

Human and ecosystems interaction and its ecological impacts in Mountains: Lesson from land use development in nature conservation areas in the Himalayas, India

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ABSTRACT

The Himalayas in India is one of the biodiversity hotspots of the world. Therefore, there are many nature protection areas (NPA) such as National Park/Biosphere Reserves etc. have been established to support ecosystem conservation alongside development of local economy and the people. Currently NPA occupying about 10% landscape in the mountains of the Indian Himalaya. This study aim to understand how human behavior is changing under shifting political, socio-economic and environmental conditions and to determine that consequently how the landscape have been changing in the region. Understanding the impact of human activity on natural resources is of critical importance in developing the way for effective management strategies. Empirical studies undertaken based on the identified indicators to study whole scenario development. Following the empirical studies the remote sensing data/ imagery were used to study the landscape development in multi-temporal dimensions.

Agriculture is main land use activity and strongly linked to the forests and provides sustainability to local people living in the Himalayan mountains in India. Therefore, for the future sustainability it is important to have a scientific understanding about the driving forces and their role in temporal patterns of land use change in the Himalayan mountains. We understand the facts that human activities and decisions are influences by several factors responsible for the observed land use and consequently the landscape change trends. Local perceptions on these issues were varied. A theoretical agent model was developed using the existing data sets to evaluate and predict the outcome of scenario development in Himalayan mountains (Nautiyal and Kaechele, 2007a) Theoretical agent model developed here draw attention on agent/farmer behaviour and land resource use for his livelihood in temporal dimension. The current study would be helpful to intend the new approaches for the development of the methodological and theoretical aspects to study the complex human ecosystem interactions in Himalayan mountains for the sustainable landscape development.

Keywords: Human-Ecosystem Interaction, Natural Resources, Remote Sensing, Landscape, Sustainable Development, Himalayas

Methods and approaches used for the study

We have done empirical studies in the region for more than one decade including data collection from different branches of the ecosystems/landscape pertaining to land use, resource collection and forest resource utilization, production system analysis, monitoring of biodiversity and studied over all rural ecosystems functioning etc on one hand and on the other data gathered on socioeconomic survey concerning demographic and economic data such as population density and change in population, income-expenditure of the rural households from different branches of the rural ecosystems etc in the Central Himalayan region. Following the empirical study we used satellite data as historical record pertaining to land use was difficult to obtain for last 3-4 decades. In order to evaluate sustainable resource management and economic development, a novel theoretical agent model was designed based on the complex interaction between human and ecosystems.

Relevance of our paper for the conference

Background and purpose of the conference look for to explore the causes and consequences of current land use trends and dynamics related to society, economy and environment. In this endeavor we have done our study in Indian Himalayan mountains and identified the driving forces for landscape change in fragile Himalayan environment and causes and consequences of the overall land use development with emphasis on human and ecosystem interaction in the region. All the sectors such as agriculture, animal husbandry, medicinal and aromatic plants cultivation, natural resources utilization pattern and interaction of forests and domestic sector within the rural ecosystems were studied in detail and evaluated in economic and ecological currencies. Therefore, we have an impression that our work relates to the conference.

1. Introduction

All over the world there is growing consensus about sustainable landscape development of the resulting human ecosystem interactions when dealing with conservation and utilization of the resources in environmental planning simultaneously and more particularly in those areas where there are many conflicting interests are existing (Gomez-Sal et al., 2003; Nautiyal and Kaechele 2007b). The Himalayan mountain in India in these viewpoints are one of the highly influenced areas in the world due to the human activities (Nautiyal and Kaechele 2007c). Natural landscapes are an important ecological, economic, and social/cultural resource that give the basis for the sustainability of any region and which contribute significantly to the quality of life of the local people (Environment Waikato, 2003; Brabyn 2005). Effects of human activities on ecosystems are a big concern all over the world and it is particularly important to understand that how human decisions regarding land use influences the rural landscape where people dependency for variety of purposes is comparatively high. For the continued existence of

the human being in any area the study of various aspects of the interactions between human and local ecosystems/landscapes is the key to understand the development process and simultaneously that can provide the basis for designing and developing the strategies for future sustainable landscape development (Mander and Jongman, 1998; Roberts et al., 2002). In the mountains sustainable landscape development requires additional attention as it also affects sustainable landscape development in the plains. Concerted research efforts in mountain ecosystems may contribute to combat the degradation of ecosystem services, which partly contributes to devastating floods in the plains (Saxena et al., 2005).

