Interaction Of Food Production Household Energy And Environmental Change In Hill Environments: A Simulation Approach[*]

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Introduction

The ecological balance in the hills of Nepal is extremely fragile. Rugged terrain, light erodable soils and uneven rainfail which are characteristic of the hills of Nepal are continuoulsy being subject to numerous pressures. These pressures are rapidly disturbing the fragile ecological balance. Attempts to reestablish the ecological balance could be a losiug battle as losses of natural resources through soil erosion, flooding, draught, salinity and other physical changes are generally irreversible and leave growing population with fewer means to meet their needs.

Although the precise nature of the ecological stress in the hills has not been carefully assessed, the implications of this process are alarming. Increasing deterioration of hill environments in Nepal could effect in various ways a large section of the population in the Indo-Gangetic plains, where the number runs to over one hundred million. In the past these problems had been limited both in scale and extent and some oppertunities existed for out-migration and extension of cultivated area. Today, there remain few options.

The Problem of Policy Choices

There exists a wide range of policy choices involving food, house-hold energy and environmental stress in these areas. Ecological changes, sudden increases in fossil-fuel prices, food shortages and declining food production capacity, ineffectiveness of population control policies, rapid depletion of natural resource and other scarcities have caught analysts off guard. Not only is there a lack of concensus even within different aspects of some specific problem, but also there is insufficient under-standing of these problems and their interrelationships with each other. While certain policies can easily attract decision makers to favour them, they may have seriously adverse side effects in unexpected quarters. The critical problem in policy decisions is the lack of awareness of the different trade-offs inadverently made on account of a lack of evaluations of alternative policy choices.

An understanding of how the changing nature of resource exploita-tion and an evaluation of its cumulative impact upon food production and environment seems to be immensely useful for understanding the potentials for development, and in the design of integrated develop-ment efforts. For this it is necessary to link conventional economic analysis of production activities with physical or resource models that can identify the nature of the changing resource base on account of different rural needs. Equally significant is the need to monitor the environmental changes arising out of different policies and demand con-ditions so that it is possible to establish some measures of trade-offs.

Questions regarding agricultural technology choices have to be ass-essed from a production as well as environment perspective. Emphasis will alter with the characteristics of a particular area and the time frame involved. Discussions regarding energy clearly point out that it is inadequate to focus only on production because changes in the household energy supply conditions will ultimately affect rural produc-tion as well. The increasing importance of improving the local resource base and the need to adopt better technologies to exploit these resou-rces cannot be over-emphasized. While on the one hand, there are pro-blems of availability of some of the important inputs, an uncritical imposition of modern technology has aggravated problems of inequality, unemployment etc. on the other. The role of physical resource, the

nature of technology choices, the multiple use of local resources, the interrelated problems of agricultural and rural development, as well as the changing nature of rural environments require that we view rural areas in terms of a more comprehensive perspective.

Overview of Hill Agroecosystem

The overall model describing the hill agroecosystem has been built from different submodels. The different submodels are related to resource supply, demand conditions and production activities. The link between the submodels can be identified either by resource or by information flows. For the current purposes of the study, a fairly simplified picture of the hill agro-ecosystem has been used. This is shown in Figure 1. Each block in the diagram corresponds to a submodel.

Land Use Submodel

The land use submodel describes the levels of different types of land available in each period as a result of the demand for different land based resources, whether it is for household energy, livestock or cereal grain production. The purpose of this submodel is to identify the stock of forest pasture and arable land in each period. Changes in each land use category is determined by the stock in every period and the inflows (additions) and outflows. There are a wide number of variables including policy decisions influencing the inflows and outflows. For instance in the case of forest land, it is increased by the amount of land to be afforested and decreased by the extent of deforestation. In trying to represent these in equation form, it is necessary to consider other variables and parameters also. The procedure is similar for other land use categories.

Wood Supply Submodel

Wood supply is increased by the growth of trees and afforestation. It is decreased every year by the amount that is harvested and the mortality rate of trees. The amount of new wood available can be derived from the area afforested between periods t-1 and t and the density of new trees which have been planted. In order to be able to add the new tress to the old stock, it is necessary for the new trees to meet a certain minimum number of years to mature. If the time period is less than this factor, supply of new wood for harvest would be restricted.

