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FRAMEWORK FOR AN ADAPTIVE POLICY SIMULATION MODEL

Introduction

This section describes how some important sectors of the five districts are each separately integrated in order to assess their effects of the environment. Some indicators have been developed to assess the impacts of different policy action on the environment.

Conceptual Framework

Quantitative evaluation of alternative policies is of major concern to policy-makers. Formulating appropriate agricultural and natural resource policies requires a proper understanding of the internal characteristics of the area under study, its sectoral interactions, and relevant external relations. A complicated pattern of interactions exists between the various sectors of these five districts.

The hill farming system is complex and crop production, animal husbandry, and forestry are intricately linked. They simultaneously determine the living standards of the farm families, income, and employment levels, as well as affect their surrounding environment. Forest lands provide fuelwood, fodder, and timber. Croplands provide food, fodder, and crop residue. However, crop lands also require manure (and thus fodder) and litter from forest lands. Thus, livestock connect these land resources by converting fodder into draught power and dung nutrient, in addition to providing food and income to households.

Large parts of these districts are still isolated pockets which are insulated from market forces. Transport network and communication facilities have not reached many parts of these districts. Movement of people and farm products to urban centres is difficult. Tourism plays an important role in some of these districts. Areas that are relatively close to the road head are able to sell excess produce, but, by and large, the majority of households are many days' walk away from the road or market centres. Since such households are predominant in all districts, it is a major assumption of this study that market forces are weakly active in these areas, primarily because markets for many of the resources consumed and produced in the areas are non-existent.

Traditional techniques used for policy analysis, such as single market studies, frequently fail to evaluate the impacts of changing policy alternatives and exogenous assumptions over the broad range of economic variables and performance measures. Single market studies are limited in their abilities to evaluate cross commodity effects. General equilibrium models are extremely complex and require comphrehensive data, which are generally not available, especially at the district level, as in this study. Recently, more attention has been focussed on multimarket and multicommodity models. Multi-market models extend the more simplistic single market models to include distribution and some general equilibrium analysis (Braverman et al. 1983). These models, by relating commodity and market factors, more realistically trace the effects of policy change in different sectors than do single market studies. Environmental concerns can also be integrated within this framework, depending upon the extent of information that is already available. The essence of multimarket and multicommodity models is a set of consistent equations reflecting the technological, behavioural, economic, and institutional characteristics of producers and consumers, and market equilibrium conditions for both commodities and factors. The system is useful for determining different values of variables that can be influenced directly by policy. The system of equations can be developed econometrically.

Adaptive policy simulation (APS) models provide alternative, flexible methods by which multicommodity and multimarket interactions may be evaluated. Indirect, feed back, nonlinear, time-delayed, and other kinds of relationships can be dealt with appropriately within a logical framework if APS models are used. Another advantage of the APS model is that it allows the incorporation of many theoretical and empirical results of partial studies (Mayers 1988; Jensen et al. 1991; Low and Kelton 1982; Nijkamp et al. 1990; Braverman et al. 1987), i.e., the system is flexible.

This chapter outlines the development of an APS model used in this study which has the following three basic components.

- The first part of the model involves the external assumptions that define the current state of technology in each district, the set of policy/impacts and the behavioural parameters for supply and demand.

- The second component of the model includes the domestic supply and demand of food and natural resource products (crop, forest products, and livestock production), trade (import/export), and some exogenous variables (population, price, etc.) and their forecast over time.

- The third component of the model provides estimates of various performance/sustainability indicators derived from the model to evaluate the effects of policy shocks on selected performance/sustainability indicators.

Major Assumptions

Some major assumptions of the model are as follow:

- producers and consumers are price takers in both the product and factor markets, and
- relative prices of important products and factors will increase over time in relation to national price trends.

The other assumptions that have been made are reported in the respective sections that follow.

Linkages and Specification of Model

The APS model employed in this study establishes linkages between various sectors through several behavioural, structural, and accounting relations.[1] The model can thus provide information about the consequences of relative changes in prices and other policy actions on production, consumption, natural resources, and the environment. The ultimate impact of any policy interventions will be reflected in income and other indicators of social wellbeing as well as the environment, e.g., carrying capacity.

The APS model consists of different sectors and sub-sectors. The districts considered are essentially rural in nature. Some pocket areas classified as urban are too small to have any significant impact and, hence, are not treated separately. The sub-sectors include agriculture, livestock, forestry, food, trade, income, and employment among others and are interrelated through exogenous variables (prices, population) and also through supply and demand and market clearing relationships.

Each sub-sector is represented by supply and demand relationships. The supply side is defined in terms of factor prices and/or quantities, thus allowing for policy interventions. In certain cases, the supply side is composed of diaggregates, for example in the case of fuelwood, where a district's fuelwood demand is met by supply from different sources (forests, shrublands, farmlands, etc) across different regions (high mountain, mid-mountains, Siwaliks, etc).

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1 The behavioural demand and supply equations used in the model have micro-economic foundations. The parameter estimates used in the behavioural equations have been borrowed from studies carried out by various scholars in the Nepalese context. In limited cases, where such parameters were not available, estimates for the *terai* and rural India (non-food demand) have been used.

The demand side of the model depends primarily on population size and growth. Furthermore, income and prices are important determinants of the consumption levels of different commodities. Income and prices are used to influence demand depending on the availability of parameters. By incorporating income and prices on the demand side, this study deviates from the traditional method commonly used in Nepal where demand projections are based on per capita needs and population growth, i.e., constant coefficient method. Therefore, the method employed in this study (on the demand side) addresses, for example, households' access to food as constrained by their income and relative prices (food security) as well as food (calorie) needs (food sufficiency).

The demand and supply systems in each subsector can be further classified into three main sectors, namely, food, natural resources, and other activities/sectors. The food sector consists of those subsectors that provide food to households. It consists of the fuelwood, fodder, and timber resources as well as the different subsectors that are related to land use. In addition, the model consists of other sectors that are related to these two sectors on both the demand and supply sides as well. The other sectors include labour use, income, and trade which interact with the other two sectors. Furthermore, some activities that are not common across districts are also included in this sector, e.g., tourism in Rasuwa. Such activities are discussed separately below. Finally, the environmental sector consists of a set of outcomes resulting from food, natural resources, and other activities as well as the influence of the exogenous sector. Certain indicators have been developed to assess the environment, e.g., carrying capacity. In this study, therefore, the environment is viewed in terms of the outcomes of the integration of different sectors and subsectors in an economy along with the influence of the exogenous sector. Each is discussed in turn below. Figure 2.1 illustrates a simplified relationship between these major sectors. Figure 2.2 provides a more detailed diagram of the sectors and subsectors and their linkages that are taken into account in this study.

Exogenous Variables

Price

Foodgrain prices and other important prices are forecasted over time up to 1998 on the basis of a simple time trend relationship. The assumption made in forecasting prices is that district prices will change according to the national trend. Time-series' data (1975-1989) collected by the Department of Food and Agriculture Marketing Services (DFAMS 1990) have been used for this purpose. Since district prices may have been different from the national prices in the base year (1991), calibration to the intercept term of the regression equation was made using price information available for the district or the closest district in question as reported by DFAMS.[2] In addition, some aggregate price series have also been derived for each district on the basis of each district's production and individual commodity prices.[3] These aggregate prices vary across districts and are used in the food demand sector.

