

*Dynamics of Land Use Changes and Forest Degradation in a Himalayan Watershed – A
System Analysis with Bio-Economic Modelling*

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Dynamics of Land Use Changes and Forest Degradation in a Himalayan Watershed – A System Analysis with Bio-Economic Modelling

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Abstract: The land use change and the state of forest resources are affected by several economic, technological and institutional factors. Analysis of such a change becomes more important in view of the changing cropping patterns and declining forest density in Himachal Pradesh. The phenomena being highly complex, use of bio-economic programming model incorporating economic and ecological factors appears highly attractive tool of analysis, particularly at a micro watershed scale with relatively homogeneous conditions. This study uses such an approach for Chabri micro watershed of Himachal Pradesh. The objective function of the model is to maximise the discounted gross margins from different set of activities, namely, agricultural, livestock and forestry over the model horizon spread over a period of 20 years into the future. This serves as a proxy for the watershed utility function. With the incorporation of variance and co-variance matrix of the gross returns over the last few years, the model becomes non-linear. After incorporating several relevant constraints on land, labour, capital, and biomass availability and use, the model was solved under alternate policy regimes by using General Algebraic Modelling Systems (GAMS). In addition to the input-output budgets of agricultural crops, livestock and livestock products and forest activities, estimates of tree biomass density by different land use types and biomass use in the watershed serve as important inputs to the model. The equation of biomass growth is based on

the logistic growth model incorporating the parameters of carrying capacity and periodic losses. The model was calibrated to ensure that the results of base scenario represented the ground realities. Though the new emerging cropping pattern, replacing traditional crops with horticultural crops has led to higher incomes but the same are accompanied with increased income risk. Cropping pattern is dominated by vegetable crops, such as, capsicum, beans, and tomato, and flower crop of chrysanthemum for the entire model horizon when income risk is considered equivalent to that in the existing cropping pattern. This shows diversification strategy on the part of the native farmers in the study watershed rather than going all out to maximise the profits. The model tries to investigate the effects of alternate policy scenarios on income levels, cropping patterns, biomass use and its growth, and labour and capital requirements over next twenty years (2006 to 2026). Since biomass extraction activity is meant only to meet the subsistence requirements rather than serving as commercial activity, the results of alternate policy scenarios, such as, the use of improved energy sources, substitution of improved livestock, increase in emigration rate, do not show much variations in cropping pattern when compared to the base scenario. Biomass in the base scenario has a tendency to decline after the middle of model horizon due to higher requirements of biomass with increasing population. Biomass grows continuously at a higher rate, if there is an increase in emigration rate due to better employment opportunities outside the watershed. Biomass also witnesses a continuous growth when the use of liquefied petroleum gas (LPG) is encouraged. Though the substitution of improved livestock reduces biomass extractions, yet the biomass growth trend remains more or less the same as in the base model scenario. Even though, the current level of extraction may appear sustainable in the short run, a high degree of periodic losses and insufficient regeneration may pose serious implications for long term

sustainability of biomass in the watershed. Positive response through appropriate government policies can, however, change the scenario for the better. Whereas the efforts like tree plantation and removal of decaying trees will augment the regeneration process, a strict check on forest fires and illegal/unscientific extraction of timber and forest products will help in containing periodic losses. Efforts to raise higher fuel efficiency by promoting improved cooking stoves and the use of LPG along with substitution of crossbred livestock for local livestock can be a beneficial policy option for reducing biomass use and extractions. Use of briquettes made of pine needles can serve not only as an important substitute for fuel wood but may also help minimizing the risk of biomass loss due to forest fires. Development of human resources in the watershed to match the emerging employment opportunities outside the watershed can also be a useful policy option to reduce population pressure, and hence the use of natural resources in the watershed.

1. Introduction

Himachal Pradesh is a part of the northern ranges of Himalayas, where greater and middle Himalayas are covered with snow or devoid of any soil, and the outer Himalayas (*Shivaliks*) are characterised by steep slopes, torrential rains, fragile ecology and rapid deforestation (Yadav, 2006). Increasing population pressure and inappropriate economic policies are further deteriorating the sustainability of natural resources. Declining forest density in Himachal Pradesh in the recent past has become a cause of concern for the policy makers as well as for the environmentalists (FSI, 2003). While total biomass productivity exceeds human and animal consumption by a wide margin, there is a progressive loss in forest

cover (Moench and Bandyopadhyay, 1986). Simultaneously, changing land use and cropping patterns have evolved with integration of commercial horticultural crops (Sharma et al., 2007; Singh, 1999). Growing area under horticultural cash crops over the last few years has put increased pressure on forest resources through land clearing, declining agricultural residues and increased demand of increased production and marketing risks. The environmental consequences for the local communities can not be ignored, and requires immediate attention by the policy makers. This represents a complex and dynamic phenomena involving interaction of bio-physical and socio-economic factors requiring a multidisciplinary modelling approach to analyze it rather than following a simplistic single disciplinary approach. A bio-economic model provides a useful interface between human behaviour and biophysical processes in terms of resource extraction and stock changes (Holden, 2004; Sankhayan et al., 2003). This approach incorporating economic and ecological factors appears more realistic at a micro watershed due to relatively homogeneous conditions found at this level. This study presents such an effort at a micro watershed level in the western Himalayan state of Himachal Pradesh. The main objective of the study is to maximise discounted gross margins from all activities over the model horizon serving as an important proxy for the watershed utility. It also analyzes the effects of alternate policy scenarios on land use changes and forest degradation and economic well being of the local communities. Knowledge so generated is likely to be useful in identifying suitable policy options for the abatement of the ongoing degradation processes for ensuring sustainability of natural resources in the region.

2. Background of the study area

Situated in Solan district (latitude $30^{\circ} 57' - 30^{\circ} 58'30''$ N and longitude $77^{\circ} 10' - 77^{\circ} 12'$ E), Chabri micro watershed falls in the wet-temperate forest zone of Himachal Pradesh (GOHP, 2002). This zone constitutes about 31% of the state forest cover (GOHP, 2007). The entire state constitutes a major natural watershed in north Indian region encompassing watersheds of four major tributaries of Indus, namely, Chenab, Ravi, Beas and Sutlej, and that of Yamuna. The micro watershed under study is a catchment area of Chabri, a rivulet that drains into Ashwani, a tributary of Yamuna. It is a small mountainous, oval shaped valley with steep slopes, typical of the landscape pattern in the mid hill zone of the state. Due to differences of moisture availability, while the northern slopes of the watershed are densely forested, the southern slopes have mainly grasslands mixed with patches of forest and scrub. Altitude of the watershed ranges from 1600 to 1950 msl and the average temperature vary from -4°C to 28°C during the year. The average annual rainfall was 596 mm and snowfall was 65 cm during the period 1993-2003 (GOHP, 2005).

