1,015	1,262	31,304
Shrubs	92	199	1,115	2,632	84	2,989	254	2,271	9,635
Total Stocks	59,242	11,028	26,766	8,654	4,488	81,489	11,169	7,823	210,658
Annual Productivity									
Timber	2,204	159	924	223	21	1,300	254	44	5,129
Roundwood	2,480	378	1,482	293	167	1,949	508	252	7,509
Twigs	2,440	179	637	89	195	650	20	7	4,217
Shrubs	92	179	924	2,052	28	1,300	254	1,009	5,837
Total Growth	7,216	894	3,967	2,657	412	5,199	1,035	1,313	22,693
Wood Consumption									
Urban Fuelwood	2,419	404	417	271	67	107	865	230	4,778
Rural Fuelwood	10,487	1,771	1,495	2,849	1,905	2,150	3,106	842	24,607
Industrial T&FW	821	345	821	345	220	304	72	72	3,000
Total Wood	13,727	2,520	2,733	3,465	2,192	2,561	4,043	1,144	32,385
Wood Balance									
Annual Prod	7,216	894	3,967	2,657	412	5,199	1,035	1,313	22,693
Annual Cons.	13,727	2,520	2,733	3,465	2,192	2,561	4,043	1,144	32,385
Net Balance	(6,511)	(1,626)	1,234	(808)	(1,780)	2,638	(3,008)	169	(9,692)

source: Wood supply and fuelwood consumption figures taken from HESS estimates.
Industrial timber figures taken from data adapted back to 1991 from Forestry Department, Table 3.5. p. 3-15. Timber demands are taken as 1/2 of the FSMP figure as it is estimated that the other 50% eventually winds up back in the fuel stream for final consumption. The industrial firewood consumption is the difference between the HESS-estimated total woodfuel sales of 3 million tons and the estimated purchases by the household sector of 1.1 million tons, leaving 1.9 million tons.

The most recent attempt to examine wood-resource sustainability for Pakistan using a wood balance is found in the documents produced as part of the Forest Sector Master Plan for Pakistan (Forestry Department, FSMPP, 1992). These estimates are clearly an improvement over their predecessors. Consumption estimates are based on an assessment of wood used in industry and the preliminary results from the HESS project. Supply estimates are based on forest inventories, and assessments undertaken of the production of trees on farms. The total annual consumption is estimated at 29.5 million m^3 (20.7 million tons) per year and annual production is estimated at 14.4 million m^3 (10.1 million tons). This leaves an annual deficit of approximately 15.2 million m^3 (10.6 million tons) per year. On the basis of this figure, the conclusion is reached that all forests in Pakistan are liable to be destroyed within the next 25 years.

Using a similar approach relying upon wood energy balances, wood consumption has been shown to exceed sustainable wood production for a large number of developing countries. For many of these, this deficit has been projected into the future to demonstrate that wood resources are at risk of being destroyed within the foreseeable future. This approach, relying on a wood deficit or wood "gap", has been used for all of the following countries: Sri Lanka (Meier and Munasinghe, year); Ethiopia (O'Keefe, *et al.*, 1981); Kenya (O'Keefe, *et al.*, 1984); Tanzania (Nkonoki and Sorenson, 1984); Zimbabwe (Hosier et al; 1985); and a number of other African countries (Anderson, 1986). However, dissatisfaction with the results of these planning exercises and an awareness of the shortcomings of the techniques deployed have led to a critique of the "gap" approach to woodfuel planning. Energy planners have begun to move away from the use of the gap approach to energy and fuelwood planning for many reasons, some of which are explained below.

B. Wood Balance, Projected "Gaps", and Fuelwood Availability

The use of wood balances gained in popularity as attention was drawn to the household energy problems throughout the 1970's and 1980's. If a base-year fuelwood account was estimated to be in deficit, the projection of this deficit or "gap" into the future led to the annihilation of all forest energy supplies within the foreseeable future. Such gloomy scenarios are useful as political tools to draw attention to the need for action. In fact, the "gap" approach to planning is most commonly used in the electricity sector to decide when new electrical capacity must be brought on-line in order to allow load growth to continue undisturbed.[2] In the wood-energy sector, the idea has been the same. If projected fuelwood consumption exceeds supply, action must be taken to prevent the "gap" between estimated production and consumption from destroying natural forest resources. On a *prima facie* level, the case for action is very clear and powerfuel.

However strong its force as a political argument may be, "gap" analysis can be extremely misleading, except in its most qualified form. The projection of a geometrically increasing consumption

[2] While it may be possible to think of a "gap" approach to electricity planning as being fairly harmless, the truth is that it has been as inaccurate and potentially harmful in the electricity sector as it has been in the fuelwood sector. Most of the over-building of electric generating plants which has taken place in the world has been based on a "gap" analysis. Thus, a "gap" analysis is at least partially responsible for the overcommittment made by electric utilities in the US to nuclear power, which has been an extremely costly error. The same criticism of the gap analysis presented in the text against its use for fuelwood could equally as well be applied to the application of gap analysis in the electricity sector.

requirement against an arithmetically increasing supply is a technique which dates back two centuries to the classical political economist, Malthus. Malthus reasoned that if population increases geometrically while food supplies increase arithmetically, natural brakes on population are necessary to keep the two in line. Wars, famines, disease, and vice are the four inevitable brakes serving to keep human population in check.

Not long after his ideas were first published, Malthus' gloomy scenario for humanity was demonstrated to be wrong. In the second edition of his treatise, he attempted to correct the idea that society was doomed because food supplies will only increase arithmetically. In fact, productivity increases brought on through technological innovation have been shown to keep the population-resource problem in check. In response to food shortages and scientific advancement, techniques were found to make food production increase more rapidly. Although periodic problems do arise, starvation, wars, and epidemics do not epitomize food production systems around the world. Nevertheless, the idea of population outrunning resources has come to be associated with Malthus' name, even though he acknowledged the errors in the reasoning at an early stage.

If in the description of the Malthusian dilemma, the word "wood" is substituted for the word "food", then woodfuel "gap" analysis can be clearly seen to be a form of Malthusian doom-saying. Wood consumption increases are driven by population growth and therefore rise at an exponential pace. Wood supplies, however, increase at an arithmetic rate, leading to the inevitable shortage or depletion of woodfuel resources. The fault in this analysis, as the fault with all Malthusian thinking, is that it ignores the role of scarcity as a feedback mechanism which can elicit technological innovation in the areas of fuel conservation, interfuel substitution, and supply enhancement.[3] The doom and gloom scenario will come true if and only if a carefully-defined set of assumptions are not violated. These assumptions normally amount to a statement to the effect that if consumption patterns do not change and if there is no feedback inherent in the system to change the relationships identified in the base-year of the scenario. In other words, the scenario assumes that if all relationships defined in the base-year are accurate and all other factors are held equal, then the projections embodied in the scenario will come true. That is, if nothing else changes and there is no natural regeneration or recovery following harvesting, wood resources will be exhausted. The critical role of these strong assumptions is frequently glossed over or completely ignored in the gap analysis.

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[3] Although the thrust of the argument is slightly different, this point was made earlier in the case of Pakistan by McKetta (1990).

Part of the confusion no doubt arises from the sloppy use or even confusion of the terms "consumption" and "demand". Energy planners frequently begin their analysis with an assessment of past and present consumption, which is simply the quantity of a specific energy form which is being utilized at the time of a survey. Frequently, they refer to it as "demand", which is not correct. The term "demand" refers to a schedule of quantities of a given commodity that would be consumed at given prices. For consumption to be specified, the prices or (in the case of non-marketed fuelwood) availability conditions must be carefully specified. Projecting all factors influencing demand is an extremely complex task, so planners have normally invoked *ceteris parebis* assumptions in order to project consumption. The result is a gloomy, often misleading, picture of woodfuel availability. However, in reality, all other conditions relevant to wood supply are constantly changing, so the scenarios rarely come to pass.

The misleading nature of these gloomy "gap" projections is highlighted by Leach and Mearns (1988) for the case of Tanzania. The evidence presented in one article (Nkonoki and Sorenson, 1984) estimated that wood resources should have been completely exhausted by 1990. Leach and Mearns point out that this has simply not happened. In fact, recent field research from Tanzania would have it that national forest resources are in very good shape, given the heavy pressure they are under (Hosier, 1993). No rural afforestation campaign can take credit for the survival of national forest resources. Rather, woodfuel resources regenerate well following harvesting, and have provided large quantities of woodfuel on a sustainable basis. The massive forest destruction predicted in the gloomy scenarios has simply not come to pass.

Although no projections seem to come true as predicted, the absolute failure of wood "gaps" to materialize has called the credibility of such planning efforts into question. The reaction of many in the donor community has been to dismiss all claims for a "crisis" in the woodfuel sector as being unreasonable and unworthy of further attention. Donors have lost interest in any talk of efforts to increase wood energy supplies as previously forecast crises have failed to materialize. The attempt to create a political crisis of woodfuel availability has backfired, with the net result that the credibility of woodfuel energy planners has been called into question.

Does this mean that energy planners are wrong to project scenarios on the basis of estimated wood balances? No, it does not. The fault of energy planners has not been that they have utilized wood balances, deficits, and gaps to make their point. The problem is that their analysis did not go far enough. It ended with the deficit or "gap" projections, instead of beginning with it. They should use it as a starting point to understand the dynamics of woodfuel supply and demand (Hosier et al, 1990), instead of simply claiming the unquestionable need for more trees.

Simply because alarmist woodfuel planners make poor projections and carry out simplistic analyses does not mean that the woodfuel sector can be ignored. Problems of woodfuel supply and consumption are too complex to be reduced to a single number, be it surplus or deficit. No matter how sophisticated the sampling techniques used, national level figures representing woodfuel availability are crude tools. National level estimates can mask tremendous variation in local availability. Woodfuel supplies can demonstrate tremendous spatial variation over a very small area. Scarcity can exist in the midst of plenty, and can be lost in the plentitude. Scenario projections are an imperfect attempt to elucidate local availability problems by substituting time for space in the projection process. In a similar manner, national estimates mask the supply problems which can be specific to certain groups, such as the landless or the poor. A national woodfuel balance is like a snapshot undertaken at one point in time. By itself, there is no way of deciphering the direction of the trend in consumption or production. Considerable effort is necessary to understand even the conditions which define the current situation. In short, a wood energy balance is a limited tool. It should not be abandoned because of its limitations, but it should be viewed as a tool to increase our understanding of the problem, not as an end in itself.

If energy planners are going to do an adequate job of understanding the wood energy question, they need to spend considerable effort looking behind the woodfuel balances at spatial and social variation in woodfuel availability. They also need to spend time studying the conditions which define the current woodfuel availability situation. The idea is not to say simply that more woodfuel is necessary. The idea is to pinpoint problems necessitating outside involvement as opposed to cases where the natural response to environmental stress is handling the shortage unaided. Only by making these distinctions can any meaningful planning and management of wood resources procede.

The following discussion analyzes data obtained from the HESS project and elsewhere to try to understand more thoroughly the coordinates of woodfuel supply and demand in Pakistan. After a brief discussion of forest area and wood energy, attention turns to an assessment of the spatial variation in availability, to evaluating the feedback responses undertaken by wood users, and to examining the broader implications of current wood-use patterns. Only then, after a more complete evaluation of base-year conditions, are a set of future scenarios developed and presented.

C. Forest Resources and Fuelwood Use

The preceding discussion of the weaknesses of the wood "gap" approach to forest energy planning should not be taken to indicate that there is no problem of forest management in Pakistan. The fact remains that Pakistan's forest resources face a severe threat. Serious efforts are required to prevent the few remaining patches of Pakistan's indigenous forest mosaic from being obliterated. However, these forest resources are threatened not by the demand for firewood which is fairly well confined to wood production on farmland, but rather from forest encroachment and degradation. In perception and in reality, fuelwood use must be de-coupled from forests and the environmental threat of deforestation. Pakistan is fairly far along the progression from fuelwood being produced from forests and indigenous trees to the stage where it is drawn from treees planted on private farmland in the same manner as agricultural crops. During the completion of the transition, it is essential that natural forests are protected and preserved to save them for future generations.

The term "deforestation" has become an emotionally-charged international environmental issue, and its linking to fuelwood use is unfortunate and unwarranted. Unfortunately, its definition has never been precise. For example, Allen and Barnes(1985) point out that the FAO evaluations of global deforestation have used different definitions of deforestation than other documents attempting to evaluate its magnitude and impact. While some definitions talk about the conversion of moist, tropical forests to any other form of land use, others speak more generally about the loss of forest cover in general, or the conversion of closed forests to open forests. These vagaries, together with the emotionally-laden nature of the term, have led one author to suggest that the term "deforestation" no longer be used by itself, unless it is qualified by the type of land conversion taking place (Hamilton, 1989). For the following discussion, the word "deforestation" will be avoided, leaving the focus on fuelwood, production, harvesting, and use, and forest conversion.

Table 2 presents estimates of Pakistan's forest cover for the century from 1880 and until 1980. The table combines both open and closed forest area to give an estimate of total forest area cover. These estimates are taken from official government records, and therefore are not comparable to canopy cover estimates undertaken by way of remote sensing. Two things are readily apparent from the table. First, even one hundred years ago, Pakistan was not heavily forested. At the time of the first estimate in the table, only 16% of the country's land area was estimated to be under forest cover. This is a low percentage given that the present-day average for Asian countries is 21%; for African countries, it is 23%; and for North and South America, it is 32% and 53%, respectively. On the basis of this, it would be unreasonable to expect Pakistan to have a large share of its land surface under forest cover.

TABLE 2 PAKISTAN FOREST COVER

Year	Closed Forest (km^2)	Open Forest (km^2)	Total Forest (km^2)	% Forest Cover	Estimated Pop'n ('000)	Arable Land (km^2)	Human Settlements (km^2)
1880	43,970	97,560	141,530	16.1%	21,126	104,390	6,000
1890	42,430	94,450	136,880	15.6%	22,724	98,420	3,560
1900	40,790	91,900	132,690	15.1%	18,755	104,670	4,040
1910	39,050	86,270	125,320	14.3%	20,119	140,400	4,410
1920	37,590	82,330	119,920	13.6%	20,720	141,650	4,810
1930	35,520	78,770	114,290	13.0%	24,097	152,050	5,690
1940	33,410	74,990	108,400	12.3%	29,256	134,120	6,760
1950	30,110	69,060	99,170	11.3%	35,028	162,560	8,020
1960	26,610	63,900	90,510	10.3%	43,795	176,830	9,870
1970	25,090	53,670	78,760	9.0%	66,211	199,950	13,780
1980	23,610	43,700	67,310	7.7%	86,647	196,620	16,280

Source: WRI and IIED, 1985, p. 268.

The second factor which is readily apparent from the forest area data in the table is that the past century has not been kind to forest resources in Pakistan. From a forest-cover base of nearly 16% of the surface area of the country in 1880, the total forest area has dwindled to half this size (7.67% forest cover) by 1980. The estimates derived for 1990 as part of the Forest Sector Master Plan (FSMP) place the fraction of Pakistan's surface area covered by forest at 4.8%.[4] According to these figures, forests have decreased to less than 1/2 of their former areal extent over the past one hundred years. Approximately 80,000 km^2 of forest area was converted to other land uses in the century from 1880 to 1980. By anyone's standards, this trend must be considered disturbing. Perhaps not so surprising is the fact that the pace of forest loss has been accelerating. The largest fraction of forest loss has taken place in recent decades.

The obvious factor to link to the accelerating forest loss is population growth. The final three columns of Table 2 contain three different land-use category estimates which can be used to explain this loss in forest area. The first of these is population. From 1880 to 1980, the total population of Pakistan quadrupled in size. The population growth rate currently approximates 3.1%, giving Pakistan the most rapid population growth rate in Asia. From a forest resource endowment of 0.67 ha of forest per capita in 1880, the per capita forest ratio dropped to 0.08 ha/person by 1980.

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[4] It is not clear whether or not the FSMP estimates are at all comparable to the other estimates of forest cover presented in the table. The FSMP estimates, taken from Landsat imagery (Wightman, Holmgren, and Rana, 1992), are probably more accurate than the WRI/IIED estimates. The net effect of including the FSMP estimates along with the other estimates is that it undoubtedly exaggerates the scale of recent forest losses.

The last two columns in the table are land-use changes normally accompanying increases in population: cultivated land and land devoted to human settlements. Both of these factors increased over the time period included in the table. Cultivated land increased by nearly 90,000 km^2, and human settlements absorbed another 10,000 km^2. These two population-related land-use categories increased by more than the decrease in forest area over the same time period. Shifts in land-use, from forests to agriculture and settlements can be thought of as accounting for the majority of the decrease in forest cover.

For the period since 1975, the data in Table 3 demonstrate that the quantity of cultivated land in Pakistan has increased only slightly. The net area sewn has remained relatively constant. Most of the recent increases in cropped area have come from increases in the quantity of land which is double-cropped. Thus, it is the intensity of cultivation and not the areal extent of cultivation which has accounted for the increase in cropped area. As a result, recent forest losses are probably not attributable to land conversion for agriculture. At the same time, the population has continued to increase, while forest area has decreased. Recent forest area losses will have to be tied to some other population-related factor.

Table 3 Agricultural Land Use in Pakistan

Year	Net Area Sewn		Double Cropped		Total Cropped Area	
	(M Ha)	% Total	(M Ha)	% Total	(M Ha)	% Total
1975/6	15.06	17.1%	2.96	3.4%	18.02	20.5%
1976/7	15.07	17.1%	3.14	3.6%	18.21	20.7%
1977/8	15.22	17.3%	3.27	3.7%	18.49	21.0%
1978/9	15.41	17.5%	3.89	4.4%	19.30	21.9%
1979/0	15.61	17.7%	3.61	4.1%	19.22	21.8%
1980/1	15.41	17.5%	3.92	4.5%	19.33	22.0%
1981/2	15.53	17.7%	4.25	4.8%	19.78	22.5%
1982/3	15.77	17.9%	4.36	5.0%	20.13	22.9%
1983/4	15.66	17.8%	4.33	4.9%	19.99	22.7%
1984/5	15.61	17.7%	4.31	4.9%	19.92	22.6%
1985/6	15.77	17.9%	4.51	5.1%	20.28	23.1%
1986/7	16.06	18.3%	4.84	5.5%	20.90	23.8%
1987/8	14.72	16.7%	4.80	5.5%	19.52	22.2%
1988/9	16.09	18.3%	5.73	6.5%	21.82	24.8%

source: Ministry of Food, Agriculture and Cooperatives, 1992, pp 110-114

While establishing a correlation between recent population growth and forest decline is a relatively straightforward matter, identifying the precise causal mechanisms of forest decline is not. However, identifying the mechanism responsible for forest destruction is necessary to give both a better understanding of the nature of forest resource management and an improved ability to design policies and programs which will help solve the identified problems.

The most frequently-cited link between population growth and excessive forest resource utilization is fuelwood use. As population grows, the need for subsistence fuelwood for cooking increases. The logical jump from increased fuelwood use to decreasing forest area is easy to make. However, it is not always true. Virtually all research on rural energy utilization in South Asia has begun with the fuelwood-deforestation link as a working hypothesis. Nearly all of it has ended up refuting the validity of that link. Field-based research from India (Reddy et al, 1989); Bangladesh (Briscoe, 1981); and Nepal (Bajracharya, 1985), all arrived at similar conclusions: rural fuelwood use rarely leads to deforestation.

Rural householders rarely have the strength nor the equipment necessary to harvest entire trees for firewood. They are more likely to harvest only branches and dead wood than the entire tree. If firewood becomes scarce, they may increase efforts to harvest mature trees, but they also will rely increasingly on dung and crop residues. As such, their efforts might lead to forest degradation if they live in the vicinity of accessible forests, but access to forest resources is obviously far from universal. With most land being privately-held, many rural households face limited choices as to where they can obtain fuel. Although exceptions to the rule do exist, their efforts to obtain subsistence fuelwood needs rarely result in wholesale forest destruction. Rather, the major cause of deforestation in these other South Asian case studies is the expansion of agriculture into previously unsettled areas. When new land is brought under cultivation, forest cover is cleared. After land privatization and initial clearance, the remaining forest cover, which is frequently on common land or in forest reserves, may be degraded gradually and eventually disappear.

The data gathered as part of the HESS consumption survey is generally consistent with these findings from elsewhere in South Asia. Table 4 provides estimates of the quality of wood used for fuelwood by households which collect or purchase their fuelwood in rural or urban areas. Most rural households collect their own firewood. About half of them claim to collect roundwood (large stems and branches) and about 86% collect small branches, twigs and shrubs. Although less than 30% collect only dead roundwood, about 40% claim to collect only dead twigs and shrubs. Urban fuelwood collectors demonstrate a greater tendency not to utilize roundwood and to avoid collecting green wood. Thus, fuelwood collectors will utilize a mix of roundwood and smaller wood, and seem to favor obtaining dead wood when it is available.

This evidence contrasts with that for households purchasing fuelwood. In both urban and rural areas, nearly 90% of households purchasing fuelwood preferred to purchase roundwood. More than 50%

of the households interviewed refused to purchase leaves, small twigs, shrubs, and other types of wood. Thus, the supplying of fuelwood to the market can be linked more directly to the harvesting of entire trees than supplying fuelwood for own consumption. In contrast, fuelwood collection for own use is more likely to rely upon gathering deadwood, harvesting shrubs, and lopping branches. The former can be more frequently linked to tree harvesting than the latter. Although this is not direct evidence of a deforestation-fuelwood link, it does demonstrate that trees are more likely to be cut down to supply the market than to provide rural households with collected firewood. Households collecting firewood are likely to use low-quality biomass from shrubs and twigs for firewood. Their efforts are unlikely to result in the harvesting of entire trees, let alone lead to deforestation. Once households begin purchasing fuel, they will insist on purchasing roundwood, not twigs and stems. Their demands are met through tree harvesting, not just lopping branches or harvesting shrubs. But is this harvesting of trees likely to lead to the destruction of indigenous or natural forest cover?

TABLE 4 QUALITY OF FIREWOOD USED

Rural Households	Stems & Branches (roundwood)	Leaves, Twigs & Bushes	Roots
Number of Rural H'holds Collecting Wood: 6,764,000			
% Collecting Specified Wood	51.1%	86.6%	7.1%
% Not Collecting Specified Wood	48.9%	13.4%	92.9%
% Collecting Dead Wood Only	27.5%	38.8%	32.3%
% Collecting Green Wood Only	36.5%	19.1%	31.7%
% Collecting Both	36.0%	42.1%	36.0%
Total	100.0%	100.0%	100.0%
Urban Households			
Number of Urban H'holds Collecting Wood: 374,000			
% Collecting Specified Wood	39.2%	65.0%	6.8%
% Not Collecting Specified Wood	60.8%	35.0%	93.2%
% Collecting Dead Wood Only	43.0%	42.4%	52.0%
% Collecting Green Wood Only	20.0%	18.4%	8.0%
% Collecting Both	37.0%	39.2%	40.0%
Total	100.0%	100.0%	100.0%

Rural Households	Roundwood	Leaves, Twigs & Bushes	Other
Number of Rural H'holds Purchasing Wood: 3,284,000			
% Purchasing Wood Type: 1st Choice	81.8%	22.3%	2.8%
% Purchasing Wood Type: 2nd Choice	8.9%	23.9%	8.4%
% Purchasing Wood Type: 3rd Choice	0.0%	0.2%	1.7%
% Not Purchasing Wood Type	9.3%	53.6%	87.1%
Total	100.0%	100.0%	100.0%
Urban Households			
Number of Urban H'holds Purchasing Wood: 2,220,000			
% Purchasing Wood Type: 1st Choice	90.8%	11.7%	7.5%
% Purchasing Wood Type: 2nd Choice	4.3%	18.8%	13.7%
% Purchasing Wood Type: 3rd Choice	0.0%	0.0%	1.2%
% Not Purchasing Wood Type	4.9%	69.5%	77.6%
Total	100.0%	100.0%	100.0%

source: HESS Demand Survey.

The data in Table 5 have been assembled to address this question. In all provinces except Baluchistan, the majority of trees are gathered from privately-owned land. Only in Baluchistan do the majority of wood collectors collect wood from state or forest land. In no province is common or village land a major source of firewood, largely because few common areas with trees still exist. The number of trees felled by province reflects the heavy population pressure in Punjab and Sindh. These two provinces alone account for nearly 68.9% of all of the trees harvested by households. Most of these trees are on privately-held land. In addition, these two provinces contain only 24% of the nation's forest cover. The nation's forests clearly cannot provide the bulk of the trees being harvested as they are not in the locations where the demand exists. Most of the forest area is in the NWFP area and the northern areas, which are relatively sparsely populated. The forest areas are simply not the source of most of the trees being harvested by households in Pakistan. This is not to say that in the past, the harvesting of fuelwood has not contributed to forest losses. Rather, it is to say that at the present moment and in the immediate future, most trees are being harvested and most firewood is being collected from trees outside the forests. Fuelwood use by rural households is not a major cause of forest degradation and loss.

TABLE 5 TREE HARVESTING, FIREWOOD PURCHASES AND FOREST AREA BY PROVINCE

Province	Place of Collection: Own/ Private Land %	State/ Forest Land %	Village/ Common Land %	# of Trees Felled 10^6	Purchased Firewood 10^6 t	Forest Cover Area 000 ha
Punjab	44.8%	26.4%	2.1%	5.42	6.65	608
Sindh	77.2%	13.4%	6.1%	2.04	2.06	399
NWFP	51.7%	18.8%	7.3%	1.63	1.37	1,684
Baluch.	18.2%	78.0%	2.6%	1.75	1.21	592
Other	NA	NA	NA	NA	NA	941
Total	54.1%	25.5%	4.1%	10.83	11.39	4,224

source: Number of trees felled is taken from the HESS data base as found in Leach (1993). The data on collection location and quantity of firewood purchased for consumption is taken from the HESS demand survey, unpublished data. The area of forest cover is taken from the Forestry Sector Master Plan, (1992), p. 2-5.

The information about the quantity of firewood purchased shows that like the number of trees harvested, the largest quantity of firewood purchased is found in Punjab and Sindh provinces. Again, these are not the provinces with the greatest quantity of land under forest cover. But as will be discussed later, the results of the survey of woodfuel market survey demonstrate that the majority of firewood sold in a given province comes from that same province (AFTAB, 1993). Only in the case of Baluchistan is firewood drawn from Punjab and occasionally Sindh. From the collection, purchasing, and forest data in this table, it appears that neither fuelwood collection for own consumption nor fuelwood harvesting for market pose major threats to the nation's few remaining forest areas.

