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Assessing rural resources and livelihood development strategies combining socioeconomic and spatial methodologies

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This study employed a combination of socioeconomic and spatial methodology to assess the rural resources and livelihood development strategies in the hills of Nepal. Socioeconomic data were collected through family survey from spatially randomly selected farm households and linked to GIS using family's respective geographical position and spatial distributions were observed by interpolation. Biophysical conditions were assessed using remote sensing (RS) and geographic information system (GIS) technology. Both conditions were linked with each other and the relation between socioeconomic development and resource degradation was observed. Deforestations around high-income areas and near road and market center were less compared to low income areas and far from the road and market center. Spatial distribution of living standard parameters, including family income, food availability, dependencies on resources owners, shows a decreasing trend as the elevation increases. It was found living standard of the people was relatively better those occupied good quality agricultural land and situated near the road and market center as compared to those who occupied low quality agricultural land and situated far from the road and market centers. A multivariate regression model was run to assess association between socioeconomic and biophysical conditions by taking farm income as dependent variable and cost distance to the market and land quality as independent variable. Multivariate linear regression showed that cost distance to market and land quality indexes can explain the income potential of a farm in a given location. Future strategies of reducing cost distance to the market through road improvement and increasing the quality of land through soil and water management activities were found sustainable livelihood and resource use approaches.

Keywords: Combining socioeconomic and spatial methodology; Spatial differentiation; Nepal

INTRODUCTION

In many mountainous regions of Asia, poverty, deforestation and land degradation processes are major development challenges as poor socioeconomic condition and natural resource degradation follow a certain spatial gradient leading to further resources degradation and socioeconomic differentiation (Doppler et al., 2006; Bahadur KC, 2005a,b). Farming systems in these areas are characterized by the inter-relationship of complex natural systems and human society (Doppler 1998; 2006). Many researchers argue that forest clearing for agriculture should be analyzed by means of a cost–benefit perspective to see trade-offs between forest and agricultural land in a "sustainable development" perspective (Ehui and Hertel, 1989; Kaimowitz and Angelsen, 1998; Angelsen, 1999; Barbier, 2001; Wunder, 2001; Alix-Garcia et al., 2005).

Traditionally, socioeconomic and environmental issues were seen as separate especially by conservation proponents (Adhikari et al. 2004; Oates, 1999; Sanderson and Redford, 2003; Du Toit et al., 2004; Wilshusen et al., 2002). More recent approaches however see poverty and natural resources management as intrinsically connected. They were developed in the "sustainable livelihood and resource use approaches

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(Scones, 1998; Leach et al., 1997; Ellis, 2000) and in vast literature on participatory approaches (Chambers, 1989; Pretty, 1995; Hutton et al., 2005).

Recent trends in environmental and socioeconomic modeling have moved towards the use of integrated assessment methodologies to balance multi-issue problems with multiple stakeholders (Rotmans and Van Asselt, 1996; Jakeman and Letcher, 2003). Park and Seaton (1996) attributed the rise of integrative research in natural resource management as realization the discipline-specific approaches are often not appropriate for policy analysis. McKinney et al. (1999) noted the interdisciplinary nature of problems requires new methods to integrate technical, economic, environmental and social aspects into a coherent framework.

The integrated methodology has to incorporate different kinds of socioeconomic and spatial data and methods. However, the main problem of combining socioeconomic and spatial methods are to link and combine the data and analysis because of the availability of information at different aggregation levels (Lentes, 2003). In recent years researches have attempted to link social science data at household and community level to remotely sensed and other spatial data to study the effects of human activities on land (Rindfuss et al. 2003; Fox et al., 2003; Walsh et al., 2003).

This paper presents a methodological approach of combining socioeconomic data with the remote sensing and GIS derived biophysical and infrastructure data to assess the future resources and livelihood development strategies in rural mountainous watershed in Nepal. This study analyzed how resource availability, utility potential, use and management under the different physical and environmental condition leads to differentiation in resource use, management and living standards of farm families. It analyses the influence of land and water resources availability, use and management on decision-making and income of families within these mountain areas.

METHODS

Study Area

Study area constitutes a small mountainous watershed in midhills of Nepal (Figure 1). The greater part of the watershed is a mountainous under hill forest and upland cultivation. The area has a sub-tropical climate with a mean annual rainfall of 1404mm. The elevations of the highest and lowest point are 1960m and 217m above mean sea level respectively. The watershed can be divided into fertile, relatively flat valleys along the rivers (lowland) and surrounding uplands (middle land) with medium to steep slopes (highland). Agricultural land in the valleys is under intensive management with multiple cropping systems and is mostly irrigated. Paddy, potato, wheat and vegetables are major crops cultivated in the valley. Rain-fed agriculture, with or without outward facing terraces, is practiced on rest of the agricultural land, many of which is not suitable for crop production without strong soil and water conservation measures because of their high erodibility and low productivity (ICIMOD, 1994).

The development in the watershed is not uniform. The lowland valley stretching from Galaudu and Pokhare Khola near the highway and local market center is one of the most fertile and economically important areas of the watershed. The local economy and employment opportunities of these semi-urban areas differ from rural areas. Semi-urban centers are directly connected to Kathmandu valley by highway, have alternative sources of energy and income in addition to agriculture. Rural people in the surrounding areas are primarily dependent on arable agriculture and livestock for their livelihood. This high variability in the ecological and economic conditions makes the watershed an appropriate site to study the effect of different factors to the socioeconomic development and sustainable management of natural resources.

Based on hypothesis “socioeconomic conditions and resource degradation follows certain spatial gradients”, the watershed are divided into three strata: Highland: remote area with little infrastructure, poor access to markets, low education and monetary orientation, low production potential of land and subsistence orientation. Middle land: better infrastructures than in highland zone but with fewer infrastructures than lowland, good access to road market, high level of education, production potential and monetary orientation than highland but less than lowland. Low land: relatively flat land, better access to road and markets, higher education and monetary orientation and high production potential thus characterized as market orientated economy as compared to other zones. These gradients are considered as the factors determining the different potential of development in the space and in different family groups.