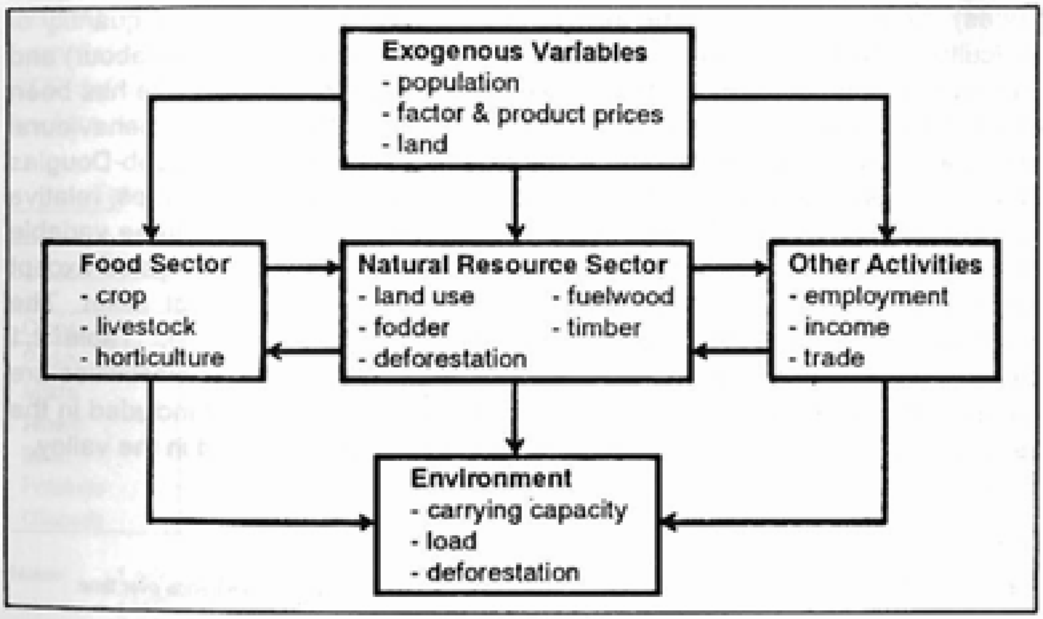
Population

The population forecast made by the National Planning Commission (NPC) using the most recent Population Census (1991) has been directly used for each district. The high variant projection scenarios have been used.

District Area

The land area of a district is assumed to remain constant throughout the study period, but land use within a district can change. The areas under Langtang National Park and Shivapuri watershed that fall within a district are assumed to have remained unchanged. In addition, natural resources from such areas are assumed to be unavailable for harvesting and private consumption. Furthermore, in some districts, where the high Himalayas are located, the second grazing that is allowed has been incorporated in the analysis.

Figure 2.1: Relationships between the Major Sectors



2 Time-series' data on prices is not available for all districts. Many of the series that exist are also not complete (DFAMS 1990).

3 The details are given later in the appropriate section.

Food Sector

Agriculture

Supply Side. Six crops have been considered in each district, namely, paddy, maize, wheat, millet, oilseeds and potatoes. These six crops account for over 90 per cent of the cropped area in most of the districts. Foodgrains are supplied by this sector.

Constant Area Forecast. Based on past trends, the cultivated area of each crop is assumed to grow over time at some constant rate, independant of prices. Such independent or exogenous growth assumptions are shift factors. The constant area growth of each of these crops is forecasted using a simple trend (semi-logarithm) based on historical data reported by DFAMS 1990 (Equation 1).

$$\text{Crop Area}_{i,t} = a_{i,} + b_{i,} \text{Ln (Year)} \quad (1)$$

where i = crops (paddy, maize, millet, oilseeds, and potatoes)

Behavioural Yield Response. Crop yield was assumed to be influenced not only by the shift factor (i.e., the constant yield growth assumption[4]) but also by changes in the relative crop prices in question as well as the relative prices of competing crops. To what extent farm households respond to changes in the relative prices depends very much on the relative strength of supply yield elasticities (own and cross prices). Crop yield can also be influenced by changes in the relative quantity of agricultural inputs (e.g., use rates of chemical fertiliser, bullocks, and labour) and changes in irrigated area.[5] For base yield rates, an average yield rate has been used. The results are given in Chapters Three to Seven. The behavioural equations describing the yields of different crops are specified in Cobb-Douglas form. Crop yield is assumed to be a function of the relative prices of crops, relative changes in area irrigated, and relative changes in the quantity of three variable inputs (labour, bullocks, and fertiliser). All crops are assumed to be irrigated except millet, and fertiliser is assumed to be used for all crops except millet. The estimating yield equations used are reported below (Equation 2).[6] Table 2.1 provides the values of the elasticities used in Equation 2. Separate elasticities are not available for each rural area considered. Bullocks input is not included in the valley's crop yield function since bullocks are not traditionally used in the valley.

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4 Note that the shift factor could be negative if some crop yields show negative trends over time.

5 Quantity elasticities had to be used in the absence of price elasticities.

6 Note that for all the rural areas, the same parameters are used in the yield function. No parameter estimates for each crop on a district basis are available. However, the variables associated with these parameters change across districts.

Production: The domestic (district) production of each crop is determined as the cropped area (Equation1) multiplied by the crop yield (Equation 2). Net production from domestic sources is domestic production minus allowances for seeds and other loss factors, including the milling factor (Table 2.2).

$$Y_{i,t} = BY_{i,t-1} \cdot \left(\frac{P_{i,t}}{P_{i,t-1}}\right)^{p_i} * \left(\frac{R_{i,t}}{R_{i,t-1}}\right)^{r_i} * \left(\frac{F_{i,t}}{F_{i,t-1}}\right)^{f_i} * \left(\frac{L_{i,t}}{L_{i,t-1}}\right)^{l_i} * \left(\frac{B_{i,t}}{B_{i,t-1}}\right)^{b_i} \quad (2)$$

Where:

Y_i = yield of crop i (i=1,..,6);
$BY_{i,t-1}$ = lagged yield rate of crop i;
P_i = price of crop i;
R_i = irrigated area of crop i;
F_i = fertiliser use rate of crop i;
L_i = labour use rate of crop i;
B_i = bullock use rate of crop i.

Superscript are elasticities (see Table 2.1).

Cultivation Cost. Data on the cultivation cost per hectare were obtained from the Irrigation Master Plan Report (DOI 1989) for the eastern hilly and mountainous regions and was adjusted to reflect conditions in the Bagmati Zone. Labour, bullocks, seeds, manure, and pesticides were the major variable inputs used for deriving cultivation costs. The prices for these agricultural inputs were obtained from field visits and have been forecasted to grow at the rate of the agricultural GDP deflator reported in the Economic Survey (1990). Table 2.3 provides the per hectare use rate of inputs used in the study.

