An interdisciplinary systems analysis of land-use changes and forest/soil degradation at the watershed level in Nepal using dynamic bio-economic model

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Abstract

Researchers, planners and other concerned institutions are contending with varied arguments and explanations on burning issues of deforestation and forests/soil degradation in the Himalayan region for long; and a common consensus regarding the causes of these processes has not been reached yet. Since land-use, land-use changes especially agricultural land expansion and degradation of forests and soil in developing country are related to socio-economic characteristics, population and livestock growth, technological change, consumption patterns, etc., their dynamics need to be analyzed by incorporating both the socio-economic behavior and ecological processes simultaneously. This paper, representing an effort to offer some deep insights in this debatable topic, discusses and develops a dynamic bio-economic model for analyzing land use changes and forest/soil degradation processes under systems approach. The modeling technique is basically drawn from simultaneous global optimization with mathematical programming algorithm which incorporates both the production and consumption problems at the watershed level in Nepal. Five different relevant policy scenarios, namely business as usual with two per cent population growth rate and five percent of discount rate (and other parameters and scalars), reducing population growth rate to 1.5 per cent per annum, increasing prices of major crops (maize, paddy, wheat and millets) by 10 per cent, reducing emigration of active labor force from current rate of 20 to 10 and 15 per cent from the watershed have been tested. Planning horizon of the model extends for 25 years and the objective function consists of discounted net income flow from agriculture, livestock and forestry production subject to constraints on land, labor and capital availability along with the fulfillment of minimum cash and consumption requirements for the entire watershed in each period. The outcomes of this modeling exercise indicate that while reduced labor emigration rates and increase in major agricultural crops' prices lead to expansion of agricultural land at the cost of forest and other non-agricultural lands and shift of clearing activity from degraded forest to nearby forest land and more soil loss; reduced population growth rate shows the opposite effect. The land clearing is severer in the case of reducing emigration rate to 10 per cent than 15 per cent. Thus the model disentangles the systems behaviors of both socio-economic and ecological interactions at the watershed level with policy implications on reduction of population growth and maintaining current rate of off-farm employment for slowing down the agricultural expansion and processes of forest/soil degradation.

Key words: Agricultural expansion, bio-economic model, forest/soil degradation, land-use changes, Nepal, watershed

1. Introduction

Researchers, planners and other concerned institutions are contending with varied arguments and explanations on burning issues of deforestation, especially agricultural expansion, and forests/soil degradation in the Himalayan region for long; and a common consensus regarding both proximate and underlying causes of these processes has not been reached yet. A recent review study by Upadhyay et al. (2005) has revealed contrasting findings in terms of forest degradation/regeneration and soil degradation with their significant variations in the nature and extent in this region. With an improved understanding of natural processes and measures to promote decentralized and participatory development, e.g. community forestry, many degraded lands are being turned around (Banskota, 2000; Carter and Gilmour, 1989; Fox, 1993) as opposed to the conventional view points of Himalayan degradation. The major portion of the region is in transition from self-subsistence to open economies with integration to regional and global markets which probably explain the varied nature of land-use changes and forest /soil degradation processes. There are ample evidences that yet growing rate of population and high dependency of economy of Nepal on agriculture, livestock and forestry productions would manifest into a downward spiral of forest and soil degradation problems (e.g., Balla et al., 2000; Bajracyarya, 1983; HMG/ADB/FINIDA, 1988; Thapa and Weber, 1995).

Deforestation, though seen in many guises, can be defined as change of land cover with depletion of tree crown cover to less than 10% (FAO 2000). Changes within the forest class (e.g. from closed to open forest) which negatively affect the stand or site and, in particular, lower the production capacity mainly due to anthropogenic behaviour, are termed forest degradation. In most cases, degradation being a more subtle concept does not show as a decrease in forest area but rather as a gradual reduction of biomass degradation (quantitative), and loss in biodiversity (qualitative) (Sankhayan and Hofstad, 2001). Thus the forest degradation should be analysed both in terms of land cover and biomass stock changes over time in order to fully understand the processes in their entirety. Nepal is especially susceptible to high rates of soil erosion due to factors, such as, steep slopes and agricultural activities on these lands, present and past glaciation, high rainfall intensities due to orographic effects, and sparse vegetative cover. The factors responsible for high rate of soil erosion include steep slopes, unstable geology, short periods of heavy rainfall, high speed winds, flooding, drought, rapid increase in human and livestock population, uncontrolled and excessive grazing, poor soil management practices, improper forest harvesting, unmanaged mining activities, forest fires, environmentally unsound infra-structural activities, unplanned urbanization, inappropriate land-use practices, etc (Pratap and Watson, 1994; ICIMOD, 1998).

Since land-use, land-use changes especially agricultural land expansion and degradation of forests and soil in developing countries are related to socio-economic characteristics, population and livestock growth, technological change, consumption patterns, etc., their dynamics need to be analyzed by incorporating both the socio-economic behavior and ecological processes simultaneously (Holden and Shiferaw, 2004; Sankhayan and Hofstad, 2001; Upadhyay et al., 2005; Upadhyay et al., *in press)*. The modeling exercises under systems perspective are thus capable of reflecting the reality more closely, by considering the problem in its entirety rather than in isolation, and in turn generate valuable insights on sustainable use of forest and soil resources. The results of such modeling effort could significantly contribute towards formation of sound and pragmatic policies, plans and programs relating to land-use changes, forests and soil degradation (Holden and Shiferaw, 2004; Sankhayan and Hofstad, 2001). An integrated approach to modeling, capable of capturing interdisciplinary and cross-sectoral behavior, and combining elements of different modeling techniques probably best serve the objective of analyzing land-use change processes (Veldkamp and Lambin, 2001). In view of criticism of national or global level deforestation models due to high level of data aggregation and their inability to reflect the local level realities by several of the past scholars (e.g. Barbier, 2001; Kaimowitz and Angelsen, 1998; Sankhayan and Hofstad, 2000) a watershed level modeling approach like this can be considered reasonably well to reflect the socio-economic behaviors and biophysical conditions and their interrelationships under this perspective.

The main objective of this study in this context is to analyze the effects of five different policy scenarios on land-use changes, forest degradation/regeneration and soil degradation processes by using a dynamic bio-economic model at the watershed level in Nepal in a dynamic framework under interdisciplinary systems approach. The modeling exercise comprises of full account of agriculture, livestock and forestry activities with their consequent impacts on biomass and soil stocks under nine distinct land-use categories for the planning horizon of 25 years. First, I describe the watershed characteristics, bio-economic model and five model scenarios. Secondly, the model results on land-use changes, biomass development and soil losses under each of five scenarios are discussed; and the results are compared with those of the base scenario. Finally, policy implications of the results are presented with overall conclusions.

2. Watershed characteristics, data acquisition and bio-economic model

2.1. Descriptions of the watershed

The Mardi watershed (83º50'E to 83º 56' E and 28º19'N to 28º29'N) covers an area of 144 km^2 representing an average mid-hill watershed of Nepal (Fig 1). The elevation range in the watershed is 1000m - 5588 m above mean sea level from valley floor to mountain peaks with ridges of various aspects, hill slopes of varying degrees and the valley floors (Awasthi, 2004). The watershed consists of *Lahachok, Dhital, Rivan* and *Lwang-Ghalel* Village Development Committees (VDCs- the small political units at the village level in Nepal) and partial area of *Dhampus* VDC. The watershed is close to Pokhara town, the headquarters of the western development region of Nepal, and thus is assumed to be partially integrated into the market. The closest and farthest settlements in the watershed, namely Lahachok and Sidhing, are about 15 and 45 km northwest from Pokhara. There are 3,520 households in the watershed with a population of 18304 (population density of 127 persons/Km^2) in the base year 2003.

The climate of the study area varies from warm and humid subtropical to cool and dry alpine along with the elevations. Rainfall is monsoonal with average annual rainfall of 4300 mm, of which 80-85% occurs between June and October. Major soil types found in the watershed are Luvisol, Cambisol, Rigosols, and Fluvisols (Awasthi, 2004). Conservation area management and community forestry are the two main management regimes for natural resources. While the Annapurna Conservation Area Project (ACAP) manages the upper part, the lower part is under the jurisdiction of the District Forestry Office where community forestry programs are implemented. Agriculture, livestock and forestry productions that are interlinked to each other are the mainstay of the watershed economy. The major land uses and their characteristics are summarized in Table1.