Database development and analysis

Spatial data

Spatial data were gathered from satellite images, Global Positioning System (GPS) survey, analogue maps and digital GIS data. The spatial database consisted of land use maps derived from remote sensing data (Landsat MSS acquired on 10th October 1976, Landsat TM of path/row 141/41, acquired on 4th Feb, 1990 and 13 March, 2000), air photos of scale 1:50,000, 1992 and topographical maps of 1:25,000, 1995. Land use maps of 1976, 1990 and 2000 were obtained by performing supervised digital image processing (Bahadur, 2008) for satellite images of the respective years of the study area. This set of land use maps was used to examine land use change.

Socioeconomic data

Socioeconomic data were obtained from family survey of spatial random sampling of 90 families using structured questionnaires. During the family survey, the geographical position of each sample household was recorded using GPS. The sample is split in three groups of equal size dividing the watershed into three zones: lowland, middle land and highland. Descriptive statistics were used to describe socio-economic characteristics of households. All reported incomes are sums of annual cash and subsistence activities. Farm income is calculated as the difference between farm revenue and farm expenses. It is derived from a calculation where it is the residual after deducting all expenses excluding the costs and income of family owned resources (Doppler, 1998). Cost of own labor is not included in the income calculations. Off-farm income is defined as income earned by family members by engaging in

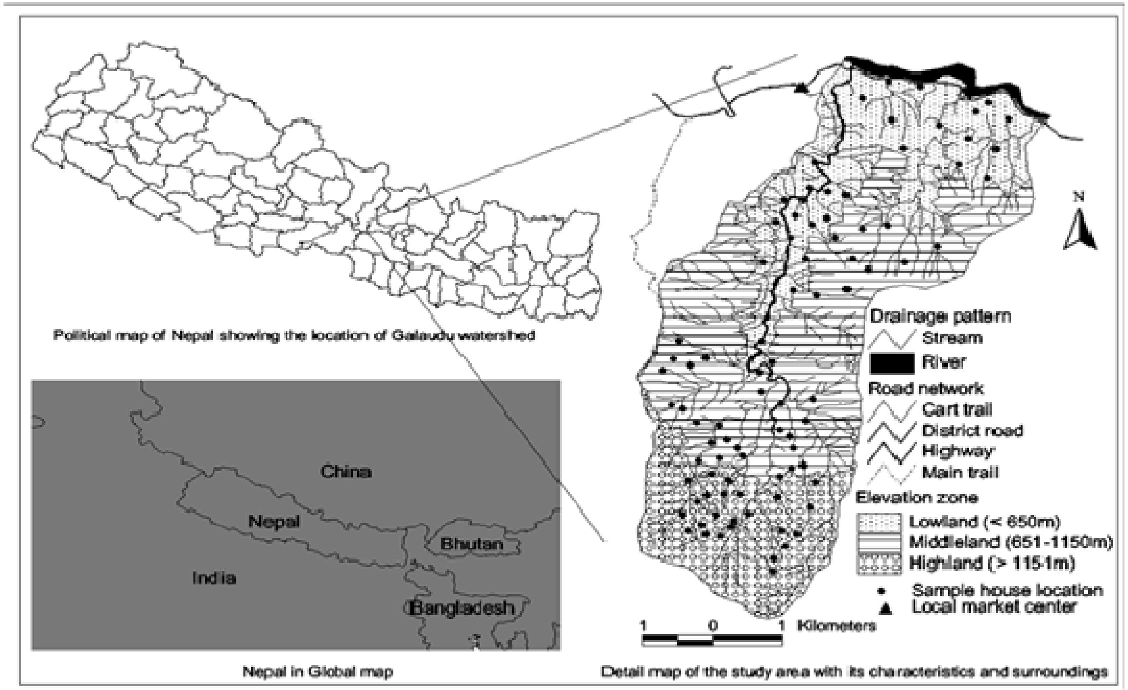

Figure 1. Location of the study area

activities other than the farm and/or the household which includes earnings from permanent employment and from self-generated income activities. Crop income is the economic value of subsistence and cash crop production over a year grown by a household less costs of production. Income from fruit production is included in crop income. Remittances are all income transfers in cash and in kind between households. Family income is calculated as the sum of farm income, off-farm income and income on family owned resources.

Socioeconomic and spatial data integration

Family level socioeconomic and the spatial data are integrated to each other to transfer the use of dataset (Bahadur KC, 2005b).Relation between socioeconomic and biophysical condition can be established and based on the relation, socioeconomic parameter such as farm and family income can be estimated from the biophysical conditions of the area. Geographical position of each sample household was used to link the socioeconomic and spatial data. After linking the GPS receiver to a computer, the recorded data was exported into Arc View GIS. By this process a map was obtained in which the location of all the sample households in the watershed can be seen. Subsequently, a common key field (household number) was introduced to both the point attribute table in GIS and the survey databank. With this key field, relational databases were made. In this database, the complete set of records from the sampled families was linked with their respective location. Before the constructions of thematic socioeconomic layers, spatial autocorrelation of socioeconomic variables were tested using the Moran's I and Gerry's C test and found them highly spatially auto correlated. Since the survey data was available at point level for the sampled household only, the regionalization and spatial representation required the creation of surfaces from the sample points. This was performed using Inverse weighted distance interpolation. Based on the randomly selected family's location in the area, the spatial distribution of farm and family income were prepared.

Hypothesis

First hypothesis is "socio-economic conditions differs with different ecological regions and plays a pivotal role in land use decision-making". In the mountainous area, poor socioeconomic condition and natural resources degradation follow a certain spatial gradient leading to further resources degradation and socioeconomic differentiation. Resource availability and quality differs in different spatial gradients and these differences have strong influences on socio-economic development. "Higher altitude and increasing distance from the market center leads to less local participation in forestry management, higher level of resource degradation and the lower level of living standard". The second hypothesis is "socio-economic parameters such as farm family income of a given location can be explained by the biophysical characteristics of the area". The spatial position is of importance with respect to distances between fields, family houses, markets, schools, credit and savings facilities and other services, or locations with off-farm job opportunities.