Considerable efforts have been made to analyze the changes in broad land use and land cover types in the Himalayan mountains (Virgo and Subba, 1994; Thapa and Weber, 1995; Schweik et al., 1997; Jackson et al., 1998; Rao and Pant, 2001; Gautam et al., 2002). Yet, knowledge on changes in the spatial patterns of agricultural land use, the driving factors behind these changes, and their implications within the context of sustainable development is limited (Hurni, 2000; Sankhayan et al., 2003; Semwal et al., 2004). Therefore, an in-depth study examining the complexity of rural ecosystems for sustainable land use development will be very helpful in designing and developing appropriate strategies for sustainable Himalayan landscape development. The effectiveness of sustainable land use development requires a detailed understanding of the patterns and processes that exist within both the natural system itself and the human institutions associated with the use of the resource (Deadman, 1999). Therefore, to understand the complexity of the system and its behaviour under different socio-economic conditions, a detailed knowledge of the system is necessary. The main objective of our study was to analyse the land use change and consequently the ecosystem responses in the Indian Himalayan mountainous region.

2. Study area

The study area falls in the Central Himalayan region where more than 25% area is protected for achieving the conservation goals and that certainly exceeds the average protected areas for the whole Indian Himalayan region (10%). The region has great ecological importance in terms of the diversity of the natural resources. This is accredited by establishing the world famous national park, “Valley of Flowers,” and a Himalayan Biosphere Reserve, “Nanda Devi,” (now both the regions are known as World Heritage Site – the ‘Nanda Devi Biosphere Reserve’) in this region for the conservation and management of biodiversity and ecosystem services. The Central Himalaya is divided into three agro-ecological zones: Lower elevation (<1000masl), middle elevation (between 1000 and 1800 masl), and higher elevation (>1800 masl to human settlements 3600masl). We have taken the study region of higher region of the Central Himalaya which falls in nature protection area and located between 30⁰17’N-30⁰ 41’N latitude and 79⁰40’E-80⁰5’E longitude (Figure 1) and simultaneously represents the whole higher elevation zone of the area. There are 47 villages located in the study region and with this article data for ten villages are presented. Total population of the villages was 2253

including 782 male adults, 781 female adults, and 750 children below 15 years of age (Nautiyal et al., 2003a).

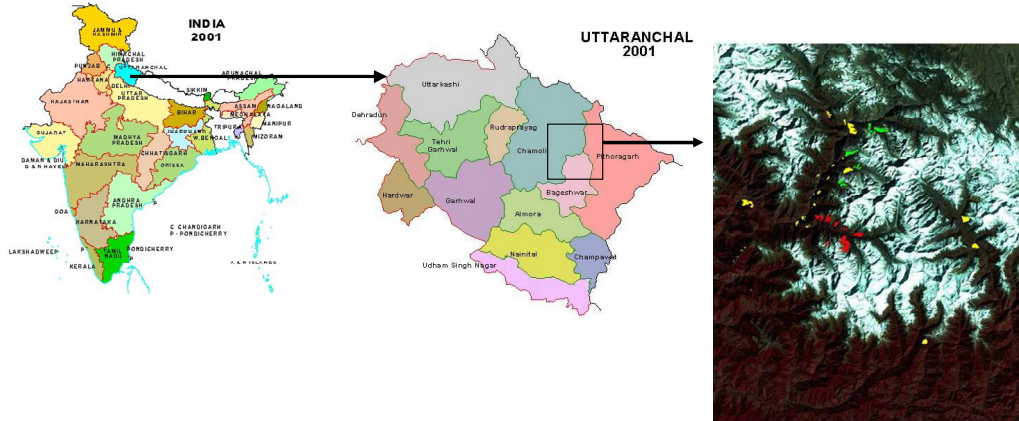


Figure 1. Location of the study area in the Indian Himalaya (Landsat-7 ETM+ image covering the area)