The watershed measuring about 8.96 km^2 encompasses nine villages with total of 102 households having human population of 703 and livestock population of 471. Out of the total watershed land area, about 68 hectares are under cultivation (Table 1). The mixed farming system with cultivation of field and horticultural crops, livestock rearing and forest product extraction is quite similar to other regions of the state. The farm size is rather small with 46 percent of the households owning less than one hectare land.

Table 1. Area under different land uses in the Chabri watershed

S.N.	Land use type	Abbreviation used	Area (ha)	% of total land area
1	Total cultivated land area in rainy season	CULT_K	68.14	7.6
2	(i) Irrigated Cultivated land area in winter season	CULTI_R	31.44	3.5
	(ii) Unirrigated Cultivated land area in winter season	CULTU_R	36.70	4.1
3	Land under orchards	ORCH	7.08	0.8
4	Culturable wasteland	CULTW	15.00	1.7
5	Fallow land	FALLOW	2.78	0.3
6	Pastures and grassland	PASTGZ	257.00	28.7
7	Protected forests	PFOREST	302.00	33.7
8	Reserve forests	RFOREST	220.00	24.6
9	Land under non-agricultural uses	NAGRIU	24.00	2.7
10	Total for the watershed (2 to 8)		896.00	100

Of total cultivated area, 4.1% is rain fed and 3.5% has year round irrigation facilities, (Table 2). There are two distinct cropping seasons, namely, the rainy season (*kharif*) and winter season (*Rabi*). The most widely cultivated crops during the *kharif* season are maize, tomato and capsicum as against wheat and barley during the *rabi* season. Beans, potato, ginger and cabbage are also grown on some land area mainly as cash crops. While the vegetable crops on unirrigated land are grown only in the *kharif* season, these crops are grown in both the seasons on irrigated land. Cultivation of flowers, such as, carnation, gladiolus, chrysanthemum and lily, has become very popular in the recent past, which presently occupies about 8.19 hectares of the land. The flower growing activities are not only relatively more profitable, but also ensure better utilization of household labour through well spread out operations throughout the year. Farm households also grow several other crops for self consumption but only on a very small and negligible proportion of land area that could not be accounted for in this study.

Table 2 Cropping pattern in Chabri watershed during the year 2005-06 (Area in hectares)

Crop growing season	Crop	Crop growing months	Area under crops			% of total cropped area
			Irrigated	Un-irrigated	Total	
Rainy	Maize	July-October	13.20	14.98	28.18	22.0
	Pulses	July-October	1.80	0.64	2.44	1.9
	Ginger	July-October	0.28	0	0.28	0.2
	Capsicum	July-October	6.48	0	6.48	5.1
	Tomato	July-October	6.02	0	6.02	4.7
	Beans	July-October	3.40	2.08	5.48	4.3
	Potato	July-October	1.64	0	1.64	1.3
	Cabbage	July-October	0.16	0	0.16	0.1
	Miscl. / <i>Kharif</i> fallow	July-October	3.00	6.27	9.27	7.2
	Total Rainy season		35.98	23.97	59.95	
Winter	Wheat	Nov-June	3.56	6.29	9.85	7.7
	Barley	Nov-June	4.24	6.52	10.76	8.4
	Garlic	Nov-June	0.92	0	0.92	0.7
	Ginger	March-June	0.37	0	0.37	0.3
	Mustard	Nov-June	0.04	0.12	0.16	0.1
	Tomato	March-June	5.22	0	5.22	4.1
	Capsicum	March-June	5.20	0	5.20	4.1
	Peas	Nov-June	2.36	0	2.36	1.8
	Potato	March-June	0.68	0	0.68	0.5
	Cabbage	March-June	0.04	0	0.04	0.0
	Miscl / <i>Rabi</i> fallow	Nov-June	0.62	23.77	24.39	19.0
Total Winter crops		23.25	36.70	59.95		
Annual	Gladiolus	July-June	3.04	0	3.04	2.4
	Carnation	July-June	3.08	0	3.08	2.4
	Chrysanthemum	July-June	1.72	0	1.72	1.3
	Lily	July-June	0.35	0	0.35	0.3
	Total Flowers		8.19	0	8.19	

According to official records, about 58% of the watershed area is under state-owned forests, classified as reserved forests and demarcated protected forests. These two types of forests in the watershed fall in the category of Himalayan temperate forests, where coniferous trees and broad leaf trees exist either separately or in mixture. Being located in the dense forest region, the inhabitants of the watershed have heavy dependence on forest biomass for meeting their requirements of fuel wood, timber, fodder and grazing. With a view to protect diversity of flora and fauna in the region of which this micro watershed is a part, a total of 108 km² was declared as a sanctuary in 1976 (GOHP, 2005). Extraction of all forest products

have been prohibited in this area since late 1990s by the interim orders of the Indian Supreme Court in response to Public Interest Litigation. Thus, the removal of any dead or decaying trees, grass, and driftwood is prohibited (Sekhsaria and Vagholikar, 2004). Following these orders, the timber use rights of the local people in the forests were also annulled. Although, logging activities are strictly prohibited, people freely extract fuel wood, small wood for different uses, fodder leaves, and grass. The animals also freely graze in the protected forests. Besides, the logging rights in the forests were recently banned in the rest of state by an interim-order passed by the High Court of Himachal Pradesh in 2006 in response to a public interest litigation (UNI, 2006).

3. Methodology

3.1. Non-linear programming bio-economic model for Chabri watershed

The dynamic non-linear programming bio-economic model has been used to analyse a relatively complex system with a large number of interacting economic and biophysical variables. Data used in the model on land, labour, capital, factor and product prices and other parameters for various activities are obtained from farm household surveys. The model considers optimization of agent's (watershed in this case) objective function incorporated as discounted gross margins subject to a set of constraints, such as, land area according to quality, seasonal labour requirements and capital availability.