Linking land use dynamics to economic, ecological and physical factors and institutional policies

The approach adopted here to analyze the spatial relationships between overtime changes in land uses to some major ecological and economic factors, and institutional policies that are expected to have influence on changes in the watershed land use is to begin by examining the degree to which patterns of agricultural conversion can be attributed to a set of factors that have been identified as significant at broader scales in Nepal and elsewhere, namely topography, prior land use patterns, socioeconomic condition and institution governing access to land (Gautam et al., 2004; Bahadur KC 2005a, ; Bahadur KC and Doppler, 2004).The land use polygon themes for 1976 and 2000 generated from the land use assessment were overlaid in Arc View GIS Version 3.2 (ESRI, 1997) and location and extent of land use change were mapped and area of changes computed. The polygon theme of changes generated by overlaying the two land use themes (1976 and 2000) was then overlaid with the following GIS layers one at a time to see the spatial relationships between land use change and the respective factors including: i) 2500 m interval road buffers, ii) local economy, iii) forest governance arrangements, and iv) socioeconomic condition.

Spatial income modeling and testing future development strategies

Modeling

After the integration of socioeconomic and spatial data and creation of socioeconomic thematic layer, continuous thematic layer for both socioeconomic and spatial data are available. GIS based multiple regression model (equation 1) was established to estimate the spatial distribution of farm income. Based on the assumption of identical land quality in different places is expected to provide the same production and income generating potential for farms. Land quality indexes of the agricultural land uses were estimated across the watershed based on the slope, whether irrigated or not which are not only relevant for direct comparison of available land resources but also serves to relate the socioeconomic conditions, assessed by the micro survey to the physical conditions of the farm land by means of functional relations. Cost distances from the different parts of the watershed to nearest market center was measured using GIS based cost weighted distance model (ESRI, 1997). The distance grid cells to travel from different location of the watershed to nearest market center were prepared. At last, the entire grid cells were combined thus both socioeconomic and biophysical condition of each and every grid cell was available together. By exporting the grid cell information to a spread sheet and then to the SPSS software package, correlations between variables were observed. Cost distance to nearest local market center and land quality parameters were found significantly highly correlated with farm incomes. Finally, multiple regression analysis was carried out by taking farm income as dependent variable and cost distance to nearest market center and land quality parameters as independent variables. Estimated income and impact maps for different scenarios were constructed by bringing back the regression result into the GIS:

$$y = 76021.82 - 547.4\,x1 + 3189.97x2 \qquad (1)$$

y = farm income/ha (NRS)
x1 = land quality index
x2 = cost distance (travelling time from and to market center in minutes)
n= 24047 grid cells
R^2=0.729
F test = 13508.786
sig. F=0.000
T-Stat for constant = 186.642
p-value = 0.000
T-Stat for coefficient of land quality index = 14.866
p-value = 0.000
T-Stat for coefficient of cost distance = -145.196
p-value = 0.000

The features of this GIS based multiple linear regression model indicated a good explanatory value of the relationship with a measure of determination (R^2) of 0.729 and sufficiently high levels of significance for the whole function (F-test) as well as its components (t-tests), which exceeded a probability level of 99% in all cases. The model aims at regionalizing the current income situation and uses statistical dependencies for the simulation of the effects of future strategies. In general, the transfer of the estimation to all the sample location showed reliable results. In highland areas, income declines with the distance from road and market center, higher elevation with upland areas. These low-income zones are reflecting the combined effect of remoteness and the less favorable land conditions. The high-income areas are located relatively near to the main road, local market center, at lower elevation areas of valley bottom where as low incomes areas are located more on the hilltops at higher elevation, mainly steep slopes, far from the road and market center. This difference again reflects the resource (especially land) quality of the areas and their connection to market center through road networks.

Application of model for future strategy testing

The GIS based multiple regression model used for income estimations was used to estimate potential future income generation in different scenarios of farm management. For this purpose, the land quality index of the grid cells and cost distance from the each of the grid cell to the nearest market center were modified from the current situation. The farm management model is based on the changes of the land quality index according to the requirements of the defined scenarios. The value of the land quality index depends on the terrain slope, state of agricultural land whether irrigated or not, of the grid cells (Bahadur, 2005b). Slope cannot be modified, what can be modified is the weight associated with the state of land whether irrigated or not, soil and nutrient losses according to the slope (Bahadur, 2005a) and practiced or assumed management of the land (Lentes, 2003). Since the index represents the differences in the quality of the land, different land qualities can be simulated with the model by changing the weighting factors of the individual classes as required for the setting up of scenarios. Modifications of the weights of individual grid cell of different themes allow the simulation of future land quality index of the respective grid cell. The final land quality index for each grid cell is calculated by multiplication of weight given to each of individual grid theme. Higher land quality index signifies better land quality. In the multiple linear regression models, this was used alone and together with the cost distance to explain the farm income. In future farm management model construction, consideration was given for example what would happen if the given weights are modified to match the desired scenario. If the final weight of a grid cell increases for example from 1 to 1.1, the higher future land quality index for the given cell can be expected. Likewise, if the final weight of a grid cell decreases for example from 1 to 0.9 than smaller value of future land quality index for the given cell can be expected. Cost distance values after the improved road scenarios were used for simulating the effects of improved infrastructure on the income/ha of the sample household. For this purpose, the functional relationship found in the current situation was applied with the new cost distance values. The new income/ha for each and every grid cell was estimated and compared with the current situation and differences were taken as the impact of improved road.