Table1: Major land uses in the base year and their descriptions

Land-use class	**AgL* (ha)**	**NAgL** (ha)**	**Descriptions**	**Mean distance (km)**	**Possible crop rotations*** **
LU1	689	35	Plain irrigated land with slope <5° spread on the floor of valley bottom, best agric-land, locally known as *Khet*.	2.5	P-F-F, P-F-M P-W-F, P-W-M
LU2	986	100	Upper slope plain/terraced land without irrigation facility second best agric-land, locally known as *Pakho Khet*.	2.0	P-F-F, P-F-M P-W-F, P-W-M
LU3	1210	135	Upper slope terraced land where some lands fall near homestead and are more productive, locally know as *Bari* land.	2.0	M-ML-F, M-ML-W M-ML-MT,M-PT-F M-NB-F
Sub	*Total*	*2885*	*LU1+LU2+LU3 = Total Agricultural land (about 22% of the total area of the watershed)*		
LU4	0	2488	Mixed Hard Wood forest land in the lower elevational range, dominated *by schima-castanopsis-alnus* species	1.68	Over the model run if some land is cleared from these land uses then according to defined possible crop rotations for the given land use cultivation is done.
LU5	0	2489	Oak forest land in the middle elevational range	7.2	
LU6	0	3318	High Mountain Mixed Forest, in the upper elevation range dominated by rohedendron and betula species.	8.9	
Sub	*Total*	*8295*	*LU4+LU5+LU6 = Total Forest land (about 58% of the total area of the watershed)*		
LU7	0	858	Shrub or degraded forest land due to heavy grazing pressure (degraded forest)	3.0	
LU8	0	613	Upper elevation grazing land also called Pasture land	10.0	
LU9	0	73	Abandoned steep land previously under agricultural system in LU3.	3.0	
Others	0	1406	Not relevant for model purpose		

* AgL = Agriculture land; **NAgL = Non-agriculture land; *** P = Paddy, F = Fallow, M = Maize, W = Wheat, Ml = Millets, MT = Mustard, PT=Potato, NB = Naked Barley

Notes: (i) For modeling purpose (based on the watershed's reality) about half of the LU5 and LU6 are taken as inaccessible forest areas and hence only half of the areas have been used in the actual model

(ii) The estimates of area under different land uses and their classification are based on detailed Geographical Information System (GIS) study by Awasthi (2004) and Field Survey (2003).

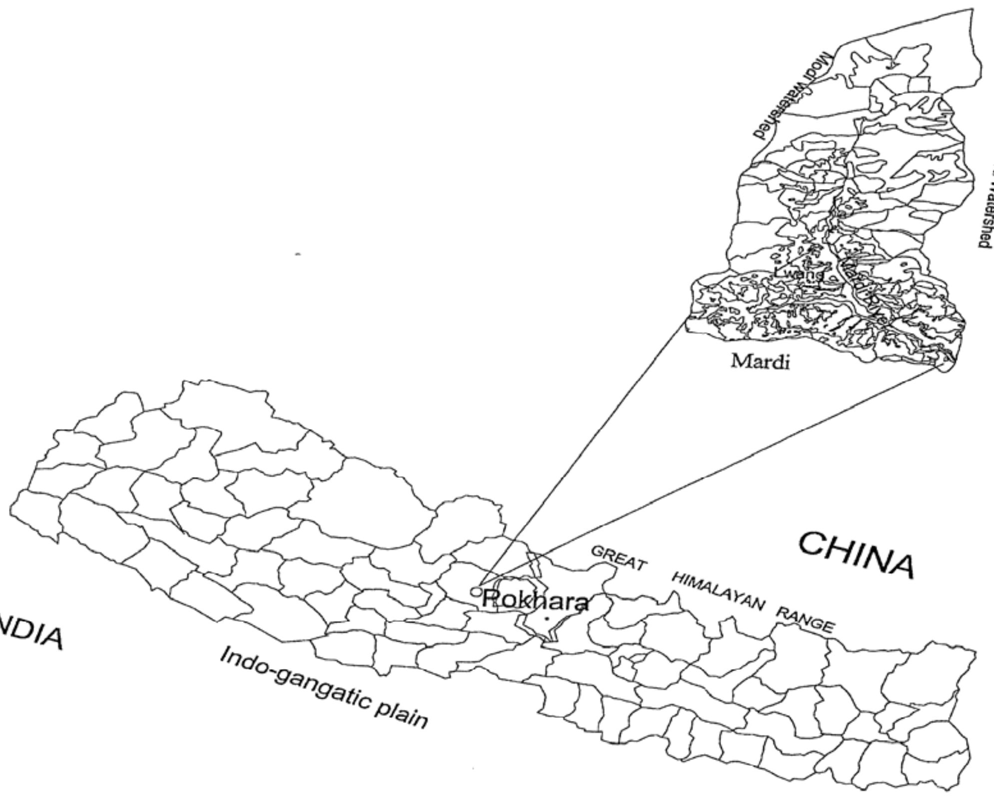


Fig1: Map of Mardi watershed

2.2. Data acquisition

Relevant socio-economic and bio-physical data were collected through a field survey undertaken during January to June of year 2003 by using appropriate sampling methods. Two hundred households in the watershed were interviewed with a semi-structured questionnaire to collect detailed production and consumption data. Seven participatory rural appraisal (PRA) exercises with the key informants representing all sections of society at different locations of the watershed were conducted to collect information regarding crop budgets according to crop rotations, land clearing activities, forest product harvest and other socio-economic aspects of the watershed from historical perspectives (Chambers, 1994). Data related to land uses, population and livestock growths are obtained from other published sources. A baseline survey done in the year 1996 by ACAP office was also used to verify the data used in the model. Personal and group observations were made as and when necessary.

In order to estimate biomass for each land-use category, trees' (45 different tree species in the watershed were recorded) diameter at breast height (dbh) and height were measured for 13 sample quadrants of 10m x 10m size for forest land uses LU4 and LU5 and 18 quadrants for LU6 according to probability proportional to size. Also tree dbh and height from four 10m x 10m quadrants for each LU1, LU2, LU3, and LU9 and six quadrants for LU7 were measured along with crown cover percentage, mean distance of the plot from the nearest village, elevation, slopes, aspects and other plot characteristics. Transect walk method was used to select the sample plots and plots were distributed according to elevation of hills, i.e. in about each 100 meters height plots were established while walking along the ridges. Allometric equations developed by Sharma and Pukkala (1990) for different species in Nepal were used to find the stem volume of trees measured and then volumes were converted into biomass by multiplying them with specific wood density of relevant species. The ratios for stem to branch and stem to foliage biomass as reported in Annex 3 of HMG/ADB/FINIDA (1988) were used to get branch and foliage biomass. Bush biomass was calculated by measuring two crown diameters and height of the bush fallen in the sample quadrants mentioned above in each land uses and later putting these values to allometric equations developed by Hofstad (1997). For grass biomass estimates, six 1m x 1m sample plots for each land uses were selected and all the grasses above ground were clipped and dried in an oven for 48 hours and dry biomass was measured. Later, the estimates of dry biomass obtained from above methods in given sample plots were averaged and converted into Mg per hectare estimates. Biomass of agriculture residue for agriculture lands was estimated by the help of information from PRA. Due to the unavailability of biomass growth functions for various species in the hilly region of Nepal, I used the growth rates (α_j) as percentage of standing stocks and biomass ratio for below ground biomass for each land use from the study by Singh et al. (1994) in the similar bio-physical conditions in the hilly range of northern India. Data on soil losses from each land use class were obtained from a study done in the same watershed by Awasthi (2004). The soil loss estimates for different crop rotations were gathered from experts' opinion and these estimates are later apportioned for each crop rotation for each land use based on the gross soil loss estimates for that land use as mentioned in Awasthi (2004).

2.3. Dynamic bio-economic model

The bio-economic model used for this study incorporates linear optimization techniques with translation of the systems behavior of the production and consumption patterns along with the interaction of bio-physical conditions into mathematical programming language. General Algebraic Modeling Systems (GAMS) software is used for running the model in a personal computer. The solutions are global optima which are obtained by simultaneous optimization of the objective function taking all the constraints into account for the entire planning horizon at once and hence the results can be considered reliable unlike in the case of dynamic non-linear problems where there might be more than one optimum in general and thus the solutions are from local optima. The model was calibrated to test its reliability based on the results particularly of area under various land uses, agricultural areas under different crops and density of standing biomass, which are in line with the information obtained from the field survey in base year 2003. The model performed reasonably well to reflect the over all ground reality of the watershed condition these days in the hilly region of Nepal.