It is not clear from this national-level data what the most serious sources of continuing pressure on Pakistan's forest areas are. Part of the pressure undoubtedly comes from continuing land clearance from agriculture, even if it is unrecorded, illegal, and undertaken in small doses. Some of the pressure probably comes from forest encroachment for grazing and expanded pasture lands. Part of the pressure probably also comes from illegal felling for timber sales. Some small portion of the pressure on forest resources undoubtedly does come from the increased demand for firewood. But it is unfair and simply untrue to claim that the continuing pressure to clear forest resources is largely attributable to fuelwood demand. Forest pressure comes from multiple sources. More focused studies are necessary to establish the primary source of forest loss for any period of Pakistan's history, including the present.

Although the source of forest pressure remains unclear, the fact that Pakistan's indigenous forest areas face severe management challenges is without question. The working papers from the FSMP program highlighted some of these challenges. The upland forests in general require more careful management and protection which involves the local people. The scrub-oak buffer zone which has naturally protected many of the upland forests has been seriously degraded and is in need of better management which involves the local population (Pleines, Grosenick, and Phillips, 1991). In the mangrove forest areas, only three of the naturally-occuring five species can still be found in Pakistan's coastal areas, and those which remain are threatened by the increasing salinity of the water (Beg, 1991). Riverine forests are also showing decreased areal extent and productivity due to both harvesting pressures and the reduced flooding brought about by increased use of the river for irrigation purposes (Ashraf, Chaudhry, and Grosenick, 1991). The conservation of these indigenous forest areas are environmentally important to the nation in order to provide a continuing source of raw materials for local people, to protect the habitat for wildlife, and to preserve the biological resources found in the country (Wilkinson and Khan, 1991).

Indigenous natural forests are under threat for a number of different reasons, and their protection is vital to the nation's conservation plans. Neither plantation forestry nor farm forests can replace the biological resources found in the indigenous forests, even though they can provide many of the same products. The nation's indigenous forests form a vital part of the nation's environmental heritage. The tasks facing Pakistan's forestry sector in the area of natural forest management are extremely large. Their massive magnitude is virtually independent of the question of fuelwood supply for domestic purposes. Indigenous forests in Pakistan will require greater management and protection even if the entire household sector shifts away from firewood use toward LPG and electricity.

CHAPTER II SUMMARY

General dissatisfaction with the "Gap" approach to wood energy planning has arisen throughout the energy planning community. "Gaps" have been shown to be be very misleading, and should be a starting point or tool in the analysis of woodfuel availability, not the conclusion or goal in the analysis.

Using the HESS data, the woodfuel "gap" for Pakistan has been estimated at 9 million tons per year. This gap is very close to that estimated by the FSMP. However, it is not reliable as a planning target as it represents a static picture of the present situation and ignores trends demonstrating significant interfuel substitution and tree planting on the part of wood-using households. The following sections will demonstrate that these activities can go a long way toward mitigating future supply problems, making the gap irrelevant.

Pakistan has lost approximately half of its forest cover over the past century. Most of this forest loss has been to provide land for cultivation. Major efforts to protect and conserve Pakistan's indigenous forest base are necessary to prevent the total destruction of the nation's indigenous forest resources.

Despite the fact that total cultivated land has not increased significantly in recent decades, Pakistan's forests remain under significant pressure. However, the form of fuelwood used by wood-collecting households, the location of wood supplies to markets, and the mismatch between demand centers and forest supplies would indicate that fuelwood demand exerts only a small fraction of this pressure on forest areas. Timber demand, agricultural clearance, and overgrazing are the more potent forces serving to keep pressure on Pakistan's forest resources.

Most fuelwood in Pakistan is and must continue to be drawn from trees planted expressly for timber and energy purposes on farmland. This process of shifting the source of fuelwood supply away from natural forests to on-farm, trees deliberately planted for marketing is part of the process of conversion to long-run fuelwood sustainability. As a result, natural forests require greater protection to preserve them for environmental reasons. On the other hand, tree-planting on farms must be monitored and supported to ensure that trees are planted in order to supply future timber, roundwood and fuelwood needs on a sustainable basis.

CHAPTER III

Facets of Fuelwood Availability: Behind the Balance

One of the arguments advanced in the last chapter was that reducing the complexity of a national wood resource supply system to a single number, a fuelwood balance or "gap", leads to poor planning in at least two ways. First, the "gap" estimate is a single number taken from a static snapshot of the woodfuel supply situation. As such, it ignores feedback responses inherent in the woodfuel supply system. As such, a "gap" virtually always overestimates the size of the woodfuel deficit. Second, when used as the goal of an analysis instead of a tool to achieve a better understanding of the woodfuel supply system, it actually obfuscates and confuses attempts to improve upon an understanding of the determinants of woodfuel supply and demand. The estimation of the "gap" should represent the beginning, not the ending, of the analysis of woodfuel availability.

This chapter attempts to look "behind" the woodfuel balance at different regional and socio-economic patterns of woodfuel availability. The base-year fuelwood balance was presented at the beginning of the previous chapter. This chapter begins by focusing upon different measure which can be used to assess the spatial variation in wood availability and scarcity. A great deal of time and effort is spent on this discussion because wood scarcity is the key to both other factors which attract energy planners to the fuelwood discussions: equity and the environment. After the extended discussion of fuelwood scarcity, the discussion turns to an assessment of energy-use by different socio-economic groups to try to pinpoint those groups for whose well-being woodfuel scarcity may prove detrimental. Then the discussion turns to an assessment of the environmental implications of continued woodfuel use at the local and global levels.

A. Spatial Variations in Availability

Another weakness of the wood energy balance or "gap" approach to woodfuel planning is that it assumes that all consumption takes place at one point on the earth's surface. The mental image that is brought to mind by this realization is one of having all of the woodfuel to be consumed in the country piled up at one place and burned in one giant bon-fire by all of the households in the nation. Even relaxing the analysis one step further to the regional level does little to improve upon this mental picture: the result is six bon-fires instead of one. Whereas in reality, we know that woodfuel use is virtually ubiquitous, spread out unevenly across the surface of the nation over the course of the entire year. As a result, localized supply shortages and surpluses can occur, and not be discovered by woodfuel balance calculations. If competent wood energy planning is to provide meaningful policy inputs, it must disaggregate woodfuel supply and demand spatially in order to distinguish between those places facing a localized shortage and those facing a surplus. This exercise must take place independent of or in addition to the regional or national woodfuel balancing exercise.

1) Regional Indicators: Searching for Scarcity

The availability of woodfuel at any particular location is the resultant of the intersection of a number a complex vectors of both a physical and social nature. On the physical side, moisture availability, temperature, altitude, ecosystem type, vegetation cover and human interference all result in an existing level of standing stocks with a concomittant growth rate. On the social side, population density, agricultural activities, settlement patterns, cultural practices, and natural resource management practices all interact to produce a social matrix of fuelwood availability. Fuelwood scarcity is a population-pressure issue: problems can arise from either the physical or the social side or the equation. This means that the process of sorting out regional patterns of fuelwood availability and scarcity is complex and requires the examination of a large set of factors. As a result, the resolution of the process is neither as neat nor as convenient as a woodfuel balance.

For example, using the data in Table 6, if all that were being considered were the absolute level of wood production per hectare, the Desert and Semi-arid zones would be considered to be the greatest areas of wood shortage. However, the population has distributed itself naturally in response to the physical productivity of the land, so that these unproductive areas carry the lowest population density. In terms of physical scarcity relative to population density, the Semi-arid and Desert zones do not appear to be bad at all due to the low population pressure. When large village or cities are formed in these areas, they may place severe pressure on their surrounding hinterlands for fuelwood supplies. From these data, it is unclear where fuelwood is considered the most scarce.

This discussion brings up several concepts which are useful in the discussion of fuelwood scarcity. In any discussion of fuelwood scarcity, there are important distinctions to be made between absolute physical scarcity, relative physical scarcity, and economic scarcity (DeWees, 1989). ***Absolute physical scarcity*** occurs, where little fuelwood is found due to low productivity. This situation is due to natural causes, such as low rainfall, and has nothing to do with human interference. ***Relative physical scarcity*** of fuelwood can be said to occur when local supplies are limited relative to the consumption pressure placed upon them.

This does take into account both physical productivity and population pressure. When fuelwood supplies are scarce in relative physical terms, scavenging for biomass fuels to supplement fuelwood supplies will occur. This is where environmental damage to the soil can also occur. From the social-economic perspective, ***economic scarcity*** can be said to exist when fuelwood becomes more scarce (and more expensive) than its closest substitutes. Absolute physical scarcity is an indicator of an unproductive environment. Relative scarcity is an indicator of potential environmental degradation occuring, and economic scarcity represents a stressful situation from a social perspective.

The evidence assembled by the HESS project would indicate that while some areas of Pakistan demonstrate absolute physical scarcity, the most common situation is one of moderate relative physical scarcity. Households have begun making increasing use of substitute fuels, particularly lower quality biomass substitutes, and planting trees to alleviate this felt scarcity as well as to earn money through timber sales. However, fuelwood in Pakistan is only at the beginning stages of economic scarcity. Its price has increased to the point where it is comparable with the price of kerosene per unit of energy delivered to the cooking pot. The price of fuelwood is higher per effective energy unit than the financial price of LPG or natural gas. However, large transactions costs, in the form of supply availability and access problems, keep these other modern fuels from posing viable substitutes for most of Pakistan's population. Firewood markets appear to even out availability in the supply of fuelwood. This is confirmed by the subjective assessments of the respondents to the household consumption survey. Over 90% of firewood users claimed to experience no problems due to a shortage of firewood supply. The realization that there are different types of fuelwood scarcity helps explain why trying to decipher evidence of fuelwood availability is so difficult and unrewarding. The sections below explore some of the factors which complicate interpretations of household responses to fuelwood scarcity.

Table 6 Regional Measures of Woodfuel Availability

Measure	Units	Irr Hi North	Irr Hi South	Irr low North	Irr low South	Barani	Forest/ Highland	Semi-Arid	Desert	Total Pakistan
Physical Measures										
Area	'000 ha	9,185	1,987	3,186	4,461	2,788	12,997	25,383	25,234	87,723
Wood Stocks	'000 tons	59,190	11,020	26,780	8,660	4,460	81,660	11,160	7,850	210,780
Wood Growth	'000 tons	7,080	910	3,980	2,660	420	5,220	940	1,480	22,690
Wood Balance	'000 tons	-6937	-1357	1597	-573	-1554	2,301	-3,175	407	-9291
Stock Density	t/ha	0.64	0.55	0.84	0.19	0.16	0.63	0.04	0.03	0.24
Growth Density	t/ha/yr	0.08	0.05	0.12	0.06	0.02	0.04	0.00	0.01	0.03
Population Pressure Measures										
Population	'000	51,932	6,787	11,365	9,060	7,141	5,940	20,784	2,693	115,702
Pop'n Density	person/ha	5.65	3.42	3.57	2.03	2.56	0.46	0.82	0.11	1.32
Balance/cap	t/person	-0.134	-0.200	0.141	-0.063	-0.218	0.387	-0.153	0.151	-0.080
Balance/ha	t/ha	-7.6E-4	-6.8E-4	5.0E-4	-1.3E-4	-5.6E-4	1.8E-4	-1.3E-4	2.0E-4	-1.1E-4
Balance/Rur H'hold	t/rur hh	-1.288	-2.010	1.857	-0.569	-1.734	4.030	-2.302	0.295	-0.628

Source: HESS Project Data-Base.

a) Reduced Consumption of Higher Quality Biomass Fuels

The most natural response to relative scarcity of fuelwood is to reduce consumption. Thus, if all households began with the same consumption needs, those households presently consuming the smallest quantity of firewood would be considered to be living in the region with the most severe relative scarcity of firewood. This interpretation is confounded by the frequency with which fuelwood is obtained outside the market and the relative complexity of the interfuel substitution process. As a result, inferring scarcity from consumption levels is quite a difficult and often unrewarding task.

As fuelwood becomes more scarce, collectors must expend a greater amount of effort to gather sufficient fuelwood to meet their household needs. Those producing fuelwood for the market can either raise their asking price for farmgate firewood, find alternative income-generating activities, or continue producing firewood at an auto-exploitative price (an imputed loss). For households collecting fuelwood for own consumption, the choice is either to spend more time collecting firewood, to use less energy in the cooking process or to begin utilizing alternative fuels. In any event, the shortage of their major cooking fuel has led to economizing behaviour. If they choose to utilize alternative fuels, the closest substitutes are liable to be other biomass fuels, such as crop residues and dung. These alternatives can be used in the same cooking appliance as is firewood, the preferred option. Modern fuels, such as kerosene, electricity, or LPG, cannot.

This fuel-supply situation can be represented by the marginal cost curves found in Figure 1. The horizontal axis represents the number of energy units of being produced by a household. The vertical axis represents the cost per unit of household energy. The various curves on the graph represent the cost of supplying household energy from the various sources at a household's disposition. If the household focuses only on the cost of supplying energy from firewood (MC_1 in the figure), then a very small increase in the effective price will lead to an equally large increase in the cost of supplying energy to the household. However, if the household looks beyond just roundwood at the entire spectrum of possible household fuels, it will see an array of marginal cost curves resembling those included in the graph. Thus, if the household is able to perceive of itself as being in the market for energy instead of the market for firewood, then these other options are available. A lower quality biomass fuel is normally a higher cost biomass fuel. Under normal circumstances, this higher cost is internalized, particularly by the woman who is collecting the fuel. That cost is normally expressed in the greater collection time necessary to obtain one energy unit of the fuel. However, it can also be thought of as the greater quantity of pollution which is largely absorbed into the lungs of the household cook and her family when dung (or crop residues) are burned in an open fire.

The framework presented in Figure 1 is useful to convey four different points. First, it can be used to show that if a rural household focuses only on roundwood supplies for firewood, it can face a wood-shortage situation. However, if it widens its horizons to include all household fuels, its options are more numerous. As a result, the total supply of household energy in the form of biomass for any given household can be viewed as constituting an envelope curve (MC_t in the figure). This envelope curve is comprised of the sum of the quantities of different fuels which can be supplied at different price (or imputed cost) levels. Since this is the curve for one household, when these curves are aggregated across the entire market, the net result is that the total supply curve for the entire market becomes extremely elastic. This helps explain the lack of depletion effects in the price trends for fuelwood, as noted below.

Second, the concepts represented in Figure 1 also explain why most households using dung and crop residues utilize it to supplement fuelwood. Once a household has broadened its horizons to include these inferior higher cost fuels, it need not focus solely on them, but also can continue to use them in conjunction with firewood. Frequently, they will not have enough of the inferior alternative to completely misplace the quantity of

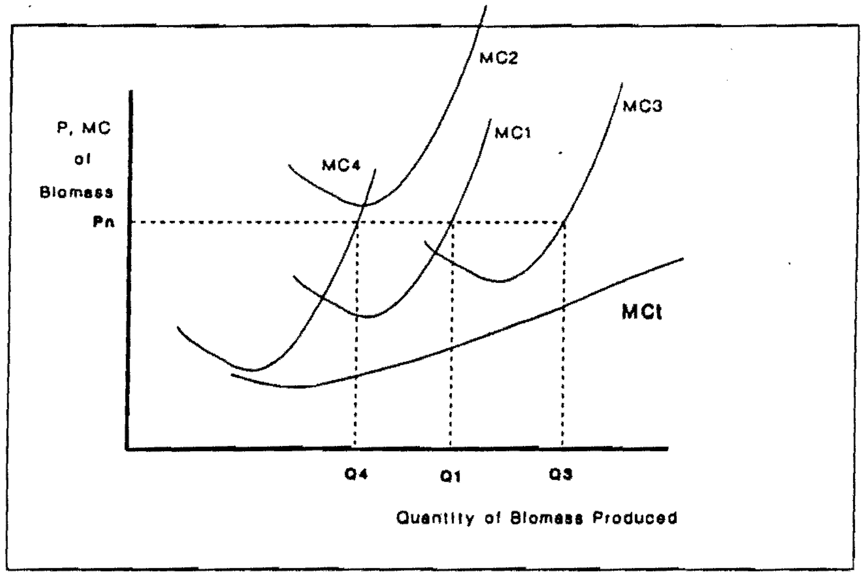

FIGURE 1 MARGINAL COST OF PRODUCING BIOMASS FUEL

fuelwood used, so they must use a combination of both. The results of the HESS household energy consumption survey estimate that of the 6.71 million rural households cooking with dung (out of 11.04 million rural households total), only 210 thousand (3.1% of dung users) cooked with dung alone. The remainder, 6.5 million (or 97%) used dung in conjunction with other fuels. In a similar vein, while 6.45 million rural households used crop residues for cooking, only 400 thousand (6.2% of residue users) cooked with residues alone. When all the costs of energy procurement are considered, firewood is normally a more attractive option. When it becomes scarce (meaning that the cost of gathering wood increases), those using it will supplement it with other biomass fuels which may be obtainable at a similar total cost (higher pollution costs, but lower labor costs).

Third, if crop residues become available only during one season of the year, they could be conceived of as constituting a lower total-cost supply of household energy for that time being. This might be represented by a curve below and to the left of MC_l. For that fuel and that period of time, the crop residue represents a higher quality alternative. This can be seen to be the case of cotton stalks. It also explains why so many households use crop residues. They are general lower quality fuels in terms of pollution emissions (see below), but they may be easier to collect than firewood for that season when they are available. Out of all rural households in Pakistan, it is estimated that only 4.6 million do not use some form of crop residues for fuel. Many of these might be considered to have no access to crop residues because of being landless (about 2.6 million rural are estimated to be landless households who use no crop residues--see below). It also explains why fuelwood consumption is relatively low in the Irrigated High Productivity Northern areas of Punjab. The lower per capita fuelwood consumption is largely compensated for by a higher consumption of dung and crop residues, notably cotton stalks. The data in Table 7 show that the per capita energy consumed by way of firewood in rural households in the Northern High Productivity Irrigated zones is the lowest in the country. This might be taken as an indication of wood scarcity. However, the total per capita energy from biomass is relatively high, indicating that other biomass fuels are used due to greater availability or lower costs.

Fourth, evidence already presented has shown that households purchasing firewood prefer to purchase only roundwood, or the highest quality biomass. What this means is that many households can sell the firewood they collect at a profit when compared to the value of the time required to collect it. They will utilize the lower quality biomass resources which are available at roughly similar costs. The market intervenes into what was previously a subsistence activity, enabling rural women who can collect firewood and other biomass energy resources, to earn some money from their activities. Whether they actually sell this fuel or consume it themselves, their ability to collect can be seen as an income supplement.

Table 7 Per Capita Biomass Fuel Consumption: Rural Areas Only

	Fuelwood Consumption (MJ/cap/yr)	Dung Consumption (MJ/cap/yr)	Crop Residue Consumption (MJ/cap/yr)	Total Consumption (MJ/cap/yr)
Irr High North	4,441	1,763	2,035	8,301
Irr High South	5,894	2,692	939	9,548
Irr Low North	3,643	1,004	2,116	6,841
Irr Low South	6,492	2,012	895	9,514
Barani	4,633	1,400	539	6,604
Forest/Highland	7,222	1,057	369	8,719
Semi-Arid	4,624	2,081	441	7,165
Desert	6,627	327	42	6,996
Total	4,903	1,716	1,391	8,066

source: HESS Consumption Survey estimates.

Unfortunately for the purposes of the present analysis, comparisons of the consumption levels of woodfuel in different regions can be very misleading as an indicator or woodfuel scarcity. Although households will reduce consumption in the face of scarcity, they will also reduce it in the face of increasingly available alternative biomass fuels or a number of other factors, as discussed below. It is not possible to infer that firewood is relatively scarce in physical terms simply because consumption is low.

b) Fuelwood Market Development and Interfuel Substitution

Fuelwood market activity may provide no more clearcut indicator of fuelwood scarcity than comparisons of fuelwood consumption levels. Following on to the last point raised above, the decision to begin purchasing biomass fuels is an important one from the perspective of the energy transition to modern fuels. Once a household has taken the decision to purchase biomass fuels, household energy decisions are simplified as the cost of fuel use is measured in monetary terms, not labor terms. As a result, households will tend to make decisions resembling those predicted on the basis of micro-economic theory. The movement of households from one fuel to another should then become easy to predict on the basis of relative prices and availability.

What forces influence the household's decision to begin purchasing firewood? Basically, if a household behaves rationally in simple economic terms, it will begin to purchase fuelwood when purchasing becomes cheaper than collecting. If the household's choice is between collected and purchased wood, then the trade-off facing the household decision-maker is between the price of the wood or the value of the time which goes into collecting the wood. Two things can happen to make purchasing wood seem more attractive. First, wood can become extremely scarce. It will thereby require a long period of time for collection. Second, the value or expected wage of the household members doing the collecting will increase. In turn, this can take two forms. Either the potential earnings of the individual will increase through education or improvement in human capital, or the probability of that person earning a wage income will increase through the creation of more jobs in the immediate vicinity.[5] Because of the large number of biomass substitutes normally available (except in desert environments where absolute physical scarcity prevails), scarcity rarely forces households to purchase fuels. Rather, it is either the lack of access to land from which biomass resources can be harvested or an increase in the value of household labor which causes households to gather firewood. Urban households are more likely to purchase biomass fuels than rural households because the value of labor in the urban areas theoretically has a higher opportunity cost to it.

Viewed from this perspective, the firewood market can be thought of as a market with two segments. The first consists of those people who attach such a high value to their labor and are willing to pay other people to collect firewood for them (this is represented in the left panel of Figure 2). Because of the limited number of people with such high expected earnings to be able to purchase firewood, the total demand of these households is only sufficient to support only a very few firewood dealers. The bulk of the people using firewood do not place a high value on their time. As a result, they will gather firewood for own use (this constitutes right-hand graph of Figure 2). As development procedes, the value of people's time is anticipated to increase, moving households from the right panel to the left panel. As the

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[5] The equation representing the decisionmaker's trade-off in the following way. The householder will choose to purchase firewood if:

$$p * q \leq (e(w) * t) * q$$

where p and q represent the price and quantity of firewood, respectively, e(w) is the expected value of the labour spent on collecting firewood, and t represents the time spent collecting firewood. Absolute firewood scarcity is represented by an extremely high value for t. e(w) can change based upon an increase in employment opportunities generally or an increase in the anticipated earnings of an individual due to education and training. It is also interesting to note that households not wishing to purchase firewood can lower the quantity of firewood gathered, still keeping the imputed expenditure on firewood less than the required cash outlay to purchase firewood. For a more complete discussion, see Hosier, 1985.

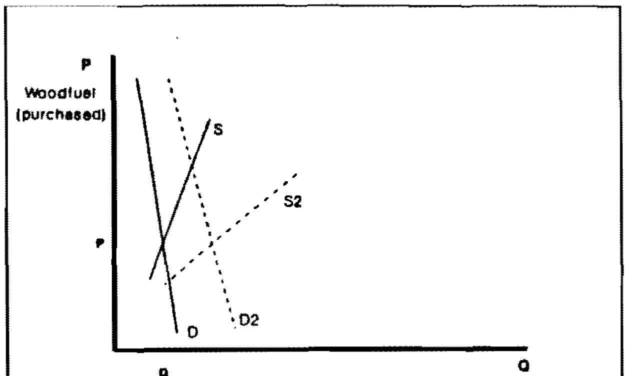

Figure 2a

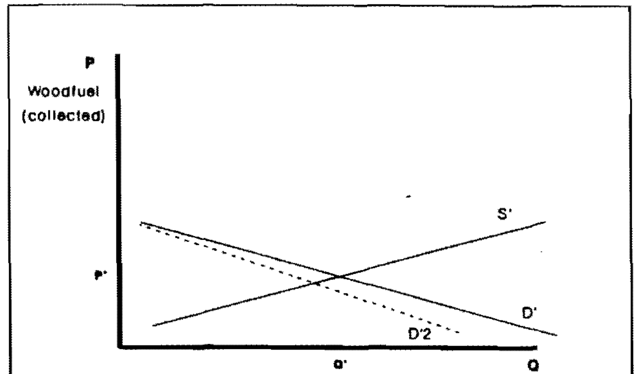

Figure 2b

FIGURE 2 SEGMENTED MARKET FOR WOODFUEL

demand curve in figure 2a expands, that in figure 2b contracts. Through time, the two will be relatively close together, both in terms of the prices involved and the quantities of firewood supplied through each.

Increasing development of the market for fuelwood results from either absolute fuel scarcity or the increasing value of the labour expended in collecting the fuel. Thus, rises in rural standards of living and increasing urbanization are important determinants of the level of fuelwood market development. Evidence from the analysis of interfuel substitution shows that the choice to adopt modern fuels over woodfuel is governed largely by income (Crosetti and Ouerghi, 1993). In a similar manner, the choice to move to firewood from crop residues and dung is also largely determined by income. As a result, there is very little which can be done by energy policy to accelerate the energy transition, or the transition to modern away from fuelwood to modern fuels.[6]

c) Increased Tree Planting

Another response which rural household can make to a scarcity is to increase the quantity of woody biomass on their farms. Although this scarcity response is less important for landless households having nowhere to plant trees, it is extremely important for all farming households. While in theory, farmers in the region experiencing the greatest fuelwood scarcity might be anticipated to be the most active tree planters, this ignores the fact that farmers may be planting trees for purposes other than fuelwood production. In fact, according to the results of the HESS consumption survey, most respondents planting trees did so for timber (44.9%); fuel (29.8%), fruit (10.6%), and other environmental reasons (14.7%) (Leach, 1993, p. 15). While increased tree planting activity might be taken to indicate fuelwood scarcity, it also might also indicate proximity to a large effective demand for industrial timber or fruit. It also might simply indicate that trees grow well in an area and that people have a tradition of tree planting.

[6] One caveat to be raised to this conclusion is that the econometric analysis upon which it is based draws from a cross-sectional analysis, which is liable to underestimate the importance of price in determining consumption patterns due to the limited variation in the prices of the goods being consumed. Perhaps longitudinal data will provide more optimistic conclusions about the ability of policy to encourage interfuel substitution.