RESULTS

Farm family income and spatial distribution

The results of farm, off farm and family income are

Table 1. Farm and family income by sub study zone, 2003

Income (NRS)	Lowland	Middle land	Highland	Overall
Farm*	35396	29498	8228	24375
	(27523)	(27940)	(4874)	(25428)
Per hectare of cultivated land*	56327	26027	15117	32490
	(47205)	(15799)	(12067)	(34091)
Per person*	5840	3883	1442	3723
	(4498)	(2391)	(1028)	(3475)
Off farm**	8283	5614	4781	6226
Family*	43679	35113	13011	30601
	(34607)	(27750)	(6748)	(28719)
Per person*	6835	4730	2219	4595
Per labor unit*	16844	12211	6061	11705

NRS=Nepali Rupees (1US$= 80 NRS) Figure in parenthesis are standard deviation
* and ** =Significant at 99% and 90% respectively

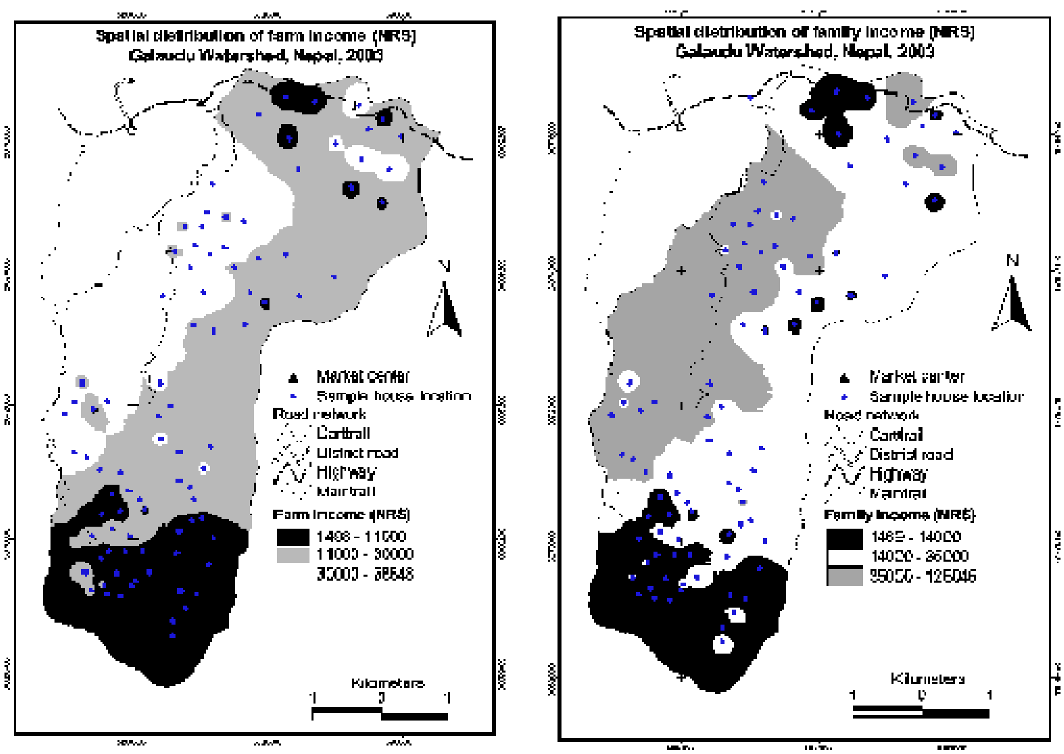

Figure 2. Spatial distribution of farm and family income

presented in Table 1. In crop year 2002/03, farm income was 35,396; 29,498 and 8,229NRS in lowland, middle and highland areas respectively. Average off-farm income was 8,283, 5,614 and 4,781NRS in lowland, middle land and highland respectively. The average annual family income was 43679, 35113 and 13011NRS in lowland, middle land and highland respectively. According to Kruskal Wallis test, there were statistically significant differences between sub-study zones in farm, off farm and family incomes (probability of 99%). A pair wise test of significant differences between two sub-study zones in family income (Mann-Whitney Test) showed that lowland and highland and middle land and highland were highly significantly different but lowland and middle land did not differ so much in the level of family income.

The spatial distribution of farm and family incomes are presented in Figure 2. Income differentiation in the space shows a higher farm and family income in the most favorable zones and near to road and market center. The spatial differences in farm income between these sub-

Table 2. Change in land uses by sub-study zone in between 1990-2000

Land cover	Lowland			Middle land			Highland		
	1990	2000	Change	1990	2000	Change	1990	2000	Change
Forest (ha)	395.8	371.8	-24	688.9	566.9	-122.0	391.2	251.0	-140.2
Upland agriculture (ha)	76.8	95.8	+19	239.4	353.6	+114.2	98.5	221.8	+123.3
Lowland agriculture (ha)	360.6	365.4	+4.8	365.9	373.8	+7.9	83.3	100.2	+16.9

zones are mainly due to the proportionally smaller size of irrigated land per family in highland areas and their productivity as compared to lowland. Besides, vegetable farming, which is intensively practiced in lowland areas, could be another reason for having high farm incomes at lowland areas. This was also confirmed from the higher farm income per ha of cultivated land and per person from the lowland areas as compared to highland zone (Table 1). Farm income was more or less similar in lowland and middle land. Families in these areas were able to earn similar levels of farm income because of well-terraced land, more intensive use of external inputs and crop diversification allows crop rotation and reduces risk of crop failure. Farm income accounts for greater share of the family income in all three sub study zones. Family income per person and per labor unit were significantly higher at low land as compared to highland which could be due to the accumulated effect of land quality, education level of farmers, distance from market and road.

Agriculture, forest land use land cover dynamics and their relation to physical, economical factors and institutional policies

To characterize the volume and quality of land resources available and even more the decision-making of people who use the land, the development of land uses over time as well as differences according to the location in the area and the conditions of the locations in the space is to be understood. During ten year periods from 1990 to 2000 forestland declined by 10.6% while upland agriculture increased by 9.6% and lowland agriculture by 1% (Figure 3). The annual rate of forest loss in the study area was about 1.1%. Land uses change may be attributed to the spatial location of land.