The dynamic mathematical programming bio-economic model developed at village level (Sankhayan et al., 2007; Sankhayan and Hofstad, 2001) and later used at watershed level in Nepal (Sankhayan et al., 2003) has been modified to account for the conditions characteristic of the watershed for this study. The model is then solved by using the general

algebraic modelling system (GAMS) (Brooke et al., 1998) and runs over a time horizon of 20 years, i.e., 2007 to 2026.

The aggregate utility (U_t) at time t for the watershed can be expressed as follows:

$$U_t = \sum_i^u \sum_{j=1}^s (a_{ijt} y_{ijt}^{ca}) + \sum_{i=u+1}^v (a_{it} y_{it}^{la}) + \sum_{i=v+1}^w (a_{it} y_{it}^{fa}) \quad t = 1, 2, \dots, T$$

$$\text{Where, } a_{ijt} = (p_{it} q_{ijt}) - \sum_{r=1}^m (c_{rijt} x_{rijt})$$

$$a_{it} = (p_{it} q_{it}) - \sum_{r=1}^m (c_{rit} x_{rit})$$

The abbreviations used in the above relations are as follows:

y_{ijt}^{ca} = level of i^{th} crop activity ($i = 1, 2, 3, \dots, u$) grown in j^{th} category of land ($j = 1, 2, 3, \dots, s$) unit during the t^{th} year ($t = 1, 2, 3, \dots, T$).

y_{it}^{la} = level of i^{th} livestock and livestock product activity ($i = u+1, u+2, u+3, \dots, v$) during t^{th} year.

y_{it}^{fa} = level of i^{th} forest activity ($i = v+1, v+2, v+3, \dots, w$).

a_{ijt} = is the per unit gross margins from i^{th} crop activity grown in j^{th} land category during the t^{th} year.

a_{it} = is the per unit gross margins from i^{th} activity other than crop activity during the t^{th} year.

q_{ijt} = yield of the i^{th} crop grown in j^{th} land category during t^{th} year.

q_{it} = yield of the i^{th} non-crop activity during the t^{th} year.

c_{rijt} = cost of r^{th} resource used on i^{th} crop in j^{th} land category during year t .

c_{rit} = cost of r^{th} resource used on i^{th} non-crop activity during year t .

x_{rijt} = the quantity of r^{th} resource used per unit of the associated crop activity.

x_{rit} = the quantity of r^{th} resource used per unit of the associated non-crop activity.

p_{it} = per unit prices of products.

Analytical framework of the bio-economic model is explained in the flow diagram presented in Figure 1.

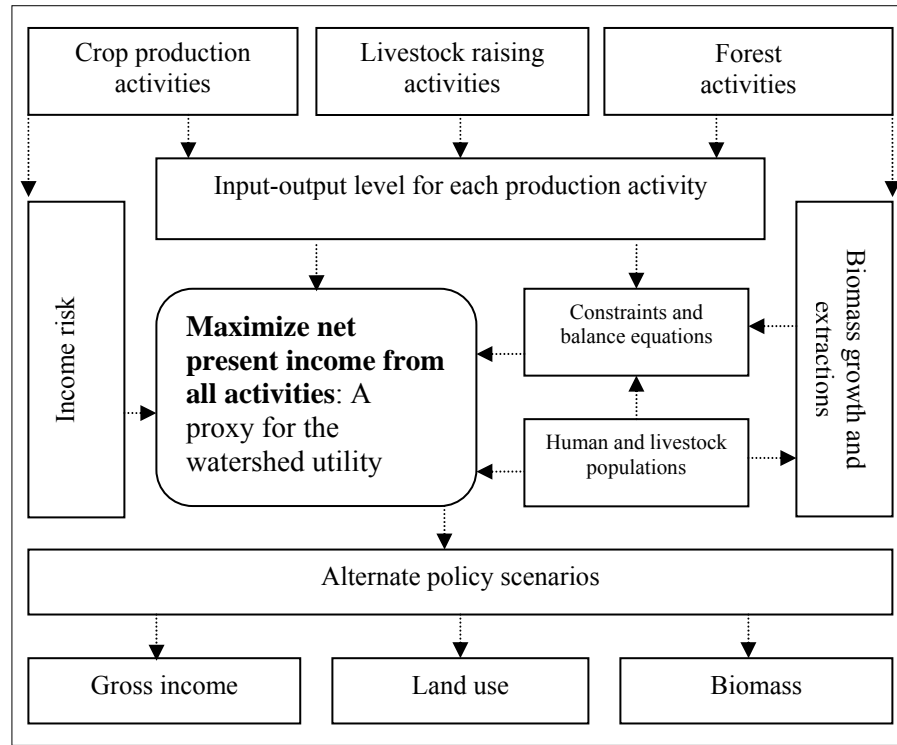


Fig. 1. Analytical framework of the bio-economic model

The model considers maximization of net present value of aggregate utility at watershed level as follows:

$$\text{Maximize } \sum_{t=1}^T 1/(1 + \partial)^t U_t ,$$

Where, ∂ is the annual percent discount rate, taken as 5 percent per annum in this study, to convert the stream of gross margins over the model horizon into present value equivalent.

The variations in yields and prices of crops over the last five years have been incorporated in the model with variance-covariance matrix (Hazell, 1971). This makes the

risk equation quadratic and the dynamic model non-linear. Like the income/gross margins, the variance has also been discounted in the model. Whereas discounting of income helps in analysing the present value of the future income, the discounted variance in income over time brings us closer to reality by ensuring that the risks in gross returns become less important in the distant future. The model incorporates the following set of activities and constraints:

3.2. Activities used in the model

The model includes three subsets of activities, namely, crop, livestock and forest activities. Relatively minor crops are not considered for modelling purposes. Thus, crops that are grown on at least half hectare of land area are included in the model. The model provides for labour hiring for all activities during each of the 12 months.