Figure 1

Diagrammatic Representation of Hill Agroecosystem Model
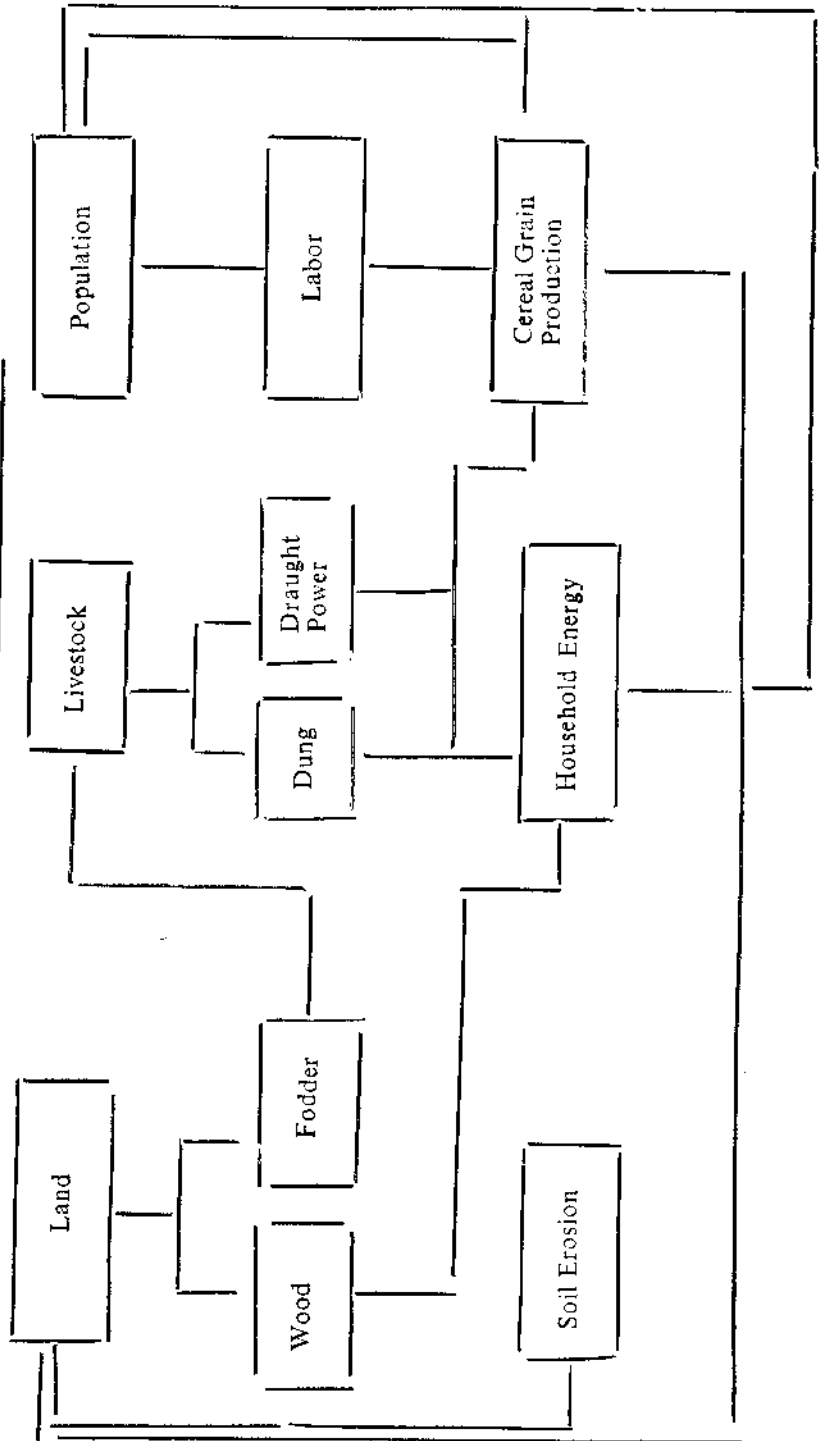
Fodder Supply Submodel

Total fodder supply is derived from forests, pasture and arable lands. Forest fodder supply is a function of the forest area and the amount of fodder per unit area of forest. It is clear that we are not considering the possibility for the annual growth of fodder. Pasture fodder supply can be determined similarly. In so far as fodder supply from arable land is concerned, this is assumed to be a function of crop residues and, to simplify our analysis, it is assumed that this is known.