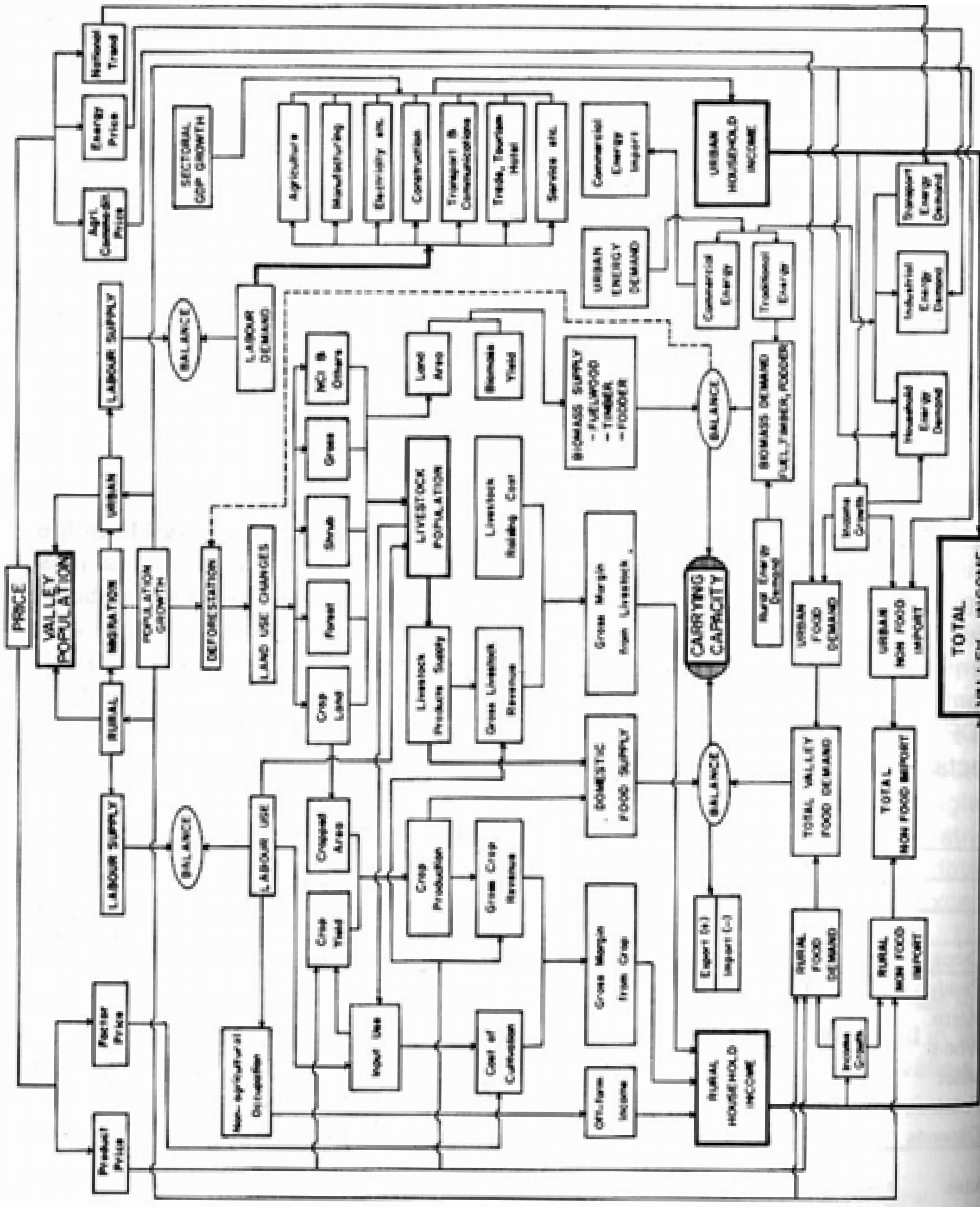
Table 2.1: Own and Cross Price and Input Quantity Supply Elasticities

Elasticities with respect to							
Crop prices			Input quantities				
	Own	Cross		Irrigation	Fertiliser	Labour	Bullock
Crops	P_i	P_j	P_j	r_i	f_i	l_i	b_i
Paddy	0.272	na	na	0.130	0.250	0.250	0.050
Maize	0.180	na	na	0.043	0.048	0.160	0.150
Wheat	0.282	-0.012[1]	-0.08[2]	0.311	0.25	0.147	0.180
Millet	0.050	na	na	na	na	0.092	0.070
Potatoes	0.250	-0.010[3]	na	0.150	0.123	0.125	0.150
Oilseeds	0.200	-0.080[4]		0.275	0.030	0.097	0.170

Notes: 1 refers to wheat yield w.r.t. to potato price
2 refers to wheat yield w.r.t. to oilseed price
3 refers to potato yield w.r.t. to wheat price
4 refers to oilseed yield w.r.t. to wheat price
na refers to not applicable

Source: Pudasaini 1984

Figure 2.2: Schematic Diagram Depicting the Linkages of the Model Kathmandu Valley



Gross Margin. Gross margins for different crops were then derived simply by subtracting the variable cultivation costs from gross farm revenue (gross crop revenue plus value of by-products [DOI 1989]. Gross crop revenue is the sum of gross revenue of each crop. Gross revenue of a crop was obtained by multiplying crop production by crop price. Assumptions regarding the quantity and prices of crop residue are given in Table 2.4.

Demand Side. As with the supply system, the demand side of the model specifies a set of demand response equations for different groups of food commodities consumed in rural and urban areas, in order to project their future demand growth pattern. The basic outcome of the model employed in this study is, therefore, determined not only by the supply response but also by the consumption response to prices and income.

The food demand of rural households depends on their dual functions, i.e., as households and as firms (Singh, Squire and Krichner 1984). As households, their demand depends on income, household size, and relative prices, but unlike other (e.g., urban) consumers, their incomes also depend on changes in relative farm prices because these also change their farm income through crop supply functions.

The present exercise limits itself to five types of food commodities cereals (paddy, wheat, maize, and millet); vegetables (potatoes); milk; meat; and oils and fats (mustard oil and ghee). Meat and oils and fats are supplied by the livestock sub-sector. The per capita domestic consumption of these food groups was derived from the total production adjusted for losses and seed allowances.

The per capita demand of these food commodities is assumed to be a function of relative prices, per capita income, the strength of prices (own and cross), income elasticities, and base period per capita availability. The demand parameters required for this study were derived from a more recent demand study (Mudhbary 1988).[7] The parameters derived from this study are for low, average, and high income households (Table 2.5). The demand functions used are also of the Cobb-Douglas type. The specifications of the behavioural demand equations used in the study are given in Equation 3.

Table 2.5 provides the values of the demand and price elasticities used in the demand equations for different areas. It is worth noting that the income generated by the model is introduced in the model's demand equations. Thus, for farm or rural households, changes in food prices affect demand directly as well as indirectly through income because changes in food prices will affect crop income and, thereby, household income. The model works out the net effect automatically

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7 This is the only study of its kind carried out in Nepal. Mudhbary used the Almost Ideal Demand System (AIDS) to estimate his demand coefficients based on NRB Multipurpose Household Budget Survey data.