3.3. Constraints in the model

Households are assumed to make decisions subject to a number of constraints. Constraints for land were incorporated according to crop growing seasons, i.e., *kharif* and *rabi* by different land use types, such as irrigated and unirrigated land. Because of incorporation of crop activities by crop growing seasons in the model, land availability constraints are used within homogenous land units accordingly. Labour availability constraints (man equivalent days) are considered according to months. The labour availability increases with growth of population over the model horizon. This can be supplemented through labour hiring. Only 15 percent of the annual gross margins during the t^{th} year are assumed to be available for working capital during the $t+1$ year. This constraint has also been used for sensitivity analysis in a model scenario.

3.4. Biomass Growth

The biomass growth equation is based on the logistic growth model (Renshaw, 1991) which explicitly incorporates carrying capacity.

$$B_{t+1,j} = e^{(\rho-\lambda)} B_{t,j} / [1 + B_{t,j} (e^{(\rho-\lambda)} - 1)/K_j]$$

Where, B = total above-ground biomass, ρ = intrinsic growth rate of biomass, λ = loss due to miscellaneous factors such as decay, fire, illegal felling, etc., and K = carrying capacity of land. The subscripts t and j represent time period and land use category.

The total biomass extraction (TBX) is given as follows:

$$TBX_t = \sum_b C_{b,t} * P_t$$

Where, C is the per capita consumption of biomass, t is time period, and b represents biomass type, classified as fuel wood, fodder, timber and other uses.

Human and livestock population growth in the model is expressed by:

$$P_{t+1} = P_t * (1 + \delta)$$

Where, P_t is the total population (human/livestock) in the watershed during year t and δ is its corresponding average annual percent growth rate.

3.5. Parameters used in the model

Parameter values used in the model are either derived from the survey data or taken as the general approximation representing the ground reality. Table 3 presents the values of some of important parameters used in the model.

3.6. Model scenarios and their calibrations

In addition to the base scenario which represents business as usual, three different scenarios have been introduced to analyse the dynamics of cropping pattern and forest growth in the study watershed. A brief explanation of these scenarios has been presented in the table 4. To represent the ground reality, model was calibrated for the base year in respect of cropping pattern and stock of biomass available as estimated from the survey data. The model was then run under different scenarios over a period of 20 years, i.e., from 2007 to 2026. For the model time horizon, the basis for the biomass calibration was the past and future perceptions of the people and foresters in the watershed along with our own field observations and the overall trends at state level. The scenario analysis was carried out to examine the relative significance of available policy options on the outputs of model.

Table 3. Values of some important parameters used in the base model scenario

S.N	Parameter	Unit	Value of parameter
1	Households in the watershed	Number	102
2	Size of household -average	Number	6.89
3	Workers per household -Average	Number	2.65
4	Growth rate of population	% per annum	1.60
5	Livestock in the watershed	Number	471
6	Growth rate of Livestock	% per annum	1.04
7	LPG connections in the watershed	Number	31
8	LPG cylinders consumption by each connection	Number	4
9	Cost of using one LPG cylinder	Rupees	314
10	Discount rate	% per annum	5
11	Fuel wood equivalent of one LPG cylinder	Tonnes	0.23
12	Proportion of gross margins ploughed back into business	%	15
13	Growth rate of tree biomass	% per annum	1.01
14	Periodic loss of tree biomass through decay, fire, etc.	% per annum	0.51
15	Initial tree biomass density by land units	Tonnes ^{ha}	CULTI_R=2.82, CULTU_R=10.70, ORCH=4.56, FALLOW=13.16, PFOREST=728.27, PASTGZ=8.40
16	Annual use of tree biomass	Tonnes	F_LEAVES=121; F_WOOD=549; TIMBER=141

Note: Abbreviations for land use units are the same as given in table 1.

Table 4 Brief description of different model scenarios

S.N.	Abbreviation used for scenario	A brief explanation of the scenario
1	BASE	Business as usual depicting current state
2	HULPG	LPG connections and annual usage increase by 5% every year
3	SCBRD	Cross bred livestock grows by 2.08% per annum and local breeds are reduced by 2.87% per annum so that the total number at the end of model horizon remains same as exists at present.
4	HEMIG	Emigration out of watershed increases by 2% per annum

3.7. Method for biomass estimation

Forest biomass was estimated by using the following allometric equation used in the adjoining Himalayan region of Nepal (Sharma and Pukkala, 1990).

$$\ln v = a + b * \ln (d) + c * \ln (h)$$

Where, \ln is natural log, v is stem over bark volume in m^3 , d is diameter in cm, h is height in meters, and a , b , c are the parameters for the dominant species in the watershed.

The over bark volume (v) of each tree obtained from the above relation is then multiplied by the species specific wood density (WD) to get the stem biomass (SB) in tonnes as follows:

$$SB = v * WD$$

Species specific wood densities (air dried and with 12% to 15% moisture content) and stem to branch and stem to foliage biomass ratios for different species were obtained through literature search (HMG, 1988; Jenkins et al., 2005; Luna, 1996; Sharma and Pukkala, 1990; WAC, 2006). Although this approach would result in an overestimation of stem biomass because bark was not separated from stem wood in the calculations, it was the best available method for biomass estimation at a landscape scale as demonstrated by earlier studies in the Himalayan region (HMG, 1988; Sankhayan et al., 2003; Sharma and Pukkala, 1990).

3.8. Data Collection

The data relating to crop, livestock and forest activities in the watershed was collected mainly through a household survey. Whereas, the data on agricultural and livestock activities pertain to the year 2005-06, the data relating to tree biomass is based on survey undertaken in April/May, 2006. All the 102 households in the nine villages of the watershed were interviewed for obtaining the information relating to demography, land holdings, livestock, cropping pattern, input-output of crops, and forest related activities. One must keep in mind that due to prohibition on extractions from the forests, figures given by the inhabitants are most likely to underestimate the total forest biomass usage. Tree biomass of reserved forest was however, not included in the model as the use of this forest by the local people is negligible due to severe restrictions, greater distance from village habitations, and relatively lesser availability of fodder trees. The participatory rural appraisal method (Chambers, 1994a; Chambers, 1994b) was used to gauge local perceptions about the availability of forest products and of the past and present condition of forest.