Maximization of aggregated utility (U_t) derived from sum of discounted net income from agricultural, livestock, forest products and imputed value of leisure for the whole planning period at the watershed is an objective function of the model. Meeting basic requirements of food grains, cash, fuelwood and timber for human population and fodder requirement for livestock are also main objectives, which enter into the objective function through a mechanism of hierarchical achievement of them as hard constraints. These minimum required consumption levels based on the field observation are exogenously fed into the models which increase progressively along with population and livestock growth over years. Followings are the assumption made in the model:

- The whole watershed is treated as a single decision making entity in relation to forest/soil uses since the collective decisions on the landscape level is prevalent in the rural watershed and the externality caused by agric-forestry-livestock productions in the whole watershed is internalized with this assumption unlike in the case of household level modeling that is unable to capture the externalities.
- Households are assumed to follow satisficing approach (Simon 1952), i.e. there are hierarchy of objectives of the household, e.g. meeting the minimum consumption needs of

agricultural, animal and forest products, meeting minimum cash needed for basic necessities like clothing, education, etc., enjoying leisure, and then comes the profit issue at the end under several information or market imperfections prevalent in the watershed economy.

- The model assumes semi-perfect market and non-seperability case is implicit as we have included the consumption side with flat demand for different products and hierarchies of objectives are to be satisfied before going for profitability option.

2.3.1. The objective function

The objective function:

$$Maximize \sum_{t=1}^{T} (1/(1+\rho)^t) * U_t \ .$$

where,

$$U_t = \sum_j \sum_c (a_{cjt} * AgL_{cjt}) + \sum_f (a_{ft} * FP_{ft}) + \sum_s (a_{st} * LS_{st}) + w_t * LE_t \qquad (1)$$

$$a_{cjt} = \sum_i p_{it} * q_{icjt} - \sum_r (\mu_{rcjt} * X_{rcjt}), \qquad (2)$$

$$a_{ft} = p_{ft} - \mu_{ft}, \qquad (3)$$

$$a_{st} = \sum_l (p_{lst} * q_{lst}) - \mu_{st}, \qquad (4)$$

AgL_{cjt}= Number of hectares cultivated with given crop rotation c (there are nine different crop rotations used in the model as described in Table1) in jth land use (there are nine land uses in the model) during the tth year (t=1,2,3,…,25).

FP_{ft}= Amount of forest product f (f = fuelwood, timber and fodder) harvested in year t.

LS_{fts} = Number of livestock s (s = buffalo, cow, goat/sheep) raised in year t.

LE_{t} ‘ = Amount of labor (man days) enjoying leisure in year t.

q_{icjt} = Yield of the ith crop under cth rotation from jth land category at tth year.

q_{lst} = Yield of lth livestock product (l = meat, milk, farmyard manure) from livestock s in year t.

x_{rcjt} = The quantity of rth resource (r= fertilizers, manure, input costs) per ha of cropped area under cth crop rotation in year t.

p_{it} , p_{ft} , $p_{lst,}$ w_t and μ_{rcjt} μ_{ft} μ_{st} are the per unit prices of products (crops, forest and livestock products, leisure) and input (for agriculture, forest product and livestock) costs respectively.

$a_{cjt,}$ $a_{ft,}$ *and* a_{st} are per unit net cash income from agriculture, forest product and livestock productions during year t.

ρ = annual percentage of social discount rate, taken as five percent per annum.

2.3.2. Activities in the model- decision variables

Activities or the decision variables, whose optimum level for each period are determined by the model based on simultaneous global maximization of the objective function subject to the constraints, are mainly related to production of agriculture, forestry and livestock products, sales and purchase of the products, land clearing and abandoning, labor hiring out and buying of fertilizers for agricultural productions. The model deals with the agricultural productions in more detail because the systems behavior in the agrarian rural economy is mostly guided by agriculture production and consumption practices and these are intricately linked with forestry and livestock production systems simultaneously. The number of hectares allocated for given crops, e.g. paddy, is determined based on crop rotations, fertilized or non-fertilized and type of land uses given the constraints defined in the model. Sales and purchase of the products are determined by the balance of production and minimum requirement for the given product. Land clearing can take place in each land use category and this brings new land for cultivation from the uncultivated area. The model also handles abandoning of cultivated land which is caused either by low returns to labor on farm for the given land use or lack of labor availability to cultivate in the given period of time. If the labor force in the watershed in certain leisurely month is available then there is some limited hiring out possibility of labor for some casual incomes to supplement the basic requirements. Based on the ground reality of the watershed the model assumes maximum five percent of the total labor force can be hired out at the given month. Labor hiring in is not relevant in the case of rural watershed like ours as no labor hiring in is common practice at the watershed level these days.

2.3.3. Constraints in the model

Watershed-household is assumed to make decisions under a number of constraints such as labor, land and capital availabilities, biomass development and extraction, and fertilizers and manure availability. This model is crucial in handling labor constraint as available labor resource determines the levels of competing productions of agric-forestry-livestock products. Labor requirements for per unit activities are exogenously defined as parameters and for agriculture production the requirements of labor is binding for the entire rotation covering a year as the crops are grown as per the chosen rotation. Total labor used for agriculture, forest and livestock production, land clearing and leisure activity less labor hired out in a month in a given year is equal to the total labor available for that month in that year. Labor time required for traveling from village to land uses is also accounted which adds up to the labor requirements parameter for different activities. Labor availability over time increases with growth rate of population, which is already calculated as parameters and fed into the model as right hand side of the constraint over its run. Land available for cultivation during the current period is the land available for cultivation in the previous period plus the land cleared during the current period minus the abandoned of cultivated land area. Of land clearing and abandoning activities, only one can enter into the model at a time.

The minimum consumption requirements for agriculture, forest and livestock products should be met either through production in the watershed or through purchase from outside of the watershed. This constraint is given through the balancing equations for each product as “production + purchase – consumption – sale=0” in each year. The proceeds coming from the sales are used for meeting the minimum cash needs of the population in the watershed. The model assumes a minimum level of cash requirements for the whole population for different purposes, e.g., salt, sugar, clothing, medicines, education, etc. to be met. The constraint in the model in this regard is set as total cash surplus from sales proceeds of the products or borrowing should be greater than or equal to the total minimum cash requirements for the entire watershed. The constraint for biomass products’ harvest is given as total harvest for each product should not exceed the total standing biomass product wise in each land use in each period.

2.3.4. Computation of major variables and parameters

Biomass growth and use

The biomass supply and demand (harvest or consumption) are dealt in the model in terms of biomass products f (f = fuelwood, timber and fodder). This is based on the initial estimates of six types of biomass namely, stem, branch, leaf, grass, bush and agriculture residue with some factors (e.g., only 60% of stem and 5% of branch biomass constitute timber biomass pool and 40% of stem, 90% of branch, 5% of bush and agriculture residue forms the fuelwood biomass pool, etc.) that are used to calculate the total availability of biomass pool (Mg/ha) for each product. Biomass growth function is computed as:

$$BM_{t+1,f,j} = BM_{t,f,j} * (1+\alpha_j) \quad \ldots\ldots (5)$$

where, BM (t, f, j) stands for Mg of biomass for f^{th} product per hectare during the t^{th} year in j^{th} land category.

This biomass density is used as an indicator of forest degradation/regeneration in this study. The growth rate of vegetation, α_j , is an exogenously determined parameter in per cent of the stock per annum in the j^{th} category of land. The total remaining biomass in year t+1 i.e., net of biomass growth and the losses due to harvest and forest fire is calculated as:

$$TBM_{t+1,f,j}=BM_{t,f,j,}(1+\alpha_j))*AREA_{t,j} + LABN_{t,j}*\Delta BM_{t,f,j}-(FP_{t,f,j}+FIRE_{t,,i} +LCLR_{t,j}*\Delta BM_{t,f,j}) \quad ..(6)$$

TBM, AREA, LABN, LCLR, ΔBM , FP and FIRE respectively, stand for total biomass, land area, abandoned land area, cleared land area, change in biomass density (Mg/ha) due to clearing or abandoning, quantity of biomass extracted product wise and biomass loss due to fire. Symbol Δ refers to change in or difference of biomass density. Biomass density for rest of the period is calculated by dividing the resultant total biomass in each period by the resultant land area for each category.