Table 2.2: Loss Factor Assumptions

Grains	Seed Requirements	Milling Loss	Other Losses and Damage
Paddy	53 kg/ha	38%	10%
Wheat	120kg/ha	4%	10%
Maize	24kg/ha	3%	10%
Millet	20kg/ha	7%	10%
Potatoes	800kg/ha	0	15%

Source: DFAMS (1990) Annual Bulletin on Food Accounts (in Nepali)

Table 2.3: Input Use Per Hectare

Inputs	Paddy	Maize	Wheat	Millet	Potatoes	Oilseeds
Labour (mandays)	222	160	128	140	217	91
Bullocks (pairdays)	51	38	38	36	45	25
Fertiliser (kg)	18	16	24	na	14	10
Manure (MT)	3.62	3.87	3.75	2.50	7.80	2.16
Seeds (kg)	49	24	120	20	900	15
Others (Rs)	47	20	50	na	20	na

Notes: na = not applicable
Source: Basic data from Irrigation Master Plan (1989)

Table 2.4: Quantity and Price of Crop Residue by Crops

Crops	Paddy	Maize	Wheat	Millet
Residue (MT/ha)	1.3	1.1	0.8	0.8
Price (Rs/MT)	500	500	500	500

Source: Irrigation Master Plan (1989)

because changes in farm profits (gross margin) are fed in through income. Per capita base consumption values of the different foods consumed were derived from the availability section.

$$PD_{i,t} = PD_{i,t-1} * \left(\frac{I_t}{I_{t-1}}\right)^{d_i} \prod_{j=1}^{5} \left(\frac{PR_{j,t}}{PR_{j,t-1}}\right)^{e_{i,j}} \qquad (3)$$

Where:

$PD_{i,t}$ = per capita demand of ith food;

$PD_{i,t-1}$ = lagged per capita demand;

I_t = per capita income;

$PR_{j,t}$ = price of jth food;

d_i = income elasticity of demand for ith food;

$e_{i,j}$ = price elasticity of demand for ith food

(i=1...5; j=1...5).

Livestock

Livestock are a key component of hill farming systems, connecting crop lands and forests by converting fodder into draught power and dung nutrient. Hill farmers who cultivate land also raise livestock and depend heavily on forests to support both. Given this interdependence, the livestock population can be linked with different land categories (croplands, forests, and grazing lands). By linking livestock with land use data, the model can capture the effects of changing land use patterns on the livestock population and hence on livestock products and livestock income.

Table 2.5: Demand Elasticities' Estimates

Food Commodities	Elasticities with Respect to Commodity Prices					
	Cereal	Vegetables	Meat	Milk	Oils	Income
	Estimates for Low Income Households					
Cereal	-0.82	0.06	-0.05	0.13	-0.03	0.351
Vegetables	-0.59	-1.10	0.26	-0.96	-0.12	1.650
Meat	-1.68	-0.26	-1.35	-1.10	0.50	2.615
Milk	1.26	-0.15	0.19	-0.50	0.44	0.766
Oils/Fats	-0.28	-0.08	0.21	-0.20	-0.76	1.421
	Estimates for Average Income Households					
Cereal	-0.63	0.05	-0.10	0.06	-0.02	0.308
Vegetables	-1.06	-1.10	0.24	-0.64	-0.18	1.764
Meat	-1.76	-0.17	-1.05	-0.52	0.34	2.480
Milk	0.15	-0.18	0.10	-0.52	0.36	1.227
Oils/Fats	-0.45	-0.06	0.23	-0.04	-0.69	1.152

Note: Low, average, and high income households refer to Rasuwa and Kabhre; Sindhu; Nuwakot, and Dhading households respectively.

Source: Mudhbary 1988

Livestock Population Forecast

The livestock sector is driven primarily by the four land uses categories, namely, cultivated areas, forest areas, grazing areas (shrubs area + grasslands), and adjacent non-cultivated inclusions (NCI). Regression analysis was conducted by using cattle population as the dependent variable and land use data for 38 hill and mountain districts of the Eastern, Central, and Western Development Regions as explanatory variables. After estimating different models, a model that reasonably captured the relationship between cattle population and land use categories was selected to integrate the livestock population with land use. The regression equation (corrected for heteroscadasticity) estimated was in double log form (Eq 4). What Equation 4 basically states is that cultivated area has the strongest influence on cattle population, followed by adjacent NCI, forest area, and finally grazing areas. A ten per cent increase in cultivated area leads to almost five per cent increase in cattle population. All the four types of land use categories affect cattle population positively. Similar exercises could not be conducted for other types of livestock since data were not available. However, for the few years of data on other types of livestock population reported in the DFAMS 1990 report, regression on other livestock population was conducted by considering cattle population as the independent variable. Using these results, the other types of livestock population were linked with cattle population. As a result, changes in land use in a district not only lead to changes in cattle population but also to changes in other types of livestock population, and, hence, livestock products' supply. The other types of livestock included are buffaloes, goats, sheep, pigs, and chickens. Pig and chicken populations are assumed to be independent of land use and are forecasted on the basis of time trends.

$$Ln(Pop) = 1.9516+0.4788*ln(A\_1)+0.2966*Ln(A\_2)+0.0298*Ln(A\_3)+0.1310*Ln(A\_4) \quad (4)$$

The t-ratios are: intercept (4.21); (A_1), (3.79); (A_2), (2.10); (A_3), (0.80); (A_4), (1.72).

R^2=0.93; and where: Area_1,Area_2,Area_3,and Area_4 represent cultivated, non-cultivated inclusions, shrub and grass, and forest areas respectively.

Livestock Products' Supply

DFAMS (1990) collected data on livestock products' supply for each district over a five-year period. Conversion ratios between livestock and adult population and livestock products were calculated to obtain livestock products' supply. Milk yield rates were also derived to obtain milk supply. Ghee supply was also calculated by assuming that 30 per cent of the milk production goes into ghee production. The milk to ghee production factor was assumed to be four and five per cent respectively for cow and buffalo milk. Finally, wool production was estimated by assuming that about half a kilogramme of wool can be harvested from each adult sheep in a year.

Bullocks

Fifty per cent of the cattle population are assumed to be males and out of this 66 per cent are assumed to be bullocks. The resulting bullock numbers were divided by two to obtain bullock pairs. Each bullock pair was multiplied by 219 days (working days) to arrive at the bullock pairdays' supply to be used in crop yield response function and cost of cultivation.

Manure

Manure supply was obtained by multiplying each adult grazing animal by 1.13MT manure/year (Irrigation Master Plan). The conversion factor of grazing animals of adults is 0.66.

Natural Resources' Sector

The natural resources' sector consists basically of forest products that are harvested by households to meet their consumption needs, including those of livestock. Natural resources refer to three forest products, namely, fuelwood, fodder, and timber. Since forests are one type of land use category competing with other land use categories (agriculture, grasslands, and others), the natural resources were first developed in terms of land use to account for the land use changes that occur over time.