3. Methodology

In the Indian Himalayas, agriculture, animal husbandry, forests and domestic sub-systems are interlinked and have flow of resources within and with the market. To analyze and understand the land use land cover change and developmental scenario in the region, data pertaining to agriculture, including medicinal plants cultivation, animal husbandry, natural resource utilization pattern, forest and domestic sectors and socio-economic profile of local people are analyzed at three points of time (i.e. 1970-80, 1980-90 and 1990-2000). The study is important as based on the ecological and economic analysis of rural ecosystem and land use the information could be generated to understand the causes and consequences of scenario change and developmental process in any region (Farrow and Winograd, 2001).

To understand the process that how the people have been changing their life and prioritizing the activities due to variety of factors (such as environmental, policy, socio-economic) and therefore, how the natural ecosystems also changing with the human activities need to have a long term study of any region. The work done for last decade in the Himalayan region of India facilitate the start of work in this direction and thus the work plan for the data analysis was developed (Figure 2). All the farmers were surveyed to determine average land holding size, area under different crops, crop compositions, cropping patterns, crop rotations, animal husbandry and forest resource collection. In addition, investigations were made to notice the farmers' perceptions towards development and what they thought about factors responsible for the conditions at the

time, such as the implementation of policies, socioeconomic change, population growth, national economy, limitations for land use, resource, infrastructure etc. To gather this information, each household was visited at least 5-6 times during the study period. To generate the data on land use we have measured the crop diversity more accurately. Total land use data was generated with survey methods (questionnaires + field experiment based) to assess the actual area under cultivation of different crops during winter (October/November to April/May) and rainy (May/June to September/October) seasons in the study region. The area used for each crop at that time and in the recent past (during 1970 to 1980) was calculated for all the crops by interviewing the villagers of the region. The head (elderly person) of each family was interviewed for this purpose. All the information collected was subsequently cross-checked by taking personal observations during the field experiments. The methodology pertaining to study the rural ecosystem functioning is described in detail in Nautiyal, 1998; Nautiyal et. al., 2003a,b; Rao et.al., 2005, Nautiyal and Kaechele 2007b). The remote sensing data for the current study are used two times a year particularly during two crop calendar (winter and summer) of the region almost a decade interval starting from 1972. The acquisition dates of the imagery are (11-02-1973; 26-10-1972; 20-04-1979; 26-10-1979 (Multi-Spectral Scanner-MSS); 21-05-1992; 22-10-1992 (Linear Imaging and Self Scanning-LISS-1); 29-03-2002; 23-10-2002. (Enhanced Thematic Mapper-ETM+)). The methodology pertaining to remote sensing data analysis was followed by Nautiyal and Kaechele (2007a,b,c).