Data on tree biomass were collected by locating 70 square shape plots in the six dominant land use categories used in this study. To encompass the range of topographic conditions and spatial distribution in regard to human settlements, the location of plots was chosen by judgement sampling method which is a non probability sampling method based on the researcher's own judgements about the representative population (Kothari, 1990). The number of plots was proportional to land area under specific land use categories. To increase the normality of the field data, however, the plot area was increased for land use categories with smaller proportions of the total land area (Squiers and Wistendahl, 1976). In every plot, plant diameter at breast height (dbh), i.e., 1.37 meters from ground level, was measured with a

diameter tape (FSI, 2002). Tree height was measured by using a standard inclinometer approach. All trees with a diameter at breast height (DBH) greater than 5 cm, identified to species and their abundance were counted within each sample plot. Stems that split below breast height were counted as separate trees.

Data on land use in the watershed have been obtained from the village revenue records and the department of forests. Data on yield and prices of crops for the last five years were obtained from the Department of Land Records, State Department of Agriculture, H.P. and from a related study conducted by Agro-Economic Research Centre, Shimla (Singh et al., 2006). Some data gaps were bridged through additional information obtained from cooperative marketing societies, discussions with the cultivators, extension workers, government officials, NGOs and local leaders in the study area.

4. Results

The results of alternate policy options as reflected through different model scenarios are discussed in respect of biomass requirements, growth of biomass stock, cropping pattern and incomes of households.

4.1. Biomass requirements of human population

In the base scenario, tree biomass requirements of human population are observed to increase constantly over the model horizon (Figure 2). An increase in LPG use over the years will lower the pressure on forest biomass as brought out by the second scenario as a result of substitution of fuel wood by LPG. Biomass requirements in this scenario increase at diminishing rate and finally start falling near the end of model horizon. The Scenario 3

representing substitution of cross-bred cows for the indigenous breeds does not have any relevance to human requirements of biomass and is, therefore, identical to the base model scenario. With higher emigration out of watershed as reflected in model scenario 4, the total human biomass requirements remain almost constant over the entire model horizon. Thus the impact of population growth rate on increasing biomass requirements as reflected in the base scenario is negated by the increased emigration of people to towns and cities in search of better employment opportunities.

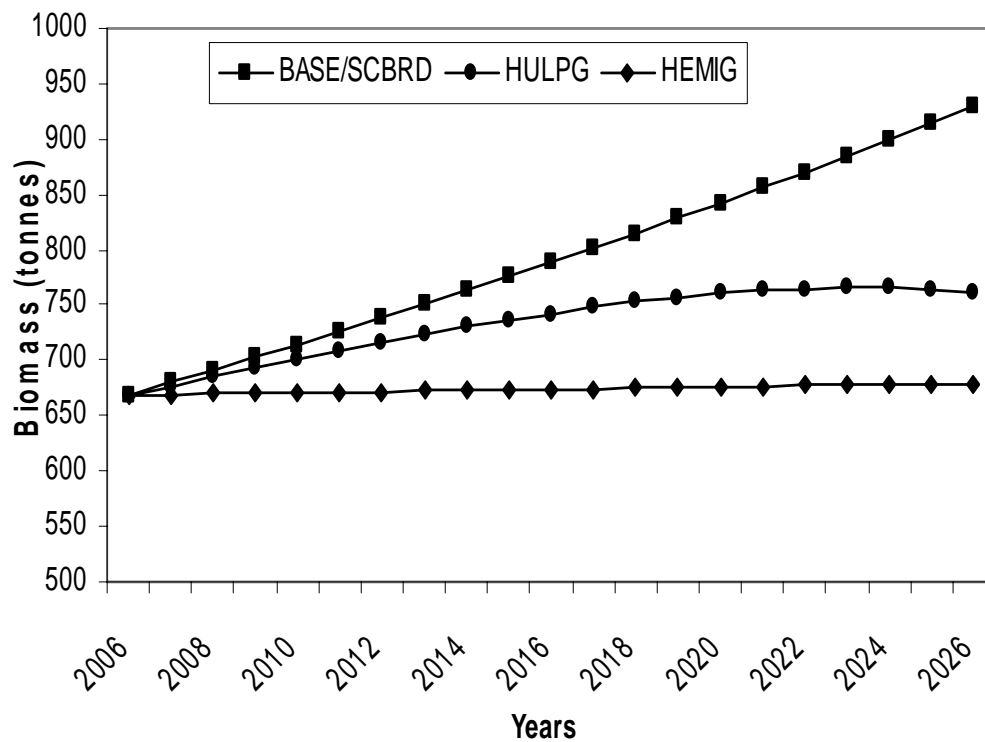


Fig. 2. Annual human biomass requirements under different model scenarios

4.2. Biomass requirements of livestock

For livestock, fodder leaves especially that of oak trees are required mainly during the dry season, when other sources are rather scarce. Only model scenario 3 has relevance for

assessing tree biomass requirements of livestock over the years (Figure 3). The other two scenarios related to LPG use and emigration will be identical to base as they do not influence livestock requirements. Whereas, in the base scenario livestock requirements of biomass increase over the years with growing number of livestock, in model scenario 3 due to substitution of crossbred livestock to local breeds, biomass requirements decrease initially and then remain almost constant. The main reason for such a trend is the greater decline in local breeds as a result of substitution by relatively fewer cross bred animals.