Human and livestock population, its growth and migration

The population during time period *t*, P_t, is given by the following equation:

$$P_t = P_0 * (1+\delta)^t + IM_t - EM_t \quad (7)$$

Where, δ = average annual percent growth rate, IM = immigration and EM = emigration.

The total population of the watershed during year *t* is obtained by summing the population over the households. IM_t is taken to be “0”. EM_t is estimated at 20 per cent of the active labor force for year

2003. Given the ratio of workers to total population (RWP) and average working days per month (WDM), both exogenous estimates, labor availability during t[th] year and m[th] month is found out as:

$LABOR_{t,m} = RWP * WDM_m * Pt$ (8)

For computation of available livestock population in each year, a fixed growth rate of three types of livestock namely, cattle, buffalo and goat are used in order to avoid the complexity of livestock development dynamics.

Soil loss by land use

Agricultural activities under different crop rotations by land use classes and non-crop lands (NAgLs) in each period have significant impacts on soil loss. These losses are calculated as:

$$TSL_t = \sum_j \sum_c (AgL_{cjt} * SL_{cj}) + \sum_j (NAgL_{jt} * SL_{jt})$$

where, TSL_t = Total soil loss from both agriculture and non-agriculture lands in year t

SL_{cj} = Soil loss coefficient (Mg/ha) for c^{th} rotation under land use j

SL_{jt} = Soil loss coefficient (Mg/ha) for land use j (non-agric-land)

$NAgL_{jt}$ = Non-agriculture land area under land use j

2.3.5. Descriptions of model scenarios

A brief descriptions and relevance of the scenarios are presented in Table2. These scenarios are selected because of their high relevance for analyzing such a complex bio-economic systems in a rural hilly watershed of Nepal.

Table2: Model Scenarios and their descriptions

Name of Scenario	Descriptions
BAU	Business As Usual (BAU) i.e. the base line case where 2%population growth rate, 5%discount rate and other parameters, scalars for production and consumption activities are given.
POPG	*Reducing current population growth rate- 2% to 1.5%* per annum. Population hypothesis postulates that increase in population pressure boost demand for crop, livestock and forest products resulting in clearing more land for cultivation, forest products and grazing in rural economies in general. This scenario by reducing population growth rate tests the impacts of population pressure and a priori expectations are less pressure on land resources and less soil loss.
OFEMP1 *OFEMP2*	*Reducing current labor emigration rate- 20% to 10% that means more labor force available in the watershed.* *Reducing current labor emigration rate- 20% to 15% that means more labor force available in the watershed.* Off-farm employment activities for rural labor force are well known in the rural-urban linkages and economics of migration literature. Currently the watershed is facing shortage of labor force due to high level of labor emigration for different purposes (mainly employment and education) and as a result land abandoning in the steep agric-land is becoming common phenomenon these days. With these two scenarios, I analyze the relative impacts of different rates of off-farm employment on land uses and forest/soil usage. This is important to foresee if there is less employment opportunity outside the watershed then what would be its consequences on land based activities in the watershed; and a priori expectations are more pressure on lands with more clearing, and more biomass and soil loss.
AGRPR	*Increasing prices of major staples- Paddy, Maize, Wheat, Millets by 10%* In general increasing prices of agricultural produce would make agriculture more profitable and hence incentive to expand the agric-lands. The increased incomes are expected to encourage investment in agriculture, including greater clearing of frontier forest area for cultivation. In contrast, subsistence economy would behave differently by clearing less land in response to increase in output prices. The expected results are more land being cultivated and hence more biomass and soil loss.

3. Results and Discussion

The results obtained from final run of the model are presented in a logical sequence in order to closely observe the systems behaviors of land-use changes and forest/soil degradation or regeneration under five different policy scenarios (cf. Table2); and draw several policy conclusions at the end. The presentation sequence follows results and discussion on land use and land -use changes; biomass growth and harvest by land use; soil loss by land use; and finally overall policy conclusions. The model was run for the planning horizon of 25 years i.e. from year 2003 to 2027 as this period can be considered medium range planning horizon enough to see the agric-livestock-forestry production systems' sustainability and their environmental impacts, such as, soil loss, forest degradation and/or regeneration.

3.1. Land use and land-use changes

The model is structured in terms of land area trading taking place within the given land use category, which is presumed to have two possibilities, i.e. either AgL or NAgL and total geographical area for the given land use in each year remains the same. Over the model run, depending on labor availability and relative profitability and/or to meet the minimum consumption requirements NAgL of any land use can go for AgL due to clearing and vice versa due to abandoning if agriculture becomes no more profitable but the changed area remains within the same land-use category as shown in Table 3. The model reveals several interesting results in terms of land-use changes over years and these changes by land use and in terms of total AgL are summarized in Table3.

The abandoning from LU3 at different levels in the year 2003 is found in all the scenarios and later (after 15th year) some portion of the same land use gets cleared for AgL need due mostly to more labor force availability and to fulfill the basic needs of grains for the growing population. This reflects the field reality that abandoning of LU3 is not uncommon; and at the same time based on the labor availability and profitability different amount of other land uses mostly LU4, LU7 and LU9 get cleared in the later years of the model run under different scenarios (Table 3). The fact of abandoning of LU3 in the base year is supported by current situation of field as farmers are motivated to plant tea crop in steep and upper elevation of some part of LU3; and other constraints as mentioned above are also helping abandon the lands under this category. Thus the model handles both the clearing and abandoning processes clearly to show the future scenarios of land use changes at the watershed level.

The results as summarized in Table3 show the highest amount of clearing is taking place under OFEMP1 (28%) followed by OFEMP2 (15%) scenarios, which are as per a priori expectations. The clearing percentage is calculated based on the difference between total AgL lands at the end of base year 2003, i.e. it excludes the abandoned land which was previously under agriculture, and the total AgL at the end point of year 2027. However, increase in prices of major crops (as shown under AGRPR case) doesn't show significant increase in total AgL as compared with BAU case. This implies farmers are not responding the price signals (with at least 10% increase) in terms of expansion of total agric-lands partly due to resource constraints (since labor hiring in is restricted in the model); but it is clear that they shift the crop rotations to the crops whose prices are increased in the model scenario as indicated by increase in amount of cleared land in LU4 category by shifting it from LU7 as in BAU case (Table 3). These scenarios give important policy implications in two counts: i) to see at what levels of decreases in labor emigrations and increase in agricultural products' prices the watershed experiences higher level of total AgL expansion, and ii) which land uses are more susceptible to encroachment due to decrease in labor emigrations and price increases. The least clearing is found under POPG scenario (1%) which is also in line with our a priori expectation; and this fact can be explained by less number of labor forces available for the productions and less amount of minimum consumption requirements to be fulfilled under this case.

Of the whole clearing activities, LU4-which is the nearby forest land with high amount of biomass stocking and relatively more productive if converted into agriculture use, is more susceptible to be encroached showing the reality of such happenings in the past at the watershed; and under the present systems behaviors it would be likely case in the future too if no institutional intervention (this model does not include institution as such) comes into force. However, there is strong presence of institutions, namely forest user groups, women's group, ACAP, etc. at different levels in the watershed these days, which have positive impacts on forest management and land clearing is not prevalent. But, some parts of government managed natural forests are seen with adverse impacts of illegal harvesting and minor encroachments at present.