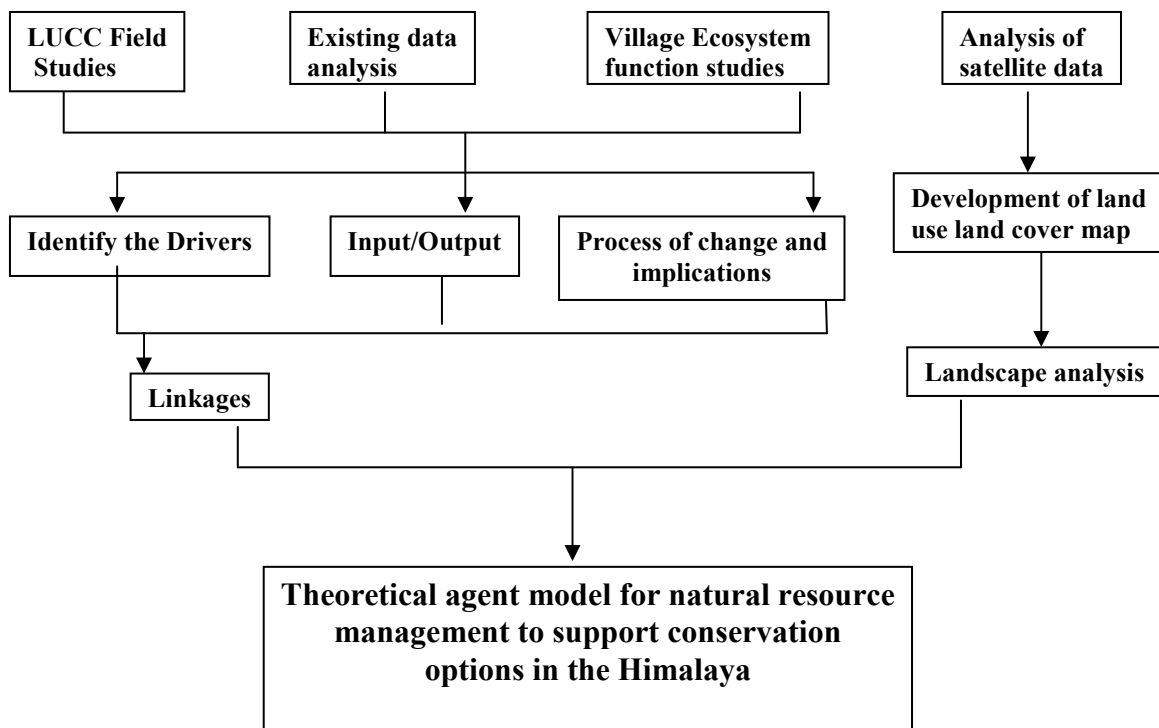


Figure 2. Work-flow of methodology for the study (Nautiyal and Kaechele, 2007a)

4. Results and Discussion

4.1. Monitoring of rural ecosystems

The study was done in view to consider every sector of the rural ecosystems of the study region and for this it is crucial to identify the important indicators which could represent the over all scenario. This is because that in a rural ecosystem study, it is impossible to measure every variable of the system. Therefore, the indicators which could permit to summarize the complex information of system in this endeavor are necessary to be identified (Farrow and Winograd, 2001). That may help to explain that how things are changing in spatio-temporal dimensions. For this study we have identified a few of the indicators such as change in occupation, land use, resource collection and productivity of the farm management to monitor the development in rural ecosystem. The study in this direction also investigated the farmers' perception concerning the driving forces responsible for current trend. From scientific point of view above both approaches needs to be linked in micro-oriented interdisciplinary research, which allows research that analyse the influences of household processes on economical and ecological processes (Klevmarken, 1983; Nelissen, 1991; Rao et al.,2005; Bisht et al.,2006). The results of our empirical study are presented here with the few examples, such as the data on some of the branches of the rural ecosystem function — land use, resource collection, income of farm management etcetera and influence of conservation policies on human behaviours. The data for this study are gathered for last three decades and for the current analysis, the period of 1970–80 was the starting period to study farmer behavior and ecosystem functioning of the region. Therefore, in the context of time (t1), it is important to analyze the system functioning and consequently the behavior of the farmers of the area. The empirical studies were undertaken with a view to understand the human and ecosystem interaction under changing environmental, political and economic conditions. Following are the results from our empirical studies with a few basic examples which are described briefly in view of multi-functionality of the landscape research.