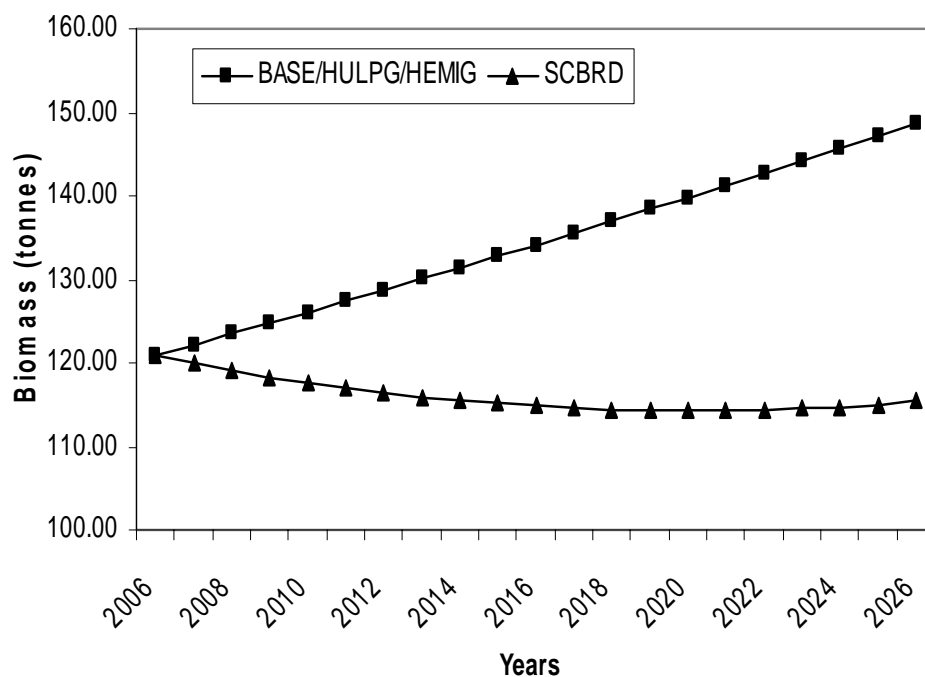


Fig.3. Biomass requirement of livestock in model scenario 3 compared with that in the base scenario

4.3. Total biomass extractions in different model scenarios

Among all the model scenarios, the tree biomass extractions to meet the fodder, fuel wood, timber and miscellaneous requirements in watershed are the highest in the base

scenario (Figure 4). Relative significance of different policy options in lowering the biomass extractions and pressure on forest resources is highlighted by the three alternate policy scenarios representing lower extraction levels.

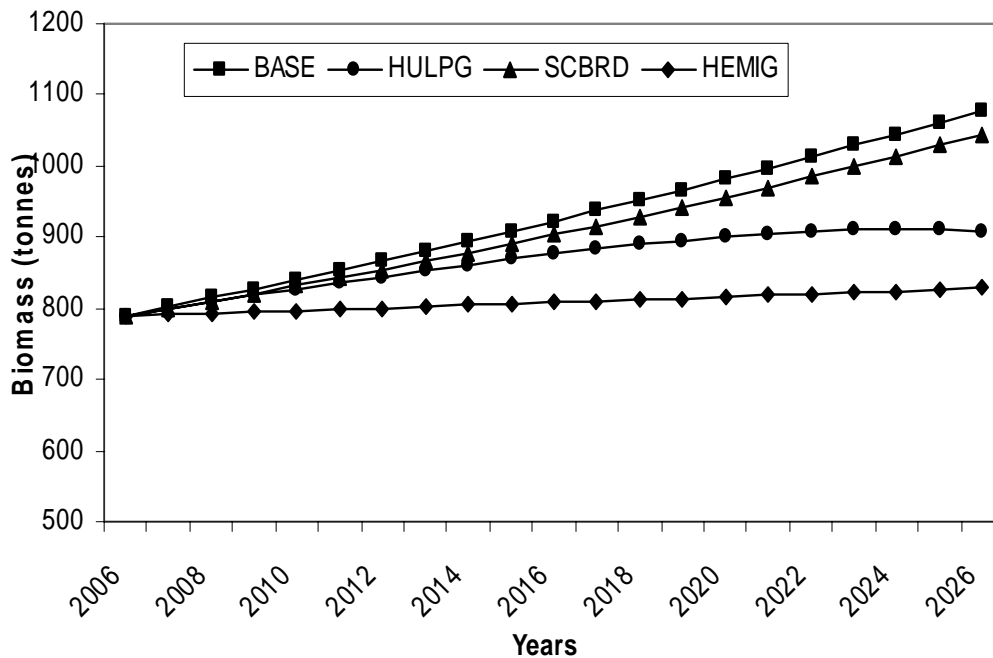


Fig. 4. Total tree biomass extracted under different model scenarios

With higher rate of emigration as represented by model scenario 4, biomass extractions remain not only at the lowest level but also almost constant over the entire model horizon. More use of LPG reflected by model scenario 2, also results in lower biomass extractions over the years when compared to the base scenario. After showing an increase in the first half of model horizon, it remains more or less constant during the later years. This decline in biomass extractions is due to substitution of LPG for fuel wood. In model scenario 3, which represents substitution of cross bred livestock for local breeds, biomass extraction

increases over the entire model horizon, though remaining slightly lower than that in the base scenario throughout.

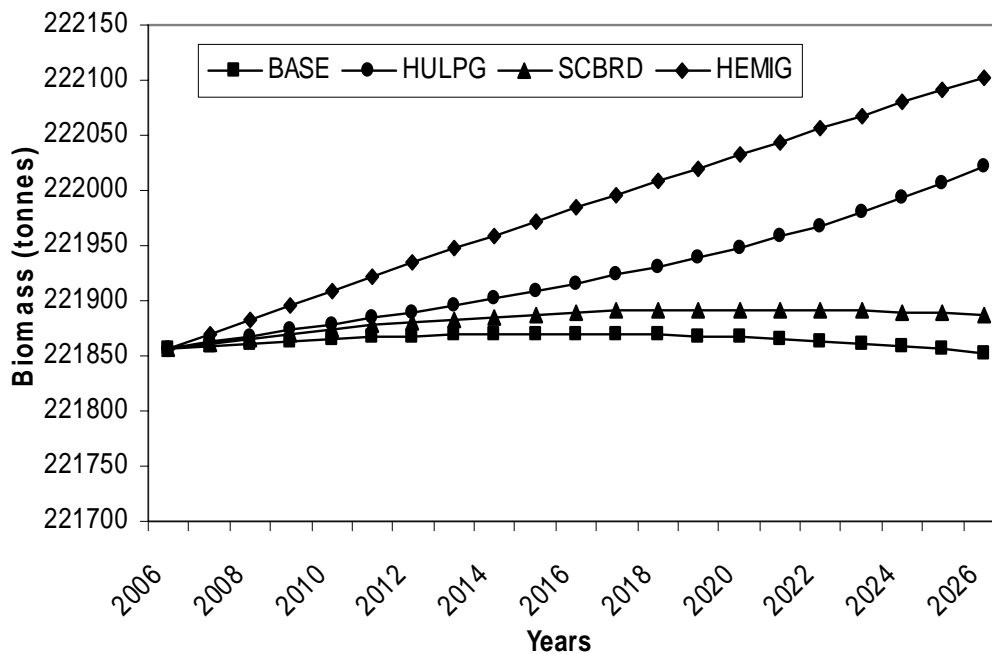


Fig. 5. Growth of stock of tree biomass under alternate model scenarios

4.4. Growth of biomass stock over the years

Simulation of the available biomass stock in the watershed is carried out by using logistic biomass growth model, incorporating the carrying capacity, growth rate, extractions and periodic losses. In the base scenario, there is a slight increase of biomass stock in the beginning of the model horizon that tapers off at a later stage (Figure 5). It shows that the biomass production in the watershed may be sustainable in the short run but with growing human requirements for tree biomass, it may be hampered in the long run as reflected through the continuous decline in biomass stock. Substitution of improved livestock as presented by the model scenario 3 shows some improvements in biomass stock over the base scenario, but