Land Use Dynamics

The forestry sector use data collected by LRMP (1986), the Forestry Master Plan (MPFS 1988a, and 1988b, and 1988c), and the Water and Energy Commission Secretariat (WECS 1987). The forestry sector is the most complex and, as a result of the lack of information, various simplifying assumptions have had to be made which are discussed below. LRMP (1986) reported several different land-use categories, namely,[8]

- natural forest: accessible and inaccessible;
- area planted to forest;
- shrublands;
- grasslands;

8 Refer to LRMP (1986) for details on the definition of these land categories.

- adjacent NCI;
- NCI within gross cultivated area;
- net cultivated areas; and
- other waste lands.

Land-use changes in many hill districts of Nepal are closely associated with deforestation. As the destruction of open access forests takes place, forest land is changed into shrub and grass lands and eventually into barren and agricultural lands (Shrestha 1989). Not all natural forests in the hill districts are accessible. Hence, the accessible forests were first derived by using the accessibility factor reported in MPFS (1988a), and this class of forest was assumed to have declined at one per cent per annum during the period from 1978 to1989. From 1992 onwards, the extent of deforestation was assumed to depend on firewood deficit (explained below). The net reduction in accessible forest area that takes place in each district in the above manner leads to change in land use, and this change affects the environment, depending on the direction and magnitude of interclass land transfers as a result of deforestation.

Given the lack of time-series' data on land flow between various categories, some simplifying assumptions regarding inter-class land transfers have been made on the basis of the field observations of experienced foresters and of case studies. The annually deforested areas were assumed to have been transferred into different land use categories in different ecological belts (Table 2.6). The reasons for making the assumptions (Table 2.6) regarding the distribution of deforested area are that, firstly, land in each region is assumed to remain constant throughout the period under study; secondly, even though land use changes within the above classes of land use take place, the net result appears to be a declining trend in forest area, and an increasing trend in other uses, although small; and thirdly, after deforestation takes place, the area generally turns into shrubland. Since the rate of migration from the hills to the inner *terai* (Siwaliks) has been high and the terrain less harsh than in the hills, a 50 per cent conversion factor has been assumed for the Siwaliks in the case of agricultural land. In the mountain region, a lower conversion factor was assumed because of relatively harsher terrain. According to the above assumptions, land use in each class, therefore, changes over time with the total land area in each belt remaining constant.[9]

In addition, mapped cultivated areas, which are the sum of gross cultivated areas (i.e., net cultivated plus NCI within gross) and adjacent NCI, also change over time. Within gross cultivated area, the NCI within gross (NCIG) is assumed to remain constant. This is because the area under NCIG includes trails, paths, irrigation channels, terraces, and so on within farm lands, school compounds, and other public use areas, and it is assumed that such areas do not change over time. The

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9 Also see Forestry Master Plan (HMG/ADB/FINNIDA, 1988a, 1988b) on these issues for more details.

total forest area calculated is then the sum of accessible, inaccessible, and planted forest area (presently zero in most cases).[10]

Table 2.6: Assumption on Land Transfers due to Deforestation by Ecological Belt

Land Class	Siwaliks	Mid-mts and Other
Shrublands	15%	50%
Grasslands	15%	15%
Agriculture	50%	20%
Adjacent NCI	15%	10%
Residual	5%	5%

Note: Other includes high mountains.

Finally, all the above categories of land use in the district's sub-regions (Siwaliks, mid-mountains, high mountains, and high Himal) were added together to derive the district land use classes. The resulting value was then deducted from the total land area of the district to arrive at the residual land use class. Residual value was then derived at the district level. Protected areas or natural parks were treated accordingly.

Forest Area Adjustments

Species' Composition

LRMP (1986) defined hardwood, conifer, and mixed wood as constituting forest composition. The area under each species was then derived for use as base year weights. Species' composition is gradually undergoing a change because most useful and wanted plants and grasses are being harvested and grazed, and they are being replaced by unwanted species and weeds such as *Eupatorium.*

Crown Cover

Three classes of crown cover exist (D2, D3, D4)[11]. Crown cover is based on canopy density. On the basis of base year values, projections were made for each type of crown cover forest. One assumption that warrants rethinking is that the crown

10 Information on annual planted area was not available for all the districts and therefore could not be accounted for. However, the model developed has provisions to account for area planted in the forestry sub-model.

11 D2, D3, and D4 refer to 10-40%; 40-70%, and above 70% crown densities respectively.

density of each time period is assumed to remain constant throughout the forecasted period based on the base year density. Over time the crown density is also likely to change, with higher density forests being converted to lower density forests. The densities of planted and protected areas may improve over time from low to high density. If appropriate assumptions or parameters can be provided, this can be incorporated into the model.

Water and Energy Commission (WECS 1987) reported the yield rates of forests of different densities and composition on the basis of a 100 per cent crown density assumption. Factors have been provided to adjust for species and density composition in order to adjust the forests to 100 per cent crown density. The factors are as follow:

- density class 2 = .25;
- density class 3 = .55; and
- density class 4 = .85.

By multiplying the areas under different density classes for each region by these factors one can arrive at the 100 per cent adjusted, crown density forest area.

Forest Products' Supply and Demand

Fuelwood

Yield Rate Assumptions. WECS (1987) reported the fuelwood yield rates for different forest species from forests and other lands as follow:

- hardwood forests - 5 air dry tonnes (adt)/ha;
- conifer forests - 1.25 adt/ha;
- mixed forests - 3.75 adt/ha;
- shrublands - 0.69 adt/ha;
- grasslands - 0.10 adt/ha;
- NCI adjacent - 0.69 adt/ha; and
- farm trees - 3.5 adt/ha.

Fuelwood Supply and Demand.

The yield rates assumed above were multiplied by adjusted crown density areas for each forest species in each region. The sum of the values of fuelwood from all sources in turn gives the total fuelwood supply. The demand for fuelwood was estimated to be 588kg (290kg from forests, 194kg from private trees, and 104kg of crop residue) per person per year (MPFS 1988b). The total demand was derived by mutiplying this value by the total population. The fuelwood balance was then derived as the difference between supply and demand.

Fodder

Yield Assumptions. Fodder is supplied from various sources that have varying yield rates. The yield rates assumed for fodder supplied from different sources are defined in Table 2.7. Furthermore, it was assumed that one per cent of net cultivated area will provide fodder in the Siwaliks and five per cent in other mountain regions. Fodder yields from cultivated land were assumed to be 1.4 TDN/ha and 1 TDN/ha respectively in the Siwaliks and other mountain regions (MPFS 1988b and WECS 1987).

Supply and Demand.. Supply of fodder in a district is the sum of the production (yield multiplied by area) from different sources and sum across regions. Demand is based on the number of LSU for grazing animals adjusted to the adult livestock population. Details on livestock projection are given later. The demand per adjusted LSU was assumed to be 0.6327 TDN/LSU/year (MPFS 1988a). Fodder balance is the difference between supply and demand.