Soil Erosion Submodel

Soil erosion is the result of an interaction between a variety of forces and physical conditions. Rainfall, temperature, wind, types of land use, slope of terrain, soil chemistry and land use practices, etc., all influence in varying degrees the levels of soil erosion. One approach adopted for this study is the Water–Balance model, which utilizes the concepts of energy flow, with the difference that the flows are not of those of energy but of silt. The advantage of this approach is that it can be directly linked with the land use system.

On the basis of this approach, five major variables can be identified to determine the levels of soil erosion. These are precipitation, evapotranspiration, runoff, water holding capacity of the soil and the extent of land area. Evapotranspiration in each successive period is made a function of the levels of evapotranspiration in the earlier period and the area under forests. Potential runoff can then be evaluated on the basis of the rainfall, evapotranspiration, and soil moisture holding capacity. To arrive at an index of soil erosion, this is multiplied by the area and the appropriate soil erosion coefficient.

This is a simple approach to a very complex problem. The objective is not to be able to arrive at a precise measure of soil erosion, but to develop a reasonable accounting system that can serve as a proxy for environmental deterioration. The construction of the model is such that it responds primarily to changes in land use in rural areas.

Household Energy Submodel

Firewood, dung and crop residues are the important types of con-

ventional sources for household energy in rural areas. In the Nepalese hills, firewood has been the most important source of household energy for a long time. Because of the increasing pressure on forests it is considered to be a major source of the problem in the future.

Per capita household energy demand refers to the energy required by individuals for cooking, heating and, to a smaller extent, lighting. It does not refer to the energy demand for agricultural production. Conventionally the demand for energy has been postulated in terms of income and price levels. In the case of the Nepalese hills, however, a simpler formulation is necessary on account of the lack of estimates regarding rural income and prices and their effects upon household energy consumption levels.

Per capita household energy demand in each period is postulated as a function of some base level of energy consumption and an aggragate growth factor. Two alternatives are considered. One uses the posibility for introducing biogas while the other does not. As the supply of firewood is unable to meet total household energy demands, use of cowdung, and kerosene enter the system. Kerosene costs reflect the opportunity cost of the loss of local based energy inputs (firewood and dung). The model also allows for a reduction in the amount of wood being used by households as the travel time increases.

Livestock Submodel

Our primary interest in the livestock submodel is to find the amount of fodder demand, the supply of draught power and animal waste. Other products like milk and meat are also important, but these are not considered.

Population and Labor Supply Submodel

A very simple population submodel has been used, where the total population in each period is made a function of its growth rate. Labor force is determined by the participation rate.

Cereal Grains Production Submodel

The production function approach is used for estimating the cereal grains production for each period. A generalized aggregate four variable Cobb-Douglas production function has been used for this study.

Model Application

The conceptual outline and logical structure for the model were discussed earlier. The problem now is to develop the model into an operational framework and then employ it to explore the implications of alternate policies-some on the resources side, some on the household energy side-for food supply, household energy mixes, and soil erosion. Although it is possible to evaluate each of the policies or combinations for its impact on each of the important variables, it is also possible to explore the trade-offs involved.

It was argued earlier that rural development efforts had not adequately taken into account the role of local resource supply and how this was related to the general fulfillment of basic needs--food and energy. This model has been formulated so that some of the additional factors like the changing mix of household energy sources, soil erosion and the chang ng nature of land based resources, can be considered in addition to the analysis of food production. This is not to minimize the role of food production; as a matter of fact the model will explicitly show how changes in food production can be related to the changing mix of household energy sources caused by depletion of one or more land-based resources. This analysis attempts to expand upon the traditional group of factors that have been used in analyzing production.

The central thrust of the study is to evaluate the scope for productively integrating the different rural activities in the hill environment. This is not an effort to establish the validity of an energy-intensive approach to rural development or for that matter an ecologically-balanced approach. While the impact of different policies and conditions is evaluated, the primary objective is to underscore the inter-relationships of food production, local resources supply, household energy mixes and environmental change.

Comparisons of the different policies and conditions are accomplished by running the model for each time period according to that specific policy or condition. Evaluations can then be made either by comparing the relative rates of change for certain key variables or by comparing the different levels of certain groups of variables with other variables. The model is run for a period of 19 years for each policy.