it fails to sustain at the current level. The highest growth in biomass stock is recorded under model scenario 4, which is mainly due to higher emigration rate and the resulting reduced requirements of fuel wood and timber. Higher use of LPG as represented by scenario 2 also shows desirable growth of biomass over the years. The situation can be further improved with popularising the use of improved energy sources, such as, biogas, electricity and solar energy.

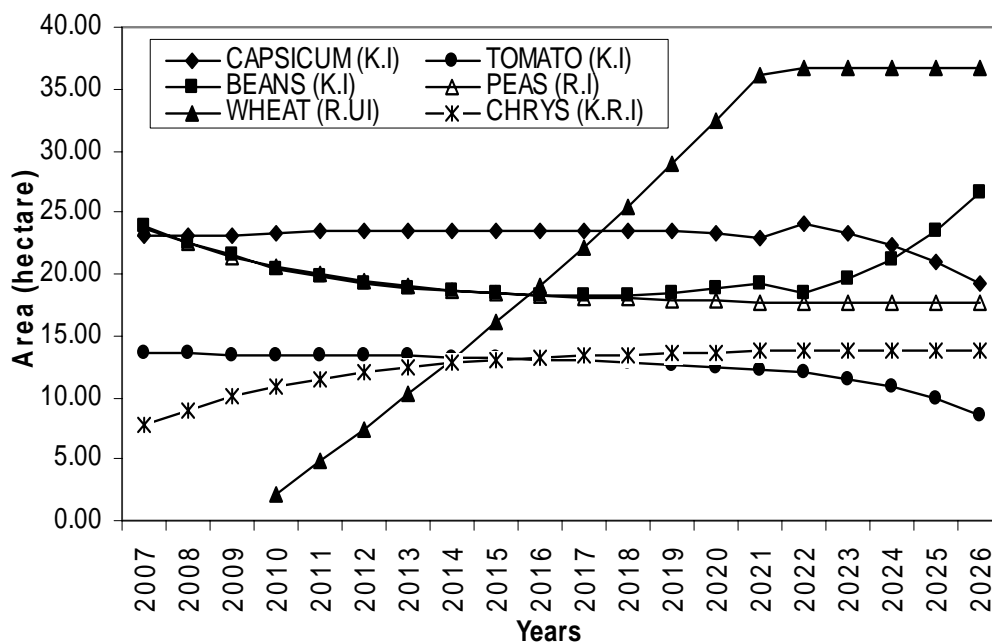


Fig. 6. Dynamics of cropping pattern in the base scenario

4.5. Cropping pattern

Due to the very nature of alternate policy regimes considered in this study, there is not much variation in cropping pattern when compared to the base scenario of the model. The base scenario represents an optimum cropping plan with consideration to the minimisation of income risk. For achieving this, VIT (total variance of income) is held constant over the model horizon at a level calculated by keeping the current cropping pattern over the entire

model horizon. This is mainly done for knowing the potential of optimum cropping pattern in raising the income level with the risk level of the existing plan. Maximisation of TDGM (total discounted gross margins) results in raising the watershed income to 593691 thousand rupees, which is nearly double than the cropping plan of base year. Whereas, capsicum, beans and tomato are grown in *kharif* season, peas and wheat are grown in *rabi* season on irrigated and unirrigated land respectively (Figure 6). Chrysanthemum being an annual crop, however, occupies the land in both the seasons. By comparing this scenario to the existing plan, it is observed that the farmers are more considerate to risk rather than the profits as they diversify agriculture by cultivating several crops with low risk level than only a few crops that maximize the income. However, crops such as maize and barley, which are dominant crops in the watershed, are missing in the optimum plans either due to fewer margins or due to the constraints of model.

4.6. Household income and input requirements

Net present value of the total gross margins in each of the alternative model scenarios is presented in table 5. The substitution of cross bred livestock for local breeds helps in raising the income of people. An increase in emigration rate lowers the watershed income by causing labour scarcity that has to be meted out by hiring labour from outside the watershed and thus raising the input costs. There is little possibility of supplementing farm income by remittances received from the emigrants from the watershed due to the high expenditure requirements in the towns and cities. Whereas, the more usage of LPG has a favourable effect on biomass growth, the burden of extra costs for the purchase of LPG will lower the watershed income.

As far as the capital requirements are concerned, they will move in the similar direction with the change in TDGM in each model scenario. The constraint related to capital availability is one of the major reasons for such a trend. Though the substitution of cross bred livestock requires less labour than the base level, higher use of LPG will require more labour during the entire model horizon. It is mainly due to labour savings from the forest activity and the resultant alterations in the cropping pattern.

Table 5. Changes in income (total discounted gross margins) and some other important parameters under different model scenarios

S.N.	Model Scenario	TDGM (000, Rupees)	Capital requirements (Rupees)	Labour requirements (Man Days)
1	BASE	593691	139880	251
2	HULPG	574369	134743	690
3	SCBRD	593788	139907	242
4	HEMIG	580931	136526	6935

5. Discussion

Crop cultivation is the main activity in the watershed using bulk of the available labour and capital resources. It contributes the largest component of farmers' income. Though the dependence of hill farming system on livestock and forest activities do not have much contribution to the income, yet it commands a special significance due to the interdependence of different components of the farming system (Tulachan and Neupane, 1999). Traditional practices based on the principal of self sufficiency and religious and cultural approaches further strengthen these mixed agricultural systems. Higher profits from cash crops like

flowers and off season vegetables, distant markets and poor marketing infrastructure discourage the commercial rearing of livestock. Even if the contribution of livestock activity to total income of the watershed is not very significant, it is still an integral part of the hill farming system for meeting the requirements of milk, farm yard manure and bullock draft power. The livestock rearing has become more important in recent years with the substitution of improved livestock for local breeds. Since the forests are government owned and there are several restrictions on forest product extractions, its contribution in the watershed income is also negligible. Due to traditional dependence on forest products for miscellaneous needs, however, forest product extraction activities still command a significant role in the Himalayan farming systems (Gouri et al., 2004).