Table 8 Trees Planted by Zone

	% of wood users Planting Non-fruit trees (%)	Non-fruit Trees Planted per Planter (trees)	Total Estimated Non-fruit Trees Planted (million trees)	Per capita Non-fruit Trees planted (trees)
Irr High North	19.5%	62.0	68.76	1.324
Irr High South	4.7%	4.1	0.17	0.025
Irr Low North	10.1%	14.3	1.29	0.114
Irr Low South	10.0%	32.7	3.60	0.397
Barani	15.4%	11.2	1.60	0.225
Forest/Highland	17.7%	35.6	3.95	0.664
Semi-Arid	13.9%	132.6	32.23	1.550
Desert	7.1%	8.3	0.18	0.068
Total	15.4%	59.8	111.79	0.966

source: HESS consumption survey data base.

Table 8 summarizes the data about the planting of non-fruit trees by agro-ecological zone. According to these data, tree planting activities appear to be the most common in the High Productivity Irrigated Northern areas and the semi-arid areas. While in both cases, this might be attributed to greater relative physical scarcity, but it does not necessarily mean that these are the areas of the most severe wood scarcity. Even evidence taken from tree-planting levels is not conclusive because of the many confounding factors which can also result in the same tendencies.

In summary, there is no clear-cut case for which of the regions or zones in Pakistan faces the most serious wood scarcity. There is no single province where firewood appears to be scarce according to all of the many potential indicators presented. This reflects three important points. First, even the regional level may be too coarse a scale to pinpoint localized fuelwood shortages. A more detailed and refined sampling frame designed to pick up differences at the district or ward level would be necessary to definitively identify those areas facing severe shortages of firewood. The costs of such an undertaking may not be justified, given the level of complexity required. Second, inferring fuelwood scarcity from levels of market development, consumption, interfuel substitution, and increased tree planting levels is difficult, and can even be misleading due to the number of confounding factors and the different levels of environmental variation. It is possible to identify some important considerations that are relevant to fuelwood planning for the different regions. These will be presented in more detail later. Third, by and large, woodfuel does not appear to pose a serious problem throughout most of urban and rural Pakistan. If there are localized shortages, they appear to be well-provided for through the fuelwood market. The national-level deficit does result from regional-level deficits. However, none of these deficit areas appears to be consistently short of firewood according to all of the indicators used.

2) Urban vs Rural Pressure

The physical and social indicators of fuelwood availability failed to reveal any clearcut pattern of regional firewood scarcity. Although the status of regional fuelwood availability depends upon which indicator one chooses to examine, no one province demonstrates across-the-board shortages. This evidence is supported by the results of the firewood market survey. An additional question relating to spatial variation in firewood availability focuses on the differences between urban and rural consumption. In particular, while rural households may be self-sufficient in firewood production and use, urban households cannot. The size of the drain which urban areas place upon rural firewood resources varies according to a large number of different factors. Theoretically, a city draws fuelwood from its hinterland in an increasing radial distance. The result is a series of concentric circles of increasing radius centered on the urban market center. These concentric rings are gradually defoliated as the radius of fuelwood harvest increases to provide for the fuelwood needs of the city. While actual cases of towns and villages exhausting fuelwood resources in their immediate hinterland are rare, they do exist.[7] On the basis of this simple economic geography, the scarcity of firewood in a particular urban market will be reflected in the distance which the firewood is transported to get to the market. Other important factors indicating an urban fuelwood problem might be prices, unavailability of modern fuels, and a large urban consumption relative to total regional woodfuel use.

Some data previously presented contains some information which is useful to understanding the dimensions of urban fuelwood use. In general, firewood consumption per capita is lower in urban than rural areas. Modern fuels are more accessible to urban dwellers than rural dwellers making them viable, and frequently utilized alternatives. Collecting fuelwood is less common in urban areas. This is due partly to a scarcity of trees in urban areas and partly to the greater opportunity cost of labor attributable to greater employment opportunities. Because of infrequency of wood collection, a larger share of firewood is purchased in the urban as against the rural areas. On average, 86% of the firewood consumed in urban areas is purchased, as opposed to 32% in the rural areas. The fuelwood market is a more essential, established component of urban life than it is of rural life. The development of the fuelwood market is important to guarantee the continued provision of woodfuel in both urban and rural areas.

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[7] The most clearcut case of firewood being exhausted in concentric rings around a rural town is found in Hamer-Digernes, 1979, for the case of Bara, the Sudan.

Table 9 summarizes additional measures of the intensity and magnitude of urban fuelwood consumption. The first factor is the percentage of the population in each region which is considered urban. This provides background to understanding the woodfuel supply network in each zone. The Irrigated North Low Productivity Zone and the Semi-Arid zone are both estimated to have more than 40% of their population living in urban areas. About 87% of the firewood used in the urban areas of the Semi-Arid zone is purchased, and over 97% of the urban firewood used in the Irrigated Low Productivity Northern Zone is purchased. The urban areas in these two zones is heavily dependent upon the firewood market for the provision of household energy. Not too surprisingly, urban firewood demand constitutes the highest percentage of total firewood use in these two zone. The only other zone in which urban consumption comprises more than 20% of the total firewood consumption is in the desert area. When compared to rural firewood consumption, urban firewood consumption is relatively insignificant. In no region does urban firewood use constitute a disproportionately large share of total regional consumption.

On average, slightly more than half of the urban households surveyed utilize firewood. However, the largest percentage of firewood users is found in the Irrigated High Productivity South and the Desert Zone. In both of these areas, more than 70% of all urban households used firewood. These zones also displayed the highest percentage of urban energy consumption being derived from biomass fuels. The urban areas in the Irrigated High Productivity North zone also demonstrated nearly 80% of the total household energy being derived from biomass fuels. In the Desert zone, the importance of biomass fuels in the urban areas is inflated by the limited access to modern fuels. In the High Productivity Irrigated areas, the relatively plentiful supply of marketed biomass and the limited access to modern fuels both contribute to the importance of biomass in the urban areas.

According to the survey of fuelwood traders (AFTAB, 1992), for the most recent load of firewood, the average transport distance is over 300km for the Semi-Arid and Desert areas. This is more that 10 times the average distance firewood is transported to urban markets for the rest of the country. This is also consistent with questions asked to firewood traders about the source of their firewood. In all regions except the Semi-Arid and Desert zones of Baluchistan, the firewood for the market had originated either within the zone itself, or else very nearby. With an average distance of 9km for Punjab and 32 km for Sindh, very little transport of firewood across provincial boundaries is necessary. The major urban center surveyed, Karachi, drew firewood from an average distance of 34km. On average, the urban centers in Pakistan do not appear to draw firewood from exceptionally long distances. On the other hand, the firewood being supplied to the drier areas of Baluchistan is frequently drawn from Sindh, and to a lesser extent, Punjab. Clearly, this pattern of fuelwood supply reflects the physical scarcity of forest resources in these drier areas.

In general, the population of the urban centers in Pakistan meets its firewood consumption needs through the firewood market. This market appears to behave efficiently, bringing firewood into the urban centers from the rural hinterlands. From the evidence gathered as part of the HESS project, urban firewood use does not constitute a disproportionate share of national consumption. Neither does it appear to place an undue burden on the firewood resources of the rural areas. With the exception of the Semi-Arid and Desert Areas, fuelwood is not drawn from long distances into the urban areas of Pakistan. Most local needs are provided from the local areas. Except for these semi-arid cases, there appears to be little cause for concern about urban demands placing a heavy strain on rural firewood resources.

Table 9 Urban Fuelwood Pressure

Measure	Units	Irr Hi North	Irr Hi South	Irr low North	Irr low South	Barani	Forest/ Highland	Semi-Arid	Desert	Total Pakistan
Urban Pop'n as % of Total Population	%	27.2%	29.1%	42.2%	22.4%	7.8%	19.7%	48.2%	24.4%	30.5%
Urban Fuelwood Consumption as % Total Consumption	%	18.7%	18.6%	21.8%	8.7%	3.4%	4.7%	21.8%	21.4%	16.3%
Percent Urban Households Using Firewood	%	65.8%	78.8%	47.1%	57.7%	64.6%	38.0%	32.0%	72.5%	52.3%
Percent Urban Households Using Natural Gas	%	22.6%	12.6%	24.3%	35.3%	19.6%	44.5%	39.1%	31.4%	28.9%
Percent Urban Households Cooking with LPG	%	9.9%	1.5%	3.6%	3.2%	32.9%	10.9%	8.9%	3.8%	8.2%
Percent Urban Households Cooking with Kerosene	%	23.2%	1.5%	43.2%	8.0%	45.6%	30.4%	32.2%	2.5%	26.9%
Percent Urban Households Using Electricity	%	81.5%	60.8%	81.1%	76.6%	100%	91.9%	77.9%	47.5%	79.0%
Percent of Urban Household Energy From:										
Biomass Fuels	%	77.4%	87.7%	65.3%	57.2%	60.7%	45.4%	47.5%	79.4%	66.8%
Modern Fuels	%	22.6%	12.3%	34.7%	42.8%	39.3%	54.6%	52.5%	20.6%	33.2%
Average Distance Fuelwood Transported to Urban Markets	km	9*	*	10*	*	68	62	281	19	86

source: HESS Demand Survey Data-Base and Fuelwood Market Survey.

* The data from the Fuelwood Market Survey makes no distinction between the northern and southern irrigated areas. The categories presented therefore are simply High and Low Productivity areas.

3) Market Forces and Trends

Another indication of the relative availability of firewood is its price. At one point in time, firewood would be expected to be more expensive in those places where it is more scarce or it must be transported from the furthest distance away. Through time, the price of fuelwood might be expected to increase in real terms. According to Hotelling's rule, if a resource is being exhausted, its price would be expected to increase at an annual rate approximating the interest rate. Thus, those areas where fuelwood is most scarce should have the most expensive firewood. Likewise, if firewood is increasing in scarcity, it should also be increasing in price.

TABLE 10 RETAIL PRICE OF FIREWOOD IN MAJOR CITIES
(Constant 1981 Rupees/ 40kg)

	1957	1967	1977	1987	1991	Current Price 1991 Rs/40 kg
Karachi	21.75	18.41	22.95	24.62	22.21	44.38
Lahore	18.16	17.04	22.48	26.56	28.38	56.69
Sialkot	16.18	16.07	23.62	25.91	26.54	53.02
Rawalpindi	16.66	15.64	21.85	30.55	27.95	55.83
Peshawar	11.94	15.44	29.12	28.19	27.85	55.63
Quetta	NA	NA	21.28	21.58	21.39	42.73
Islamabad	NA	NA	22.96	30.55	27.92	55.78
AVERAGE	16.94	16.52	23.47	26.85	26.03	52.01

Annual Percent Change

	Decade '57-'67	Decade '67-'77	Decade '77-'87	4 Years '87-'91	Entire Period *
Karachi	-1.54%	2.47%	0.73%	-2.45%	0.06%
Lahore	-0.62%	3.19%	1.81%	1.71%	1.66%
Sialkot	-0.07%	4.70%	0.97%	0.61%	1.88%
Rawalpindi	-0.61%	3.97%	3.98%	-2.13%	1.99%
Peshawar	2.93%	8.86%	-0.32%	-0.30%	3.92%
Quetta			0.14%	-0.22%	0.04% *
Islamabad			3.31%	-2.15%	1.54% *
AVERAGE	-0.25%	4.21%	1.44%	-0.76%	1.58%

Source: Federal Bureau of Statistics.

* Time period used for Quetta and Islamabad is 1977-1991.
For other cities, entire period refers to 1957-1991

Table 10 summarizes firewood price information collected for 7 major cities in Pakistan by the Federal Bureau of Statistics. These data demonstrate two points of importance.[8] First, in recent years, there is relatively little spatial variation in the price of firewood for the cities for which records are kept. In 1991, at current prices, the average annual price of firewood ranged from a low of 43 Rs/40kg maund in Quetta to a high of 57 Rs/40kg maund in Lahore. This price variation represents about 27% of the average price of firewood. For a country as large and diverse as Pakistan, this price variation is relatively small. This limited variation in prices suggests that the market is able to effect spatial arbitrage. If prices get too high in one market center, firewood will be transported in from another market center in order keep prices from getting too high. This is an important function for fuelwood markets, and is also an important indicator of their relative efficiency.

The second important point to be raised about the data in Table 10 was also highlighted by Leach (1993). When corrected to account for inflation, there has been very little increase in firewood prices during the period for which data are available. In fact, for the entire period from 1957 to 1991, the average price of firewood in urban Pakistan increased at a rate of 1.58% per year. The greatest increase in firewood prices for that period was found in Peshawar at 3.92% per year. Although this might be attributed to the large influx of Afghan refugees in this area, an examination of the beginning and ending prices in the region indicate differently. Although firewood prices in Peshawar started out much lower than they did in the remainder of the country, by 1991, they were not significantly higher than in the neighboring cities of Rawalpindi and Islamabad. The relatively rapid price increases in Peshawar then should not be attributed neither to increased demand from refugees nor to higher final prices, but rather to spatial arbitrage. With the construction of better roads and a demand center at Islamabad, traders are able to engage in transshipment of firewood in order to maximize profits. This also has the effect of equilibrating prices through space, as mentioned above.

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[8] The prices gathered for firewood by FBS as presented in Table 10 are slightly higher than the figures obtained as part of the HESS Firewood Traders Survey. The reason is that the FBS monitoring process controls for species, asking for the price of one maund of either kikar (*Prosopis spp.*) or babul (*Acacia nilotica*) whereas the firewood survey simply asked the price of a maund of firewood. The prices obtained as part of the HESS Firewood Traders Survey are listed below:

	Rs/maund		Rs/maund
Irrigated High Productivity	33	Semi-Arid	36
Irrigated Low Productivity	27	Desert	59
Barani	33	Karachi	47
Forest/Highland	32	Total	36

From this examination of firewood price trends, it does not appear that the price of firewood is significantly higher in any one city than another. Neither does it appear that the price of firewood has demonstrated significant depletion effects due to increasing scarcity at any one point in space. The relative efficiency of the transport system and the strong elasticity of supply have served to avoid significant depletion effects. What does appear to be the case is that prices have been equilibrated throughout the urban areas of Pakistan due to the increased ease of movement from one city to another. Spatial arbitrage appears to have kept spatial price differentials to a minimum.

The linking of wood quality to the failure of firewood markets to demonstrate depletion effects also can be used to explain why the high quality shisham and mulberry timber has demonstrated a dramatic increase in price over the past 20 years. In real terms, the wholesale price of shisham at Changa Manga has increased by over 10% per annum from 1973-1987. For the top three grades of mulberry, the wholesale price has risen over 7% per annum (Grosenick, 1990). This indicates that if wood quality is held constant (ie., supplies can only be drawn from the same marginal cost curve), then timber can be seen to be becoming more scarce. However, for firewood, it is impossible to hold quality constant as lower quality biomass fuels are close to being perfect substitutes for higher quality biomass fuel. Therefore, the price has not increased significantly in the recent past, and may never do so.

The evidence gathered by the Federal Bureau of Statistics on Pakistan's firewood markets supports the conclusion that there has been neither a gradual escalation in woodfuel prices nor one city in which prices are significantly higher than others. Spatial price equilibration of firewood prices through arbitrage has led to a relative convergence of firewood prices in different urban centers. Through time, firewood prices have demonstrated a tendency to increase slowly even though the price of high-quality hardwood for commercial timber has increased steadily in price. This can be attributed to the fact that low-quality biomass can substitute for high-quality biomass when used as energy. This leads to not only a deterioration in the quality of biomass used as energy (first by households collecting fuel), but also to an eventual deterioration in land quality as more nutrients are removed from the site of biomass production. More is said about the problem of woodfuel use and environmental deterioration in a later section.

B. Wood Energy and Social Equity

In addition to a national-level wood balances hiding spatial variations in wood availability, they also obscure differences in access to wood resources by various social groups. Poorer and landless households frequently face a more difficult time obtaining firewood and other energy sources than do wealthier households. Thus, from a policy perspective, variations in access to energy resources by different social groups is an important consideration. This section first examines household energy use by income or expenditure category for all households in Pakistan. Then it turns to an examination of rural household energy use by land ownership.

1) Energy Use by Expenditure Category

Typically, poor households have a more difficult time obtaining their basic human needs. While markets are relied upon to allocate energy resources, in some cases, government intervention is justified to ensure that poorer households have access to adequate supplies of energy. Table 11 contains estimates of per capita household firewood consumption broken down according to expenditure category. For rural households, there is no clear pattern with respect to firewood use and income. The percentage of households using firewood increases from the low to the highest expenditure categories. So does per capita firewood consumption. But both patterns are complicated by unpredicted shifts in the middle income category. For urban households, the pattern is straightforward: firewood consumption decreases with income. This is true both with respect to the percentage of firewood users and the quantity being consumed. As urban incomes increase, households move away from firewood to more modern, conventient fuels. This gives firewood the status of an inferior good, in economic terms. Wealthier urban households make less use of it than do poorer urban households.

Table 11 Per Capita Household Firewood Consumption By Income Category

	Rural Households		Urban Households		All Households	
Expenditure Category	% Using Firewood %	Average Household Cons kg/cap/yr	% Using Firewood %	Average Household Cons kg/cap/yr	% Using Firewood %	Average Household Cons kg/cap/yr
Low	86.6%	390	65.0%	317	81.8%	378
Med	93.4%	386	53.6%	295	80.4%	367
High	92.5%	397	35.5%	245	68.0%	363
All Households	91.0%	391	52.3%	301	79.0%	373

source: HESS Household Energy Consumption Survey Data-Base.
Low Income includes households with Expenditures <18,000 Rs/hh/yr.
Medium Income includes households with Expenditures <48,000 Rs/hh/yr.
High Income includes households with Expenditures >48,000 Rs/hh/yr.

Another way to examine this shift in firewood use is through the household procurement of firewood. As indicated earlier, more households might be expected to resort to purchasing their firewood as incomes rise. Thus, the decision to purchase firewood reflects not just the difficulty of collection, but rather the difficulty of firewood collection relative to the value or opportunity cost of the labor which must be diverted to the task of firewood collection. Table 12 includes estimates of the percentage of households using firewood who purchase their firewood, collect their firewood, and both purchase and collect firewood. These data demonstrate that for both rural and urban areas, the percentage of firewood users purchasing firewood increases with income. Along the same lines, the percentage of firewood users choosing to collect firewood decreases with income in both urban and rural areas. Thus, wealthier households choose to purchase firewood instead of subjecting themselves to the drudgery of firewood collection. It is worth noting in passing that nearly 30% of all firewood-using households in rural Pakistan (about 27% of all rural households) purchase firewood. This represents a very high level of market involvement for what is normally considered to be a subsistence good produced within the household sector. This has important implications for the sustainability of firewood resources in Pakistan and will be returned to later.

Table 12 Firewood Procurement by Expenditure Class

% of Firewood Users Procuring Wood via	Rural Households			Urban Households			All Households		
Expenditure Class	Purchase %	Collect %	Both %	Purchase %	Collect %	Both %	Purchase %	Collect %	Both %
Low	22.5%	69.1%	8.3%	78.4%	18.8%	2.1%	32.6%	60.2%	7.2%
Middle	29.8%	58.5%	5.7%	85.0%	9.4%	5.6%	41.7%	48.0%	10.3%
High	40.2%	50.8%	9.1%	91.6%	5.8%	2.3%	51.3%	41.0%	7.6%
Total	28.8%	60.9%	10.3%	84.3%	11.5%	4.2%	40.1%	50.8%	9.1%

source: HESS Household Energy Consumption Survey Data-Base.
Note: Percentages in each expenditure class for each settlement type (urban, rural, or all) add to 100%.

The previous two tables demonstrate that poor urban households tend to be more dependent upon firewood and upon the ability to collect that firewood. Poor rural households, while no more dependent upon firewood than richer urban households, are still more dependent upon collecting firewood than are wealthier households. From the perspective of social equity, there is a legitimate concern with the energy expenditures of the poor. Do their expenditures on energy resources, particularly woodfuel impose an undue burden on them? If too much money must be spent on energy, insufficient funds will be available for other important purchases. Thus, although energy availability has not caused poverty faced by many households, when it is scarce or expensive, energy can contribute to the further impoverishment of the poor.

Table 13 contains estimates of the percentage of income devoted to firewood and all energy expenditures by the method of firewood procurement for urban, rural and all households. For households purchasing firewood, the average wood expenditure and the average total expenditure on all energy resources are expressed as a percentage of total household expenditures. For those households purchasing firewood and those households who both purchase and collect firewood, the categories are slightly more complex. In these cases, the quantity of wood used in the household is mulitplied by the average firewood price in the area to provide an imputed valued of the wood which is collected (in the collection case) or used (in the collection and purchase case). Average percentage expenditure on other energy resources is then included as a separate category demonstrating the actual financial outlays on energy as a percentage of total expenditures for firewood collectors. Total outlays, which include the imputed value of all firewood used, are then expressed as a percentage of total expenditures. For non-wood users, only the average total expenditure on energy as a percent of total expenditures is included.

Three facets of the table deserve mention. First, the percentage of total expenditures devoted to energy procurement decreases across all income categories. This is consistent with the economic maxim referred to as Engel's law which states that as incomes rise, the share of total expenditures devoted to necessities (such as food or even energy) will decrease. This maxim holds for all household groups. Poorer households, virtually by definition, spend a larger share of their total income on energy as it is a basic need.

Table 13 Firewood and Energy Expenditures by Income Category

	Woodfuel Buyers Buyers only		Woodfuel Collectors Collectors only			Both Buy & Collect			Woodfuel Non-Users
	Wood Expend. as % of Total Expend.	Total Fuel Expend. as % of Total Expend	Imputed Value Collected Wood as % of Total Expend.	Other Fuel Expend. as % of Total Expend.	Total Fuel Expend. as % of Total Expend.	Imputed Market Value All Wood Used as % of Total Expend.	Other Fuel Expend. as % of Total Expend.	Total Fuel Expend. as % of Total Expend	Total Fuel Expend as %of Total Expend
<u>Rural Households</u>									
Low	10.5%	19.0%	14.0%	9.0%	23.0%	12.6%	9.3%	21.9%	15.5%
Mid	7.3%	12.9%	9.6%	6.0%	15.7%	9.4%	6.1%	15.5%	9.8%
High	3.9%	7.2%	4.1%	2.6%	6.7%	5.4%	3.4%	8.8%	5.9%
All Rural Households	6.2%	11.1%	8.5%	5.4%	13.9%	8.6%	5.6%	14.2%	9.7%
<u>Urban Households</u>									
Low	9.6%	15.7%	10.3%	6.1%	16.4%	12.1%	6.7%	18.8%	8.9%
Mid	6.4%	10.9%	7.4%	4.1%	11.5%	6.0%	4.1%	10.1%	6.1%
High	3.3%	6.5%	2.8%	2.6%	5.4%	3.5%	4.4%	7.9%	3.8%
<u>All Urban Households</u>	5.7%	9.8%	6.6%	4.1%	10.7%	6.1%	4.4%	10.5%	4.9%
<u>All Households</u>									
Low	10.2%	17.5%	13.8%	8.8%	22.6%	12.6%	9.1%	21.6%	12.6%
Mid	6.9%	12.0%	9.5%	6.0%	15.5%	9.0%	5.8%	14.8%	6.8%
High	3.7%	6.9%	4.1%	2.6%	6.7%	5.2%	3.5%	8.7%	4.1%
All Households	6.0%	10.6%	8.4%	5.3%	13.7%	8.3%	5.5%	13.8%	5.8%

source: HESS Household Energy Consumption Survey Data-Base.
The income categories are as follows:
Low <18,000 Rs/hh/yr;
Middle <48,000 Rs/hh/yr; and
High >48,000 Rs/hh/yr

The second point worth noting is that the percentages spent on energy and firewood represent a relatively low fraction of total expenditures. Momentarily ignoring the cases which include imputed values, the highest share of total expenditures devoted to income is found in the urban and rural low-income categories for households purchasing firewood. The percentage of total expenditures devoted to energy approaches 20%. This does not appear to be a terribly high percentage. This does not mean that there are no households in Pakistan which feel energy expenses consuming a large share of their incomes. There undoubtedly are. But the average figures for the different groups identified in the table are within reason, and do not appear to point to any energy-poor groups.

The third component of the table which elicits some interest is the ability of purchasing households to reduce energy expenses, thereby effectively augmenting their income through gathering fuelwood. For households in the same income category and the same settlement type (urban or rural), the total expenditure and the percentage expenditure on fuels other than firewood are roughly equivalent. The difference in the total energy expenditures is accounted for by the fact that households collecting fuelwood will tend to utilize slightly larger quantities (typically of lower quality biomass), making the total expenditures including the imputed firewood values, about the same. Thus, firewood collection is an important way in which urban and rural households can reduce their cash outlays on energy, thereby effectively supplementing their income.

In summary, urban households treat firewood as if it were an inferior good: as total income rises, reliance on firewood decreases. For rural household, the pattern is not so clear. Other factors, such as access to land and resource endowment, serve to confound the relationship between rural income and firewood use. More will be said about this below. However, one pattern that is clear is that firewood-using households in both urban and rural areas demonstrate an increased tendency to purchase firewood as incomes rise. For rural households, although the move away from fuelwood may not be obvious,the move from collected to purchased wood, the first small step in the energy transition, is. Finally, household expenditures on energy do not appear to be exhorbitant even for the lowest income groups. While there may be some households devoting an unhealth share of their income to energy, such cases remain hidden in the tables presented.

2) Analysis by landholding

The previous section failed to identify any significant relationship between income and fuelwood use for rural households. This is not surprising, given that resource endowments and access, not income, is the driving factor in determining rural standards of living. If, for policy purposes, we want to identify that rural group experiencing the greatest energy hardship, income will probably not provide a useful guideline. In South Asia, other authors have indicated that an understanding of land-ownership, or the converse, landlessness, is essential to understand access to energy resources (Bajracharya, 1985; Briscoe, 1979; Reddy, 1980).

Table 14 summarizes data on rural household use of firewood, dung, crop residues, LPG for cooking and kerosene for cooking. In the table, rural households are grouped according to their relationship to the land in three categories. The first category includes owner-occupiers or Farmer-owners, that is to say, those households which own their own farms and operate them. The second category includes lease-hold farmers or Farmer, Non-Owners. These are farm operators who do not own farms, but instead lease them. The third category consists of households which neither own land nor operate farms. These are considered to be the landless, and consist of people with a number of different occupations, including school teachers, nurses, factory workers, farm workers, government workers, and so forth. About 36% of rural respondents fall into the Farmer-Owner category, about 13% fall into the Farmer-Non-owner or tenant farmer category, and about 51% of the rural respondents were classified into the landless or Non-Farmer category.