A specific area in the central hills of Nepal has been selected as the basic reference point in the quantification of the model. However, as the calibration had to be carried without the benefit of a field survey, data for many of the parameters have been drawn from a variety of sources and conditions--with some assessment as to their appropriateness to Nepalese conditions. Thus, while the model does refer to a particular area, it has to be treated as a hypothetical case. Another range of estimates would exist for different parameters. There may very well be the possibility of a non-linear type of change in the case of some of the land--based resources. To have attempted to verify all of these aspects would have been quite beyond the scope of one study. Since the overall functioning and interaction of the model is quite sensitive to the values of the parameters, the crucial roles of the values selected cannot be overemphasized. If other estimates are used, the results will no doubt provide a different picture.

Nature of the Area

Because of the enormous variations in the micro-environmental conditions in the hill areas, it is necessary to select a small area that is fairly homogenous. It was therefore decided to select a smaller area about which some information was available. The area is known as Thak in the western region of Nepal and was the subject of another study.[1] Furthermore, the study of the area had attempted to review the nature of population resource relationships; it was felt that it would be appropriate to evaluate quantitatively the changing conditions.

The basic information about Thak is presented in Table 1. Thak, in many respects, represents a relatively better-off area:

"In Thak, there was nearly one hectare (2.5 acres) of all types of land per man engaged in agriculture, compared to an average of just over one third of a hectare for the western hills as a whole; there are 0.64 acres per capita of cultivated arable land, as opposed to an average of only 0.18 acres per capita in western hills generally. Like-wise, the forest in Thak is renowned for its luxuriance and size. The relative affluence can be seen in their housing, personal possesions, clothing and diet."[2]

1. Alan Macfarlane, **Population and Resources**. Cambridge: Cambridge University Press, 1976.
2. Macfarlane, **op cit.**, p. 293.

TABLE 1

GENERAL INFORMATION ABOUT THAK (1969)

Population	1810
Forest (hectares)	320
Scrub and Grazing land (hectares)	140
Arable land (hectares)	128
Buffaloes (No.)	167
Oxen (No.)	135
Cows (No.)	64
Average Fodder Consumption (kg/day/Animal)	10

Source : A. Macfarlane, Population and Resources,
(Cambridge: Cambridge University Press, 1976),
pp. 37–49.

This is somewhat of a disadvantage because Thak may not be a typical hill area. However, since other areas have not been as accessible for information as Thak has been, there is not much choice. From a conceptual point of view, this need not be looked on as a handicap as the focus of the study is on being able to integrate the different aspects of rural environment; rather than on being able to predict a crisis point for the area in question. In a relatively worse area, by way of natural endowment of resources, the magnitude of changes and impact will be more pronounced and adverse, but the basic structure and logic of the postulated relationships would not change to any substantial degree.

Policy Choices

Although it is possible to assess the impact of a fairly wide range of policies, only a few have been selected for the purposes of this exercise. The policies selected are directed at the different subsystems in order to highlight the range of choices available. While the direct impact of a policy on the immediate subsystem may be quite apparent, this exercise helps us to assess the further influence upon the other subsystems which are interrelated. Rather than exhaust the policy options available just for one subsystem, the focus has been on evaluating the effects of different types of policies.

The first analysis involved a continuation of current trends and policies. This implies a continuation of the present trends in some of the subsystems (like population and livestock growth) while in others, it reflects the assumptions of the most probable conditions prevailing in the future (like the increasing substitution of dung for fuelwood as wood supplies become scarce).

The second policy was directed at reducing population growth by fifty percent from the current 2 percent per annum to 1 percent per annum. Even for a very small area like our hypothetical example, a fifty percent reduction in population growth can be expected to be the most optimistic assumption regarding population control policies.

The third policy is directed at increasing the supply of local resources -- an afforestation policy of 10 hectares per annum. This represents an annual increase of 3 percent in forest area on the basis of the available 320 hectares at the present. In terms of increases in wood volume also, this corresponds to a net growth of roughly 3.5 percent per annum. The benefits of this policy accrue only after seven years on account of the tree maturity constraint.

The fourth policy was directed at the house hold energy sub-system by exploring the impact of introducing biogas technolgy. This policy option assumed no time lags involved in the energy available from biogas plants including its uniform availability to the entire population. The first assumption is not very serious as biogas plants can be constructed within a few months if all the necessary materials are available and the current model runs on an annual basis. Relaxing the second assumption, however, required an evaluation of the factors influencing the use of biogas plants and this was not possible without the benefit of a field survey.