Timber

Yield Assumption. Average timber yield rates assumption made on the basis of MPFS 1988a (Table 2.8) were used to project timber supply.

Supply and Demand. The total timber supply was calculated as the sum of the yield rates times area under forest adjusted for density. The per capita timber demand was assumed to be equal to 0.079 cu.m/year (MPFS, p 51) in all districts. The total population multiplied by this per capita equals the total timber demand. The balance is the difference between supply and demand.

Table 2.7: Fodder Yield Rates from Different Sources (MT/ha in TDN)

	Siwaliks	Mid-mts	High Mountains
Forests	0.56	0.43	0.54
Grasslands	0.58	0.28	0.76
Shrublands	0.77	0.77	0.77
Adj NCI	0.24	0.24	0.24
Tree Plantation	--	1.44	1.44
Crop Residue:			
paddy:	0.66	TDN/MT of harvest	
maize:	0.28	TDN/MT of harvest	
wheat:	0.28	TDN/MT of harvest	
millet:	0.61	TDN/MT of harvest	

Source: HMG/ADB/FINNIDA 1988a

Table 2.8: Timber Yield Assumptions

Siwaliks	Mid-mts and Others
0.714 cubic metres/ha	0.286 cubic metres/ha

Source: HMG/ADB/FINNIDA 1988b

Deforestation

Given the biomass supply and demand, it is possible to provide an estimate of the rate of deforestation that may occur. The difference between supply and demand of biomass (fuelwood, fodder, and timber) can be negative or positive. If the balance is positive, no pressure will be exerted on forests, hence, deforestation is not likely to occur. If the balance is negative, i.e., there is an excessive demand for biomass, and this situation persists over time, forest degradation will take place and eventually lead to deforestation. The process of degradation and deforestation depends on biomass stock, annual incremental stocking rate, and excess demand. This study defines deforestation occurring when the biomass stock is depleted to meet excess demands.

The existing biomass stock at any time determines the annual stocking rate and, consequently, the annual (sustainable) harvest rate. As biomass stocks depleted over time, the annual stocking rate also depleted at a faster rate, thus reducing the annual sustainable harvest rate. Deforestation takes place when the excess demand is met from the existing biomass stock. Therefore, it is essential to have an idea of the biomass stock per hectare of forest land for a given species, maturity, and crown density class. As already discussed above, all the accessible forest areas were adjusted to 100 per cent density assumption. The biomass yield assumption described above is the sustainable yield possible from the given biomass stock adjusted to 100 per cent density. In addition, an estimate of the biomass stock per hectare of the adjusted accessible forest area is also necessary to get an idea of the rate of deforestation that is likely to occur.

It is likely that the biomass deficit will somehow be met by households to fulfill their biomass needs. Biomass is supplied by different sources and unfulfilled demands will be met through the depletion of forest biomass stock, i.e., overexploitation under an open access regime. Thus, on a hectare of forest land, the depletion of stock over time will eventually lead to deforestation if excess demand continues. Therefore, the rate of deforestation will depend on the magnitude of unfulfilled, excess demand for biomass. If the unfulfilled, excess demand equals the biomass stock of a hectare of forest land, then one hectare of forest land will be deforested. If, on the other hand, the excess demand is less than the biomass stock of a hectare, then deforestation will be less than a hectare. Likewise, if excess demand exceeds one hectare of biomass stock, then deforestation will also exceed one hectare.

The model allows estimation of excess demand. The biomass (firewood, fodder, and timber) yield issues have already been dealt with above. Now an estimation of the biomass stock of a hectare of forest land is required. The estimate of biomass stock per hectare varies in Nepal. For example, in the Arun Valley in East Nepal, where population pressure on forest land is not as severe as in most districts in the Bagmati Zone and where forest density is also greater, the estimated average biomass stock per hectare of forest land is fairly high (Table 2.9). In the case of the districts in the Bagmati Zone, the population pressure is greater and forest density is lower for various reasons (see Mahat 1987). Thus, it can be assumed that the average biomass stock per hectare of forest land in the different districts of the Bagmati Zone will be 25-50 per cent less than the estimated average biomass stock of hill forests (149MT/ha) in the Arun Valley (Bhadra et al. 1991). If there is excess demand, it leads to deforestation and the extent of area deforested is fed back to the accessible forest area as a loop, and use changes due to this effect are updated leading to new biomass supply estimates. This cycle continues over the time frame of the model.

Other Activities

The three sectors discussed above do not include all the economic activities of each district. Other activities, such as labour use, trade, and income generation, are also important. These activities and how they are linked to the above sector and subsectors are discussed in this section. In addition, some activities that are not common to all districts are also discussed in this section. Despite including all these activities, the model has not been able to cover all the activities/sectors that exist in a district. The major reason for this is the lack of information. For example, Dhading's increasing success in vegetable cultivation has not been incorporated in the model. The absence of such activities, especially if such activities are important for recognising this limitation of the model when results are being interpreted. Firstly, activities/sectors that are common to all districts are discussed and the last two sections deal with tourism and horticultural activities that are specific to Rasuwa.

Labour Use

Integration of this sector into the model enables us to derive important information about the extent of labour use (employment) and its simple change estimate over time in a district. Integrating the labour use sector involves the following simple method of estimating labour availability and its utilisation in different sectors. As already indicated, population figures were obtained from the NPC. Only active population was taken into account to determine labour supply. The participation rate was not considered. Each active household member is assumed to have at his/her disposal 250 working days per year.[12] The active members were multiplied by the normal duration of work to derive the total labour supply in the district. Members are assumed to allocate their time to crops, livestock, and other off-farm activities. The total labour days used for crops was derived from the cost of cultivation data. Households are assumed to devote 100 mandays of labour to one LSU (NRB 1988). The other activities are based on the distribution of economically active population by occupation (NRB 1988). These factors for the low and average income districts are reported in Table 2.10.

Table 2.9: Estimated Biomass by Forest Type and Canopy Closure

Forest Type	Biomass Stock (MT/ha)			
	Class A	Class B	Class C	Average
Hill Forest	250	133	63	149
Lower Slope Mixed Hardwood	303	190	102	198
Upper Slope Mixed Hardwood	246	162	105	171
Temperate	316	200	120	212

Note: Class A, B, and C refer to canopy closure of >75%, 75-50%, and 50-20% respectively.
Source: Bhadra et al, Table 4.9, p.57 (1991).

Table 2.10: Distribution of Economically Active Population

District	Professionals	Office	Sales and Services	Production	Construction	General Labourers
Low Income	1.8	1.1	2.7	2.0	0.04	7.5
Average Income	1.6	1.8	3.8	4.2	1.00	8.7

Source: NRB 1988

12 This is the normal duration of work in the hilly and mountainous regions of Nepal estimated by the Nepal Rastra Bank-Multipurpose Household Budget Survey (NRB 1988).

Food

The model's trade sector is composed of import demand and export supply. Export supply consists of only food commodities that are domestically (in the district) produced. The excess food that remains after subtracting the total demand from the total supply is assumed to be exported. If, however, the balance is negative, then that amount is assumed to be imported. It should be noted that food import/export are affected by product and factor prices as well as income and population growth. Stated differently, commodity prices and per capita income affect food demand, and crop and factor prices and other inputs affect food supplies.