Table3: Summary of agricultural area change over the planning horizon (areas in ha)

Scenario	Descriptions	LU1	LU2	LU3	LU4	LU7	LU9	Total Areas
BAU	Area in 2003	689	984	821	0	0	0	2494
	Area in 2027	689	1014	856	78	47	35	2719
	Area change	0	30	35	78	47	35	224(9%)
	First clearing year		2025	2015	2011	2017	2013	-
	Area abandoned in 2003		2	389				391
POPG	Area in 2003	689	986	754	0	0	0	2429
	Area in 2027	689	986	789	0	0	0	2464
	Area change	0	0	35	0	0	0	35(1%)
	First clearing year			2015				
	Area abandoned in 2003			456				456
OFEMP1	Area in 2003	689	986	965	0	0	0	2640
	Area in 2027	689	1016	1000	572	56	35	3368
	Area change	0	30	35	572	56	35	728(28%)
	First clearing year		2025	2015	2004	2016	2009	
	Area abandoned in 2003		0	245				245
OFEMP2	Area in 2003	689	986	965	0	0	0	2640
	Area in 2027	689	1016	1000	226	57	35	3023
	Area change	0	30	35	226	57	35	383(15%)
	First clearing year		2025	2015	2009	2015	2010	
	Area abandoned in 2003		0	245				245
AGRPR	Area in 2003	689	986	820	0	0	0	2495
	Area in 2027	689	1016	855	131	0	35	2726
	Area change	0	30	35	131	0	35	231 (9%)
	First clearing year		2025	2015	2011		2014	
	Area abandoned in 2003			390				390
	Area in 2027	689	1016	829	5	0	35	2574
	Area change	0	30	35	5	0	35	105(4%)
	First clearing year		2025	2015	2017		2016	
	Area abandoned in 2003		0	416				416

The time path of changes in total AgL over planning horizon is as shown in Fig 2 and the bar diagram in Fig3 displays the total cleared and abandoned land during the whole period under different scenarios.

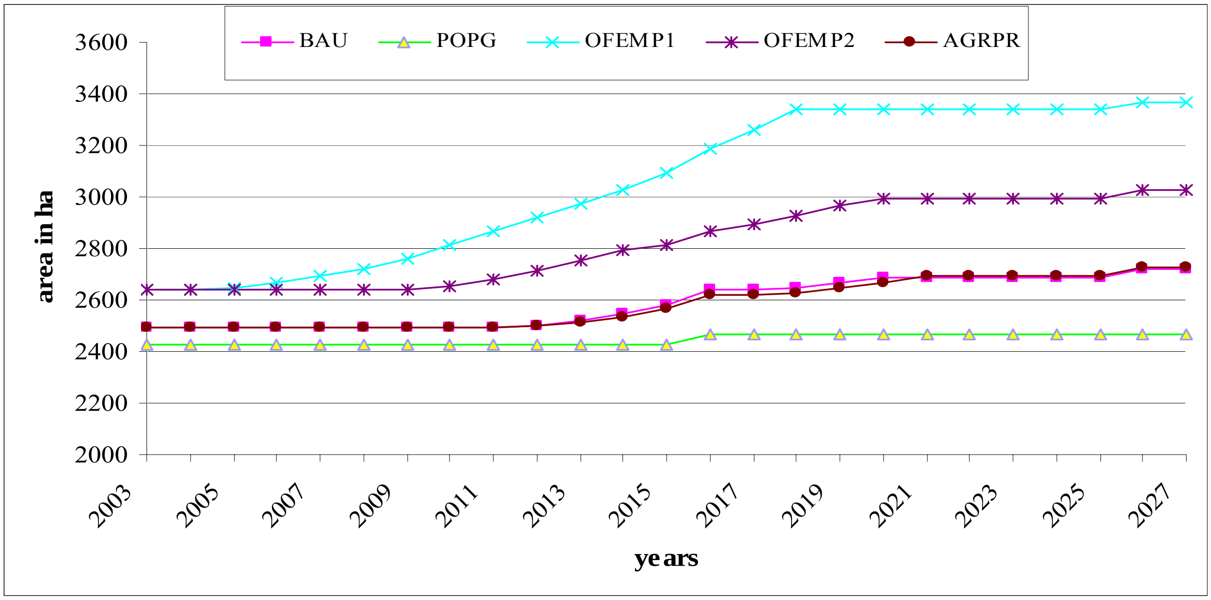


Fig2: Changes in total AgL over years under different scenarios

Overall for the whole planning period, the net clearing is positive and most in OFEMP1 followed by OFEMP2 scenario and rest all scenarios have negative net clearing (Fig 3) implying abandoning of some portion of existing AgL from LU3. These results support the findings of recent work (e.g., Awasthi, 2004; Banskota, 2000; Carter and Gilmour, 1989; Fox, 1993), which conclude that in some of the hilly watersheds forests are returning back both in terms of areas and stocking. Nonetheless, if the actual situations in the watershed turned into OFEMP1 and OFEMP2 scenarios, then the model shows that there would be more deforestation and negative consequences of it would be prevalent as demonstrated by some of the past studies (as listed in the review work by Upadhyay et al. (2005) e.g. Balla et al., 2000; Thapa and Weber, 1995). Thus, the results under different scenarios reveal important contrasting outcomes in terms of land use and land-use changes and would therefore help guiding the land policies in the days a head at the watershed level in Nepal. In this context it would be plausible to say that present day shift in institutional set up of property rights as transferred from state to local communities for the management of erstwhile 'open access commons' to 'local commons' might have played a crucial role for the forest returning back to regeneration in the watershed.

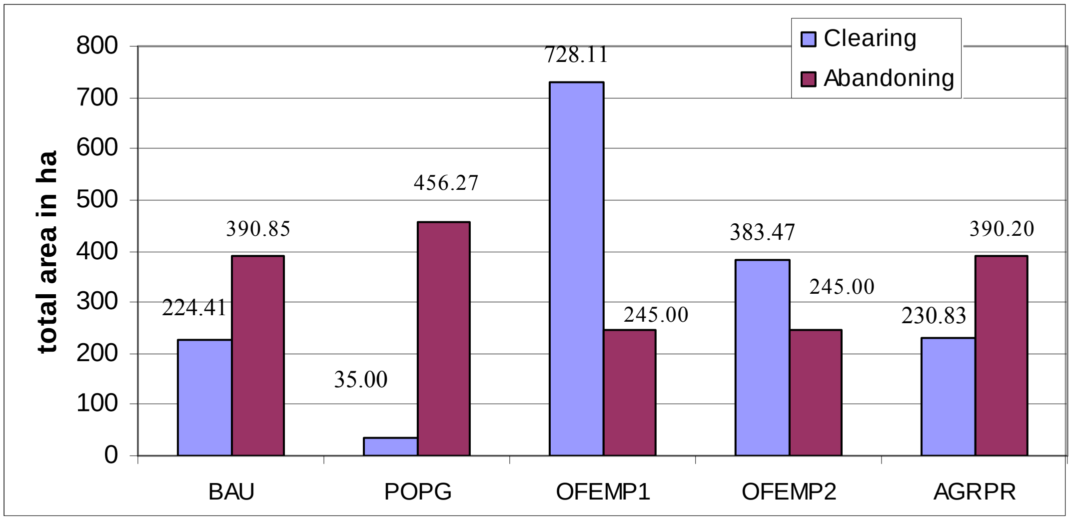


Fig3: Total areas cleared and abandoned over the entire horizon under different scenarios

3.2. Biomass growth and harvest by land use

Beside forest degradation being seen from land clearing point of view; it can also be observed through change in remaining standing biomass density (decline in biomass density) over time (Sankhayan and Hofstad, 2001). The model assumes a constant supply of biomass products, i.e. fuelwood and fodder from AgLs (no timber is coming from AgL) of each land use category and whatever is supplied is harvested each year. This assumption is based on above ground biomass from agriculture lands being harvested and renewed with more or less same amount each year relative to the whole biomass supply and harvest in the watershed.