The fifth policy that was considered was increasing the number of livestock from the current average growth rate of 1.3 percent per annum to 2 percent per annum. Although this may not appear at first as a reasonable policy for many of the hill areas because of the already large livestock population, it has been considered for two reasons. First, it was considered desirable to assess the relative impact of changes in livestock on the other subsystems and, second, because of comparatively large forest area, further increases in livestock may be a very acceptable

decision for many rural households, including possibilities for increased manure supply.

The sixth policy option deals with increasing arable land. This may be brought about either by bringing more land under cultivation or by a more intensive use of available land. In the current case the former has been assumed. An annual increase of 1.4 hectares has been used as the policy and this represents a growth rate of about one percent per annum, using the base figure for arable land as 128 hectares. The final policy choice deals with the combination of afforestation and biogas. This is simply combining what has already been discussed under the respective policies above.

Time Frame

The model has been run for 19 years beginning from 1969. The starting date of 1969 had to be used as this was the year for which most of the important basic data related. A period of 19 years was also selected on account of the special characteristics of the region. Because it was relatively well endowed in some of the resources, effects of the interaction would not be very clear for a shorter period of time. For a less endowed region, however, a shorter time period would have been appropriate.

Indicators

There are a number of important indicators that can be used in describing the state of the hill agro-ecosystem for policy evaluation purposes. In preparing the output format for the computer program of the model, it was necessary to select for display a small set of key variables which would be useful in examining the changes in the hill agro-ecosystem from different policy perspectives.

In so far as the present exercise is concerned, our main interest is in the following indicators.

Foodgrains Production. This indicator identifies the amount of foodgrains produced every year. As the population is known, it is possible to calculate the per capita availability of cereal grains in each period.

Consumption of Different Household Energy Inputs. There are four indicators under this, one for each of the energy inputs to identify the total amount of energy inputs being consumed by the population. Since the total amount of biogas produced is the same for all periods when this policy system is activated, the indicator for the biogas consumption is in percapita terms.

Index of soil Erosion. This indicator identifies a measure for the nature of change with respect to soil erosion from arable land. This index is in arbitrary units.

Apart from these the printout also shows the levels of forest and fodder supply for each period.

It is possible to derive other indicators also, but for current purposes, these indicators will serve adequately to demonstrate the nature of change in the hill agro-ecosystem resulting from different policy options.

## NATURE OF RESULTS
Continuation of Present Trends

The starting point in testing the impact of alternate policies is to see first what the overall picture is if present demand and resource exploitation trends are allowed to continue for the next 19 years, beginning with 1969.

Figure 2 shows the changes in the levels of food production, forest area, population and the index of soil erosion. Pasture and arable land have not been shown, as it has been assumed they remain constant.

The population curve is the only one that increases continuously for the entire 19 years (from 1969 to 1987) because no constraints have been introduced to check it.

The food supply curve shows three distinct stages. From 1969 to 1979 it is almost constant with a slight increase discernable. The total production was 183 tons in 1969 and it reached a maximum of 186 tons in 1979 an increase of barely 3 tons, or an annual rate of incre-