Non-food

Non-food import is driven by population growth, income elasticity of demand for non-food, and growth in income. The extent to which import demand is influenced by the growth in income depends upon the strength of income elasticity of demand for non-food.[13] The growth rate of import demand was specified to equal population growth plus per capita income growth multiplied by income elasticity of demand for non-food (Equation 5). Base year, non-food import demand was then multiplied each year by this growth rate to obtain the value of total non-food imports. Per capita income growth was derived from the model explained below.

NRB 1988 reported the import content in monthly household expenditures broken down into domestic imports and imports from India and the rest of the world (ROW). The figures were added to arrive at the value of total non-food import. Since the survey refers to 1984, the per capita value of non-food imports was inflated by the real income growth rate obtained from the model to arrive at the 1991 value. NRB (1988) estimates for rural mountains have been applied in the case of Rasuwa and rural hill estimates have been applied in the other four districts. To reflect the higher economic status of the Central Development Region, the resulting value for 1991 was multiplied by a factor of 1.25 based on the per capita income difference derived from NRB 1988.

The demand for non-food imports is assumed to be elastic. Engel's law states that income elasticity of demand for a luxury is generally elastic, i.e., the demand for a luxury is very sensitive to changes in income. Thus, we assume that non-food imports are a luxury relative to food, and also that imports originating from the rest of the world (ROW) are relatively more luxurious than imports originating from

13 The income elasticity demand for non-food is not available for Nepal. An estimate for rural India, based on results reported by Ray (1987), has therefore been used.

India. Imports originating from domestic sources are assumed to be the least inelastic but more elastic than food demand.

$$IDG_t = PG + IR_{t-1}*E \qquad (5)$$

where: IDG is the non-food import demand growth rate;
PG is population growth rate;
IR is the per capita income growth rate; and
E is the income elasticity of demand for non-food.

The base figures assumed for the value of non-food imports and the corresponding elasticities for non-food imports originating from domestic, India, and the ROW were derived from different sources and are reported in Table 2.11. The basis for assuming the elasticity values was the estimate of such values derived for India and Pakistan (Ray 1986 and Sarmad and Mahmood 1987).

Table 2.11:Average Monthly Household Expenditure and Income Elasticity of Demand for Non-food

	Expenditure (Rs)	Elasticity
Domestic	271.75	0.90
India	83.59	1.30
Rest of the World	51.66	2.00
Total	407.00	

Source: NRB 1988

Income

Households are assumed to derive their income from crops, livestock, wage labour, occupational sources, and exports. Crop income is the sum of gross margin from each crop considered in the model. Likewise, livestock income is the sum of gross margin from each livestock product. Off-farm employment (see labour use section above) also generates income. Income accruing from different off-farm employment categories is also based on NRB (1988) and has been adjusted to reflect the 1991 income levels. Thus, the total household income is the sum of income accruing from the various sectors discussed above.[14] Per capita income and growth rates

14 In the case of some districts where additional information on other economic activities is available, income accruing from such activities is also included in the total district income. For example, in the case of Rasuwa district, incomes from the tourism and horticultural sectors are

were also derived. Each year's per capita income feeds the equations that determine the import growth and food demand equations discussed below.

Tourism

The flow of tourists was forecasted by using the information reported in the Tourism Statistics of Nepal (Equation 6). It was assumed that the number of tourists visiting Langtang National Park (LNP) in Rasuwa district will be a fixed percentage of the total number of trekking tourists that visit Nepal. Past trends indicate that the average share is about 11 per cent.

The number of days a tourist stays in LNP is assumed to be seven days (Banskota and Upadhyay 1989). It is further assumed that one tourist hires, on an average, 1.04 porters but only 60 per cent of the porters are assumed to be hired locally. Assuming that a porter's wage was twice the agricultural wage, porter income was estimated. A third source of local income from tourism in the district is the expenditure of tourists on food and lodging. However, not all tourists visiting the LNP use these facilities. Survey results indicate that only 70 per cent of the tourists depend on local food and accommodation (Banskota & Upadhyay 1989). In 1989, the estimated food expenditure per day by a tourist in LNP was about Rs 1,000 and an additional Rs 377 was spent on accommodation. These figures were then updated to match values for 1991. The total tourism income accruing to the local people is then the sum of the total wages, food, and accommodation expenditure made by a tourist during the seven days he spends in LNP.[15]

$$Ln(TT) = 9.59 + 0.1077^{*}Year \qquad (6)$$
$$(81.6) \quad (11.9)$$

R_2=0.93 and where: TT is the number of trekking tourists and t-values are presented in parentheses.

Horticulture

Rasuwa district is believed to have considerable potential for horticultural development (Shrestha 1991).[16] At present, horticultural development in this district

also included.

15 Some tourists spend time on the Helambu side of LNP which is located in Sindhupalchok district. Lack of information on the number of tourists visiting LNP by this route and days spent prevented us from accommodating the tourism income flow for Sindhupalchok district. The expenditure values used are reported in Banskota and Upadhyay (1989).

16 See Shrestha (1991), 'Horticultural Development in Rasuwa.'

has only just started. Primarily apples, peaches, and walnuts were planted. Other types of fruits are also cultivated in the district.

The areas covered by apples, peaches, walnuts, and other fruits total 224, 69, 45, and 194 ha respectively. This area is assumed to grow at two per cent per annum based on three years' data on the area under fruits as reported by Shrestha. Shrestha also provides the cost of cultivation and returns per hectare. These figures were used to derive the Rasuwa horticultural income. More details are provided by Shrestha (1991).

Environmental Sector

A set of indicators was also developed to summarise the performance of the districts. These performance indicators were derived from different sectors of the adaptive policy simulation model and result from the interaction of the sectors and subsectors. Thus, environment is observed to be an outcome of the various forces at work in the food, natural resources, and other sectors of the district. Three different indicators of carrying capacity were developed to assess the environmental conditions.

Carrying Capacity in Terms of Calories

Calories are supplied by the crop sector. Seed allowances, milling losses, and other losses incurred on the farm and during storage are taken into account to arrive at the net food availabiility in edible form. Calory suppliy is assumed to be derived from paddy, maize, millet, wheat, and potatoes. Calorie supplies from other sources, which definitely exist, have not been taken into account. As a result, the calorie supply and demand reported in this exercise are underestimated. However, since foodgrains provide most of the calories to households, it can be reasonably assumed that the calorie supply and demand derived by the model account for a large part of the calorie supply.

Each type of food grain and potatoes provides a different calorie level (Table 2.12). The total of foodgrains and potatoes available in edible form multiplied by the calorie factor gives the total calorie supply of a district. On the demand side, an adult is assumed to require 2,410 calories per day.[17] The district population was converted into adult units by using the adult consumption unit (ACU) of 0.8223 reported by DFAMS (1989) for the hill regions of the country. Then supply as a percentage of demand was determined, and this reflects the calorie situation of a district in relation to its population expressed in adult units.