Households in the landless category demonstrate a more limited access to rural resources, including biomass energy resources. Because they have no access to land, in times of hardship, they are not as able to draw upon the natural environment. They are more fully dependent upon the market for their subsistence requirements, and they are therefore more vulnerable to negative economic fluctuations for their subsistence needs. According to the data in the table, the landless or Non-Farmer respondent group demonstrates a heavier reliance on the modern fuels kerosene and LPG for cooking and a lower utilization of biomass fuels (firewood, crop residues, and dung) than do the other two groups of rural households. Both the percentage of households using biomass fuels and the average per capita consumption of biomass is lower for landless households, with the exception of crop residues. In contrast, the percentage of households cooking with kerosene and LPG and their average consumption of these two petroleum fuels is higher among landless households than it is among farming households.

Households without land are forced to rely upon the market for the provision of their energy needs. Landless households constitute about 51% of all rural households. Of these, 89% use firewood and 42% of the firewood users purchase their firewood. Therefore, approximately 20% of all rural households, or slightly more than 2.1 million rural households, are landless households forced to purchase firewood. By itself, this group constitutes a significant rural market for firewood, about 65% of the rural firewood purchasers. The sheer size of this rural landless groups guarantees a significant rural market for firewood, which may be a protection against absolute tree and forest depletion. As long as farmers can sell trees, they will have an incentive to grow trees. Rural farmers have a large guaranteed market for firewood in their landless rural neighbors. The large size of this landless group may help explain both the large size of the rural firewood market and the eagerness of farmers to plant trees for market production.

The landless clearly are more dependent upon the market for the provision of their household energy needs. However, this represents a double-edged sword. On the negative side, they are at the mercy of their neighbors who do have access to land. They either must negotiate for permission to collect firewood or more frequently, arrange to purchase firewood. On the positive side, this population of landless constitutes a large firewood market to be serviced by the efforts and resources of the farming households. Despite their dependence upon the market, the energy expenditures for firewood or even commercial fuels by the rural landless do not appear to constitute an unduly large proportion of their total expenditures. Undoubtedly, there are many landless for whom energy expenditures do constitute a disproportionately large share of total income.[9] Future analysis should dissect this group further to pinpoint any problems related to the provision of energy for the poor landless.[10] For the moment, however, the energy needs of the rural landless taken as a whole appear to be relatively well-served by the markets for firewood and modern fuels.

Table 14 Household Fuel Use by Land Ownership: Rural Households Only

	Units	Farmer Owner	Farmer Non-Owner	Non-Farmer	All Households
% of Total Rural Respondents in Category	%	35.6%	13.2%	51.2%	100.0%
Firewood Use					
% Using	%	92.2%	94.4%	89.3%	91.0%
% of Users Only Purchasing	%	15.6%	17.5%	42.7%	29.4%
Consumption Per Capita	kg/cap/yr	356.3	386.5	340.1	351.9
Dungcake Use					
% Using	%	71.3%	86.1%	63.8%	69.4%
Consumption Per Capita	kg/cap/yr	149.4	240.4	147.9	160.9
Crop Residue Use					
% Using	%	63.7%	59.5%	54.7%	58.5%
Consumption Per Capita	kg/cap/yr	118.2	104.6	112.2	113.4
Kerosene for Cooking					
% Using	%	4.1%	2.1%	10.3%	7.0%
Consumption Per Capita	lt/cap/yr	0.12	0.05	0.55	0.33
LPG for Cooking					
% Using	%	0.16%	0.03%	0.71%	0.42%
Consumption Per Capita	kg/cap/yr	1.9	0.5	3.6	2.6

source: HESS Household Energy Consumption Survey Data-Base.

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[9] On average, landless who purchase firewood devote 11.1% of their total expenditures to energy. This compares to 10.3% of the Farmer-Owners and 13.1% of the Farmer-Non-Owners. Among woodfuel collectors, the percentage expenditures on modern fuels is 5.5% for landless, 5.3% for land-owners, and 5.5% for tenant farmers. Among non-wood users, the landless spend 8.7% of their income on energy as opposed to 11.0% and 12.5% for the land-owners and tenant farmers, respectively.

[10] Preliminary analysis of land-holding group by income indicates that Non-farmers or landless are more heavily congregated in the low expenditure category (36.7%) than are either the Farmer-Owners (28.9%) or the Farmer Non-Owners (30.4%). Further analysis should look at this intersection between landholding and income.

C. Environmental Implications of Fuelwood Scarcity

The excessive use of fuelwood resources can have important environmental ramifications than extend to the global level. As the previous chapter has argued, fuelwood use is not wholly responsible for the wide-spread destruction of Pakistan's forests. At worst, woodfuel use exerts a minor pressure for natural forest exploitation and degradation. However, as preceding sections have indicated, as woodfuel becomes more scarce in a relative sense, households resort to using larger quantities of crop residues and dung. The use of these biomass sources as fuels constitutes a flow of nutrients away from the soil. Over the long-run, it will lead to environmental degradation. This interaction between biomass fuel-use and soil deterioration is the first of the environmental issues discussed below. The second has to do with the quality of the biomass fuels used and the pollution which cooks and households are exposed to during its ground-level combustion for cooking purposes in rural households. The third environmental issue discussed is a global one: that of carbon emissions. To what extend will the use of biomass fuels worsen Pakistan's contribution to global warming?

The evidence presented indicates that increasing use of lower quality biomass fuels will lead to a gradual deterioration in soil nutrients and possibly in soil quality. However serious this degradation is, it is too gradual to be effectively measured through typical benefit-cost analysis. Indoor air pollution considerations would favor fuelwood over other biomass fuels, and modern fuels over fuelwood. Thus, the natural progression of the energy transition will lead to a cleaner household environment. In terms of net carbon emissions, fuelwood may be better than petroleum fuels or natural gas, and if it is planted (instead of coming from deforestation), it may even be superior to other biomass fuels. On the basis of three environmental considerations, there appears to be no reason to go beyond market forces in encouraging interfuel substitution.

1) Soil Degradation

As lower quality biomass is removed from agricultural land to hearths, the nutrients in it are also removed from the agricultural land. Unless these nitrogen and other elements are replaced, the fertility of the soil will degrade, with the eventual result that crop yields are reduced. In addition to contributing nitrogen, organic carbon and other nutrients to the soil, dung and crop residues also improve soil texture and moisture retentive capabilities. The contributions these lower quality biomass sources to soil fertility are complex and important. However, as shall be seen below, they are relatively difficult to measure.

The total supply and consumption of biomass fuels used in the household sector are summarized in Table 15. As can be seen from the percentages of total supplies accounted for by the household sector, in all cases, a significant percentage of residues is still available for alternative (non-household energy) uses. According to these estimates, the most significant biomass residues used for fuel are dung and cotton stalks. Only about 34% of the dung produced by cattle is used as a household fuel. For cotton stalks, which closely resemble wood in physical and chemical composition, the fraction rises to nearly 41%. In no other case does the percentage of generated residues used by the household sector exceed 10%. However, this raises a question about the opportunity cost of these residues. Is the residue more valuable as a soil enhancer or as a source of energy?

The best way to assess accurately the contribution of different agricultural residues to soil fertility is to examine yield-response curves. Unfortunately, such curves are not available for Pakistani conditions. However, estimations of the contribution of dung to agricultural yields reinforces the impression that it is still very effective at improving agricultural yields. Under average application conditions, for example, dung is estimated to increase wheat production by as much as 1/2 ton per hectare (Ian Twyford, personal communication). Since average nation-wide wheat yields approximated 1.8 tons per hectare from 1987 to 1991 (Government of Pakistan, Food and Ag, 1991), this represents about a 28% increase from the average figure.

Table 15 Biomass Residues: Pakistan, 1991

Residue Type	Estimated Consumption (000 tons)	Estimated Supply (000 tons)	Percent Used by HH Sector	Relevant Alternative Uses
Dung cakes	13,300	39,400	33.8%	Fertilizer
Cotton Stalks	5,148	12,460	41.3%	
Maize wastes	201	3,470	5.8%	Fodder/fertilizer
Bagasse/cane	298	12,880	2.3%	Boilers/power generation
Rice straw	141	8,160	1.7%	Fodder/fertilizer
Wheat straw	159	20,650	0.8%	Fodder/fertilizer
Saw dust	254	NA	NA	
Coconut husk	29	NA	NA	
Rice Hull	70	NA	NA	
Tobacco Residue	29	NA	NA	
Other	1,678	NA	NA	

source: HESS Biomass Supply and Consumption Data-bases.

Barring detailed yield-response data, a simpler method of estimating the value of nitrogen is to assign it the value of an equivalent quantity of commercially-available fertilizer which would have to be used to provide the same quantity of nutrients. Although this typically gives a lower estimate of the value of dung than yield-response data, it represents at least a minimum value (Newcombe, 1989). If cow dung is estimated to contain 1.7% nitrogen, then one ton of dung is equivalent to about 4 kilos of urea (46% N). If the price of Urea is taken as Rs 3900/ton (about US$ 156), then the value of a ton of dung used as fertilizer is at least equivalent, at Rs 144/ton (US$6/ton). If the economic value of the urea were taken to be as high as Rs 5,500/ton (US$220), this would still increase the value of cow dung as fertilizer to only Rs 203/ton (US$ 8/ton). Since the market value of dung for fuel is estimated in the HESS household survey as Rs 0.58/kg or Rs580/ton (US$23/ton), the cow dung has a higher value as fuel than its nutrient contents alone justify (Ouerghi, 1993). If substituted for purchased woodfuel at Rs 1/kg (the approximate survey-wide average), because the calorific content of dung is slightly lower than that of firewood (12 MJ/kg vs 16 MJ/kg for firewood) the dung is worth about Rs 0.75/kg. This still represents a higher value for the dung than is justified on the basis of the value of its nutrient content alone. However, this assumes that households choosing to use dung as fuel will apply the commercial fertilizer in place of the dung. Based upon the low rates of fertilizer application in Pakistan (less than 100kg per cultivated ha), it is more realistic to assume that households apply no fertilizer if they decide to use dung as fuel.

Another way to approximate the value of the dung used is to examine the quality and quantity of the labor used to collect it. In general, the time and effort which go into collecting dung is lower than the time spent collecting fuelwood (Ouerghi, 1993). If only the value of the male's labour is given a financial price, collecting represents a net saving to the household of nearly Rs800 over collecting an equivalent amount of firewood results.

By international standards, Pakistani dung is considered to be low in nitrogen and high in carbon, largely due to the diet of the cattle. As a result, its value as fertilizer will tend to be lower than in other contexts. On the other hand, its value as a fuel is higher. Again, it appears to be more useful as a fuel than as a fertilizer. However, a little less than 20% of the survey respondents perceived of dung as being more useful as a fuel than as a fertilizer. The majority (57.6%) perceive of it as having greater value as a fertilizer than as fuel.

From an individual household perspective, dung appears to have higher value as a substitute for firewood than it does as a substitute for commercially-produced fertilizers. Although this conclusion might change if yield-response data were utilized, from a private perspective, households appear to be making an economically rational decision when they choose to use dung as a household fuel. However, these households, which tend to be among the poorer households, have a very high discount rate, or short-term decisionmaking framework. Over the long run, if the nutrients in dung are not returned to the soil, soil depletion will occur. While a benefit-cost analysis might show the use of dung as fertilizer to be an economically-attractive decision, it would still result in a significant deterioration in soil quality and agricultural yields.

The case for crop wastes, particularly cotton stalks, being returned to the soil is not so straightforward. If left in the soil, cotton stalks can harbor pests which will destroy any future harvests. As a result, the roots of cotton stalks must be removed from the soil and either burned on-site or plowed under. In Pakistan, cotton is grown in rotation with wheat or another grain crop to avoid problems of pest carry-over. As a result, the removal of cotton stalks poses only a small threat to soil fertility. Given that nearly 6 million tons of cotton stalks go unutilized each year, this represents a significant source of potential fuelwood substitutes. More attention should be paid in the future to the increased use of cotton stalks as fuel, and its potential impacts on soil quality.

In summary, the use of dung as a fuel will lead gradually to soil depletion, if the nutrients removed in the dung are not replaced through the application of other fertilizers. However, from the household's perspective, this decision seems economically justified. Even though most households think dung is more valuable as a fertilizer than a fuel, dung is easier to collect than firewood. It is also worth more when substituted for marketed firewood than it is when used as a fertilizer. On the other hand, the environmental case against the use of crop residues, particularly cotton stalks, as household fuel is much less clear. Although the principles remain the same, the fact that cotton stalks must be removed from the soil means that there is little opportunity cost to their use as fuel. Any advancement in agricultural techniques which enables the cotton stalk to be plowed back into the soil should be carefully considered because it would have negative implications for the household energy supply. More research and monitoring are needed to follow developments in this area and to investigate these issues further.

2) Indoor Air Pollution from Household Cooking

In recent years, the scientific community has been made aware of the fact that women cooking over open fires are exposed to a large dose of toxic pollutants.[11] Total suspended particulates, complex polycyclic aromatic hydrocarbons, and carbon monoxide are

[11] The research of Dr. Kirk Smith at the East-West Center has been most influential in bringing this research on the health hazards of indoor air pollution from cooking smoke to light. The most comprehensive source of information on this source can be found in Smith, K., 1987, Biofuels, Air Pollution, and Human Health: A Global Review. New York: Plenum Press.

all common pollutants found in wood smoke. In other contexts, particularly the context of indoor air pollution from cigarette smoke, such large doses have been shown to be injurious to health. A person sleeping in a small house in the highlands of Nepal with a small wood fire burning for heat can be exposed to the carcinogenic equivalent of several packs of cigarettes. In theory, indoor air pollution from household cooking fires has been linked to the high prevalence of upper respiratory tract infections in developing countries, which in poorer countries, constitute the greatest source of morbidity and mortality.

The data in Table 16 provide a rough assessment of the quantity of Total Suspended Particulates (TSP) likely to be emitted by the combustion of various different household fuels. These data clearly demonstrate that coconut husks, dung, and dung with firewood are potentially much dirtier than firewood. In this regard, firewood really is a higher quality biomass fuel. For comparative purposes, the estimate of TSP from kerosene combustion is included, and is much lower than any of the estimates for biomass fuels. What these data demonstrate is that the "dirtiness" of biomass fuels simply reinforces the attractiveness of firewood over lower quality biomass fuels. It also reinforces the attractiveness of modern fuels over biomass fuels. If a pollution-premium were factored into to the economic assessment of the cost of supplying biomass fuels, it would serve to make higher quality biomass fuels and modern fuels more economically attractive.

Table 16 Air Pollution Potential of Different Household Fuels

Fuel	Total Suspended Particulates (TSP) (g/kg of fuel)
Kerosene	< 0.1
Fuelwood (Leucaena sp.)	8.2
Fuelwood (Average 5 species)	6.1
Dung and Fuelwood Combined	13.5
Dung	21.3
Coconut Husk and Shell	34.9

source: Smith, 1987, p 269 and p 320.

The critical link between air pollution and human health is not the TSP emitted from the fuel, but the actual exposure of humans to that smoke. As a result, the research in this area has made use of exposure monitoring to see how much of the particulates and other pollution is actually inhaled by the women cooking. Clearly, someone cooking outdoors will be exposed to less pollution than someone cooking indoors. Even among people who cook indoors, there are tremendous variations in the ventilation of the cooking space. With more ventilation and/or the use of a stove with a chimney, the exposure to the pollutants is less serious than where there is no chimney and limited ventilation. What does this mean for Pakistan households?

The data in Table 17 summarizes the results of the HESS Consumption Survey with respect to biomass-fuel users and their cooking practices. In total, about 13.5 million households cook with biomass fuels of one form or other. About 46% of these cook indoors, although a large number undoubtedly shift betweeen indoors and outdoors depending upon the weather. Very few (3.5%) of the households changing cooking location do so because of smoke. This means that nearly 6 million households are at risk of being exposed to hazardous levels of pollution from biomass fuels. In addition, only 17% of all biomass using household used stoves with chimneys. Most burning of biomass fuels takes without a chimney. Indoor air pollution and its impact on human health is a valid consideration for energy policy-makers in Pakistan. However, it is not clear what concrete actions can be taken on the basis of this knowledge.

Comparative results from elsewhere in South Asia show that most improved stoves are better than traditional stoves in terms of smoke exposure and concentrations (Smith, 1987, p 296). However, not all improvements in the efficiency of stove combustion lead to emission reductions. Improving the efficiency of biomass-fuel combustion normally involves the enclosure of the combustion chamber. This will normally increase the quantity of ground-level emissions from the fire. In addition, the goals of improving stove efficiency and reducing harmful emissions are at odds in several respects (Smith, 1987, p 315). Future efforts to improve stove efficiency will have to acknowledge these trade-offs in stove design.

Table 17 Household Cooking Practices:
All Households Cooking With Biomass Fuels

Cooking Practices	
Percentage of Households Cooking With Biomass Fuels Who Claimed to Cook In:	
Inside house (no separate room)	21.1%
Outdoors in the open air	50.8%
Kitchen (separate room)	25.1%
Other	3.0%
Total	100.0%
Percentage of Households Cooking With Biomass Fuels Who Claim to Cook With Chimney:	
Yes (chimney)	16.9%
No (no chimney)	83.1%
Total	100.0%
Households Changing Location of Cooking During Course of Year:	
Yes (changed location)	64.8%
No (did not change location)	35.2%
Total	100.0%
Reason for Changing Cooking Location:	
Too much smoke inside	3.5%
Too hot to cook inside	4.4%
It is conventient to change cooking place	4.0%
Weather conditions (rain, etc.)	87.7%
Other	0.4%
Total	100.0%

source: HESS Household Energy Consumption Data Base.

Although indoor air pollution from biomass fuels has been linked to health problems in developing countries, the anticipated health impacts have not been found. Recent work by Smith (personal communication) in South Asia and Ellegaard in Zambia (Ellegaard, 1993) has failed to turn up the higher incidence of respiratory tract infections anticipated on the basis of exposure to indoor air pollution from cooking with biomass fuels. A number of reasons can be advanced for this. First, health records in developing countries, particularly morbidity records, are poor. Second, people who are accustomed to cooking in a smoky environment development a certain level of natural immunity to smoke. In addition, they are unlikely to report a nagging cough as being unusual. Third, there are too many other confounding factors masking the smoke effects. Ellegaard's work in Zambia has demonstrated that smoking cigarettes and a "mouldy", or perhaps mildewy, house is more important than biofuel use in determining respiratory-tract health. Perhaps, the anticipated effects can only be identified in small children who do not have the same number of confounding effects. Fourth, it may simply be that rural people living in poor countries die of other diseases before the smoke-generated complications kill them. In other words, they do not live long enough to develop cancer.

Whatever the true reasons for this failure of the health effects of indoor air pollution to materialize, three things are clear from the above discussion. First, the potential exists for a large number of Pakistani households, particularly women and children, to be exposed to a large number of pollutants due to ground-level burning of biomass fuels for cooking in a poorly ventilated house. Nearly 50% of the households cooking with biomass fuels claimed to cook indoors at least part of the time. This means that about 6 million households in Pakistan are exposed to high levels of air pollution from biomass fuels. Second, the potential levels of pollution from different household fuels decrease with moves up the household energy ladder. From fuel-combustion tests, it appears that firewood is cleaner (at least in terms of TSP) than is dung and several crop residues. However, it is dirtier than kerosene and other modern fuels. As a result, the "cleanliness" of the fuel simply serves to reinforce the attractiveness of modern fuels. Stated another way, if a pollution adjustment were made to the economic value of the fuels, such an adjustment would serve to lower the opportunity cost of supplying modern fuels relative to biomass fuels. Third, the recent findings actually linking health to indoor combustion of biomass cooking fuels has failed to come up with the anticipated negative health impacts. This last point has two important implications for Pakistan. First, it is worth monitoring and carrying out more research to gauge the severity of the impact of biomass-fuel use on human health in Pakistan. Second, because of the tenuous nature of the actual link between exposure to biomass smoke and health, it is not yet sensible to attach a "cleanliness" subsidy to modern fuels. Households are in no need of such a subsidy, as cleanliness is already one of the attractions of modern fuels.

3) Carbon Emissions

Since the evidence that global warming is occuring has become substantiated, energy planners have begun to consider the global environmental impacts of energy policies. In particular, international attention has focused on the emission of greenhouse gases (particularly carbon dioxide, methane, and chloroflorocarbons) and their impact on global warming. From an energy perspective, all of these greenhouse gases are important. CO_2 is given off in the combustion of fossil fuels and biomass fuels. Methane (CH_4) is created naturally from the decomposition of organic matter, but it also escapes when petroleum is refined and natural gas is mined. Chloroflorocarbons (CFC's) are type of plastic insulator which were commonly used in refrigerators in developing countries.

Because of the high component of biomass and petroleum fuels in the household energy sector, developments in household energy have clearcut implications for greenhouse gas emissions and global warming. In a recent paper examining residential sector emissions of CO^2, Floor and van der Plas (1992, p. 13) have found that total net emissions per cooking task from household fuels are highest for charcoal, followed by natural gas, kerosene, and coal.[12] For wood, the net carbon effect depends upon whether or not the wood is sustainably managed or not. If it is sustainably managed, then the use of wood, like the use of dung and agricultural residues, represents no net carbon emissions. If wood is not drawn from sustainably managed supplies, then the net carbon emission effect is made worse.

The implication of this finding for Pakistan is straightforward. The reliance on sustainably-grown and managed woodfuel is more environmentally responsible than either reliance on petroleum fuels or non-sustainably managed woodfuel. To the extent that Pakistan's woodfuel is grown on a renewable basis, its heavy reliance on woodfuel will have no negative net impacts on the global environment.

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[12] This ranking is partly dependent upon the loss of LPG and natural gas during refining and extraction. When it escapes from the well-head, natural gas is almost pure methane, which is considered to be 70 time more effective at trapping atmospheric heat than CO^2.

CHAPTER III SUMMARY

Woodfuel scarcity is a complex phenomena, reflecting both natural productivity and population pressure. When speaking of wood scarcity, it is important to think in terms of absolute physical scarcity (where there is no wood); relative physical scarcity (where wood supplies are insufficient for population needs); and economic scarcity (where wood prices are higher than the prices of alternative fuels. Throughout Pakistan, relative physical scarcity is found in many areas, and in some areas, economic scarcity may be beginning to emerge.

Identifying those areas currently facing the worst wood scarcity is a difficult task. From an examination of indicators for the different agroecological zones, no one zone stands out as having the worst overall fuelwood situation. However, each zone demonstrates a unique pattern of fuelwood availability and use.

Households are able to mitigate the effects of wood scarcity through substituting lower quality biomass fuels for higher quality fuels. Thus, a households can optimize its energy budget with respect to energy scarcity and price.

The decision to purchase firewood is an important first step in the transition to modern fuels. Generally, it is accompanied or brought on by an increase in income or imputed household income, not increasing fuel scarcity.

The price of firewood does not demonstrate significant depletion effects, not does it demonstrate significant spatial variations between areas. The former would indicate that the supply of fuelwood is relatively elastic, as would be expected if rural households are shifting to lower quality fuels, selling their higher quality biomass fuels. The lack of spatial variations would indicate that the market is working to bring about notable spatial arbitrage.

At the national level, neither the poor nor the landless appear to be hit unreasonably hard by firewood scarcity or their limited resources. This is not to say that individual cases of energy deprivation or energy poverty compounding overall poverty do not exist. Rather, it is to say that the markets as a whole appear to do a good job of supplying fuelwood to those willing to pay. The rural and urban firewood market in Pakistan are both very well developed, and seem to operate in a healthy fashion.

The use of dung as a fuel instead of as a fertilizer is economically justified from the household's perspective. However, it does result in a gradual depletion of soil nutrients. The environmental implications of crop residue use, particularly cotton-stalk use, is not clearly so clearcut.

From the perspective of household exposure to biomass smoke, modern fuels are cleaner than traditional fuels, and are less likely to cause health problems. However, as this simply reinforces their attractiveness to households, there appears to be little which can be done about it.

With respect to global warming, biomass fuels make less of a net contribution to greenhouse gas emissions than do petroleum fuels. If they can be produced sustainably instead of from the harvesting of old growth trees, the use of biomass fuels is environmentally benign in this regard.

CHAPTER IV

Scenario Projections: Future Woodfuel Sustainability

Previous chapters have devoted considerable time and effort to discussing Pakistan's wood energy supply and demand situation for the base-year of 1991. These discussions have demonstrated that while there are locations in which firewood might be considered to be relatively scarce in physical terms, there is no nation-wide crisis of woodfuel availability. Many farmers have taken to planting trees to supply sawn timber, and additional firewood supplies are a by-product. One of the important factors preventing the emergence of a more severe firewood crisis has been the development of a market for fuelwood. This market serves to bring wood to those needing it at a reasonable cost. No depletion effects have emerged, nor has any one region demonstrated consistently higher prices for firewood than others. Even a consideration of the environmental implications of continued firewood use has failed to raise any serious obstacles to the continued reliance of Pakistan's energy system upon fuelwood. As a result, fuelwood will probably have to bear the burden of Pakistan's energy needs.

This chapter turns to an assessment of the ability of Pakistan's trees and forest resources to continue to supply woodfuel to the country for the foreseeable future. It will build several scenarios making use of different assumptions about the current levels of tree-planting activity to identify lessons about the future of Pakistan's wood energy system. These lessons, drawn from common elements of the scenarios presented, help identify important components of a policy for wood-energy development in Pakistan.

A. Scenario Development: An Heuristic Exercise

After the second chapter of this report devoted so much attention to the shortcomings of the "gap" analysis approach to wood energy planning, utilizing scenarios to explore the sustainability of wood energy supplies seems hypocritical. And yet, energy planners have no alternative but to make use of such scenarios. Being forced to rely upon planning scenarios when the complexities of the current woodfuel supply system is not well understood is one of the dilemmas of energy planning. Scientific needs to concentrate on analyzing and comprehending the present system for a single year must take a lower priority than planning needs which dictate that scenarios be utilized to assess future sustainability. However, the criticisms of "gap" analysis cannot be ignored. These criticisms have two important impacts on the approach adopted for the following analysis.