FIGURE 2

Results Under Continuation Of Current Conditions: Forest,
Foodgrains And Population Change And Index Of Soil Erosion
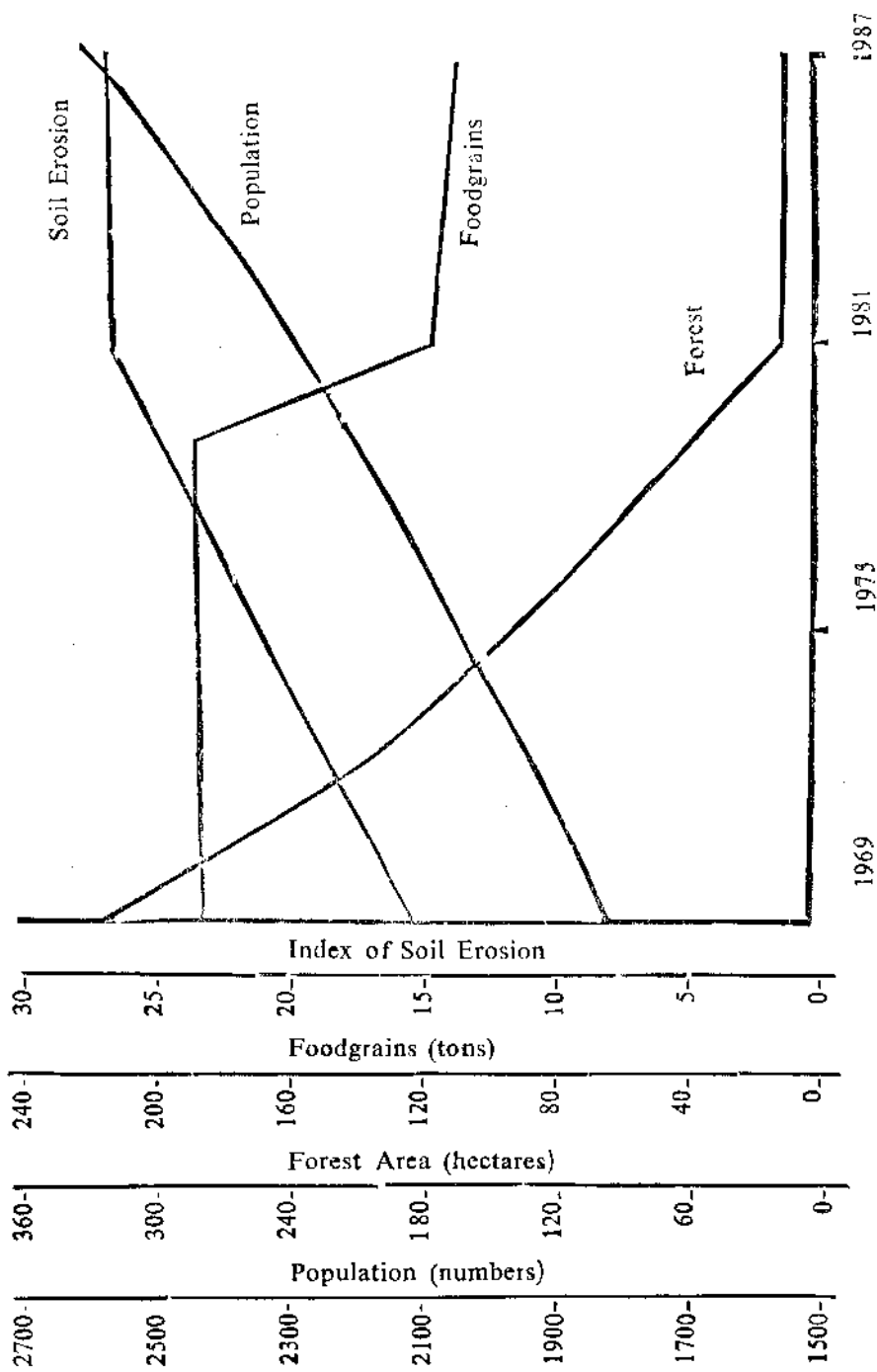
ase of around 0.16 percent. There is a sharp decrease from 1979 to
1981 from 186 tons to 113 tons. This decrease has been caused by
the fact that wood supply is no longer able to meet the fuelwood
requirements and households have begun to use animal waste for this
purpose. From 1981 there is a steady decline in production at the rate
of 0.4 percent per annum.

TABLE 2

PER CAPITA FOODGRAINS AVAILABILITY
UNDER DIFFERENT POLICY OPTIONS IN 1987

	in kg
1969–Starting Condition	101
Continuation of Current Conditions	42
Reducing Population Growth	49
Afforestation	54
Biogas Technology Introduction	77
Increasing Livestock Growth	35
Increasing Arable Land	45
Afforestation and Introduction of Biogas	78

The per capita availability of food grains stands at about 101 kg
per person in 1969 (Table 2). It gradually declines over the years,
reaching 83 kg in 1981, the year of its highest production. There
after the decline is even sharper and in 1987 it stands at 42.4 kg in
this relatively advantaged area.

With respect to forest area the graph shows a continuous rate of
decline until it is forced to stabilize at 12 hectares by our constraint.
It might be recalled that in 1969 the area started with 320 hectares.
Even at 29 acres, the net growth provides 8.74 tons of wood per
annum.

The index of soil erosion increases up to 1980, and stabilizes
after that when there are no changes in forest area. When we say
it stabilizes, this is to say that it is constant at the highest level
for the entire period. Since the soil erosion sub-model is sensitive to
changes in forest area and the amount of arable land, this result
is quite expected as there are no changes in the amount of arable
land.