By comparing the optimum cropping plan with the existing plan, it is observed that the farmers are also considerate to risk rather than the profits. This tendency is explained by the diversification of agriculture by cultivating several crops with low risk level than the crops that maximize the income only. Cultivation of traditional crops, such as, maize and barley, is still carried out by the people in Himalayan region despite low economic viability. Availability of capital has been a major constraint in agriculture, especially in newly introduced horticultural crops. In addition to the personal savings, which are dependent on annual expenditure level, the capital formation requires an efficient banking network and good enterprise in villages. The labour requirements are also bound to increase manifold with the new emerging cropping patterns (Chand, 1997). Increasing emigration rate as observed in recent past will aggravate the situation further (Sharma, 2005). Labour scarcity will pose a serious problem to the farmers especially in the context of specialised cultivation of flowers and vegetables.

Though, the biomass density is still high in the forest as a whole, the people perceive a decline in the tree biomass density over the next twenty years. Forest fire, illegal felling, unscientific lopping, decay, climate change, etc., are some of the important factors which are contributing to ongoing forest degradation. If these factors are not managed properly, it can reduce forest cover even when the overall biomass productivity exceeds demand (Moench and Bandyopadhyay, 1986). The biomass accumulation is also being reduced by changing environmental conditions, irrespective of the current density (Monte-Luna et al., 2004). Such changes due to anthropogenic pressures have adversely affected the carrying capacity of land (Ehrlich et al., 1989). In view of absence of precise estimates of the main affecting parameters, i.e., loss due to miscellaneous factors such as decay, fire, illegal felling, etc., and carrying capacity of land, these predictions can at best be taken only as indicative of the system behaviour under different model scenarios. This should be helpful in providing useful directions for devising appropriate policies for steering biomass growth in the desired direction.

The study watershed being predominantly located in a forest region with easy access and abundance of useful tree biomass, per capita fuel wood consumption was found to be relatively higher, i.e., 3.56 kg/day, than that of an average of 1.70 kg/day in the forested districts of the state of Himachal Pradesh (Rai and Chakarabarti, 1996). With improvement in transportation and other infrastructure combined with economic development in the area, several households have started using LPG as a substitute for the fuel wood (Sharma et al., 2007). However, the traditional stoves and fuel wood are still preferred due to economic reasons (Kanagawa and Nakata, 2007) for cooking, water heating, space heating, lighting, livestock rearing, etc. Among various activities, cooking requires relatively more energy

(Pohekar et al., 2005). Modern cooking fuels can provide significant health, productivity, and environmental benefits (Heltberg, 2004). But without income generation, which is reflected by opportunity cost, the rural households do not adopt improved energy sources (Kanagawa and Nakata, 2007). Depending upon the sacrifices to be made by the natives for better growth of forest biomass, the compensating subsidies on LPG is a popular option for saving the biomass. The subsidies in the urban areas can be withdrawn and the saved amount could be used for the bioenergy programmes that will improve quality of life in rural areas and reduce the pressure on forests (Ravindranath and Hall, 1995). Increased availability of LPG may prove a better alternative than the subsidies due to weak cross-price elasticities among alternate sources of fuel (Gupta and Kohlin, 2006). As the purchasing power is the only criterion for selection of cooking device (Pohekar et al., 2005), increasing level of income in watershed has a potential for the adoption of efficient energy sources. Studies have shown that the vegetative biomass requirements of improved breeds of livestock are higher due to higher consumption requirements and practice of stall-feeding (Singh et al., 2005). But due to the sufficient grasslands in the watershed, cross bred livestock are preferably served with grasses and compounded feed purchased from the market. It is due to this reason that equal consumption requirements of both types of livestock have been considered in this study.

6. Conclusions

A shift in traditional cropping pattern towards cash crops, such as, vegetables and flowers, have become a popular trend in the entire state of Himachal Pradesh over the last few years. Irrigation facilities and easy availability of capital are the major constraints in the adoption of area under these crops. Therefore, the more sincere efforts are needed by the

government for removing these bottlenecks. Knowledge dissemination about the costs, returns, risks and cultivation methods of these new crops must be provided at the farm level to encourage more people to start such ventures. Due to the high risk level attached to these profitable crops, efforts must be made to develop local market yards, better road network and easy credit facilities. Such efforts will encourage the farmers to substitute profitable cash crops for the traditional crops, thereby increasing self employment, incomes and level of living in villages. Though the rearing of improved livestock is becoming popular, yet due to distant market and lack of proper marketing infrastructure, commercial rearing is still not possible. People therefore, have to use livestock products for the self consumption only. Conducive agro-climatic conditions and better recharging of the irrigation sources are the conspicuous contribution of the watershed forests. Such benefits are, however, difficult to estimate in monetary terms. The impact of forests on sustainability of farming system is very significant in the Himalayan regions. In spite of efforts of the state government to protect the forest area effectively, declining forest density in the forest is an indication of its inability to control the periodic losses due to decay, development, fire, illegal activities, etc. Whereas the efforts like tree plantation and removal of decaying trees will augment the regeneration process, a strict check on forest fires and illegal/unscientific extraction of timber and forest products will help in containing periodic losses. Even though the demand side factors have relatively a lesser role in containing the degradation process in this forest dominated region, the efforts to raise higher fuel efficiency by promoting improved cooking stoves, LPG, biogas and pressure cookers together with substitution of fewer crossbred livestock to local livestock can be beneficial policy options for lowering fuel wood and fodder demand. Better educational facilities with an emphasis on vocational training will help in exploring better

employment opportunities in urban areas. Such opportunities will not only help in finding better economic alternative avenues for the increasing population, but will also help in relieving the pressure on forest resources.

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