4.2. Change in people occupation their perception and factors responsible

The study was initiated to understand that why and how do farmers' decisions change in view of changing natural, technological and socioeconomic conditions and what will be the implications of such changes in long term? Such analysis would be helpful to understand the whole landscape development. There are several branches in the rural ecosystems where economy of the local people was centered. These are agriculture, animal husbandry, medicinal and aromatic plants cultivation, forest resource collection, tourism and other occupation. The maximum population was engaged in agriculture sector and contribution from agriculture is high in rural economy (61%) followed by animal husbandry (19%), forest resource collection for economic gain (18%), medicinal and aromatic plants cultivation (1.5) and least were found involved in other occupation such as daily wage labour, outside jobs etc (<1%). However the three decades ago the

maximum numbers of people were involved in animal husbandry and this branch of rural ecosystem has contributed the maximum share in rural household income (40%) followed by tourism (35.2%), agriculture (14%), forest resource collection (10%) and that time minimal contribution was reported from medicinal and aromatic plants cultivation (0.2%). The people perception on overall driving forces was vary and maximum showed that current trend in rural ecosystem has emerged because of implementation of conservation policies/ creation of national park and biosphere reserve (80%), followed by limitation (22%), climate (20%), population growth (7%), national economy (10%) and least by socioeconomic change (5%). The total number of respondent for this survey was [n=1648]. An example of implementation of conservation policies is presented in Figure 3.

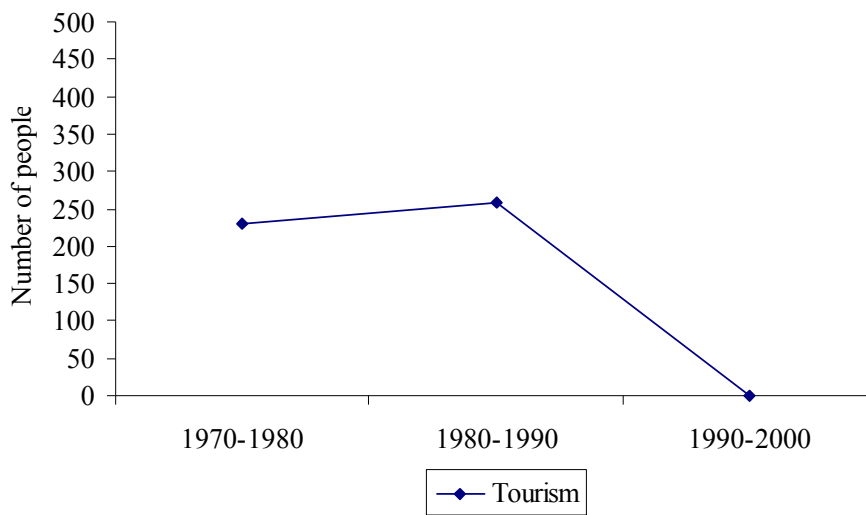


Figure 3. Engagement of the people in tourism related activities in different points of time

The tourism was one of the main sources of income of people of the region and got setback after implementation of conservation policies and this was totally stopped in 1982 after declaration of the area as a National Park and subsequently the Biosphere Reserve in 1988. During 1970 more than 200 people of the region was found engaged in tourism and peoples' interests for this occupation was increasing and during 1980 the number further increased (252) and now tourism is no more in the region (Figure 3). To replenish the loss from this branch farmers have been trying to explore the new ways to sustain their livelihood in the region.

4.3. Land use change trend in the region and farmers' innovation

Over all development in land use has resulted in the high land use intensification in the study region. The rain fed agriculture on steep terraces is the predominant form of land use and a majority of the population was found involved in agriculture. The average per capita land holding ranges from 0.19 ha. The land use change trend was analyzed from

1970 to the present. It is very difficult to analyze the land-use change pattern before 1970 due to some flaw in the methodology, missing historical ground data at our level and, more particularly, only using the conventional methods. Therefore, we have taken the land use under each crop during 1970 for reference to evaluate and to understand the land use change trends in the region. From the period of 1970–80 and 1980–90, the land use under many traditional crops was reduced between 15% and 60%. However, this trend continued, and in the year 2000, the decline in land use under traditional crops increased between 50% and 96% (Nautiyal and Kaechele, 2007d). At the cost of maximization of the areas of many cash crops a variety of traditional crops has been totally vanished from the region.