The change of land use along altitudinal gradients in determining the type of forest vegetation occurs at different physiographic regions across Nepal has been widely documented (e.g. Jackson, 1994; BPP, 1995). Little is known, however, about the association of altitudinal gradients with changes over time in forest cover. The conversion of forestland to agricultural activities was not similar throughout the watershed (Figure 3). In the highlands zone more forestland was converted to agricultural land as compared to lower elevation (low land) area. Overlaying a polygon theme of sub study zones with polygon theme of land use changes during 1990-00 showed that higher elevation forests were more dynamic compared to lower elevations. The rate of forestland conversion to agricultural activities was at least two-times higher compared to locations at lower elevation (lowland) areas (Table 2). Around 36% of the forest area in 1990 within the higher elevation zone (highland) was converted into agricultural land where as about 18% forest area from middle altitude and only 6% forest area from lower elevation (lowland) was converted in to the agricultural land in the same period.

The effect of accessibility on the changes in forest area reflected increasing conversion of forest area into agricultural activities with the increase distance from roads. 70% forest area in 1976 within 2500m distance from roads remained unchanged until 2000, whereas only 44% forest areas located 5000m far from roads were unchanged during the same period (Table 3). Proportionately lower amount of forest loss in areas of better accessibility, however, is generally an unexpected trend. Higher concentration of forest management activities in locations closer to the roads might be a reason. Likewise effective monitoring of the community forests by local user groups could be another reason for improved forest condition in relatively accessible areas (Gautam et al., 2004).

Forestry requirements and forest management objectives of semi-urban residents' area are different from those of rural people in most part of the watershed. Urban areas can thus be characterized as having a market-oriented economy, where forest management objectives are mainly for watershed protection (Doppler, 1998). An overlay of polygon theme prepared by creating a 2500-m buffer from the local market center with the land use polygon theme of changes in forest area during 1976-00 revealed that more forest area was converted from forestland to agricultural activities in the rural area than in suburban areas (Table 4). Less deterioration and loss of forest areas were observed at suburban areas whereas high deterioration and loss of forestland were observed at rural areas with subsistence economy.

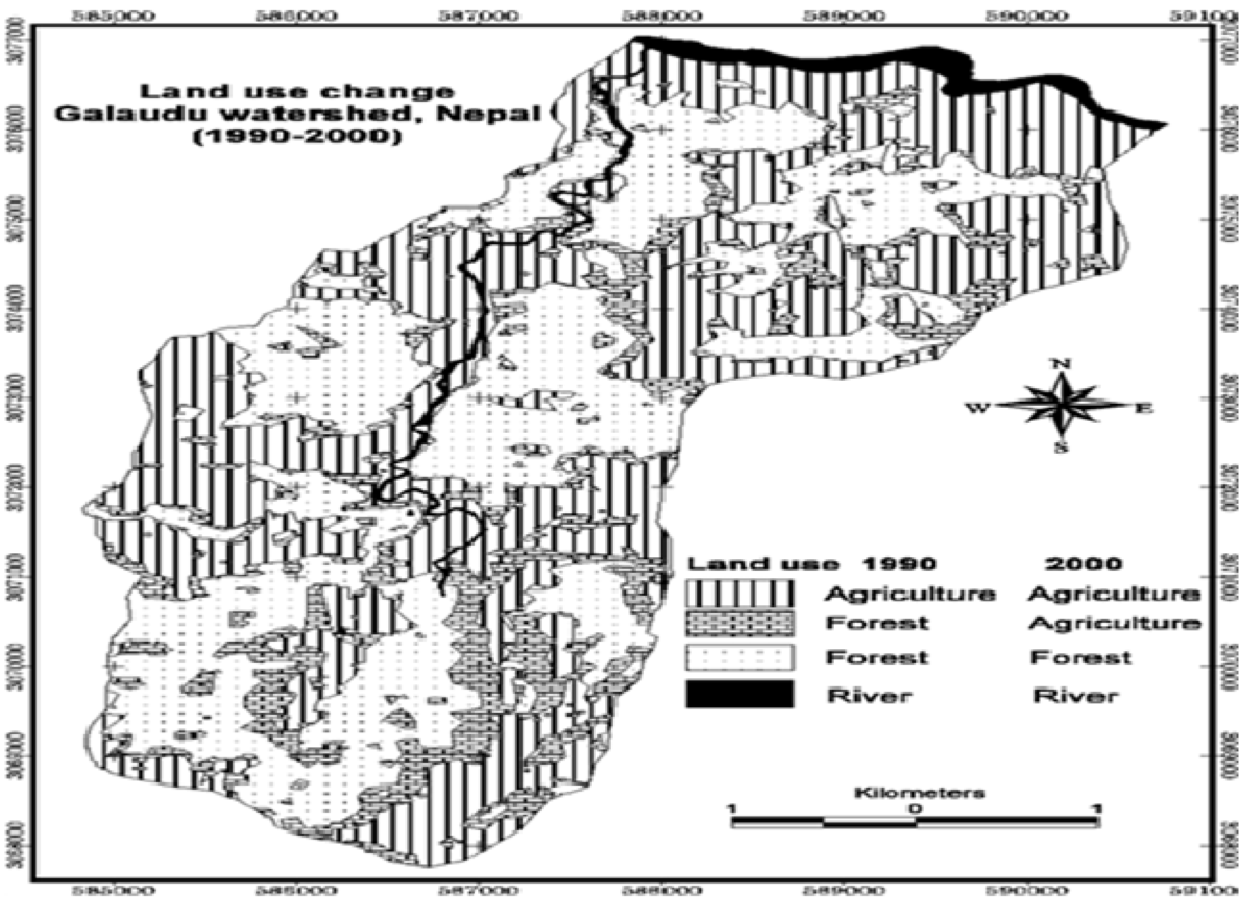

Figure 3. land use change in the period of 1990 to 2000

According to Gautam et al. (2002) VDCs with formalized community forests had significantly higher shrub lands-to-forest conversion during 1978-92 compared to the VDCs without formal community forests. The fact that proportionately less amount of forest lost and degraded those were managed with the involvement of local forest user groups supports the argument that legal transfer of resource ownership is an important precondition for successful collective outcomes at the local level. One of the distinct differences between community forests and government forests in this watershed is the involvement of local communities in forest conservation in the former case. From this point of view, the findings of this study indicate the joint investment by local forest users and local agencies may improve the prospects for successful forest conservation at local level (Gautam et al., 2004). Conversations with local forestry staff and local people revealed that the forested areas under the government control are virtually in “open access” condition as the district forestry staffs are mostly engaged in community forestry activities after the implementation of community forestry program. So the relatively high loss of forest area under state control can be explained by their condition of open access.