The first way in which the criticisms of "gap" analysis influence the following analysis is through the emphasis placed on assumptions. One of the criticisms made of past woodfuel projection efforts has been that they have assumed that woodland regeneration is nil, that rural farmers do not respond to felt scarcity of woodfuel through planting trees, and that the present patterns of supply and consumption will continue unabated into the future. These assumptions are simplifications of a complex reality, and they have been adopted for the sake of simplifying the modelling exercise. However, they all have important implications, and lead to a worsening of the "gap" between wood supply and demand. Previous scenario projections have failed to highlight the important qualifying role these assumptions play in the analysis. The role is so important that had they been slightly modified, many of the conclusions would have changed. The deployment of different assumptions in the calculation of scenario projections enables the analyst to "pick the future" that corresponds to his or her predilections. In the following analysis, the role of the different assumptions being deployed will be emphasized. Rather than labelling one scenario as a base-case or a reference case, the analysis will present a number of different scenarios and the assumptions upon which they are based. The reader is then free to judge which set of assumptions most corresponds to his or her perception of the future.

The second way in which the following analysis has benefitted from the criticisms of the "gap" approach to woodfuel planning is that its purpose is not to estimate the size of the "gap" nor the year in which forest resources will become exhausted. Rather, its purpose is that of all formal modelling exercises: to learn about the system being modelled. The presentation of the scenarios will emphasize the lessons common to all of the different scenarios developed, rather than focusing upon one scenario and its projected results. It will focus on the process of scenario development and the lessons derived from it rather than the product of a specific scenario.

In summary, the following analysis will make the assumptions embodied in the scenarios transparent while adopting an heuristic approach to scenario development. Although a woodfuel "gap" still emerges in these scenarios because consumption exceeds sustainable supply, this "gap" does not assume the dominant role in the discussion. Rather, the discussion focuses on ways in which the scenarios enhance our understanding of the sustainability of Pakistan's wood energy system.

B. Scenarios of Future Wood-Energy Sustainability

In any scenario-building exercise, a large number of factors can be varied or changed to provide alternative looks at the future. This enables the analyst to account both for uncertainties in the initial estimates of critical factors and also for uncertainties in how these factors will change in the future.

Because it is virtually impossible to anticipate changes in all of the most important variables in a scenario, every scenario represents a simplification of reality. Scenarios of woodfuel supply and consumption are no different. Literally hundreds of factors can be thought of as influencing overall levels of wood supply and demand. Scenarios which allowed all of them to vary would be confusing and difficult to follow. Therefore, in order for the scenarios to be comprehensible, it is important to limit the number of variables being modified through a series of scenarios.

Among the candidates for sensitivity analysis are the base-year levels of both supply and demand, the growth of demand, interfuel substitution, fuelwood conservation, and expanded tree-planting. With respect to base-year levels of supply and demand, the standard errors of the estimates of supply and demand might provide an indication of the inherent variability in those parameters. With respect to base-year consumption, there is relatively little uncertainty in the estimates of national wood consumption. The standard error of the national consumption estimate accounts for merely 1% of the estimate. A 95% confidence interval extends only to 2% of the national estimate, which means that uncertainty in the consumption estimate is so small that it is not worth bothering with. On the supply side, the standard error of both standing wood stocks and annual productivity is approximately 10% of the estimate. A 95% confidence interval includes nearly 20% of the estimate. This variation is significant and large, and can be attributed to the inherent variability of the factor being estimated, woody biomass cover. While the uncertainty in the supply estimate is significant, it does not appear to make much of a difference in the projected scenarios, and will not feature prominently in the following discussion.[13]

In terms of projection uncertainties, the HESS demand-model uses a combination of both logisitic regression to forecast fuel choice and multiple regression to estimate projected consumption. The results of this model provide the projected levels of woodfuel consumption used in the scenarios developed below. An interesting point about the scenarios is worth noting. While the model did predict a significant quantity of interfuel substitution, very little of it involved households moving up the energy ladder from fuelwood. Improvements in standard of living or income can encourage households to move to fuelwood from lower-quality biomass fuels. But improvements in income do little to move households away from fuelwood to more sophisticated energy carriers. Even dramatic increases in the price of wood do not push households off of firewood onto modern fuels--they only result in increased dung and crop residue consumption. If standards of living increase, some households may move away from firewood to modern fuels.

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[13] Adding an additional 20% onto the initial standing stock estimates appears to extend the duration of existing wood stocks by only about one year.

However, more households shift to using fuelwood from lower quality biomass fuels than shift away from it. This is an important result of the demand-modelling exercise: there appears to be little which can be done from a policy perspective to speed the movement of households away from fuelwood.[14]

While it is possible to allow for variations in the projected level of consumption, the following scenarios concentrate only on the case of reduced consumption of firewood through conservation or unanticipated interfuel substitution. The Reference or Base-Case Scenario developed in the HESS Demand Model includes a limited quantity of interfuel substitution brought on mostly by increased incomes. In addition to this projected level of interfuel substitution, the scenarios below allow for additional reductions in consumption, due either to increases in the efficiency of wood use, unanticipated interfuel substitution, or simply in lower consumption levels.

If the uncertainty in the base-year assessment of woody biomass supplies is large, then the uncertainty in future supplies is enormous. The number of trees being planted annually by firewood users has been estimated as part of the HESS demand survey. In contrast, the trend in tree-planting cannot be estimated. The HESS household energy demand survey estimated that about 120 million trees were planted by firewood-using households in 1991. This is clearly a significant number, but it is impossible to know for how long this level of tree planting has been taking place. Variations in the assumptions about the levels and trends in tree-planting by farmers make a tremendous difference in determining the future sustainability of Pakistan's wood resources. They therefore play the most important role in the following discussion of scenarios. The following scenarios will demonstrate the importance of the level of tree-planting by farmers for the future viability of woodfuel sustainability.

The following discussion presents three scenarios. One of them is extremely pessimistic, one uses observed numbers to paint a more moderate picture, and the third is more optimistic. The discussion will then focus on lessons which can be learned from the scenarios taken as a whole. These lessons prove to be important in the formulation of a household energy policy.

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[14] This relative insensitivity of fuelwood use may be a relic of the fact that the HESS demand model uses only cross-sectional data to forecast demand through time. If time-series data were available, this conclusion might be altered somewhat. However, results from other countries, notably Tanzania (Hosier, 1993) and Indonesia (Pitt, 1986) has indicated that there is little relationship between wood consumption and the prices of modern fuels.

1) Pessimistic Scenario: No Tree Planting by Farmers

The first scenario assumes not only that current consumption levels will continue as represented in the HESS Demand model, but also that no trees are planted by farmers. The 1991 woody biomass supply estimates developed as part of the HESS project (Archer, 1993) are not supplemented further by planted trees. Neither rural households nor wood users respond to the increased scarcity of fuelwood in any way. Although these assumptions represent a radical extreme, they are very unrealistic, as previous work has shown farmers to be actively engaged in tree-planting (Leach, 1993). However, this extreme case demonstrates the relative unsustainability of Pakistan's fuelwood supply system under this dire set of assumptions.[15]

Figure 3 presents the results of this scenario with respect to national wood stocks. Figure 4 summarizes its results with respect to the wood supply-demand balance. According to the results of this scenario, all existing tree stocks would be destroyed by the year 2000. None of the trees included in the HESS biomass assessment are projected to survive, and since the scenario assumes that no trees are planted, all wood stocks in the country disappear. The projected wood gap would become enormous, and beginning in the year 2000, all projected demands for woodfuel would have to be met from other fuels, either modern or traditional.

According to these assumptions, Pakistan's forest resources would be destroyed in order to meet the country's needs for wood energy. As was indicated above, the assumptions embodied in this scenario are extremely unrealistic. Households do plant trees, and if faced with a shortage of woodfuel, they will shift to using other fuels or even reduce consumption. However, the scenario is useful as it demonstrates that Pakistan's wood resource system is presently not sustainable without the efforts of the local population to plant trees.

2) Intermediate Scenario: Observed Levels of Tree Planting

The second scenario embodies the level of supply, consumption, and tree planting as estimated by the HESS project. The initial stock levels are those estimated by Archer (1993) and the wood consumption levels are those derived from the HESS demand model. However, in contrast to the assumptions embodied in the previous scenario, the level of tree planting is set to equal the obvious levels, about 125 million trees per year. Each tree which survives is assumed to grow to a total mass of 179 kg at the end of 10

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[15] Although the discussion here points to the unrealistic nature of assuming that no trees are being planted, this assumption has been common to many of the base-case scenarios resulting in the most infamous "gap" projections.

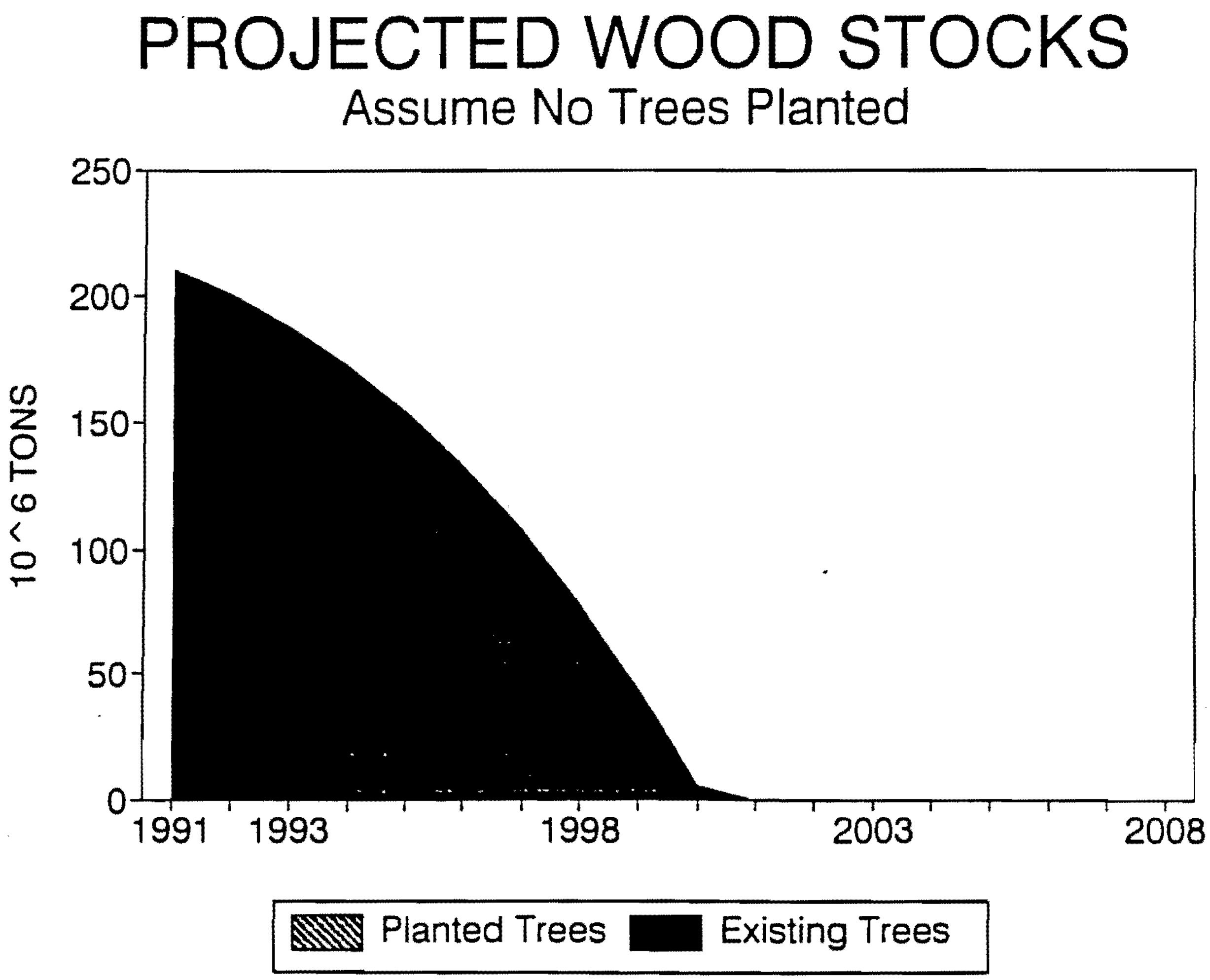
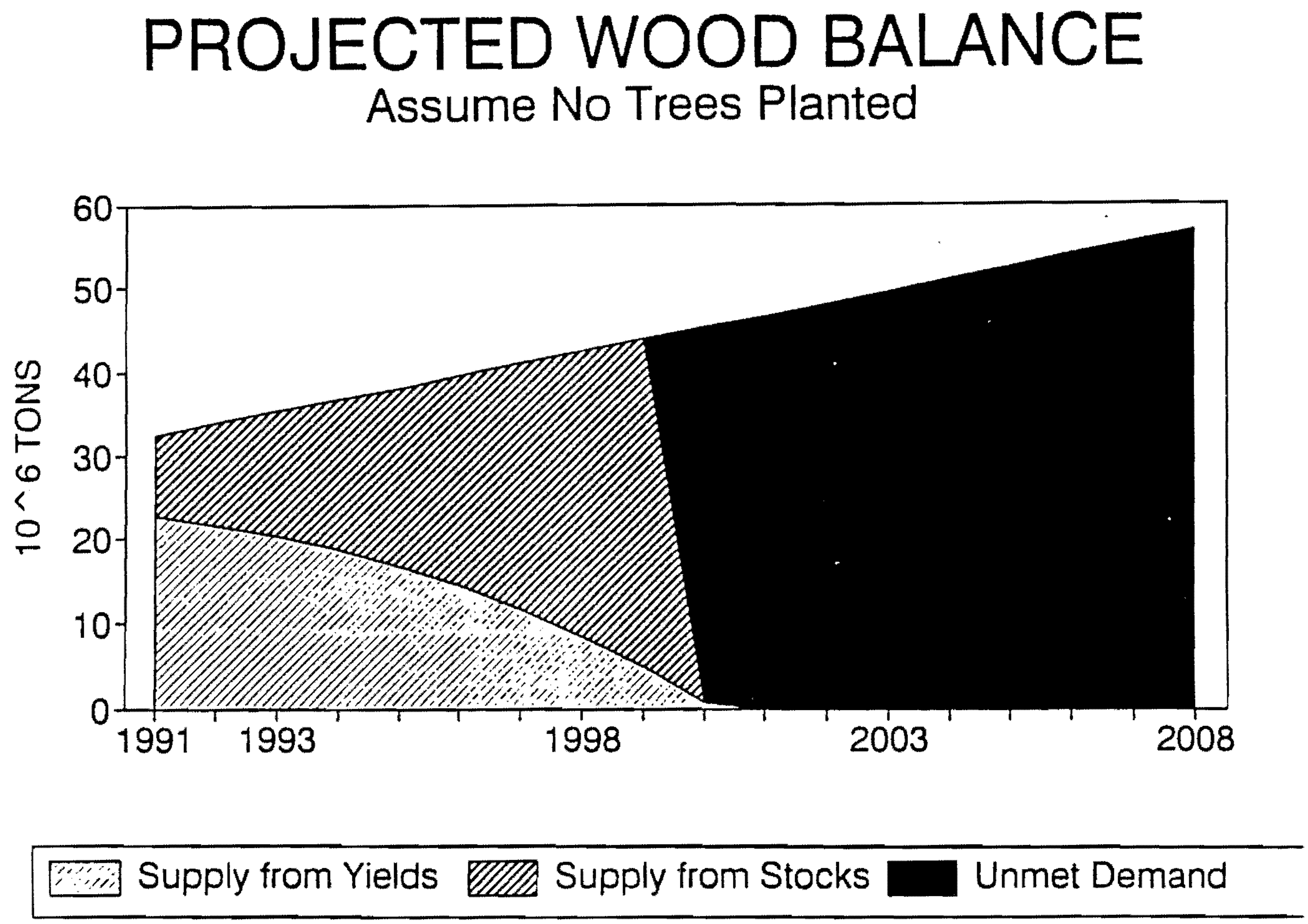

PROJECTED WOOD STOCKS
Assume No Trees Planted
250
200
150
100
50
0
10 ^ 6 TONS
1991
1993
1998
2003
2008
Planted Trees
Existing Trees

Figure 3



PROJECTED WOOD BALANCE
Assume No Trees Planted
10 ^ 6 TONS
60
50
40
30
20
10
0
1991
1993
1998
2003
2008
Supply from Yields
Supply from Stocks
Unmet Demand

Figure 4

years, at which point it is felled and uprooted, leaving no stump for coppice production. The growth curve for a planted tree is represented by the curve in Figure 5. Furthermore, the scenario projections assume that 75% of the trees planted on farms survive to maturity.

The results of this second scenario are presented in Figure 6 for wood stocks and Figure 7 for the wood demand-supply balance. This scenario results in three important phases which are present in both figures. The first phase is an adjustment period, extending until about 1996. During this period of time, the trees being planted by farmers are maturing, but have not yet begun to be harvested.[16] As a result, all wood requirements are met from the cutting of existing trees and the yields from those trees. After 1996, yields are available from planted wood stocks, and these help to slow the pace of stock-cutting. But the adjustment period is an important phase about which more will be said below.

The second phase extends from 1996 until about 2003 and involves the increasing supply of wood from planted trees, and the gradual destruction of existing wood stocks. During this period of time, planted trees become increasingly important in supplying wood needs as production and stock-cutting from existing trees declines. By the end of this period, the existing tree stocks are depleted, leaving planted trees as the sole source of firewood.

The third phase begins in about 2003 and extends through the end of the projection period. During this time period, all fuelwood is drawn from planted trees, as existing stocks have already been consumed. There is a considerable shortfall of wood supplies which must be met from either other biomass fuel resources or modern fuels. Even under this relatively optimistic assessment of tree planting and survival, wood supplies are inadequate to meet consumption requirements at projected levels over the next 15 years.

Under the assumptions embodied in this second scenario, Pakistan's woodfuel supply system does not appear to be sustainable. However, it does begin to shift from a reliance upon existing trees to a reliance upon trees planted expressly for use as timber and fuel. The scenario is based upon several assumptions which are not known with any degree of certainty. The question about when tree planting efforts began remains unanswered. Additionally, there is no reason to assume that tree-planting efforts will not intensify with increasing pressure on scarce wood

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[16] One question which remains unanswered by the data gathered through the HESS project is when this relatively high level of tree-planting began. The assumptions used for these scenarios place the beginning of tree planting at the rate of 125 million per year at four years prior to 1991. Hence, harvests are able to begin about 1996. Varying this assumption will either prolong or shorten the nature and severity of the adjustment period. More is said about this question in the text.

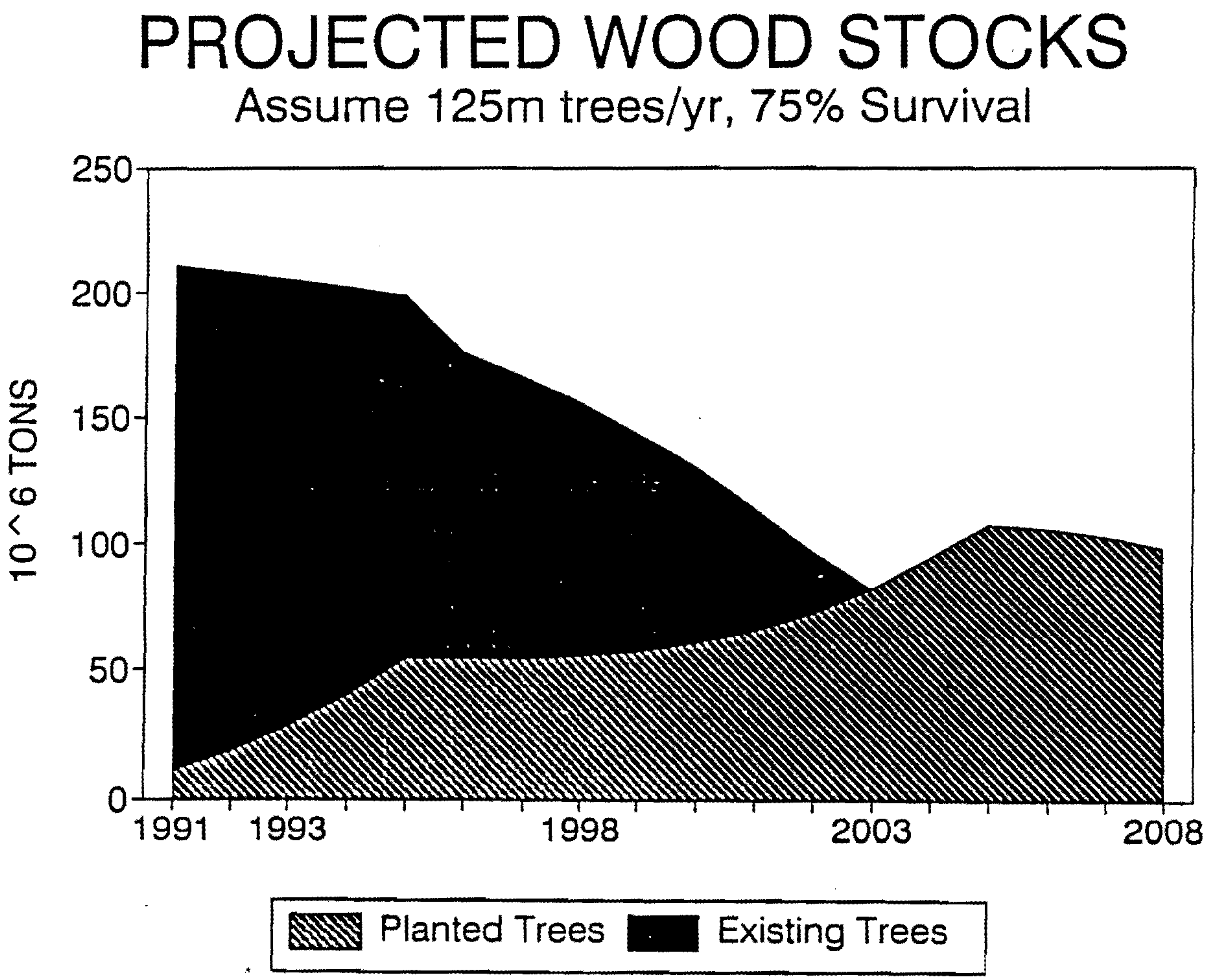

PROJECTED WOOD STOCKS
Assume 125m trees/yr, 75% Survival
10 ^ 6 TONS
250
200
150
100
50
0
1991
1993
1998
2003
2008
Planted Trees
Existing Trees

Figure 5

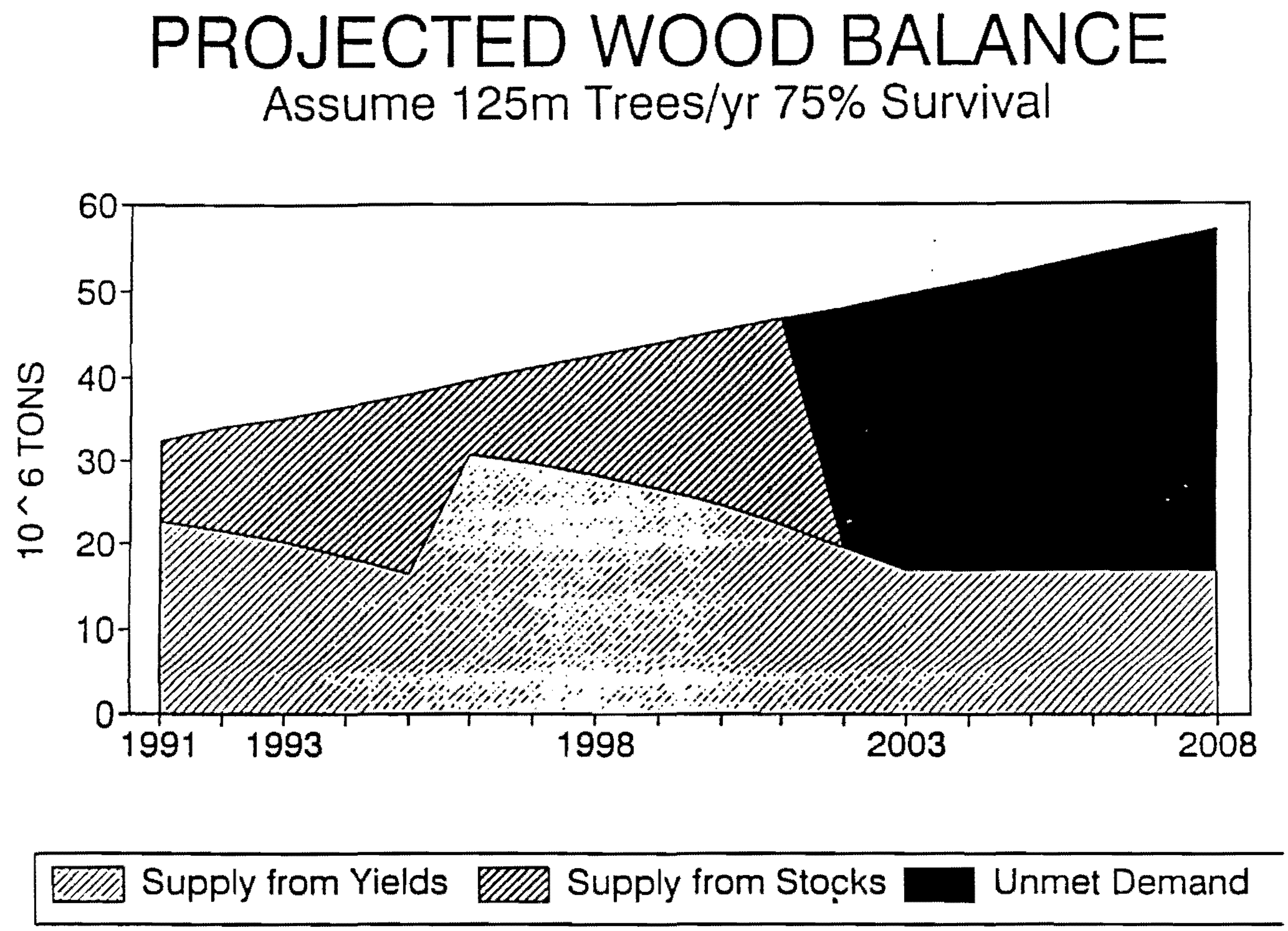

PROJECTED WOOD BALANCE
Assume 125m Trees/yr 75% Survival
10 ^ 6 TONS
60
50
40
30
20
10
0
1991
1993
1998
2003
2008
Supply from Yields
Supply from Stocks
Unmet Demand