4.3. (a) Interest for cash crops

The farmers' behavior is important to understand that why he decide on land use for that particular use(s). To understand this phenomenon the empirically evident data are required in multi-temporal dimensions. This can allow even a small-scale view to be expanded to a larger scale in order to understand and investigate the results of farmer's decision on land use and consequently the impact on the entire landscape. The farmers' behavior can not be prejudged but one can measure and investigate their behaviour through long term observations, examination and socioeconomic survey methods (Schnell et al., 1999; Atteslander; 2003; Pischke and Cashmore 2006). For this the long term study in the region was undertaken between 1994 and 2002. The decision on land use change concerning cash crops is depicted in Figure 4 at the example of potato, mustard, kidney beans (*Phaseolus vulgare* and *P. lunetus*) for commercial value and farmers' interests for such crops have been increasing in temporal dimensions. However, during three decades ago farmers were cultivating them for own consumption and not for commercial purpose. Therefore, the land use was distributed to different crops. The tremendous increment we have noticed for the potato as during 1970 only 35 farmers were cultivating this crop for economic gain however, the number reached >400 for the year 2000. Minimum number of farmers were cultivating kidney bean for commercial purpose in 1970 however, during 2000 above 200 farmers were found to be involved in commercial cultivation of kidney beans. Other cash crops such as amaranth and mustard are also showing similar trend.

4.3. (b) Interests for traditional crops

The interests for cash crops lead to further decline the interests of farmers in traditional crops cultivation. Of the five selected traditional crops we have noticed that three are (viz., *Fagopyrum* species, *Setaria italica* and *Glycine max* a typical local variety) totally extinct from the region. However, during 1970 these crops were in the fields of 400, 320 and 280 farmers respectively (Figure 5). The farmers' interest for rest of other traditional crops such as for *Pisum arvense* and *Hordeum himalayens* is also decreasing. Several studies in this endeavor reported that the area under cultivation of many of the traditional crops/landraces in the Himalayan region is shrinking very fast due to replacement of

traditional crop varieties by high yielding varieties or cash crops. The traditional crops are rich in nutrition and are able to fulfill the nutritional demand while making value added product of these crops (Maikhuri, et.al., 1996, 1997, Bisht et al., 2006). How the traditional crops/landraces of the Himalayas would be conserved is a point for policies and planning. Traditional agriculture, though suffered a major setback amidst a high cry of modern agriculture, still provides 20% of the world food supply (Trupp, 1996). The conservation and management of socio-ecological and socio-cultural setup of the local people is one step which may lead to conserve the plant-based genetic resources in rural ecosystems (Rao and Saxena, 1996; Palni et al., 1998).