Future strategies testing

Improved land management scenario

Results of the improved land management on income are presented in Figure 4. The income generating potential is increased through improvement of land management. After the implementation of assumed land management scenarios, simulated income will not be distributed evenly throughout the study area. Simulated income will still be the highest in the current highest income areas and in the area where the impact of changed management is estimated to be highest. As in the current situation, the high-income areas remain same as they were before. Nevertheless, the situations in the low-income zones, especially in highland zone were changed. While the current income in much of the highland zone is below 20,000NRS, the improved situation predicts the income per hectare to reach and exceed 25,000NRS (Figure 4).

Table 3. Change in land use by accessibility in between 1976-2000

Road buffer (m.)	Forest (ha)		Lowland agriculture (ha)		Upland agriculture (ha)	
	1976-00	1990-00	1976-00	1990-00	1976-00	1990-00
< 2500	-194.0	-38.1	+193.2	-3.5	-5.6	+41.0
2500-5000	-124.0	-30.3	+95.5	+9.6	+26.6	+19.8
5000-7500	-253.0	-146.0	+124.0	+11.6	+129.3	+134.6
> 7500	-64.4	-73.3	-15.2	+11.6	+79.4	+61.6

Table 4. Change in land use by local economy in between 1976-2000

Local economy	Forest (ha)		Lowland agriculture (ha)		Upland agriculture (ha)	
	1976-00	1990-00	1976-00	1990-00	1976-00	1990-00
1	-89.6	-98.5	-15.6	11.6	105.9	87.0
2	-246.0	-126.0	137.7	15.2	106.8	110.6
3	-225.0	-63.0	185.5	13.7	35.9	48.0
4	-73.7	-0.3	89.8	-11.1	-18.9	11.4

Note:1 = Market oriented 2 = moderately market oriented 3 = Less market oriented 4 = Rural area

The percentage increase of income with soil conservation measures compared to current situation can be seen in Figure 4. The low-income areas in highland zone benefit most from the changed management.

Improved road network scenario

Results of the improved road network on spatial distributions of the income in the watershed are presented in Figure 5. Improved cost distances were used for simulating the effects of improved infrastructure on the income/ha. On spatial level, improved situation show the great differences over the current situation. Significant impact on income of farmers was observed before and after the improvement and development of road networks in the remote areas. The impact of improved road was the highest in the remote areas where there were currently no infrastructural networks. Still, the level of income is low in this area, when it is compared to the high-income areas. In the zone with the current lowest income (20,000NRS/ha) the scenario predicts the highest increase. For the currently high-income areas, the increase of income is predicted to be less than 16%. Better response is found in the rest of area of middle altitude and most area of the highland zone, where 20 to 96% increase of income is predicted increasing with the distance from the marketplace.

Combined strategies of land, water and road improvement

Results of the combined strategies of improved land, water and road on income are presented in Figure 6. On the spatial level, the improved situation shows great differences over the current situation. Significant impact on incomes was observed before and after the improvement and development of water resources management especially in the areas of highland zone. The impact of improved road was the highest in the remote areas. Since these areas are also identified as those with the highest potential for income boost through the introduction of improved land and water resources management activities, the combination of more than one measure yields the best response. Still, the level of income is low in this area, when it is compared to the high-income areas. In the zone with the current lowest income (20,000NRS/ha) the scenario predicts the highest increase. The model results show an increasing trend of income can be achieved by combined strategies. For the currently high-income areas, the increase of income is predicted to be less than 16%. Better response is found in the rest of area of middle altitude and most area of the highland zone, where 31 to 104% increase of income is predicted in the case of combined land and road improvement and 30 to 143% in the case of combined water and road improvement. Nevertheless, the impact of