Figure 6

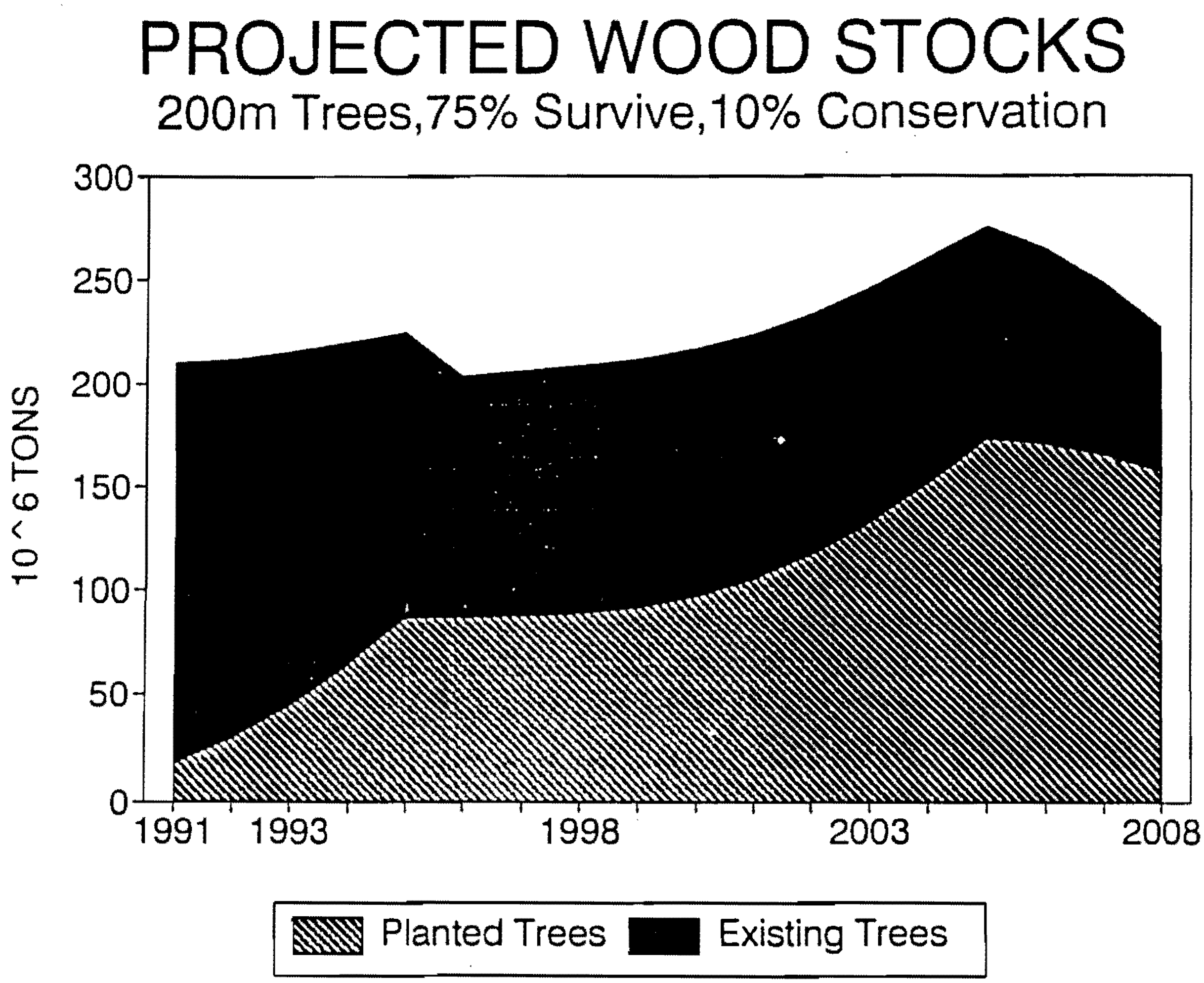
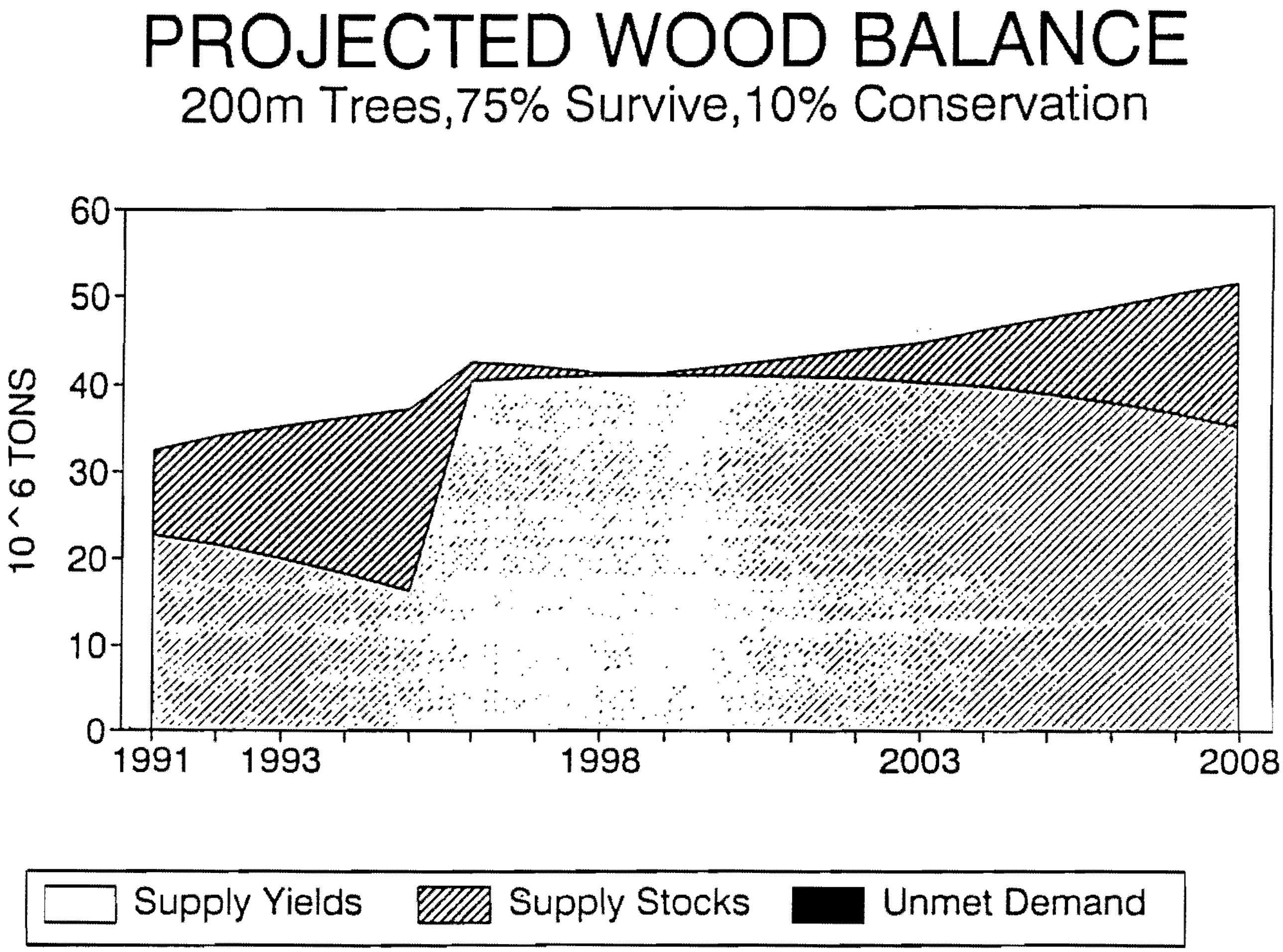

PROJECTED WOOD STOCKS
200m Trees,75% Survive,10% Conservation
300
250
200
150
100
50
0
10 ^ 6 TONS
1991
1993
1998
2003
2008
Planted Trees
Existing Trees

Figure 7



PROJECTED WOOD BALANCE
200m Trees,75% Survive,10% Conservation
10 ^ 6 TONS
60
50
40
30
20
10
0
1991
1993
1998
2003
2008
Supply Yields
Supply Stocks
Unmet Demand

Figure 8

resources. Also, evidence from other countries might indicate that households will reduce consumption patterns when faced with wood scarcity. Thus, the situation represented in Figures 6 and 7 will probably never come to pass. Rather, the true situation will resemble one with greater adjustments and scarcity responses which will not involve the destruction of Pakistan's forest resources. However, the three phases identified above are present in virtually all scenario combinations except the one which assumed no tree planting.

3) Optimistic Scenario: Increased Tree Planting and Conservation

If the assumptions behind the scenario are altered to allow a more favorable outcome, a more optimistic scenario can be developed. Under this scenario, two important assumptions are changed. First, the scenario allows for a limited amount of fuelwood conservation not already included in the HESS Demand forecast. This wood-saving is assumed to take place because of the adoption of improved stoves by a significant sector of the wood-using population. For the last 5 years of the scenario (2003 to 2008), total wood consumption is assumed to be only 90% of its projected level due to conservation. For the 5 years from 1998 to 2003, conservation is expected to reduce total wood consumption to 95% of projected levels. Although these reductions in projected demand seem modest, they are in-line with a realistic assessment of the impact of improved stove dissemination.

The second important change in the scenario assumptions involves the anticipated level of tree-planting. For this scenario, the assumption is that farmers will plant 200 million trees per year total. The scenario assumes that 75% of these trees survive for 10 years, and they are completely cleared and uprooted at that time. The growth curve for the planted trees is the same as that presented for the previous scenario. The only change between this scenario and its predecessor is the number of trees planted. This scenario assumes that there are 200 million trees planted instead of the estimated 125 million trees.

The results of this third scenario are presented in Figure 8 in terms of wood stocks and in Figure 9 in terms of the demand-supply balance. The wood stock graph demonstrates the same three phases as its predecessor: the adjustment period; the period of increasing yields from planted trees; and the demise of previously existing wood stocks. Although existing stocks do not completely disappear by the end of this scenario period (2008), they would be destroyed by several years after the scenario period ends (ca 2012). Thus, production from existing tree stocks must eventually be replaced by production from planted tree stocks. Even at the level of 200 million trees being planted per year, the production from planted tree stocks is not sufficient to meet projected demand indefinitely.

Figure 9 demonstrates that with a 10% annual reduction in wood demand and the product from 150 million surviving trees coming on-line beginning in 1995, there is never any "gap" or failure to meet projected wood demand. After the initial adjustment period, very little stock-cutting is estimated to take place, allowing overall levels of wood stocks to increase through about 2005. Stock-cutting then continues to grow at a pace which leads to the eventual destruction of existing forest stocks, and the reliance upon planted wood resources as the sole source of fuelwood for Pakistan.

C. Lessons from the Scenarios: Elements of Sustainability

These scenarios has highlighted several important points which bear further discussion as elements of household energy policy in Pakistan. The fact that all of them share common elements means that they can be used to develop a set of lessons for consideration and further investigation. Five of the lessons from this scenario-building exercise are discussed below as a prelude to a more detailed discussion These lessons, and not the description of the wood "gap", represent the contribution of the scenario-building exercise.

1) Lesson One: The Transition from Existing to Planted Trees

Pakistan's wood energy system is in a transitional phase between a reliance upon existing trees and a high throughput system dependent upon trees planted deliberately for use as timber and fuelwood. This first lesson becomes apparent in the last two scenarios, and it is reinforced by an examination of the first scenario. In none of the scenarios are existing trees sufficient to meet projected wood needs indefinitely. Existing wood stocks always decline. This means that for the wood-energy system to be sustainable, more trees must be planted and managed deliberately for wood production. The bounties of nature will be inadequate to meet future needs, and must be supplemented by human activities. The transition to a high-input/high-output woodfuel system is more advanced in some regions than in others, but it is essential that farmers in all regions of Pakistan begin to plant and manage trees on a more active basis.[17]

This phase of transition to planted woodfuel is similar to, but different from the adjustment period discussed in the context

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[17] The biomass productivity estimates have been undertaken using the assumption that net annual productivity occurs as an annual throw-off, estimated in the supply estimation exercise as relative growth rates (RGR's--see Archer, 1993). The results of the exercise might be very different if a portion of the trees were considered to be planted deliberately for clear-felling. If that is the case, then yields would probably be higher and the destruction of existing forest stocks would be neither as rapid or inevitable.

of Figures 6 through 9. In that discussion, the adjustment period was thought of as the initial five years of the scenario during which time planted trees mature, but are not yet ready for harvesting. The transition phase can be thought of as a broader time period encompassing the entire scenario and the transition from reliance upon existing trees to planted trees. The two are linked in that the further along the transition to planted woody biomass is, the shorter the adjustment period. One of the informational shortcomings with the scenario-building exercise is that we do not know for how long farmers have been deliberately planting trees on farmland for timber and fuel. If farmers have been planting trees for a long period of time, then there is in reality no adjustment period as represented in these scenarios.

It is likely that this transition to planted woody biomass is relatively advanced in some areas of the country. However, in others, it is probably less well advanced. For example, in the more recently settled Barani areas, households may still be burning old-growth wood which has been harvested as part of the land clearance process. Once this old-growth timber has been consumed, residents will have to rely upon new-growth or planted timber. Assistance will be required to ensure that this transition occurs without excessive environmental degradation. In the irrigated regions, continuous settlement and cultivation has existed for a long period of time. As a result, fuelwood demand has been met from planted trees for a long time. This transition is much further advanced than in the dryland farming areas.

The sooner this transition to planted trees takes place, the longer existing wood stocks will survive, and the closer Pakistan's wood energy system is to becoming environmentally sustainable. This transition appears to be a natural response to increasing population pressure in the Boserupian sense. However, there may be hitches in the transition, and these hitches can result in serious environmental degradation and social disruption. It is therefore in the interest of government to ensure that the transition to planted woody biomass from existing biomass take place as smoothly and naturally as possible.

2) Lesson Two: Levels of Tree Planting and Tree Farming

As highlighted by the scenarios and mentioned in the discussion of transitions, the level of tree planting is critical to the future sustainability of Pakistan's forest resources. The major difference between the second and third scenarios is the level of tree planting: the third scenario represents 60% higher levels of tree planting. For the period up until the year 2008, this appears to be an adequate level of tree planting to ensure the sustainability of the woody biomass energy system. To ensure its survival after the year 2008, a high level of tree planting will have to be achieved.

The question then becomes what is the driver behind farmers' planting of trees. The answer from the HESS survey is that farmers are planting trees for the production of timber for sale (Leach, 1993, p. 15). Of those farmers planting trees, 44.9% claimed to be planting them primarily for timber, and about 30% claimed to plant trees principally for fuel. Another 10% planted trees primarily for fruit while the remaining 15% claimed to plant trees mostly for shade and environmental improvement. The timber market, with its increasing prices for higher quality products appears to drive farmers' desire to plant trees. Firewood is of secondary importance, but is a valuable by-product of timber production. To the extent that farmers are anxious to supply timber markets, their efforts at tree-planting will also provide fuelwood for use in households. Thus, by following market signals for greater quantities of higher quality wood, tree-planting farmers are also helping supply the country with fuelwood. Keeping their involvement with tree planting at a high level is important for the future sustainability of the woodfuel system.

3) Lesson Three: Critical Role of Tree Management

The third obvious lesson from the scenarios is closely related to the second. Tree management is every bit as important as tree-planting. No one benefits if nurseries turn out millions of tree seedlings which fail to survive to maturity. For example, improving the survival rate from 75% to 90% in the second scenario has the same impact as increasing the number of trees being planted from 125 to 150 million with 75% survival. Improving the quality of seedlings being distributed or sold can help improve their survival. But more importantly, the way in which trees are planted and protected will determine their survival. There is an important role to be played in monitoring and assisting farmers to ensure that once planted, trees survive to maturity.

There is also an important role to play in improving the management of existing trees for firewood production. Yields from existing trees can be increased through more intensive management. Some of the trees being harvested for firewood, timber, and poles do coppice well, and yet the woody biomass assessment identified little evidence of coppice management. Once harvested, tree stumps will frequently be dug out instead of being managed for coppice production. In contrast, lopping or pollarding of branches appears to be a very common practice throughout Pakistan. Techniques to improve yields from coppicing, lopping, and pollarding can be investigated and disseminated to farmers to strengthen their knowledge and yields in this area. Improving the production from planted and existing trees is as important as planting trees in ensuring the sustainability of future wood-energy system. In this way, government's efforts can build upon and strengthen the efforts already being undertaken by local residents.

4) Lesson Four: Importance of Improved Efficiency & Substitution

The fourth lesson that the scenarios bring home is that improvements in the efficiency of wood use and the substitution away from fuelwood are important considerations. The wood shortfall is so large that even modest achievements in this directions to reduce the pressure on wood resources are not to be scoffed at. Conservation due to enhanced efficiency is attractive to households when it is fiscally profitable. Interfuel substitution to modern fuels results naturally from increases in income. Substitution to lower quality biomass fuels results from fuelwood scarcity, lowered incomes, and lack of access to land. All of these processes result in decreased wood consumption result from natural processes. Energy policy should encourage and strengthen these natural processes, especially since working against them is likely to be futile. Promoting "efficient" stoves which are not cost-effective and encouraging households to switch to economically unattractive modern fuels are unproductive, unsustainable strategies.[18]

In this regard, if market forces begin to signal wood scarcity, woodfuel price increases will encourage consumers to reduce consumption of fuelwood. So long as the primary source of fuelwood is production from privately-owned sources of land, energy policy can do little to force markets to demonstrate depletion effects. While some authors have focused on the role of stumpage fees to raise revenues and ensure that the full economic costs of fuelwood production are being paid by final consumers (Openshaw and Feinstein, 1989), these are only applicable to cases where fuelwood is drawn from public-held land. When it is drawn from private land, the land-owner is assumed to be compensated for the total opportunity of producing the wood, including any environmental externalities. The market price of fuelwood grown on private land is assumed to reflect these market externalities. There is therefore no need to raise stumpage taxes on this wood, which is sensible as their collection and enforcement is difficult if not totally impractical.

The baseline demand projections used for these scenarios includes some limited interfuel substitution. The third scenario includes a reduction in the projected levels of wood consumption which is important to make the fuelwood supply system sustainable. Government's role is to encourage interfuel substitution and

[18] The stove literature is replete with examples of "fuel-efficient stoves" which are thermodynamically less efficient than the open fire. Gill relays a history of quoting efficiencies that have no scientific basis, and Prasad et al. point to the impossibility of high-mass stoves being more fuel-efficient than low-mass alternatives. See Gill, Jas, Gil, Jas. 1987. "Improved Stoves in Developing Countries: A Critique," Energy Policy 14,4: 135-144. and Prasad, K. K.; E. Sangen; and P. Visser, 1984. Woodburning Cookstoves. Eindhoven: Eindhoven University of Technology, Woodburning Stove Group.

conservation, not through large, costly programs, but through making the technology available, and ensuring that the markets for household fuels work as freely as possible to incorporate all aspects of wood production into its market price. Market interference from government in the form of subsidies for one fuel or another or stumpage fees applied to wood produced on private land is not warranted. Market forces, if allowed to operate, will help solve the shortage of woodfuel. Government's role is to encourage those markets to operate.

5) Lesson Five: Population Growth without Development Leads to Eventual Forest Destruction

All three scenarios presented in this chapter demonstrate an eventual decline in forest stocks. In the pessimistic scenario, existing wood stocks are completely destroyed within the first decade following scenario initiation. In the case of the second scenario, existing forest stocks are depleted within 15 years of the base-year. In the final scenario, forest stocks last considerably longer, but will be destroyed by the end of 25 years. In all three cases, no matter what the level of tree-planting, population growth eventually drives fuelwood demand so high that it leads to the destruction of forest stocks.

This eventual demise of forest supplies is something of a Malthusian relic. While previous chapters have argued that technological innovation can provide solutions to these population-pressure problems, innovation cannot extend forest resources indefinitely. There is still some limit to reasonable levels of innovation, efficiency improvement, and tree-planting. Eventually, Pakistan's population growth will have to slow or incomes will have to increase sufficiently to allow households to purchase modern fuels. But rapid population growth without accelerating economic growth will eventually lead to the destruction of natural forest resources. The Malthusian spectre cannot be kept at bay indefinitely.

The implications for government policy are twofold. First, family-planning programmes should continue to be given a high priority. As has been argued by others examining farm forestry, population growth must slow down to enable Pakistan to live in harmony with its natural resource endowment (Hocking et al., 1992). Technological innovation cannot be counted upon indefinitely. Second, economic growth is essential to enable more households to shift to modern fuels. The reference-case demand forecast assumes that income will grow more rapidly than population over the scenario period. However, even this optimistic assessment of economic growth is not enough to ensure that the pressure on wood resources is reduced through substitution toward modern fuels. Continued economic growth and reduced population growth are essential to ensure the long-run sustainability of Pakistan's wood resources and to guarantee that environmental degradation from the use of lower quality biomass resources does not render Pakistan's land resources infertile and degraded.

CHAPTER IV SUMMARY

Despite its pitfalls, scenario-building can be a useful heuristic enterprise. Its usefulness lies not in projections of the future or estimates of the year in which a "gap" appears, but rather in the lessons it provides the planner about the system being modelled--in this case, Pakistan's wood energy system.

The analysis presented in this chapter contains three scenarios: a pessimistic one incorporating no tree planting or conservation; an intermediate scenario incorporating observed levels of tree planting; and an optimistic scenario embodying increased tree-planting and wood conservation. Although these scenarios do concur that Pakistan's wood-energy system is under considerable pressure, they also demonstrate that it is possible for the system to be sustainable for the immediate future, even though the heavy reliance on woodfuel cannot continue indefinitely.

First, Pakistan's wood energy system is undergoing (or in some regions has already undergone) a transition from reliance upon old-growth existing trees to planted trees grown on farmland. Although some regions are doubtless ahead of others in this transition, eventually all woodfuel must be drawn from planted trees. The speed of this transition is important as it holds the key to the sustainability of the nation's wood energy system.

Second, the level of tree planting on farmland is critical to woodfuel sustainability. The greater the number of trees actually being planted, the closer the system comes to sustainability. With a minimal level of woodfuel conservation and relatively high survival rates, an increase in the level of tree-planting from 125 million to 200 million trees per year appears to be sufficient to meet projected woodfuel needs through 2008. Beyond that, even greater levels of tree-planting will be required.

The third lesson accompanies the second one: the management of both planted and existing trees is very important. Farmers must keep the trees they plant alive through to maturity as well as finding ways to increase wood yields from existing trees. Improved tree management is essential to a sustainable, high-throughput wood-energy system.

Fourthly, even limited levels of fuelwood conservation and interfuel substitution away from wood have an impact on the sustainability of the woodfuel system. Market signals will encourage both the enhancement of efficiency and the movement to alternative fuels. Government's role is not to interfere with these markets, but to improve impediments to their ability to send proper signals.

Finally, even with a reduction in projected demand and an increase in tree-planting initiatives, woodfuel demand fueled by unbridled population growth will eventually outgrow supply potential, unless sufficient economic growth occurs to allow large net shifts toward modern fuels away from fuelwood. Rapid economic growth and population control are essential components of an overall programme to make the fuelwood supply system sustainable.

actually surviving to maturity. No good estimates of the survival rate of tree seedlings once they are planted on farmland exist--all such estimates are based upon impressionistic data. For example, one informed observer estimated the survival rate of trees planted on irrigated farmland to be as high as 85-90%, especially when the farmers had to pay for the seedlings (Charles Hatch, personal communication). Another estimate is that on average, about 60% of the trees planted from seedlings survive to reach maturity (Dr. A. Siddiqui, personal communication). However, estimates for the survival rates of trees planted outside of private farmlands are much lower. The 75% figure used in the previous chapter is an optimistic assessment based upon the judgement of a number of different informed observers. The true figure, and how it changes through time, is important for future monitoring activities.

The number of trees planted varies tremendously not only by year, but also by agroecological region. According to the HESS survey results, the number of trees planted per capita vary from a low of 0.2 in Barani areas and 0.03 in the Southern High Productivity Irrigated Areas to 1.3 in the Northern High Productivity Irrigated Areas and 1.5 in the Semi-Arid Areas (see Table 8 in Chapter 2). Tree-planting has a long history of tree planting in various regions of Pakistan. The tradition of *hurries* or block plantations in Sindh Province has encouraged farmers to grow acacia trees on wasteland and irrigated farmland (Leach, 1993). The Punjab Forest Department began actively promoting tree-planting on private farmland in the 1950's (Hocking et al, 1991).

This evidence goes to demonstrate that farm forestry is an established practice in Pakistan. Efforts to promote tree-planting are not beginning from a zero base. Additional efforts are required to make woodfuel sustainable, but these should begin with supporting existing initiatives and not attempting to replace them by starting from scratch or "reinventing the wheel." It is possible that by being too heavy-handed or misguided, policy initiatives can decrease the attractiveness of tree-planting. All efforts need to be made to ensure that farmers enjoy security of tenure and understand that the products of trees planted on their farmland are theirs to harvest and sell. The uncertainty of tree tenure is an important disincentive to tree-planting by farmers (Leach, 1993).

2) Reducing Volatility

Because current policy initiatives are looking to the free market to stimulate the planting of more trees on farmland in Pakistan, there is a danger that policy initiatives will lead farmers to respond by planting more trees than are needed. If this were to happen, this would lead to a decrease in the price of wood and considerable volatility in the planting of trees. In fact, Leach (1993) has pointed to a tree bust in Northwest India. This was created on by ambitious policy efforts reinforcing tree-planting in response to temporary increases in the price of wood products, particularly poles. As a result, many farmers planted trees which they now cannot sell profitably. Although the size of the wood shortfall presented in the previous chapter makes the possibility of a tree-product bust seem remote, the possibility that a glut may occur in the market for tree products still exists.

From a less alarmist perspective, a certain amount of volatility in the market for wood products is common throughout the world. For example, forest cover in the United States reached its all-time low at the end of the 19th and beginning of the 20th centuries. Since that time, the percent of the country under forest cover has varied on an annual basis (Clawson,). Analysis has shown that changes in tax codes and regulations regarding land-use can significantly change the amount of private land under forest cover. While some fluctuation in forest cover is normal, dramatic changes in regulations and taxes can lead to large, rapid changes in the land under forest cover. Although forestry levels throughout most of Western Europe fluctuate in much the same fashion,[19] the goal of forest policy in most countries is to maintain a stable, positive environment which encourages forestry without relying heavily upon subsidies, price supports, or price controls.