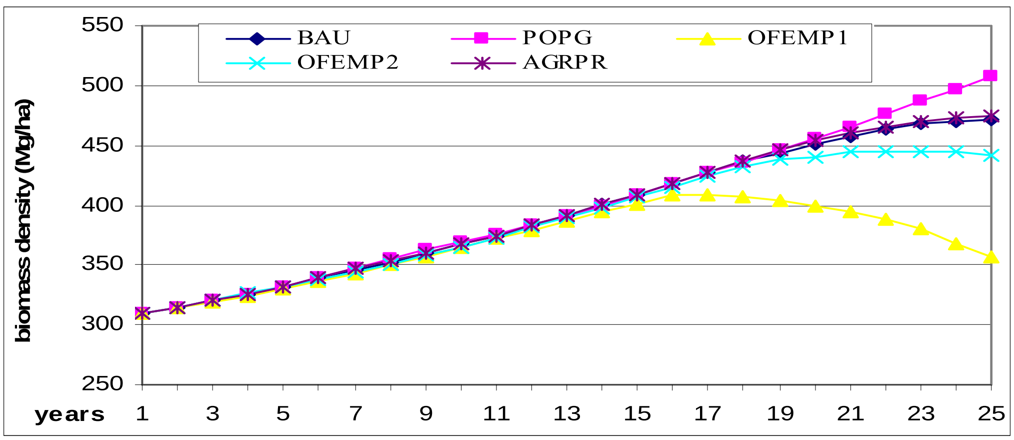
Changes in total biomass density

The changes in biomass densities with respect to land uses over the planning period take place only on NAgLs' of nine land use categories under five scenarios, which are depicted in Table4. Due to abundance of forest areas (58%) in the watershed as compared with national (29%) and other hilly watershed cases, the results show that there is significant increase in standing biomass density at the end of planning period in each land use categories implying regeneration and good health of existing forest lands. However, LU4 being major forest land in the vicinity of villages is affected mostly in terms forest products harvest as shown by relatively lowest increase of biomass density (only 15% to 64% under OFEMP1 and POPG scenarios) at the end of planning period. The variation in increases on densities at the end of planning horizon in LU5 and LU6 forest lands under all the scenarios are almost nothing due to their locations (being farther from the village) and only the minimum predefined harvest level of biomass products are taken out from these forests. The highest increase in density under all the scenarios are found in LU9; this is because most of the products are harvested from big areas of LU4 forest and LU9 itself being relatively farther than LU4 and very small in size supplies a little amount of the products in relation to the total biomass supplies from NAgLs of the watershed. The only negative percentage changes in densities are found in LU8 (pasture/grazing land) under all except POPG scenarios; this is due to the fact that this land use mostly has fodder biomass and there is heavy pressure on biomass resources in terms of fodder in all land uses (this case is discussed below). These facts are also corroborated with the ground reality of the watershed now days and the opinions expressed by local people during the field survey.

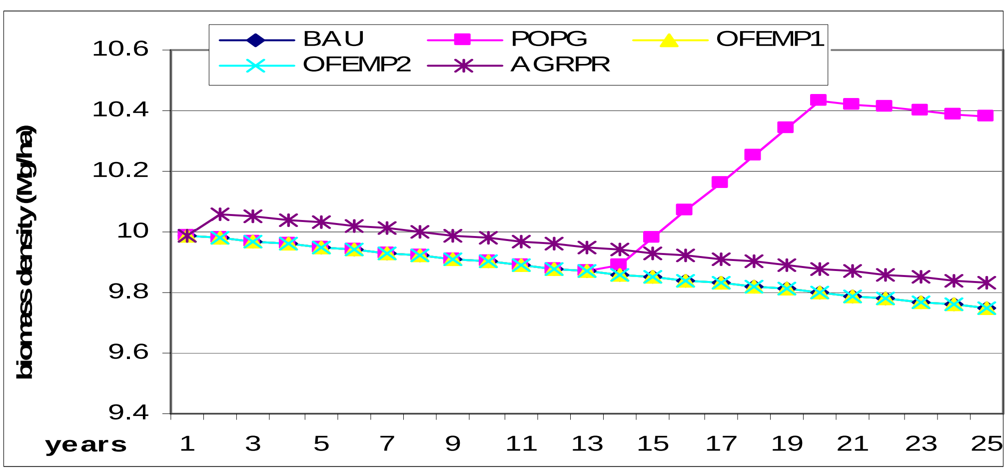
Table 4: Summary of total biomass density change over the planning horizon (Mg/ha)

Land uses	**Descriptions**	BAU	POPG	OFEMP1	OFEMP2	AGRPR
LU1	Density in 2003	10.30	10.30	10.30	10.30	10.30
	Density in 2027	15.01	15.01	15.01	15.01	15.01
	Per cent change	**45.73**	**45.73**	**45.73**	**45.73**	**45.73**
LU2	Density in 2003	14.13	14.13	14.13	14.13	14.13
	Density in 2027	21.29	19.46	20.52	20.52	20.52
	Per cent change	**50.67**	**37.72**	**45.22**	**45.22**	**45.22**
LU3	Density in 2003	22.24	22.24	22.24	22.24	22.24
	Density in 2027	45.77	46.19	44.29	44.29	45.78
	Per cent change	**105.80**	**107.69**	**99.15**	**99.15**	**105.85**
LU4	Density in 2003	309.64	309.64	309.64	309.64	309.64
	Density in 2027	471.42	508.19	356.49	441.35	474.91
	Per cent change	**52.25**	**64.12**	**15.13**	**42.54**	**53.37**
LU5	Density in 2003	450.63	450.63	450.63	450.63	450.63
	Density in 2027	734.25	734.25	741.81	734.25	734.25
	Per cent change	**62.94**	**62.94**	**64.62**	**62.94**	**62.94**
LU6	Density in 2003	519.33	519.33	519.33	519.33	519.33
	Density in 2027	949.88	945.84	965.75	954.73	948.68
	Per cent change	**82.90**	**82.13**	**85.96**	**83.84**	**82.67**
LU7	Density in 2003	35.40	35.40	35.40	35.40	35.40
	Density in 2027	62.00	61.65	62.08	62.08	61.65
	Per cent change	**75.14**	**74.15**	**75.37**	**75.37**	**74.15**
LU8	Density in 2003	9.99	9.99	9.99	9.99	9.99
	Density in 2027	9.75	10.38	9.75	9.75	9.83
	Per cent change	**-2.40**	**3.90**	**-2.40**	**-2.40**	**-1.60**
LU9	Density in 2003	41.83	41.83	41.83	41.83	41.83
	Density in 2027	98.61	90.82	98.98	98.88	98.42
	Per cent change	**135.74**	**117.12**	**136.62**	**136.39**	**135.29**

Fig4 (a and b) shows the time paths of changes in total biomass densities (i.e. fuelwood, timber and fodder densities added together) in NAgLs of LU4 and LU8 under seven model scenarios and the total biomass density constitutes both the above and below ground biomasses. The figs shown include only LU4 and LU8 for they are having experienced significant variations on changes in densities by scenarios as compared to other land uses in the watershed. The clear impacts of lessening biomass density in LU4 forest by all except POPG scenario is apparent in Fig4 (a) and degradation of pasture land due to high pressure on fodder biomass of this land category is also visible in Fig4 (b).



LU4 (a)

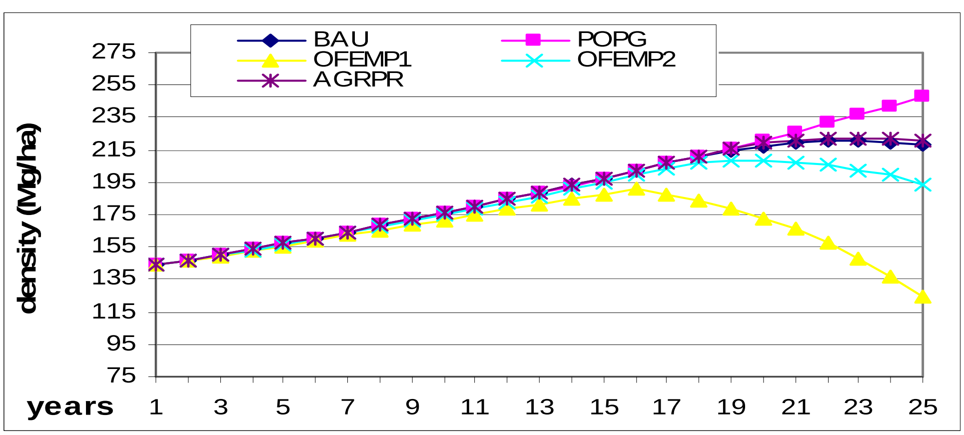


LU8 (b)

Fig4: Time path for biomass density over years in LU4 and LU8 under model scenarios