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17 This 2,410 calorie requirement per person per day is recommended by the FAO for the South Asian Association for Regional Cooperation (SAARC).

Table 2.12: Calorie Supply from Different Foodgrains and Potatoes

Foodgrains	Calorie/kg
Rice	3,450
Maize	3,410
Wheat	3,420
Millet	3,280
Potatoes	970

Source: DFAMS 1989

Furthermore, the calorie supply was divided by the total cropped area to arrive at the per hectare calorie supply of a district. The calorie need was also divided by the same area to arrive at the load on a unit of land cultivated to support the population, given an adult's need of 2,410 calories per day. From such an exercise, it is possible to quantify the number of persons that can be supported by one hectare of agricultural land.

Carrying Capacity in Terms of Fuelwood

The total fuelwood supply discussed above was divided by the different areas which supply fuelwood to determine the capacity per hectare. On the demand side, the per capita needs per year (0.588 air dry tonnes) were multiplied by the population to determine the aggregate demand. The load per hectare was derived by dividing the total demand by the total area that supplies fuelwood. The load factor defines the pressure on a hectare of land to meet the fuelwood demand and the capacity defines the current fuelwood supply from a hectare of land.

Carrying Capacity in Terms of Fodder

The fodder supply and demand per hectare of land, supplied from different sources, were derived from the model. The total fodder need was obtain by multiplying the per LSU need (0.6327MT of total digestible nutrient [TDN] per year) by the total LSU. The figures were then converted into per hectare supply and demand. Per hectare capacity and load were then determined in a similar manner to that described above.

Calibration

After defining the structural relationship and allowing the model to forecast different values, the results were calibrated to match the basic aggregate facts for each district and for the valley for 1991. Calibration is a process used to choose the parameter values which fit the available information concerning an economy for a base year (1991). The information sources used are varied and not all the structural relationships defined fit the observed values exactly. Therefore, calibration is necessary. Calibration involves two major tasks. The first is to ensure that all equations used in the model hold; i.e, all production and demand equations as well as market clearing equations must be satified for the level of income, prices, land area, etc, used in the model. In the present exercise, to ensure that base year observed values and values generated by the model match, simple interpolation of the intercept term was carried out.

Secondly, it is important to ensure that theoretical requirements of demand and production theory are met by the values of the selected variables and parameters. It is possible that the selected parameters and variables may not guarantee that such requirements are not violated in the base year by the functional forms, variables, and parameters selected. Therefore, first of all, base year values that are generated by the production or demand functions must be non-negative (non-negativity of quantities). Both approaches were used to calibrate the model in the present case[18].

Sensitivity Analysis

The role of sensivity analysis is to appraise the reliability of the results and to ensure that the results obtained from the full model simulation are not unduly sensitive to errors of magnitude that might be expected in the basic data, assumptions, or parameters used. Sensitivity analysis was carried out to test the robustness of the model by allowing output and input prices to reduce and increase by 10 per cent, one at a time, separately and jointly, together with changes in some important selected parameters used in the model.

Policy Scenarios and Impact Analysis

The adaptive policy simulation model can be used to evaluate different policy scenarios, therefore, it is useful for policy-makers. Given the structural features of the model, policy interventions can be made in different sectors and during time periods. The results of the interventions can then be compared with the baseline scenario and evaluation and ranking of different policies can be carried out. Selected policy interventions were analysed for each district. The main policy options that were evaluated are discussed below.

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18 A detailed discussion of the calibration method is given by Braverman et al. (1983).

Population

The population growth in some of the districts is already high and it exerts increasing pressure on the district's carrying capacity. Food availability is below demand in most of the districts. The forests are already under stress and unable to meet the firewood and fodder demands of the increasing human and livestock populations. Unemployment or underemployment is already high and means to generate employment appear to be fairly limited in the present situation. Some scope exists for generating employment in the agricultural sector, but, given the already large population, it is unlikely that much of the underemployed and unused labour can be further absorbed by the agricultural sector.

An exercise was conducted to examine the impact of population reduction on the economy and environment of Kabhre district. The Eighth Five Year Plan envisaged a one per cent reduction in population growth from the present level. Therefore, it was assumed that, by the end of the Eight Five Year Plan, population growth in each district would be one per cent less than the current level. To achieve this reduction, population growth was reduced gradually starting from 1993 and was increased annually to reach one per cent by 1998, i.e., the year the Plan ends.

Crop Sector Policies

Irrigation Policy

Food deficit is already a major problem in Kabhre, as stated above, and can perhaps be considered to be the singlemost important indicator of poverty and environmental degradation in the context of Nepal. Bringing more areas under cultivation does not appear to be a viable option in the context of the districts considered. Most of the cultivable land has already been brought under cultivation. Land in the non-cultivated inclusions (NCI) class can perhaps be brought under cultivation if adequate investments are made, but investment constraints do not make this option viable. Therefore, an irrigation policy intervention was examined. Irrigated area is assumed to increase in the district based on the potential of expansion estimated by LRMP. The impact of this policy is transmitted through the yield function and spreads throughout the model. Crop production, food supplies, and income all increase. Increase in income has implications for food demand as well as non-food imports, among other things.

Fertiliser Policy

Fertiliser policy includes increased use rates on the crops by 25 per cent. The impact of this policy is also realised through the yield functions. Also, additional fertiliser costs incurred were deducted to arrive at gross margins. Here onwards, the effect will be transmitted in a similar manner to what is described above under irrigation policy.

Irrigation and Fertiliser Policy

The irrigation and fertiliser policies discussed above were then jointly examined.

Irrigation, Fertiliser and Potato Policy

In this scenario, additional areas were brought under potato crops. The additional area brought under potato crops is equal to the new irrigated area. The additional area brought under irrigation enables more areas to be brought under potato crops. The reason for selecting potatoes is the fact that currently potato yields the highest gross margin per hectare.

Natural Resource Policies

Forest Supply Management Policy

Most of the accessible forests in the district are unmanaged. The Nepal-Australia Forestry Project has pointed out that old growth forests, which characterise most of the accessible forests, can yield greater amounts of fuelwood, timber, and fodder from the first year of management. If appropriate management policies continue, yield rates will further increase. *Therefore, it was assumed that a certain percentage of the accessible forests came under improved management.*

Fuelwood Demand Reduction Policy

Another policy alternative considered for the natural resource sector consists of a 10 per cent curtailment in the per capita fuelwood consumption. Reports have indicated that the introduction of new stoves has tended to result in reduced fuelwood consumption by 10 to 25 per cent, depending on the continuation of the use of improved stoves by households.

Forest Supply Management and Fuelwood Demand Policy

This policy consists of joint supply management and demand curtailment.

The above policy scenarios and their impacts were examined for most of the districts. The new policy analysis carried out has been mentioned in the respective chapters. The evaluation of the impacts of the above policy interventions was conducted against the baseline scenario. The time-frame over which policy impact evaluation was carried out is from 1993-1998 for most of the districts, except in the case of Dhading where the time-frame was extended to 2005.