For Pakistan, a certain amount of volatility in forest cover might be expected. However, this does not mean a steady decrease in the land under forest cover, as was documented in previous chapters. Like in other market economies, the goal should be to establish a stable policy environment which encourages the planting, management, and harvesting of trees on private agricultural land. The question becomes what is the best way to achieve this goal. The argument advanced in this paper is that the best way to achieve this is through allowing the market to operate unhindered rather than through attempting to manage a complex system of price supports and subsidies. Government's role should be to encourage and support private afforestation, but not through dictatorial means or subsidies. In fact, the use of forest product price supports and subsidies are more liable to lead to greater market volatility than an approach which lets an unregulated market send the price signals.

If the market is allowed to dictate tree-planting rates to farmers, there is a much more limited chance to "overshoot" required tree-planting rates. This may be one of the true causes of the pole "glut" in northwest India. The Indian social forestry

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[19] In the forest economics literature from Sweden, there is a factor called the "Volvo" factor which serves to randomly lead farmers to harvest their trees early. Whenever a forest farmer needs a new car or Volvo, he is liable to harvest a plot of his trees early. For more details, see Johannsen and Lofgren, 1987.

CHAPTER V

Policy Options

In the previous chapter, the discussion focused upon the lessons drawn from alternative scenarios with respect to the sustainability of Pakistan's wood energy future. This chapter turns to a discussion of the policy options which will have to be pursued in order to make Pakistan's wood energy system sustainable. As discussed previously, these policies incorporate greater emphasis on tree planting, the improvement of the efficiency of wood use, and interfuel substitution. In addition, this chapter devotes attention to increased monitoring of the fuelwood situation as this is essential for policy makers to track progress and important trends in the field.

In all of these areas of intervention, the woodfuel system itself, through market and non-market feedback, is already encouraging households and farmers to plant trees and substitute alternative fuels in place of firewood. The solutions to the fuelwood problem (tree-planting, interfuel substitution, and conservation) are all natural responses to market and non-market signals. Policy makers should not view themselves as the initiators or inventors of solutions to the impending fuelwood shortage, but rather as late-comers supporting the existing efforts of the local population to solve their own problems. Their eyes and ears need to be accutely attuned to the problem however, as many obstacles can complicate the transition to a planted, sustainable woody-biomass energy future. It is important that policy-directed efforts build upon and strengthen initiatives to solve the firewood shortage rather than re-inventing the problem and the solution.

A. Tree Planting

Previous discussions have made clear the fact that the level of tree-planting is extremely important to ensure the continued viability of the wood-energy system. In fact, unless about 200 million trees are planted per year, the scenarios show that the nation's remaining trees will be depleted in the near future. However, there are many questions about the levels and forms of tree-planting which still need to be answered. How possible is this target of 200 million trees being planted per year? What are the risks of over-supply that this level of effort poses? Are forest farming for timber and energy compatible objectives? Can farm forestry provide the same environmental benefits as plantation forestry or natural forest management? These are policy-related questions which need to be asked in a discussion of the continued sustainability of the wood-energy system.

1) Current Levels of Tree Planting

The results of the HESS consumption survey have demonstrated that farmers are already planting trees in significant numbers. In total, the survey results estimate that firewood users planted about 112 million non-fruit trees in 1991. They also planted an additional 13 million fruit trees in the same year. This brings the total number of trees planted by fuelwood users in 1991 to 125 million (Leach, 1993). As was shown in the preceding chapter, even if all of these trees survived to maturity, this number is insufficient to maintain stability in the supply of woodfuel. But as the scenarios demonstrated, it is necessary for the level of trees being planted to appraoch 200 million per year and a large fraction of them surviving for the woodfuel system to achieve sustainability for the immediate future.

How many trees actually are being planted on an annual basis? Apart from the survey estimate, it is difficult to know as no one source keeps comprehensive track of the numbers of tree seedlings planted. The US-AID sponsored Forestry Planning and Development Project, which works only in Barani areas (about 9 Districts), distributed about 33 million trees to farmers in its project areas during Fiscal Year 1990/1991 (US-AID, 1993). The Pakistan Forestry Research Institute estimates that for 1990, approximately 174 million seedlings were produced, of which about 60 million were given to private farmers and the remainder were planted to forest lands (Siddiqui, personal communication). Typically, between 30% and 40% of the seedlings produced by the forestry department end up being planted by farmers. In 1993, the Forestry Department estimated that it produced about 186 million tree seedlings for distribution (Forestry Department Minutes, 1993). Again, it is not clear what fraction of these seedlings are distributed for farm forestry and what fraction are planted on private land.

Although these estimates from the Forestry Department are supposed to include seedlings produced as part of the US-AID Forestry Support Program, they do not include all seedlings produced in the country. The wood management and practice survey carried out as part of the HESS Biomass Survey contained questions about where farmers planting tree seedlings had obtained them (Archer, 1993). About 30% obtained their seedlings from government nurseries and another 10% obtained them from private nurseries. But the largest share (59%) claimed to grow their own seedlings from cuttings and seeds. If this percentage is used to expand the number of seedlings obtained from official sources, then it is possible to see that 100-120 million tree seedlings being planted per year is not an unrealistic assessment of the level of tree planting by private farmers. Although 125 million trees is not sufficient to make wood resources sustainable, the step to 200 million trees from 125 million is a far smaller step than the step to 200 million trees from no trees.

However, on another level, the number of trees being planted is insignificant compared to the importance of the number of trees network is fraught with subsidies and price controls. Thus, interference with the market may be the culprit in the pole glut or bust in northwest India. Clearly, a more careful analysis is needed before the lessons from this problem area are applied directly to Pakistan, which has a very different tradition of government involvement with the market.

Two other points deserve mention in the context of reducing the volatility of wood markets. First, it is important that farmers be given correct information about the prices for various forest products. Forestry extension officers must make a point of providing farmers with a truthful (ie., unexaggerated) view of the gains to be made from planting trees. Farmers should also be made to realize that if the market is unfettered, prices will fluctuate. In this way, they can be provided with correct information which they can utilize to make a thoughtful decision about how much of their land to plant to trees.

Second, if the demand for timber is increasing, farmers are less likely to face falling prices for timber due to an oversupply than if the demand for timber is falling. Thus, the stimulation of the commercial demand for timber is an important action that can be taken to avoid a timber glut or bust. Despite a commonly-held misapprehension that a growth in timber demand will lead to a shortage of wood for fuel, timber and fuel demand are quite complementary, as indicated in the following discussion.

3) Timber vs Fuel Supply: Compatible Alternatives

At first glance, increasing the supply of timber and the supply of fuelwood seem to be incompatible alternatives. Simple reasoning would have it that timber can be burned and some firewood can be used for commercial purposes. However, this reasoning is not entirely sound. To be used as commercial timber, firewood must meet certain quality specifications. Depending upon the final end-use of the wood, a certain amount of wood is wasted during its harvesting and processing. If this waste wood is made accessible to firewood users, it can end up in the fuelwood stream. In fact, depending upon the efficiency of the saw-mills employed, a majority of the wood in any standing tree may eventually be used as fuelwood.

Whether a tree is grown on commercial plantations or on private farmlands, there will always be an element of waste when it is harvested. In Pakistan, about 50% of the standing biomass of a tree grown on farmland can be estimated to be bole wood, the commercial heart of the tree. This bole is removed from the site on which the tree was grown, leaving branches, stems, and leaves (the remaining 50%) on site. Depending upon harvesting agreements, this waste-wood is either sold as firewood or left to be collected. In any event, very little of this branchwood goes to waste. Of the half of the tree removed from the site, this is then taken to a sawmill, where up to 50% of the bole ends up as slabs or off-cuts.

Again, these slabs or off-cuts can wind up in the fuelwood stream. In total, up to 75% of any tree which is harvested for the timber market can wind up as part of the fuel stream.

This explains the seemingly contradictory reasoning behind the promotion of timber industries to increase the supply of firewood. In general, an increase in the supply of timber trees will lead to an increase in the supply of firewood. Except in the case of whole-tree harvesting, increasing both timber and fuelwood supplies appear to be compatible options. On the other hand, there are some forest industries whose growth is not compatible with making increasing supplies of timber and fuelwood available. The promotion of industries making use of whole-tree harvesting and processing should probably be very carefully considered, as it would represent the only way in which timber and fuelwood supplies cannot be increased simultaneously.

4) Forestry Benefits and Tree Farming

Discussions of forests and their benefits normally include an assessment of the environmental benefits to be derived from forests. These include such factors as reduced soil erosion, increased soil-water infiltration, reduced local temperatures, enhanced watershed protection, and aesthetic amenities. While these benefits normally accrue in cases of closed forests, they are normally outside of normal market forces. As a result, they justify a certain level of government intervention to protect and maintain forests.

These benefits can only be partially attributed to trees growing on private agricultural land. There is a small reduction in soil erosion which can be attributed to line plantings and hedgerow plantings, and trees on private land certainly private environmental amenities, such as shade. However, trees on private land do not provide the same level of public amenities as do closed forests. They behave, and should be treated in a manner similar to perennial cash-crops. Therefore, their harvesting and management should not be subjected to special government regulation, but rather left to the discretion of the private land manager.

The points being emphasized through this brief discussion are twofold. First, trees grown on private agricultural should not be subjected to government regulation and interference. The land manager should be free to make decisions and take actions relevant to their management as he or she sees fit. Second, if the environmental benefits from forestry are really considered worthwhile, then they can only be achieved through forest management, protection, and preservation. From this perspective, the Forestry Department needs to redouble its efforts to manage the few remaining natural forests in the country. Only through the protection of these remaining forests can the environmental benefits from forestry be gained.

B. Conservation

Since fuelwood consumption represents such a large quantity, it is natural to think of conservation as one of the logical policy interventions. Reducing fuelwood consumption through improving the efficiency of its use is one straightforward way to bring consumption back into line with supply. In many countries, fuel-efficient wood-stoves have attracted attention as a potential solution to fuelwood shortages. Despite the attention, actual progress in disseminating stoves has been slow to achieve the anticipated wood savings. A number of reasons can be advanced for this lack of concrete results from fuel-efficient stoves.

The first reason why woodstoves have not achieved the expected savings is that the efficiency of the open hearth or traditional fireplace was underestimated. Early work in the field estimated the efficiency of the open hearth to be about 3% (Gill, 1987). Later, more scientifically credible work has consistently estimated the efficiency to be around 12-15%. What this has meant is that early projections of potential savings were greatly exaggerated. It is easy to demonstrate savings if the current practices are 3% efficient, but improving upon 15% efficiency is more difficult.

A second reason for the limited gains from woodstoves is that many of the designs that were promoted as being fuel-efficient are actually less-efficient than the open fire. This is largely due to the fact that what may appear to be efficient intuitively is not necessarily efficient as measured scientifically. In particular, the bodies of high-mass stoves, such as the Lorena or smokeless chula designs, absorb too large a share of the heat to be as efficient as simpler metal bucket designs (Prasad, 1983). It was not until these principles were well-understood that the potential gains from fuel-efficient stoves were clarified and realistically assessed.

A third reason for the limited gains from woodstoves has to do with the convenience or rather inconvenience of the fuel-efficient stoves. It is difficult to fit large pieces of wood into small metal-bucket stoves. As a result, many wood-burning households have either chosen not to use the bucket stoves because the labor involved in chopping the wood into small enough pieces is more onerous than the labor involved in collecting more firewood. Stove-designers have now settled on metal buckets with doors which can be left open to accept larger logs. Although the gains from using the stoves in this manner are less than if the wood were chopped into match-stick sized pieces, they still represent efficiency improvements over the open fire.

In general, two conditions have been met in those cases where fuel-efficent stoves have been successful. Many of the reports of such success stories are still exaggerated (Baldwin et al, 1986). First, the woodfuel being used has to be purchased on a market, or desperately short, so that households can immediately capitalize the fuel savings into their household cash or labour budgets.

Second, in general, stove programs have been more successful where households rely upon charcoal as the woodfuel of choice. This is partly because charcoal is almost always purchased, so it meets the second condition. But it is also true because of the friability of charcoal. Because it comes in smaller pieces, it fits more readily into the small fire-boxes of metal-bucket type stoves.[20]

In the case of Pakistan, it makes sense for the Energy Wing to work on formulating a fuel-efficient stove program. However, it should in no way begin from ground zero. A great deal of credible research and development work has been carried in the field of fuel-efficient stoves. To begin from an initial testing program would be to ignore this previous work. The emphasis of such programs should be to adopt stoves demonstrated to be efficient and convenient in other contexts, and to begin testing those for local acceptability and efficiency. In this way, the program can "cut-to-the-chase" and begin immediately at the point which remains the stumbling block for most stove programs: the tradeoff between fuel-efficiency and user-convenience. These two objectives, which are both valid, are frequently at odds. Stove programs must make compromises between them if they are going to successfully save and diffuse throughout a large fraction of the population. It is important to keep in mind that the fuelwood market is an important force for conservation. Stove programs will be most successful when they capitalize on these relatively large markets for fuelwood.

C. Substitution to Modern Fuels

The natural solution to a fuelwood shortage is for households to move away from wood to other fuels, particularly modern fuels. But the research carried out as part of the HESS project has demonstrated that movements up the energy ladder are more likely to have been caused by increases in income rather than increases in scarcity. The argument presented so far has maintained that interfuel substitution is a natural process which will follow its own course. All that should be done from a policy perspective is to ensure the viability of modern alternatives to traditional fuels. No subsidies nor give-away programs are necessary to increase the attractiveness of modern fuels for households.

1) Effective Prices of Household Fuels:

Previous discussions have demonstrated that fuelwood prices have not demonstrated significant depletion effects. In fact, the prices of fuelwood have increased only slightly in the past 20 years, according to the data in Table 10. However, to see whether

[20] The Kenyan ceramic jiko, for example, has been extremely successful, largely because it meets both of these conditions. See Hymen (1987).

the price of traditional and modern fuels are comparable to households, it is necessary to evaluate prices of fuelwood per effective energy unit, otherwise known as the cost of a useful energy unit or the cost of energy to the "cooking pot".

The data in Table 18 summarizes average estimates of the cost of the various household fuels for 1991, the year in which the HESS survey was carried out. The data do not include any amortized appliance costs, so the transactions cost involved in switching from one fuel to another has not been taken into consideration. This transaction cost may prove to be prohibitive in many cases. These data demonstrate three important points. First, the cost of crop residues and dung at the end-use level is roughly equal. However, the cost of both is significantly lower than that of fuelwood, reflecting its lower quality as a fuel.

Second, the effective cost of using firewood is almost identical to the cost of using kerosene, ignoring the transactions cost involved in stove purchase. In both urban and rural areas, the financial cost of using firewood is just about equal to that of using kerosene. This should mean that many households are being to utilize kerosene for supplementing traditional fuels. If these relative prices continue, the households which have begun using kerosene as a supplement will begin using it as a primary fuel. The data in Table 9 shows that kerosene is already heavily used for cooking in the urban portions of the country. In the Barani areas, 45% of the households claimed to cook with kerosene. Kerosene will undoubtedly begin to play a more important role as a bridging fuel between traditional fuels and more convenient, modern fuels such as LPG and natural gas.

Third, the effective cost of using firewood and kerosene for cooking is considerably higher than the cost for either LPG, natural gas, and electricity. Electricity is not generally considered a desirable cooking fuel in Pakistan, and this is as it should be given load constraints. But both natural gas and LPG are cheaper than traditional fuels for those households using them. In both cases, questions of access loom large. Households have to be located near the gas pipelines to utilize natural gas. LPG bottles and stoves represent significant investments for a poorer households. But given the price differences between traditional fuels and these modern fuels, it is little wonder that there is not more political pressure to make natural gas and LPG available to a much wider segment of the population. Even if the price of LPG is doubled, it still remains cheaper than the traditional alternatives.

TABLE 18 EFFECTIVE COST OF HOUSEHOLD FUELS

Fuel	Energy Content MJ/unit	Physical Unit	Appliance Efficiency (%)	Financial Cost (1991 Rs/ unit)	Financial Cost/Eff MJ (1991 Rs/ MJ)
Crop Residue	15	kg	12.0%	0.70	0.39
Dung	12	kg	12.0%	0.58	0.40
Fuelwood-urban	16	kg	12.0%	1.01	0.53
Fuelwood-rural	16	kg	12.0%	0.98	0.51
Kerosene	35	lt	35.0%	6.62	0.54
Natural Gas	1030	mcf	60.0%	31.30	0.05
LPG	45.54	kg	60.0%	5.70	0.21
Electricity	3.6	kwh	65.0%	0.69	0.29

source: HESS Household Consumption Survey. Efficiencies are generic numbers taken from Leach and Gowan, 1987.

These data serve to demonstrate that even though firewood prices have not demonstrated depletion effects, modern fuels have fluctuated enough so that in many instances, they provide cheaper cooking alternatives for households than do traditional fuels. This serves not to emphasize the irrelevance of modern fuels to Pakistan's household sector, but rather the increasing importance of modern fuels to the household sector. The Energy Wing's has an important role to play in enlarging access to these modern fuels. Allowing the free market to operate unfettered by price controls is one important step in this direction.

2) Economic Prices and Household Fuel Subsidies:

These data represent only the financial cost to the user of cooking with these different fuels. No provision is made for the fact that the cost to the nation of these different fuels may differ dramatically from the financial cost. In the case of electricity and natural gas, considerable subsidies still exist, which are the subject of other reports undertaken as part of the HESS project. These subsidies do not appear to be wholly justified, and serve not only to send conflicting market signals to households, but also reduce the flexibility of the household fuel system. They have created a group whose vested interest lies in seeing that the subsidies continue, and this makes it more difficult to reduce them.

From Government's perspective, the optimal household fuel mix is that fuel mix which meets total household energy needs at the lowest total economic cost. Fuel subsidies simply serve to direct consumers onto fuels which are not the lowest cost alternatives. They therefore contribute to maintaining a sub-optimal household-sector fuel mix. Investment decisions must be based upon marginal costs of fuel supply, and these marginal costs are liable to diverge dramatically from the average financial costs presented above.

The argument might be advanced that the prices of modern fuels should be subsidized to enable households to switch from traditional fuels to modern fuels, thereby reducing pressure on scarce wood resources. Unfortunately, research from other countries does not support this position. In the case of Indonesia, Pitt (1985) argues that not only does the kerosene subsidy go mostly to urban middle-income households, but it also does nothing to reduce firewood demand as the two fuels are not very close substitutes. As a result, both the environmental and equity bases for the kerosene subsidy rely on unsound economic logic.

Although environmental considerations might mean that markets for traditional fuels underestimate their value to the economy, the argument presented here and elsewhere is that these extrenalities are not large enough to make a significant difference in the price of woodfuel.[21] Carbon emissions do not justify subsidies on modern fuels, as sustainably managed wood is to be preferred to modern fuels in terms of carbon. Indoor air pollution from traditional fuels may have a negative impact on human health, but this simply serves to make modern fuels more attractive. Neither soil erosion nor soil nutrient considerations make a large enough difference in the economic price of household fuels to justify subsidies on modern fuels. Environmental considerations do not seem to warrant any extra-market treatment of woodfuel, and in fact, might turn out to make woodfuel less, rather than more sustainable.

The market for woodfuel appears to be working well, and households should be permitted to use whichever fuel they find economically attractive. Government's role is not to subsidize any fuel, but rather to make sure that those households which can afford a particular fuel have access to it, when it is economically advantageous to do so.

D. Monitoring Changes and Progress

One of the assumptions underlying much of this report and the HESS project in general is that information about the household energy situation is essential to make informed decisions relevant to the household energy sector. The output from the HESS project represents an important first step to gather and maintain information relevant to the household energy sector. But for most of the data collected, it represents only a single point in time. There is little evidence about the direction of trends or how the situation has changed in recent years. To be able to sort out the trends, considerable effort should be expended to continue to collect data to monitor important trends in the household energy sector. The constant monitoring of changes pertaining to the household energy situation is one of the most important tasks that the Energy Wing can carry out.

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[21] For a detailed assessment of all of the environmental contributions made by woodfuel in the context of Haiti, see Hosier and Bernstein (1992).

This section discusses monitoring efforts, beginning with an assessment of the different concerns or problems that might appear in the different regions. These concerns are based upon evidence collected as part of the HESS project, and should be used to fine-tune other monitoring efforts. The simplest types of monitoring activities are then discussed prior to a discussion of more complex and expensive alternatives.

1) Regional Monitoring Concerns:

Insights into the regional aspects of household energy problems provide important background for any discussion of monitoring. These insights can help tailor and focus monitoring efforts designed to keep the Energy Wing informed of important developments in the field. This discussion of monitoring focuses particularly on the need to monitor changes in the woodfuel supply system as it remains the most important fuel in the household energy sector.

If one of the goals of the household energy sector is to make the fuelwood system sustainable, then the transition from fuelwood supplies drawn from old-growth trees to fuelwood supplies from trees which are deliberately planted and managed for timber and fuel supplies is essential. As previous discussions have indicated, it is not clear where in this transition most of Pakistan falls. In some areas, the transition is further advanced than in others. An awareness of this transition to sustainable supplies of fuelwood and the various stages in which the different regions find themselves is important background to a discussion of monitoring the fuelwood situation. These should also be used to set priorities for monitoring activities in the various regions of the country.

The paragraphs below summarize the information collected on the various agroecological zones and provinces of the country as part of the HESS project. While not constituting definitive "identity cards" for the regions, it is hoped that these description will provide background which can provide a conceptual basis for future monitoring activities.

Northern Irrigated Areas: More than any other area, this region (consisting mostly of Punjab), suffers from high population pressure and high fuelwood production needs. However, it is probably closer to maintaining a high-throughput fuelwood production system than any other region. The transition to a sustainable management system seems to be further advanced in these areas than elsewhere. However, care should be devoted to ensuring that no structural impediments nor institutional barriers should be allowed to prevent these transition from following through to completion.

Southern Irrigated Areas: Like their Northern counterparts, these areas (comprising mostly Sindh Province) also faces high population pressure. It also needs to be transformed into a high throughput fuelwood production system. At present, it appears to be lagging behind its northern neighbor in the transition to high production/high consumption sustainability, and the reasons are not immediately obvious.[22] During monitoring, attention should be paid to seeing that rapid progress occurs in this transition, and that tree-planting and production continue to increase in importance. Despite this concern, it must be pointed out that Sindh has been densely populated and heavily cultivated for decades. Unless it can be shown that some critical threshold is about to be crossed, the situation does not call for desperate actions, but rather concentrated attention.

Barani Areas: The dryland farming areas serve a boundary between the irrigated areas and the mountainous, highland regions. As such, they have been less densely populated over the years, and to some extent are still only now being permanently settled for cultivation. They are therefore at the the earlier stages of the transition to a high throughput sustainable fuelwood supply system. The production potential of these unirrigated areas is obviously lower than that of the irrigated areas, so they may never complete a similar transition to that expected for the irrigated areas. By many indicators, these areas face the most serious woodfuel shortages and many households have begun using alternative fuels as a result. Careful attention should be paid to monitoring indicators of fuelwood scarcity and the success of tree-planting activities, for if this is the region which is likely to demonstrate fuelwood scarcity and environmental degradation.

Forest/Highland Areas: Although these areas contain much of the remaining closed forests of Pakistan, the evidence regarding fuel availability is mixed. On the one hand, fuelwood should be plentiful due to the forests. On the other hand, fuel prices are unusually high, possibly due to inflows of refugees. It is fairly clear that there are problems of access to sources of fuelwood in these areas--the trees which are present may not be particularly accessible to the poor. The problems in these areas are twofold. First, there is a need for greater success in tree-planting efforts outside of forest areas on farmland. It is likely that survival rates for trees planted here are low, meaning that management can

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[22] The conclusion that the southern irrigated areas lag in the transition to fuelwood sustainability is based upon more limited tree-planting efforts. Two reasons might be suggested for the slowness of this transformation. First, since Sindh is more tropical in nature, more of the trees might be managed on a coppice rotation, so that the need for tree planting is lower. This reason seems rather tenuous. A second reason is suggested by Leach (1993) and is linked to the large number of tenant-farmers in Sindh Province. As a result of this, fewer farmers engage in planting trees. However, neither of these reasons seems wholly satisfactory.

be improved. Second, the forest areas need better management and protection to ensure their survival.

Semi-arid Areas: As these areas are called upon to absorb increasing numbers of people, their forests are rapidly cleared, leaving the population bereft of fuelwood supplies. Large cities like Quetta are dependent upon the market to bring fuelwood supplies from far away. So far, efforts at tree-planting do not appear to have had much of an impact on improving wood supplies. Due to the limited productive capabilities of this land, it cannot be expected to support large, dense settlements. Environmental degradation is likely to occur as a result of increasing settlement density on these areas. While tree-planting is to be encouraged and monitored, the semi-arid areas will largely remain dependent upon fuelwood production from other, high productivity areas.

Desert Areas: These desert areas have little potential to produce firewood except in the immediate vicinity of watercourses or oases. The one saving grace so far is that population density, and therefore fuelwood pressure, has remained fairly low. Despite the highest per capita consumption fuelwood figures in the country, fuelwood can only be considered scarce in absolute terms. Due to the distances from supplies of commercial fuels, fuelwood remains cheaper than most modern fuels. Care should be exercised in monitoring to ensure that undue population and fuelwood pressure is not placed on any one part of these fragile desert environments.

Although the nature of the fuelwood situation in each of the agroecological regions is different, in no region can it be ignored. Given the information available at present, the fuelwood situation is a source for concern throughout the country. Monitoring is essential to ensure that both the population's energy needs are met and local environments are not subjected to undue pressure and degradation.

2) Simple Monitoring:

The simplest factors to monitor are those which require little or no additional investment or expenditure on the part of the energy authority. In the case of Pakistan, the price of fuelwood and other household fuels is already monitored by the consumer price index division of the Federal Bureau of Statistics (FBS). On a monthly basis, they gather consumer prices from a number of different markets in the major cities across the country. These market-wide averages are then used in the computation of the consumer price index. These prices can be obtained by a phone-call or a visit to the FBS. A rapid change in the relative prices of household fuels might mean that fuelwood is becoming more plentiful or scarce, or that other fuels are becoming unavailable. Clearly, the prices of household fuels are easy and important factors to monitor.