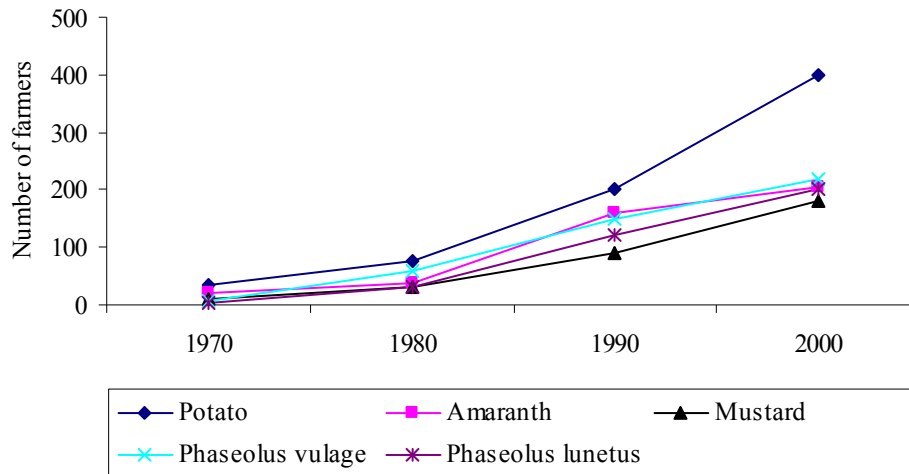


Figure 4. Farmers' preference of cash crops in multi-temporal dimensions

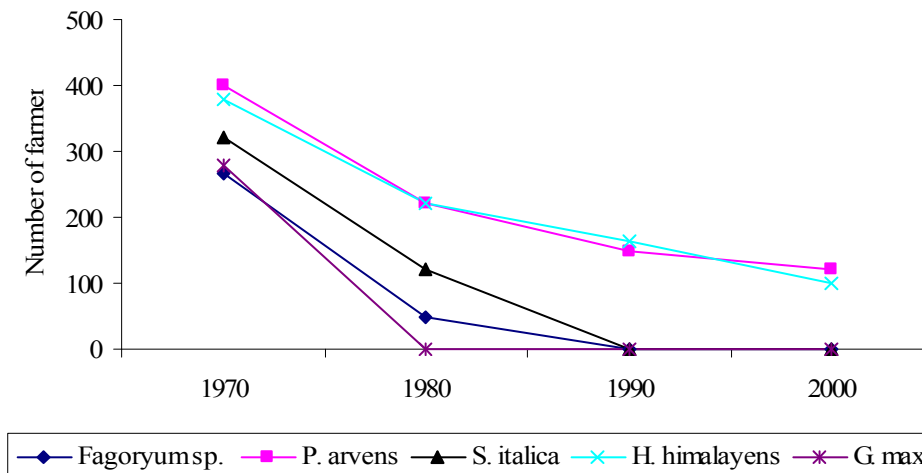


Figure 5. Farmers' preference of traditional crops in multi-temporal dimensions

4.3. (c) Domestication of medicinal and aromatic plants (innovation)

Besides, the farmers' interest for other crops such as domestication of wild medicinal and aromatic plants is also advancing in the region. The medicinal and aromatic plants for which farmers already established the market in the lower valleys of the region long ago and after implementation of conservation policies, further restriction was imposed on the collection of wild resources encouraged farmers to domesticate the area under cultivation of some of the medicinal and aromatic plants (Nautiyal et al., 2003a). Two species *Allium humile* and *Allium stracheyi* farmers brought under cultivation during 1960 and also started cultivating other six-seven species of the medicinal and aromatic plants in the agricultural land for their economic upliftment. The medicinal/ aromatic plant species which are still at smaller scale in the region are low volume - high value crops and can easily exchange or barter with local food commodities in the other areas of the region. The domestication of wild species is new paradigm shift in the Himalayan region. The people have adopted this activity as a as a problem-solving component in their economics (Nautiyal, 1998; Maikhuri et al.,1998; Nautiyal et al.,1998; Nautiyal et al.,2001a). The farmers are trying to prioritize MAPs and their interests (5 farmers in 70s) is increasing (80 farmers in 2000) in this direction (Figure 6). However, at present the contribution from this branch in rural household income is about 1.5% per year.

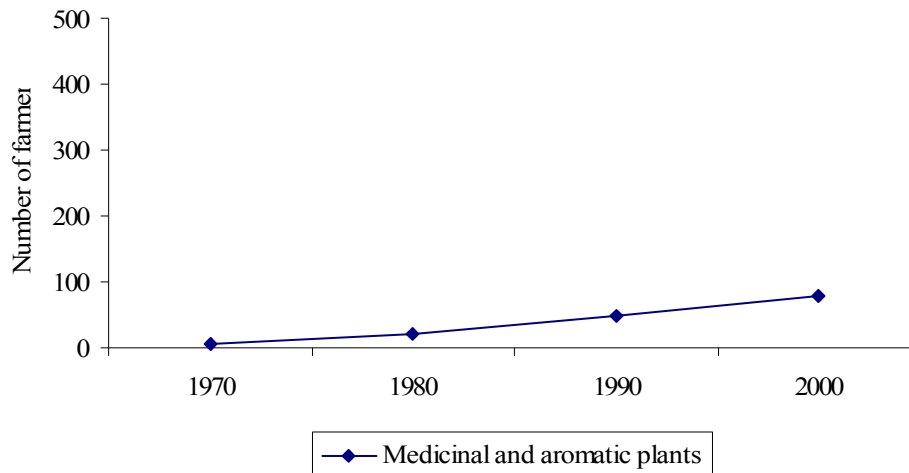


Figure 6. Farmers' preference of medicinal and aromatic plants cultivation in multi-temporal dimensions