The 1979 81 period therefore emerges as the most critical one and the changes here are more in the household energy sector. Let us briefly examine this aspect as well.

Table 3 shows the changes in the mixes of household energy inputs in total amounts for the region in question. Fuelwood and dung consumption of the area stand at 1569.42 tons and 6.22 tons, respectively, for 1969. Total fuel wood consumption declines in absolute amount for every year on account of the impact of increased travel time. From 1981 there is an increase of approximvtely 72 minutes in travel time. It is possible that this effect has been somewhat exaggerated in the model.

The consumption of animal waste reaches a maximum in 1983 and stays at this level on account of supply constraints. As a matter of fact it has even declined as changes in fodder supply will influence the amount of waste available. After wood runs out, the available dung supply is not able to provide the energy demand adequately and kerosene enters the system. It starts initially in 1981 at 201 tons but increases to 284 tons by 1987.

It is clear from the continuation of present trends that the gloomy state of the hill agro ecosystem will continue and reach a worse state. As a matter of fact, if the information base is accurate and there have been no significant changes, the Thak area may be beginning to feel the pressures already.

Impact of Reducing Population Growth

One of the policy conditions tested was a reduction in population growth from the current 2% per annum to 1% per annum. The impact is shown in Table 2 and 3.

Without any intervention, the 1987 population stands at 2585, while with a reduction in growth rate, it is 2165. The starting level is 1810. However, for most other aspects like food supply, rate of decline in forest area, etc., this situation does not differ from a continuation of current conditions. Per capita food availability stands at 48.7 kg in 1987 which is only six kg more than under the continuation of current conditions.

Total food production increases a little, at 0.19 percent per annum until 1981 and decreases at 1.2 percent per annum for the next six

TABLE 3

IMPACT OF ALTERNATES POLICIES IN 1987

Indicators	Continuation of Current Conditions 1969	1987	Reducing Population Growth	Afforestation Program
Population	1,810	2,585	2,165	2,585
Forest Area (ha)	320	12	5.2	23
Wood Supply (M³)	20,800.00	763.36	338.32	797.23
Arable Land (ha)	128	128	128	128
Index of Soil Erosion	15	26	26	26
Foodgrains (kg)	182,862.84	109,690.84	105,465.98	116,597.57
Fodder (kg)	3,160,000.00	1,560,484.11	1,527,789.07	1,663,089.65
Fuelwood (tons)	1,529.24	8.74	3.88	9.14
Dung (tons)	6.22	1,560.48	1,527.79	1,663.09
Kerosene (tons)	0.00	283.98	174.74	254.00
Biogas (per capita, ft³)	0.00	0.00	0.00	0.00

Indicators	Increasing Livestock Growth	Increasing Arable Land	Introducing Biogas Technology	Afforestation and Biogas
Population	2,585	2,585	2,585	2,585
Forest Area (ha)	12	12	22	37
Wood Supply (M³)	763.36	763.36	1,445.84	1,760.38
Arable Land (ha)	128	153.2	128	128
Index of Soil Erosion	26	31	26	25
Foodgrains (kg)	89,408.38	117,590.82	198,320.55	202,091.48
Fodder (kg)	1,534,630.71	1,812,484.11	1,612,982.40	1,737,178.01
Fuelwood (tons)	8.74	8.74	16.56	20.16
Dung (tons)	1,534.63	1,685.55	0.00	0.00
Kerosene (tons)	291.50	247.60	720	718.78
Biogas (per capita, ft³)	0.00	0.00	65,122.56	65,122.56

years. The rate of decline under this condition is greater than the rate for the earlier situation. This is so because of the changes in the forest levels in the latter years. The forest under this condition stabilizes at 5 hectares while it was 12 hectares in the earlier case. The reason for this is that the reduced population made it possible to supply an addional year with fuelwood as compared to the earlier case, and the effect of this was to leave a smaller forest area

In so far as the index of soil erosion from arable land is concerned, the effect is almost similar to that discussed under the continuation of the current conditions. The peak level is reached one year later.

Regarding the changes in the consumption of household energy source mixes, consumption of animal waste does not reach the levels identified under the earlier conditions and this is again the impact of the forest area in the latter years. Forest area influences fodder supply which influences animal waste.

The imports of kerosene are, however, much lower. It begins in 1982 at 140 tons and increases by 1987 to 174 tons.