The prices of timber are less important for household energy policy *per se*, but they may provide important indicators of the attractiveness of tree planting to farmers. The greatest source of prices is again the monitoring done by the FBS on wholesale prices for various commercial species, typically collected at Changa Manga. The Pakistan Forestry Institute also engages in monitoring prices of commercial timber. From both of these sources, the Energy Wing can easily gather timber prices which reflect on the incentive structure farmers face in considering tree-planting.

A more involved level of monitoring entails working with the Forestry Department and other forest-support organizations to monitor the tree planting and survival. As earlier discussions indicated, there is no reliable source of information on the level of tree-planting in the country. Although the Forestry Department has data about its own activities, these can only be considered as a small fraction of all tree-planting activities in the country. Forestry Department data deals only with nursery output, and as was indicated earlier, most farmers who plant trees do not obtain seedlings from Forestry Department nurseries. As a result, this data is incomplete, at best. If targets are going to be set for farmers planting trees on private farmlands, there needs to be some effort expended on monitoring progress toward those targets.

More important perhaps than simply the tree-planting activites are the survival rates of the trees being planted. As indicated earlier, there is no other information available on survival rates other than the observations from infrequent observers. Survival rates need to be monitored along with tree-planting activity.

The most cost-effective way for data to be regularly collected on both of these factors is to again utilize the facilities provided by the Federal Bureau of Statistics (FBS). In this case, FBS has a department devoted to crop forecasting and monitoring. If the argument is to be advanced that trees are to be treated like other agricultural crops, then it makes sense that their planting and survival be monitored with that of other agricultural crops. A simple box or set of questions referring to tree-planting could fulfill the data gathering needs in this area. In order to reduce the additional computational load placed on FBS from this data request, the Energy Wing might volunteer to help do the calculations or write the program for the calculations. But collaboration with FBS appears to be the only way to cost-effectively collect data on tree-planting and survival on farms.

At a different level, the most logical single factor to monitor is canopy cover. In many other countries around the world, randomly-selected flight-lines are regularly flown to take aerial photography for following changes in the percent of the land area covered by forests. These flight lines are carefully flown at pre-specified altitudes and the canopy cover estimates can be readily adjusted and compared to previous estimates. This is probably the best, most accepted method for following changes in forest cover. Unfortunately, security conditions in Pakistan prohibit the use of aerial photography. However, if an arrangement can be reached wherein pre-specified and security-cleared flight lines can be flown, this would provide the best source of monitoring data with respect to forest cover.

In addition to this information about tree-planting and use, there is also a need to collect data on the adoption and utilization of various stoves. In particular, if the Energy Wing begins working seriously on fuel-efficient stoves, this information on stove adoption will become increasingly important. Consideration should be given to suitable techniques for gathering data on household fuel use and appliance adoption on a regular basis. This alternative is discussed in more detail below.

3) More Ambitious Options

The monitoring options detailed above involve using some indirect measures as indicators of changes in the household fuel situation. Other measure, such as the number of households with gas or electricity connections, can be readily monitored through collaboration with the appropriate utilities. However, in order to keep track of changes in appliance ownership, household fuel utilization, and woodfuel use, a more detailed monitoring program needs to be established. In simplest terms, this would involve carrying out a reduced-scale household fuel energy survey on a continuing or recurring basis.

The survey carried out as part of the HESS project administered a large, involved questionnaire to a relatively large sample of households. If both the scope of the survey instrument and the size of the sample were reduced, the monitoring activity could be carried out on an annual or bi-annual basis at a relatively limited cost. Once again, the facilities of FBS could be used effectively for the questionnaire administration, but the analysis could be most effectively carried out by the staff of the Energy Wing.

How much effort would have to be involved in such an activity? Ideally, the questionnaire should contain minimum information about fuel consumption, socio-economic characteristics, appliance ownership, and tree-planting to allow a comparison with the larger questionnaire used as part of the HESS project. But the questions could be reduced in complexity in order to facilitate its administration. Although some calculations are necessary to suggest the magnitude of the sample to be used, a target might be set at 10% or 20% of the larger HESS sample of 4800 households.

In this way, the cost and time committment necessary to carry out the survey could be reduced so that it could be repeated every second year. After five or ten years, it would then be desirable to re-run the entire large exercise. In this way, household energy can become a module of the normal household survey rotation used in

Pakistan and other developing countries. This rotation would enable the Energy Wing to monitor what is happening in the field and fine-tune policies in order to incorporate the latest trends. It would also enable the Energy Wing to identify the trends are, since at present, they only have one data point to work from.

CHAPTER V SUMMARY

With careful management and planning, fuelwood can provide sustainable energy future for Pakistan's households. However, there is a transition to be made away from reliance on old-growth trees. Farm trees, deliberately planted and managed on private farmlands, must supply Pakistan's wood energy future.

Woodfuel management is challenging task. Policy efforts should focus on supporting people's initiatives at tree planting, interfuel substitution, and fuelwood conservation. The market is an important ally in this regard, which is not to be undermined through subsidies or give-away policies.

Tree planting is an essential component of a sustainable fuelwood-system. The demand for timber, not fuelwood, drives farmers to plant trees, but fuelwood is a useful by-product of the timber market. Although resource markets are subject to periodic fluctuations, stimulating the demand for timber can help avoid a tree glut .

Government should focus its attention on making commercial fuels more available in a cost-effective manner. No subsidies should be given to achieve this, but rather fuel supplies can be increased through reliance upon market forces and public investments justified by benefit-cost analysis.

If the supply of timber increases, so will the supply of firewood, as up to 75% of any tree being used for timber can end up as a waste product usable as firewood.

Fuelwood conservation through the dissemination of improved stoves is an important policy option to be pursued where appropriate and possible. However, gains from conservation efforts are liable to be modest.

Each region is liable to be at a different stage in the transition to sustainable fuelwood supply system. As such each region will present its own set of fuelwood management problems and situations. These differences are important in determining appropriate monitoring strategies and programs.

Monitoring regional trends in fuelwood availability and consumption, fuelwood and timber prices, tree-planting and changes in household fuel patterns are all important to the continued ability of the Energy Wing to develop and manage a responsive household energy policy.

Subsidies for stoves, trees, and modern fuels are not sustainable. They are misleading to households and injure the flexibility of the woodfuel supply system, which has so far, been its strength.

Forests are important as they provide environmental benefits which trees on farmland cannot. Forests need special management and protection not because they are a source of firewood, but rather because they provide these environmental benefits.

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ANNEX A:

Indicators of Regional Firewood Availability

Table 6 in the text (repeated below as Table A-1) contains estimates of fuelwood availability by region as expressed in physical quantities of wood and indicators of population pressure. In terms of physical measurements of availability, one of the most obvious factors in the table is the importance of the semi-arid and desert areas. Together, they account for about 57% of the country's surface area. Because of their limited productivity linked to low rainfall, these areas contain a small fraction of the nation's total standing stock and wood growth. The productivity of the semi-arid and desert areas is slightly more than 10% of the national average. In the simplest physical terms, these semi-arid and desert areas face a permanent wood shortage. However, this physical limitations do not seem as important when viewed in the context of the population pressure on these areas. These two areas have low population densities when compared to the rest of the country. Although the desert areas actually demonstrate a woodfuel surplus, the semi-arid zone displays a notable woodfuel deficit. For each person living in the semi-arid zone, there is a deficit of 153 kg of woodfuel. This just about equals the the comparable per capita surplus measure for the desert areas. While both the semi-arid and desert areas demonstrate limited forest supplies, the greater populaton pressure in the semi-arid areas means that it faces greater woodfuel scarcity.

Table A-1 Regional Measures of Woodfuel Availability

Measure	Units	Irr Hi North	Irr Hi South	Irr low North	Irr low South	Barani	Forest/ Highland	Semi-Arid	Desert	Total Pakistan
Physical Measures										
Area	'000 ha	9,185	1,987	3,186	4,461	2,788	12,997	25,383	25,234	87,723
Wood Stocks	'000 tons	59,190	11,020	26,780	8,660	4,460	81,660	11,160	7,850	210,780
Wood Growth	'000 tons	7,080	910	3,980	2,660	420	5,220	940	1,480	22,690
Wood Balance	'000 tons	-6937	-1357	1597	-573	-1554	2,301	-3,175	407	-9291
Stock Density	t/ha	0.64	0.55	0.84	0.19	0.16	0.63	0.04	0.03	0.24
Growth Density	t/ha/yr	0.08	0.05	0.12	0.06	0.02	0.04	0.00	0.01	0.03
Population Pressure Measures										
Population	'000	51,932	6,787	11,365	9,060	7,141	5,940	20,784	2,693	115,702
Pop'n Density	person/ha	5.65	3.42	3.57	2.03	2.56	0.46	0.82	0.11	1.32
Balance/cap	t/person	-0.134	-0.200	0.141	-0.063	-0.218	0.387	-0.153	0.151	-0.080
Balance/ha	t/ha	-7.6E-4	-6.8E-4	5.0E-4	-1.3E-4	-5.6E-4	1.8E-4	-1.3E-4	2.0E-4	-1.1E-4
Balance/Rur H'hold	t/rur hh	-1.288	-2.010	1.857	-0.569	-1.734	4.030	-2.302	0.295	-0.628

Source: HESS Project Data-Base.

At the other end of the spectrum, the Forest/Highland areas and the Northern Irrigated Areas are the most important agroecological zones as measured in terms of both total wood production and per hectare wood stocks. Together these three areas (Forest/Highland, Irrigated High Productivity North and Irrigated Low Productivity North) account for over 75% of the nation's forest supplies. The per hectare estimates of standing stocks are between two and three times the national average, demonstrating that they are the most productive regions in the country in terms of firewood. The Forest/Highland areas demonstrate a very low population density, leaving the area with a significant woodfuel surplus. The Northern Irrigated areas display the highest population densities of any zone in the country, and the Irrigated High Productivity North zone demonstrates a significant fuelwood deficit. Despite other similarities, the Irrigated Low Productivity North zone demonstrates a firewood surplus.

The southern irrigated areas provide less intense mirror images of their counterparts in the north. The Irrigated High Productivity South zone demonstrates fairly high levels of wood stocks. Because of higher settlement density, it demonstrates a significant woodfuel deficit. The Irrigated Low Productivity South zone also demonstrates a deficit, but it is less pronounced because of both lower stocking levels and lower settlement density.

The Barani zone represents a unique case. With limited total and per hectare wood stocks, it plays host to the third highest population density of any of the agroecological regions. As a result, it hosts a wood deficit which, when measured on a per capita basis, is the most severe in the country. It constitutes a relatively high center for firewood demand despite relatively low productivity.

The data in Table A-1 are relatively straightforward ratios computed from regional-level data. In contrast, the data in Table A-2 are derived from the HESS household energy survey. They present more subtle indicators of relative firewood availability based upon household assessments or consumption patterns. While the data in Table 6 are somewhat mechanical, physically-derived ratios, the figures in Table 7 are socially-based, and in need of greater interpretation.

Households might be expected to reduce firewood consumption in response to perceived scarcity. If this is true, firewood consumption would be anticipated to be highest in those areas where it is most plentiful, holding all else constant. Total firewood consumption is greatest in the Irrigated High Productivity North zone, as might be anticipated on the basis of total zonal population. However, the next two highest consumption areas are the Semi-arid zone and the Irrigated Low Productivity South zone. This is somewhat surprising as the total population for the former zone might have suggested such a large total consumption, but that for the latter would not have. More importantly perhaps, per capita consumption is highest in the Desert zone, Forest/Highland zone, and then the Irrigated South zones. For the Desert zone, this might be expected on the anticipation of space-heating requirements and the lack of either modern or traditional alternatives. For the Forest/Highland zone, space-heating requirement would also lead to the expectation of higher fuelwood consumption. For the Irrigated South zones, the reason for the relatively high per capita consumption is unclear.

Table A-2 Regional Measures of Woodfuel Procurement and Use

Measure	Units	Irr high North	Irr high South	Irr low North	Irr low South	Barani	Forest/ Highland	Semi-Arid	Desert	Total Pakistan
Firewood Consumption										
Rural Areas	'000 tons	10,496	1,773	1,496	2,852	1,907	2,152	3,109	843	24,628
Urban Areas	'000 tons	2,421	404	417	271	67	107	866	230	4,783
Total	'000 tons	12,917	2,177	1,913	3,123	1,974	2,259	3,975	1,073	29,411
Firewood Consumption Per Capita										
Rural Areas	ton/cap	0.278	0.368	0.228	0.406	0.290	0.451	0.289	0.414	0.306
Urban Areas	ton/cap	0.172	0.205	0.087	0.133	0.121	0.091	0.086	0.350	0.135
Total	ton/cap	0.249	0.321	0.168	0.345	0.276	0.380	0.191	0.398	0.254
Share of all wood that is purchased										
Rural Areas	%	36.1%	25.9%	35.1%	24.4%	23.1%	15.3%	36.3%	39.5%	31.3%
Urban Areas	%	85.9%	66.8%	97.1%	92.3%	100.0%	51.4%	86.7%	100.0%	85.9%
Total	%	45.4%	33.5%	48.6%	30.3%	25.8%	17.0%	47.3%	52.5%	40.2%
Fuelwood Market Price										
Rural Areas	Rs/kg	0.97	0.97	0.93	1.00	0.95	1.06	0.98	1.07	0.98
Urban Areas	Rs/kg	0.96	0.86	1.29	0.91	1.01	1.13	1.02	1.06	1.01
Collection Efficiency for the last Collection Trip										
Rural Areas	kg/per-hr	8.46	5.19	5.55	4.22	4.84	4.01	5.90	4.69	6.14
Urban Areas	kg/per-hr	5.55	6.61	9.51	4.64	NA	6.35	3.33	NA	5.31
% of Firewood Users Encountering Problems of Supply										
Rural Areas	%	9.8%	13.1%	1.1%	13.3%	3.5%	4.0%	7.7%	17.3%	8.6%
Urban Areas	%	10.9%	7.1%	21.3%	5.4%	3.6%	5.3%	4.7%	4.9%	9.8%
Total	%	10.0%	11.6%	7.6%	12.2%	3.5%	1.0%	6.9%	15.0%	8.9%

source: HESS Project Data-Base

If consumption is reduced in response to scarcity, then wood might be interpreted as being the most scarce in the areas with lowest consumption. Per capita consumption is lowest in the Irrigated North, the Semi-Arid, and the Barani zones, perhaps indicating a response to greater perceived scarcity in these areas. For the Irrigated Northern Areas, this might be viewed as a result of the relatively high population density. However, for the other two zones, the fuelwood scarcity, if it can be interpreted as such, can only be viewed as a mismatch between population and productive capacity. In general, evidence from using relative consumption levels to make inferences about relative availability is difficult to use and remains somewhat vague.

If markets were fully developed, market prices might provide a useful indicator of woodfuel availability. In the case of incipient markets, such as the market for firewood, price might not be so reliable a surrogate. In such cases, the fraction of firewood purchased might be taken as an indicator of relative scarcity. The percentage of firewood purchased is highest in the Desert, Semi-Arid, and Irrigated North zones. In the case of the last two zone, this is consistent with the evidence from per capita consumption. Nearly 50% of all firewood used by households in these areas is purchased, indicating both a greater reliance on the monetary market and possibly an inability to collect firewood attributable to scarcity.

For rural areas, firewood prices are estimated to be higher than the national average in the Desert, Forest/Highlands, Irrigated Low Productivity Southern, and Semi-Arid Zones. For urban areas, firewood prices are above average in the Irrigated Low Productivity North, Forest/Highlands, Desert, and Semi-Arid zones. The placement of the Low Productivity Irrigation, Desert, and Semi-Arid zones on these lists are explainable on the basis of the limited physical productivity of forest biomass in these areas. However, the placement of the Highland/Forest zone on the list is not. This last anomaly might be explained on the basis of the fact that the lowest percentage of both urban and rural households in any zone purchase their fuelwood in the Forest/Highland zone. If this is the case, then the relatively high price in these areas might be a function not of fuelwood scarcity, but rather of the undeveloped status of the firewood market. An alternative explanation might be more simple: despite the greater per capita wood supplies in these areas, the more rugged terrain makes transport costs higher, which in turn makes total costs higher. Whatever the explanation, the variations in firewood prices identified on the HESS demand survey are relatively small, representing relatively little regional variation. Although average regional price levels do not appear to have increased dramatically in response to firewood scarcity,[23] higher prices do support the relative scarcity of firewood in the Semi-Arid and Desert zones. While the same might be said about the low productivity irrigated zones, the case of the Forest/Highlands lacks a satisfactory explanation.

The time required to collect one unit of firewood can also be taken as a surrogate measure of scarcity for the non-marketed segment of firewood consumption. In this case, the lower the collection efficiency (as measured in kilograms of wood collected

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[23] The HESS survey of firewood vendors identified a much larger spread in prices than that obtained by the HESS household survey. The reason for this remains unclear at present. Nevertheless, the rankings from the firewood merchant's survey demonstrates roughly the same ranking as that of the demand survey: firewood is most expensive in Baluchistan and the NWFP (Leach, 1993). These political regions are roughly equivalent to the Semi-Arid and Desert zones and the Forest/Highland zones.

per person-hour of collection), the more scarce firewood would be considered. Among rural zones, firewood collection efficiency is lower than the national average in the Forest/Highland, Irrigated Low-Productivity South, Desert, Barani and Semi-Arid zones. For urban zones, collection efficiency is less than the national average only in the Semi-Arid and the Irrigated Low Productivity South zones (after the elimination of the two zones in which no urban households collected firewood, Barani and Desert zones).

Finally, regional firewood scarcities, the firewood-using respondents to the HESS household consumption survey were asked if they had ever encountered problems in the supply of firewood. Over 90% of the respondents answered in the negative. This can be taken to indicate that respondents using firewood found that there were few problems of availability. However, the results do vary by region, even though in no region was the percentage of respondents claiming to have encountered problems of supply greater than 25%. In general, respondents in the irrigated areas and the Desert zone demonstrated a greater propensity to have encountered fuelwood supply difficulties.

To recap, the Semi-Arid and Desert zones appear to have the most limited growing stocks of any of zone. However, the population settlement pattern is adjusted accordingly, leaving them with the lowest population pressure. The highest population pressure is experienced by the irrigated areas, particularly the Northern irrigated area including most of Punjab. It is important to note that the Barani zone faces relatively significant population pressure given the limited wood stocks and biomass productivity in the region. In terms of social measures of woodfuel availability. At the regional level, it is not clear that consumption patterns react to produce reduced scarcity. End-use considerations like cooking patterns and space-heating requirements needs may confuse these trends. However, if scarcity is reflected in lower consumption patterns, then wood might be more scarce in the Irrigated North, Barani, and Semi-Arid zones. On the other hand, if market prices and collection efficiency can be used to reflect scarcity, the Forest/Highland, Semi-Arid, Desert, and Irrigated South Zones. Using still another indicator, respondents' subjective assessment of fuelwood availability, the irrigated and Desert zones might be considered to present the greatest fuelwood availability problems. However, in no zone did more than 25% of the respondents acknowledge a hardship in fuelwood availability. In most zones, less than 10% of the households acknowledged a problem of firewood availability.

ANNEX B

A Comparison of HESS and FSMP Estimates of Woodfuel Consumption, Supply, and Balance

The following tables provide a rough comparison of the results of the HESS project with those of the FSMP project. Table B-1 summarizes the general differences in assessment of consumption of woodfuel. Table B-2 compares the approaches taken to woodfuel supply assessment. Table B-3 compares woodfuel productivity estimates and estimates of wood-supply balance. Finally, Table B-4 compares the results from the HESS Biomass Assessment with those of the FSMP farm-forestry survey.

In general, despite the different approaches and the different perspectives adopted by foresters and energy planners, the results of the two studies are remarkably similar.

Table B-1 Comparison of HESS and FSMP Approaches To Measuring Woodfuel Supply and Consumption

HESS Approach	FSMP Approach
Unified Demand/Supply Sample Framework	
DEMAND/CONSUMPTION ASSESSMENT	
Firewood Consumption: Household Energy Consumption Survey Stratified by Agro-eco Zones FBS Sampling Frame 29.4 m tons or 42.0 mcm C.I. 29.4 (+/-) 0.6 m tons	Firewood Consumption: Taken from HESS Preliminary Estimates Only roundwood component (56%) 56% of 43.5 mcm 24.4 mcm or 17.1 m tons
Timber Consumption: Taken from FSMP (deflated back to 1991) (correct for off-cuts and flow-thru) 2.2 m tons or 3.2 mcm * 1/2 or 1.1 m tons or 1.6 mcm	Timber Consumption: Detailed Assessment taken from existing provincial records 3.5 mcm or 2.5 m tons (includes industrial FW)
Industrial Fuelwood: Total Sold (-) HH sales 1.9 m tons or 2.71 mcm	
Total Consumption 32.4 m tons or 46.3 mcm	Total Consumption (1993) 29.5 mcm or 20.7 m tons
Per Capita Consumption (120 million) 0.27 tons per capita or 0.39 cm per capita	Per Capita Consumption (120 million) 0.25 cm per capita or 0.17 tons per capita

source: FSMP (1992); Archer (1993); and other HESS Data.

Table 8-2 Comparison of HESS and FSMP Approaches To Measuring Woodfuel Stocks

HESS Approach	FSMP Approach
STANDING STOCK ESTIMATION	
National Biomass Assessment: (Archer, 1993)	Three Part Methodology: 1) Coniferous Forests: Records 231.6 mcm or 162.1 m tons
Agro-eco Zone Stratification PSU's and SSU's Field Plots	2) Farmland Trees (Phillips, 1992): 70.3 mcm or 49.2 m tons 3) HESS Preliminary Supplements: HESS Prelim Total 240.0 mcm
Total Woody Biomass Estimate 210.8 m tons or 301.1 mcm Estimated SE of 9.8% (t-stat (95%) = 1.96) CI: 210.8 (+/-) 40.7 m tons CI: 301.1 (+/-) 58.1 mcm	(-) HESS Conifers (-) 104.3 mcm (-) Farmland Trees (-) 70.3 mcm Supplemental Subtotal 66.4 mcm Total of Above Components 367.3 mcm or 257.1 m tons Assume SE of 10% (t-stat 95%=1.96) CI: 367.3 (+/-) 73.5 mcm CI: 257.1 (+/-) 51.4 m tons

Suggested Improvement:
FSMP Estimates of 3 components
Con. F (+) Farmland Trees (+) HESS remnants

HESS remnants:	HESS Prelim Total	240.002 mcm
	(-) HESS Conifers (-)	104.3 mcm
	(-)Irr. + Barani (-)	114.9 mcm
	HESS remnant	16.0 mcm
Suggested Total:	231.6 (+) 70.3 (+) 16.00 = 317.9 mcm	

source: FSMP (1992); Archer (1993); and other HESS Data.

Table 8-3 Comparison of FSMP and HESS Estimation of Woody Biomass Sustainability

HESS Approach	FSMP Approach
BIOMASS PRODUCTIVITY	
Integral Part of National Biomass Assessment (Archer, 1993)	Combined Assessments of Above Components
Multiple Regression Models Using DBH as One Variable to Predict Relative Growth Rate Controlling for: Crown Damage, Productivity Amenity Value, Species, Zone	Coniferous Forests 3.3 mcm/yr Riverine, Scrub, Mangrove, & Irrigated Plantation 2.0 mcm/yr Farmland Trees 7.7 mcm/yr Others 1.4 mcm/yr
National Total: 22.7 m tons/yr or 32.4 mcm/year	National Total: 14.4 mcm/yr or 10.1 m tons/year
0.26 tons/ha/yr or 0.37 c m/ha/yr	0.16 c m/ha/yr or 0.12 tons/ha/yr
Irrig+Barani Supply 66.3% of Total (15.1 m tons or 21.5 mcm)	Farmlands Supply 53.5% of Total (7.7 mcm or 5.4 m tons)
WOODFUEL BALANCE	
Sustainable Supply: 22.70 m tons/yr Consumption: 31.866m tons/yr	Sustainable Supply: 14.402 mcm/yr Consumption: 29.550 mcm/yr
Net Balance: (-) 9.7 m tons/yr or (-) 13.9 mcm/year	Net Balance: (-) 15.2 mcm/yr or (-) 10.6 m tons/year

source: FSMP (1992); Archer (1993); and other HESS Data.

Table 8-4 Comparison of FSMP Farmland Tree Survey and HESS Survey on Irrigated Farms

HESS Approach	FSMP Approach
COMPARABLE MEASURES FROM BOTH SOURCES	
Trees Counted: Irrigated + Barani All Trees counted 596.371 million (-) Trees < 5cm 125.558 million (-) Citrus Trees 59.664 million	Trees Counted on farms 16,572 Area of Plots 807.5 ha Farmland tree density 20.52 tree/ha
Adjusted Tree Count 411.148 million Area of Irr+Barani Zones 21.607 m ha Irr+Barani tree density 19.03tree/ha	Total Trees in Farmland: 20.52(x)19.331 m ha = 396.672 m (**Note: Multiplication error in FSMP p 2-14,Tbl 2.3 gives 330.5m)
Percent Irrig. + Barani Trees With 5cm < DBH < 20cm 84.2% 20cm < DBH < 50cm 14.8% DBH > 50cm 1.1%	Percent Farmland Trees With 5cm < DBH < 20 cm 86.3% 20cm < DBH < 50cm 12.6% DBH > 50cm 1.1%
Standing Stock (Irr+Barani only): 4.533 t/ha or 6.476 c m/ha (excludes dbh<5cm, citrus, shrubs)	Standing Volume: 3.88 c m/ha or 2.716 t/ha
Annual Yield (Irr + Barani only): 0.501 t/ha/yr or 0.716 cm/ha/yr	Annual Yield: 0.399 c m/ha/yr or 0.279 t/ha/yr
Trees Planted per Tree Felled Leach (1993, p15) 11.6:1 (Sindh lowest ratio)	Trees Planted per Tree Felled Phillips (1992, p11) 10:1 (Sindh lowest ratio)
Trees Demonstrating Severe Crown Damage (Class 3 & 4): 1.13 m trees/14.08 m trees or 8.03%	Trees Excessively Lopped: 4.5%

source: FSMP(1992); Phillips(1992); Archer(1993); and other HESS Data.