Changes in product wise biomass density

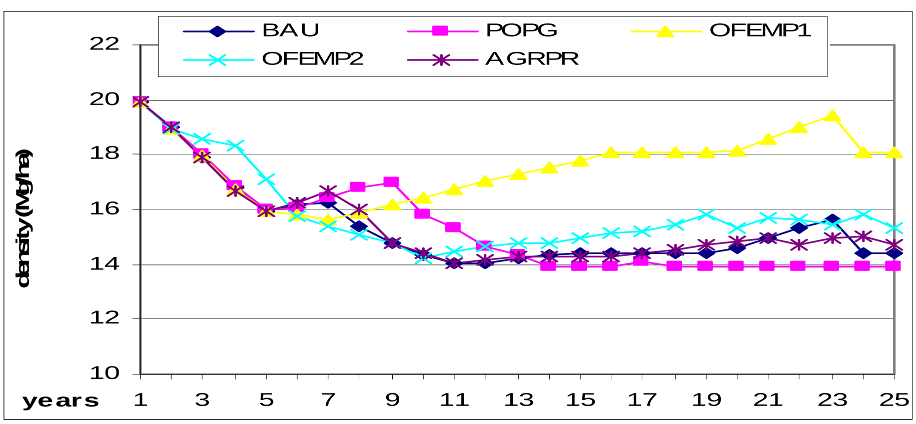
As said earlier the model was run in terms of three biomass products' supplies and demand to see the pressure on different products by land uses under different scenarios and the results would in turn yield useful policy implications in terms of biomass growth and uses by products and land uses. No significant variations in terms of changes in timber densities by land uses were observed under all the scenarios because of fulfilling the harvest levels of timber by the amount as prescribed by minimum extraction levels from NAgL of all the land uses. The time path of variations in density of fuelwood is presented in Fig5 for only LU4 forest due to its high significance in terms of changes of fuelwood density over time. The increase in density of fuelwood is less under OFEMP1 and OFEMP2 scenarios as explained by higher amount of labor force available to harvest. On the contrary POPG scenario has highest rate of increase in fuelwood density. The pressure of fuelwood harvest is clearly seen on LU4 forest under all the scenarios and even it goes to negative change in density at the end of planning period under OFEMP1 scenario. Furthermore, there appear more decreases in fuelwood densities in all except POPG scenarios in LU4 at the later years of the planning horizon (cf. Fig5) due to availability of more labor forces and saturation of total AgLs in terms of land clearing especially after the 15th year. These facts indicate, in the distant future, if off farm employment level is less and/or higher agric-corps' prices then there would be degradation in LU4 forest in terms of fuelwood biomass pool and hence suggest for proportionate harvesting of the product from other forest categories as well so as to maintain the fuelwood biomass pool in LU4 under sustainable level.



LU4

Fig5: Time paths of biomass density (Mg/ha) for fuelwood in LU4 under model scenarios

Fodder supply is relatively scarcer in relation to total demand of this product as one livestock unit annually consumes about 3 Mg of air dry fodder biomass and livestock is increasing annually. Agriculture land which comprises of about 22% of total land area of the watershed is also a major supplier of fodder and due to grazing and transhumance practices of livestock raising in the watershed the extraction of fodder is distributed throughout all land uses. The time path of fodder density change is shown only for LU4 forest where the degradation is more significantly experienced under model scenarios. Owing to the fact that relatively higher demand and lesser supply of fodder, we can observe from the figure that the fodder densities are declining in all scenarios at varying degrees. In contrast to change in fuelwood density, the decline in fodder density is lesser under OFEMP1 and OFEMP2 scenarios due to more fodder being supplied from increased AgL from clearing activity under these scenarios. Here the effects of increased AgL after clearing from NAgL of different land uses in terms of more supply of fodder are visible and only POPG scenario where no clearing takes place thus experiences the highest fall in fodder densities in NAgL of LU4. This indicates that AgL is potentially a good substitute of fodder supply for forest land and if fodder harvest is proportionately extracted from all the available sources and/or substitution of other kind of animal feeds for fodder and of improved breeds of animals for local ones (this helps reduce number of livestock) then the total pressure on fodder biomass could be mitigated to some extent. The overall findings of the model in terms of relative scarcity of fuelwood and fodder as indicated by declining in their densities especially in OFEMP1 and OFEMP2 scenarios at the terminal point are also in line with the findings from some of the past studies in the hills of Nepal (e.g. Bajracharya, 1985; Paudel, 1997; Thapa and Weber, 1995).



LU4 (a)

Fig 6: Time paths of biomass density (Mg/ha) for fodder in LU4 under model scenarios

3.3. Soil loss- a proxy for soil degradation

Land use and land-use change activities as discussed above have consequent impacts on soil degradation which is complex ecological and economic problems in agrarian dominated developing countries like Nepal. We have considered total soil loss from AgL and NAgL of all the land uses due to erosion processes as proxy for soil degradation in this modeling work. The amount of soil loss varies significantly over land uses at broader scale as indicated by the estimates of 1.3 Mg/ha/yr for LU1 to 32.3 Mg/ha/yr for LU7; and under agricultural uses by land use category coupled with crop rotations as reflected in the estimates of 1.2 Mg/ha/yr for LU with P-F-F rotation to 53.85 Mg/ha/yr for LU7 with M-PT-F rotation. Soil degradation problem as seen in terms of higher amount of soil loss due to erosion processes in the mountain agriculture systems is pervasive in the watershed mainly due to cultivation in higher elevation steep lands which are more than 30^o in slope and thus unsuitable for cultivation (Awasthi, 2004).

Table5 presents a summary of total soil loss in both AgL and NAgL and their changes between initial and terminal years of the planning horizon. When comparing the percentage change in loss amount with respect to the total soil loss under BAU in year 2003 (the estimates of soil loss are for the end point of year 2003 and hence vary among the scenarios due to different crop rotations being assumed by different scenarios at end point of year), the highest change and amount of soil losses are found in OFEMP1 case (183%) followed by OFEMP1 (122%) (cf. Table5). However, the changes in soil loss in other scenarios are less than in BAU case due mainly to the shift of cultivation from LU7 where if cultivated, the highest soil loss per unit area takes place, to LU4 land use as shown in Table 3, where less erosion prone crop rotations are grown. The least amount of soil loss is found in the case of POPG scenario as per expectation.

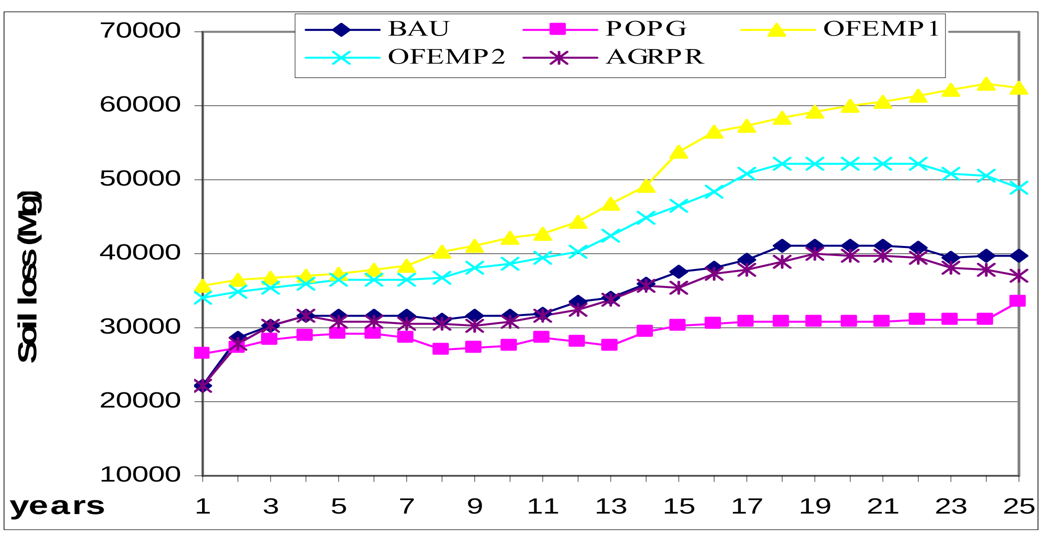
In contrary to total soil loss from AgL under different scenarios, the loss from NAgL is just reverse in OFEMP1 and OFEMP2 scenarios due to shift of some portion of land area from NAgL to AgL and the soil loss coefficients for per hectare of NAgL of all land uses are fixed. When we see the total soil loss situation under all the scenarios OFEMP1 and OFEMP2 are still having highest amount of their percentage changes. AGRPR scenario more or less resembles with BAU case in terms of total soil loss and its change. POPG case is again the lowest soil loss generating case in totality even though highest loss is seen in NAgLs under this scenario, which is due to no clearing taking place under this scenario.