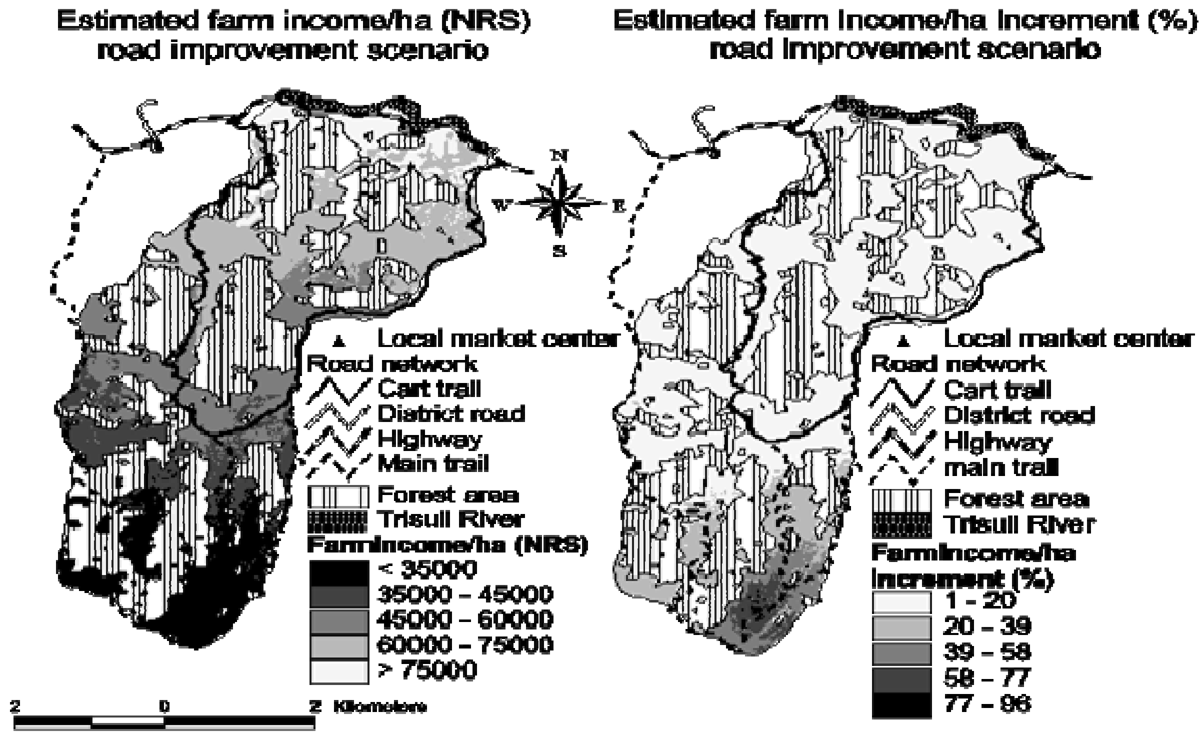

Figure 4. Assessment of the future strategies of soil conservation on farm income: Simulated farm income with soil conservation (left) and impact of soil conservation on income (right)

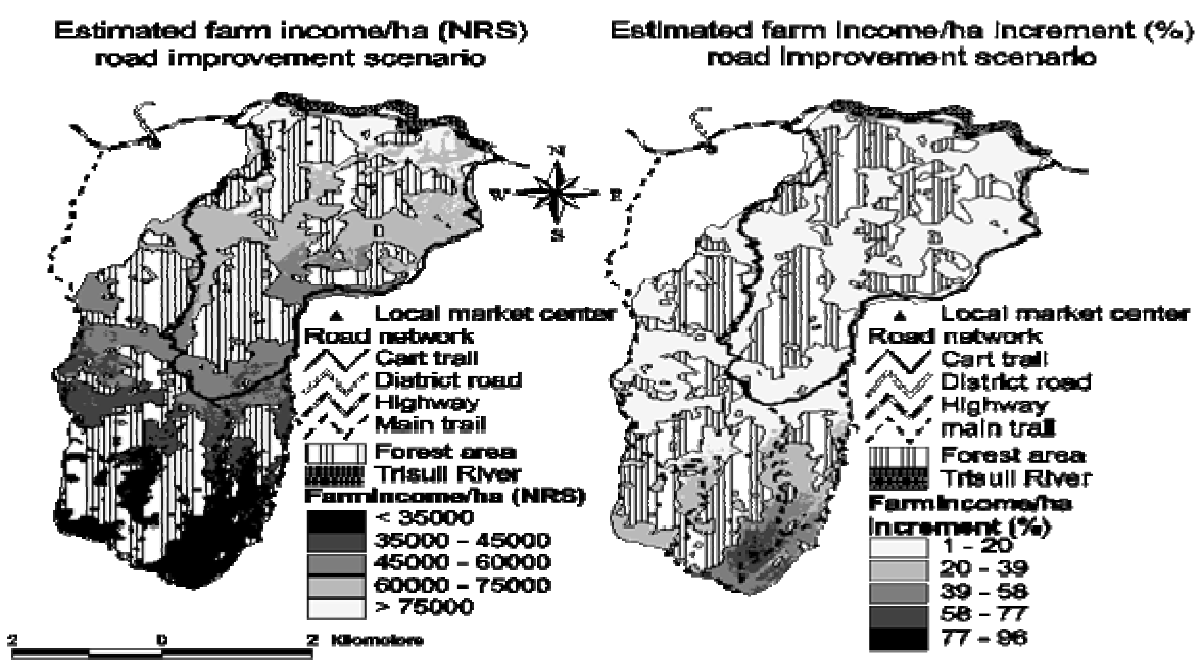

Figure 5. Assessment of the road improvement on farm income: simulated farm income with road improvement (left) impact of road improvement on income (right)