As compared to the continuation of current conditions, this situation is undoubtedly better, but the effects are not as dramatic as those expected. Let us now see the situation under some of the other policy conditions.

Impact of Afforestation Program

Another policy tested was the introduction of an afforestation program of 10 hectares per annum. It should be noted that the tree maturity constraint for new trees was set at seven years and so the effects of this program will be evident only after the first seven years for every year of afforestation.

The general results are not very much different from those discussed under a program for reduction of population growth-meaning that it is better than a continuation of present trends, but does not show any marked improvement in the performance of the overall system. Table 3 shows the changes in food, forest area and the index for soil erosion. The food supply increases at an annual average rate of 0.17 percent until 1984. Under the earlier two conditions, however, it

increased only until 1980 and 1981, respectively, for a continuation of current trends and a reduction in population growth. In 1984 the per capita availability stands at 77 kg and reaches 45 kg in 1987. The index of soil erosion rises more slowly and the peak is reached only during the last two years.

In terms of consumption of household energy inputs, the effect is quite favorable as kerosene imports enter the system only during the last two-three years at respectively 230 and 254 tons. The benefits of afforestation are evident not only in terms of the increased levels of fodder supply and consequently a larger amount of waste supply in the latter years, but also in terms of more wood being available. It would be possible to experiement here with trees of different maturity periods and with varying mixes of fodder content. Lack of information relevant to the Nepalese hills in this respect made this evaluation difficult.

Impact of Introduction of Biogas Technology

The impact of biogas introduction is most significant in terms of food production. This is shown in Table 3. The big drop evident in all the earlier cases no longer exists, although a general decline in food production is evident after 1981. While in all the former cases, food production did not exceed 188 tons, it reaches 190 tons. The annual rate of increase until 1981 is 0.5 percent per annum. In the last year the food production stands at 177 tons, giving a per capita availability of 77 kg per annum, a figure which is much higher than for any of the cases discussed so far.

In terms of other effects, however, the picture is not as favorable. The decline in forests have proceeded at the same rates as before and there are substantial amounts of kerosene imports in the latter years.

Impact of Increase in Livestock Crowth

Compared with current trends, this change is better in only one respect, and that is that food production incrases at an annual rate of 49 percent until 1983, but thereafter it falls very sharply, reaching the lowest levels (Table 3). Food production decreases rapidly in later years not only because of switch in the use of animal waste, but also because of the reduction in the number of bullock working days, which

in the current model is sensitive to the available fodder supply.

Impact of Increasing Arable Land

Another option explored was what would happen if we allowed arable land to increase by 1.4 hectares per annum? A larger figure could have also been used but the reason this was selected was that it is close to the historical averag:. The general picture is shown in Table 4.3, and the overall picture is almost similar to a continuation of current conditions with the only difference being that soil erosion index is very high. The failure to register any favorable impact on food production was probably because of the small increases in land area. To have experimented with a larger area would have been unrealistic for the simple reason that extension of cultivable land in the hills is greatly limited.

Impact of Biogas and Afforestation

The impact of a combination of biogas and afforestation were also explored and the results are shown in Table 2 and 3. Undoubtedly the most favorable picture so far is evident in this case. There is no decline in food production and it increases at an annual average rate of 0.5%. At the end of 19 years, per capita availability of food stands at 78 kg. The decline in forests is also somewhat slower and the index of soil erosion rises less rapidly; the peak is reached only in the last year.

The energy impact is similar to those discussed under afforestation and biogas programs.

SUMMARY

Eight different scenarios have been reviewed so far and while the general effect of most of the policies are discernible, it is not possible to savs at this stage which represents the best outcome. In so far as food production is concerned, biogas and afforestation do rather well as compared to other policies, including a reduction in population growth. This is however only a partial picture as the cost implications of these programs have to be considered also.

Another aspect is the question who is going to pay for the kerosene imports? There are significant levels of kerosene imports under many alternatives and it is necessary to account for the costs associated with the aspect as well.

Other consideration may also be to find out which policy leaves the largest forest area, although this by itself would not be very meaningful.

In terms of the objectives, however, a farmework has been developed to look at the agro-ecostem in the hills in an integrated manner. Although it is not possible to say that some of the results were unexpected, the model has traced the link between the different systems and it is now possible for us to asses the role of each system not only in terms of its dynamic behavior but also in terms of its effects upon the other systems.