Table 5: Amount of soil loss under different scenarios (Mg) and their changes

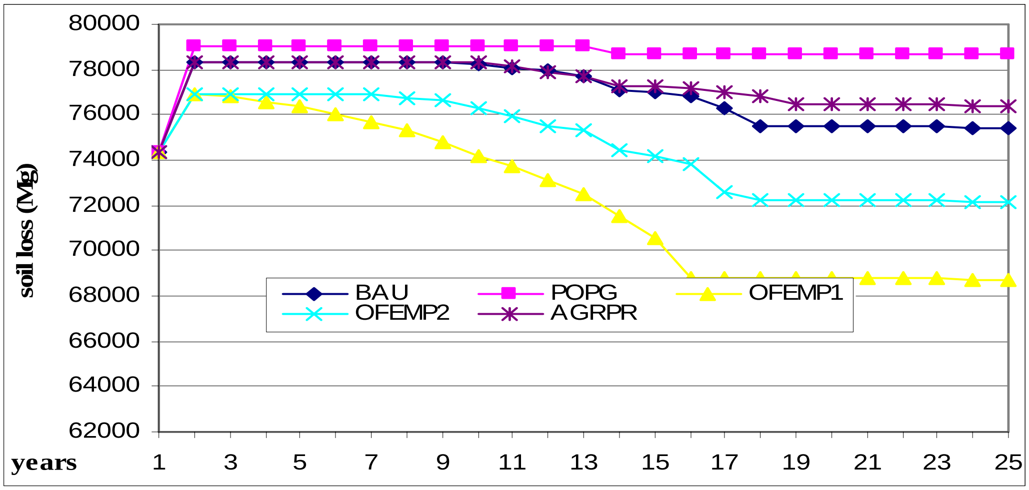
	Descriptions	BAU	POPG	OFEMP1	OFEMP2	AGRPR
AgL	Loss in 2003	22092	26433	35609	33949	22097
	Loss in 2027	39624	33638	62461	48942	37074
	Change*	17531	11545	40369	26849	14982
	Percent*	79	52	183	122	68
NAgL	Loss in 2003	74397	74397	74397	74397	74397
	Loss in 2027	75443	78651	68684	72147	76424
	Change	1046	4255	-5713	-2249	2027
	Percent	1	6	-8	-3	3
Total	Loss in 2003	96489	100830	110005	108346	96494
	Loss in 2027	115067	112289	131145	121089	113498
	Change*	18578	15800	34656	24600	17009
	Percent*	19	16	36	25	18

* The changes in amount of soil loss and percentage are calculated based on BAU value (i.e. subtracting the amount of soil loss in 2003 for BAU case with the losses of 2027 under all scenarios and calculating the percentage change taking 2003's BAU value as common denominator) to make them comparable with respect to BAU case.

The time paths of total soil loss from AgL and NAgL are shown in Fig7 a-b, where the impacts on total soil loss by different scenarios are clearly visible as discussed above.



Soil loss from AgL (a)



Soil loss from NAgL (b)

Fig 7: Time paths of total soil loss from AgL and NAgL over years (Mg)

3.4 Some policy implications

The contending stories of pervasiveness of degradation problems in this region are of paramount. Due mainly to socially non-optimal use of forests and non-forest lands, Nepal is undergoing serious environmental problems. These problems have been exasperated by several socio-economic factors such as high population and livestock growth, lack of proper land use knowledge and technology, inappropriate government policies and increasing agricultural land scarcity, mainly in the hill and mountain regions. However on the contrary, there appear to be regeneration of forest land and improved watershed conditions in some part of the hilly region as pointed out by a few of the past and this studies. The available studies under resource economics and natural resource management literature for the HKH regions have also not adequately dealt with land-use changes and forest soil degradation or regeneration issues in order to provide with theoretical and empirical tools for the better management of land resources in the rural economy of Nepal. These studies basically failed to understand the interrelationships among bio-physical, socio-economic and institutional factors simultaneously. In light of these contrasting facts, the results of this modelling effort have pointed out various scenarios of the watershed conditions in a dynamic framework yielding several policy guidelines for land use management, biomass use and soil conservation.

Under OFEMP1 and OFEMP2 scenarios, watershed household is likely to continue to rely heavily on AgL and NAgL in meeting their needs for agriculture staples, biomass products thereby contributing to higher amount of land clearing, less remaining biomass density and more soil loss. These scenarios generally depict the degradation situation in the watershed as described in the conventional Himalayan degradation literatures. The impacts of the changes in labour immigration rates are very sensitive so prudent policies suitable for off farm employment opportunities are sought. The policy implications from the results of these scenarios can be listed as follows. i.) Maintaining current levels of off farm employment is therefore very effective policy tool to reduce the pressure on land based resources. ii.) Increasing agricultural productivity and rural development efforts so that the trend of expanding agricultural land by encroaching on forest lands would be reduced; though these policies have not directly been tested in the model empirical facts suggest that rural productivity growth through these measures would reduce the pressure on forest lands. iii.) To prevent more land clearing and biomass extraction from LU4 forest, special attention must be given on it through some sort of institutional interventions as evidenced by a positive impact on forest regeneration in some part of the country by newly emerging community forestry programs. iv.) Regarding more pressure on fodder biomass pool, some alternatives of fodder demand or pressure need to be searched. v.) Relatively more availability of timber product in the forest which is more than the current harvest level, the forest user groups in the watershed can design alternative programs to harvest more timber for sales and this would substitute for land clearing activities. Policy implications number 'iii-v' are also relevant for other scenarios of the model.

While increases in agricultural crops' prices do not show a significant increase in agricultural land except shifting land clearing from LU7 to LU4 thereby less amount of soil loss and change in biomass density when compared with BAU case; decreasing population growth (POPG scenario) shows significant improvement in land conditions both in terms of no clearing, increased biomass per unit area and less soil loss. Reducing population growth by raising awareness and giving access to family planning devices to the people of watershed would help halt the degradation processes.

In the discussion of policies relevant for land-use changes and forest/soil degradation issues, it is noteworthy to recognize their space and time dimensions for improved understanding of relevant complex bio-physical and socio-economic problems. The spatial dimension can be viewed in terms of local, watershed or regional and national level policies which complement each other in meeting the objectives stipulated at the various levels. In this regard the results of this modelling exercise would form a basis for holistic policy formulation at the watershed level and some of the national level forestry polices can be suitably modified to form an integrated operational framework for land-use and forest/soil degradation issues. In relation to time dimension of policy making, one can think of two broad time horizons, namely, short term and long term. A short-term relevance of the behaviour of the watershed in terms of production and consumption of the agric-forest-livestock systems, for instance, can be meeting the survival needs of watershed household for products in absence of other alternative. While substituting the products by other alternatives, e.g, fuelwood for improved cooking devices or bio-gas, local breed of livestock for improved ones; and implementing improved technology adapted to local conditions can form long term strategies. Also, providing incentives in the form of cash, materials or knowledge for improved land uses and for no clearing of NAgLs are some of the other short-term but continuous processes. Nevertheless, in successful implementation of either long-term or short-term policies to fulfil the desired goals relating to these problems, the watershed household should define its goals and priorities and time frame of action depending on material and behavioural conditions with improved quantitative understandings of different policy options at hand. The importance of dynamic modelling and their findings are thus relevant in such cases.

4. Conclusions

This study analysed land-use changes, forest and soil degradation or regeneration under dynamic systems perspective at the watershed level in Nepal. The modelling tool used is a dynamic bio-economic model under mathematical programming framework run over a period of 25 years which revealed various interesting results in this regard at mid-hill watershed of Nepal. Available labor was optimally allocated for optimal agric-livestock-forestry productions and consumptions by simultaneous global maximization the net cash flows from these productions subject to land, labor and capital constraints for the whole planning period. Taking mean distances of each broad land-use categories from nearby village into account the model can be considered broadly a spatially explicit dynamic bio-economic model.

Different model scenarios yielded different contrasting results in terms of land-use changes, and forest/soil degradation or regeneration issues pertinent to the watershed. Reducing the rates of off farm employments opportunities in the watershed have negative impacts on forest land and biomass density whereas increasing rates of agricultural crops' prices have no significant impacts on land clearing but shift in land clearing from LU7 to LU4. Reducing population growth has significant positive impacts on forest land with less total soil loss. Relatively more land clearing and forest/soil degradation in terms of land use is found in LU4 land, i.e. nearby mixed hardwood forest for it is being in the proximity of the villages and more pressure is on fodder biomass pool due to its higher demand and lesser supply. Overall, the results are capable of explaining both the degradation issues under some scenarios and regeneration and less environmental stress issues under some other scenarios.

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