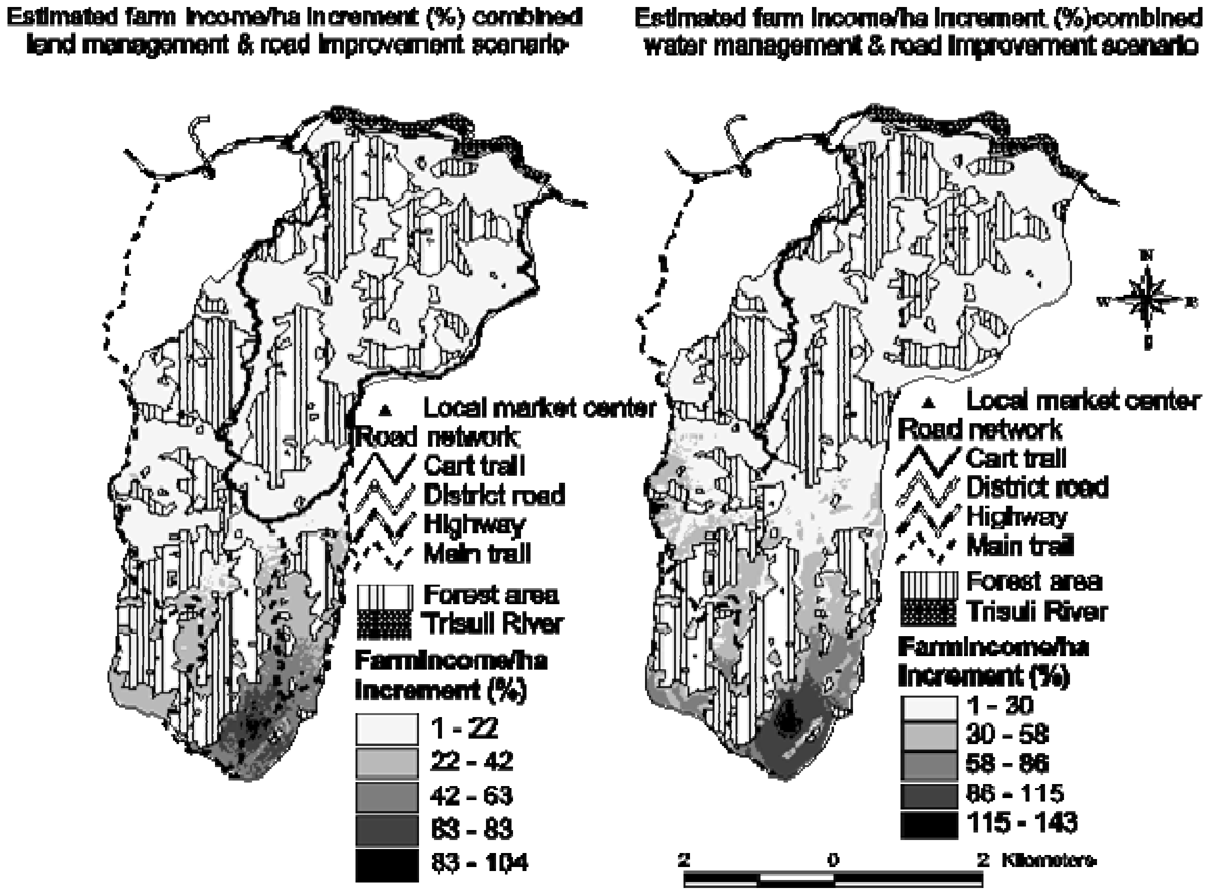

Figure 6. Assessment of the combined strategies: Impact of combined land and road improvement on income (left) Impact of combined road and water improvement on income (right)

water resources management on the sustainability of the farming system is expected to be substantial in these zones, since the cultivation of slopes induces heavy soil loss in this area too.

DISCUSSION

The focus of this research is on the development and improvement of the methodology to investigate complex problems in rural development in a systems context. This study shows that combination of socioeconomic data into GIS and observing spatial distribution of socioeconomic parameters help to understand the association between people and resources. Lentes (2003) demonstrated the use of land quality weightings and cost distances for spatial income modeling. It has been proven that the integration of family survey information and data from remote sensing can be used in a combined approach of the classical economic tools and the RS/GIS concepts. Still, further research is needed, but the stage is reached where RS/GIS is not only a tool of presenting complex data in an easy way, but do carry out quantitative and statistically based analyses. In the process of research globalization, those methodological developments contribute to quicker increase of research quality.

Socioeconomics of family resources and spatial differentiation

This study shows that qualities of agricultural land and their management, education level of settlers, off farm employment opportunities, consumption of family labor, food security, and forestry requirements of residents living in highland areas are different from those living in lowland areas of the watershed. Residents living in lowland area have alternative sources of energy for cooking and heating, most of the households have better agricultural land, better off farm opportunities being near to road and market center compared to those in highlands. This study indicated that lowland areas can be characterized as market-oriented economies and the rest is rural characterized by agriculture-based subsistence economy, where forest area is an integral component of people's daily livelihood strategies.

The study shows that there is a spatial relationship between resource use, degradation and socioeconomic status of people in the different spatial conditions of the watershed. Spatial distribution of farm income, family income, crop production and percentage of food bought show as the elevation increases, distance from road and market center increases, farm family incomes and crop production decrease. Whereas, the percentage of food bought, as an indicator of food security supply for the family increases. This shows the difference in the spatial distribution of socioeconomic attributes is due to the difference of accessibilities of road and market centers and the management of the available agricultural resources. Priority should be given to the policies relevant for creating better access to road and market centers from each corner of the watershed to improve the living standards of farmers and reduce spatial differences between the low and high land watershed zones.

Land use dynamics and other factors

The quantitative evidences of land use dynamics presented in this study, which were delivered by a time series of satellite images coupled by GIS analyses, collaborate the findings of some earlier studies (Schreier et al., 1994; Virgo & Subba, 1994; Jackson et al., 1998) that the deforestation trend in some areas of the Middle Hills of Nepal have continued even though governmental and non-governmental organizations have been carrying out different community forestation programs. One important change was the increase in agricultural area at the cost of forestland possibly due to the expansion of settlements. Even though it is only in the lower elevation area of the watershed, the positive changes in forest cover, probably due to the community forestry management programmes, provides some evidences of ecological sustainability of the resource at the lowland area of the watershed, although the reversal of the decreasing trend in scrublands during 1990-2000 period has raised some questions regarding the possible continuation of the observed trends in future. Some other important concerns related to community-based forest management in Nepal are: i) whether and how the positive changes in forest cover have benefited the local users, and ii) how sustainable are the existing community-based forestry institutions in the long run.

The investigation revealed that more pronounced changes within the forest area of the watershed in between 1976 and 2000 took place in high-elevations with steep slopes that are far from the roads. Of the two governance types existence in 2000, proportionately less forest loss took place in forest managed with the involvement of the local forest user groups. In forest area under direct government control and without any local collective action occurred relatively higher amount of forest loss.

This study also demonstrated the complexity and interrelationships involved in forest governance and management. The findings indicated the joint effort by the government and the forest user groups improves the prospects for successful forest conservation at local level. The study has been able to provide information on the influence of some major factors in bringing over time changes in land use and land cover. Such studies, supplemented with more location specific in-depth studies, would help to refine understanding of the association between land use dynamics and community-based institutions.

CONCLUSIONS

The integration of socioeconomic and biophysical attributes with infrastructure, institutional and policy changes is relevant for formulation and assessment of cause and effect patterns. Different levels of socioeconomic condition of people in different spatial gradients of the area are due to differences in access to road, markets and technological information. Socioeconomic condition, physical, ecological factors and institutional frameworks regulating natural resources policies are the main forces determining land use patterns in mountain areas.

GIS based farm income modeling can be used to simulate the future development of income situation in the different spatial gradients of the area. Future strategies of reducing cost distance through road improvement and improving the quality of land through soil and water management activities shows increasing trend of farm income and decreasing the spatial differentiation of incomes among the farmers living in the different zones of the watershed. If the tested strategies will be implemented an improvement of living conditions and reduction in resources degradation could be achieved. The combination of socioeconomics and spatial concept and methods is an appropriate methodological option for formulating and testing long-term problem solving strategies towards a better planning for improving living standard of rural farming people and sustainable management of natural resources. This concept can be relevant for strategy testing in similar regions in mountainous zones.

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