4.3. (d) Animal husbandry

The animal husbandry sector has received setback due to nature conservation policies in the study region. In last three decades the number of livestock particularly sheep and

goats reared by farmers has been declined sharply. Sheep and goat rearing is an integral part of the rural economy and these animals need the open grazing land throughout the year. After implementation of conservation policies many of the pastures have been included in the core zone. This has an external effect on farmers which forced them to reduce their animals from 22285±1650 (1970-1980) to 16350±1280 (1980-1990) to 9142±650 (1990-2000). The overall impact of nature conservation areas in economic viewpoint is setback to rural economy. The contribution of income from animal husbandry in total gross income of rural household has been declined 40% (1970) to 19% (2000). However, ecological perspective is not showing support for the current approach. This is because that grazing intensity has been increased from 3 animal units per ha of pasture land to 6 animal units per ha of pasture land in same time span (Nautiyal et al., 2003b; Nautiyal and Kaechele 2007b). Therefore, the problems related to overgrazing in pastures such as ecosystem degradation, erosion, poor quality of feed/fodder as well consequences of strict nature protection on vegetation dynamics in any region (Singh and Kaur 1983; Naithani et al. 1992; Turner et al. 1994; Swallow and Bromley 1995; Chakravarty-Kaul 1998; Sandstrom et al. 2003; Kala, 2004; Gebremedhin et al. 2004; Bernues et al. 2005; Vega-Garcia and Chuvieco 2006; Brandt and Townsend 2006; Kohler et al. 2006; Nautiyal and Kaechele 2007b) need to be accentuated logically while developing the natural resource management plan and policies for biodiversity conservation.

4.4. Landscape development: interdependencies between agriculture and forest ecosystems

4.4. (a) Resource demand from the forests to sustain agriculture

Over all the decision of farmers on land use change influence the whole landscape of the region. This is because the land use in the Himalayan mountains is not an independent sector but entirely depend on the surrounding forests resources for the sustainability. The land use change has resulted the decrease in fodder (crop by product) yield up to 35-45 percent (data not presented). On other hand due to the farmers' decision on land use change the pressure on forests for fodder collection and leaf litter for manure preparation has been increasing. The desire of farmers to secure the optimum output from agriculture land use per capita per year led to leaf litter collection from the forest increases to 223 kg/year (2000) from 100 kg/year (1970) (Nautiyal and Kaechele, 2007a). Changes from traditional to modern land use in Himalayas of India have increased the pressure on forests (Saxena et al., 2005). Similar information is reported in the studies done by Maikhuri, et. al., (1996; 1997); Palni et al., (1998). In addition introduced crops or cash crop requires more input in terms of forest biomass. However, in due course of time the productivity of the lands started declining as decline in resource availability (Nautiyal et al., 2000).

The agricultural intensification with use of high yielding/ modern varieties and purchased inputs has many negative implications particularly for the unique landscapes of the Himalayas where farmers are dependent on local resources and locally developed technologies (Maikhuri et al., 1996; Sen, et al., 2002; Nautiyal et al., 2007a). The change in production systems as well as increase in productivity brings about a change concerning the input especially stemming from the forest ecosystems. The production and consumption activities (input/output) resulting from different branches in landscape management interlink to each other, hence they influence the whole functioning of the ecosystems (Nautiyal et al., 2007b).

The few examples presented above based on the empirical studies in Himalayan region envisages the multi-functionality of the landscape in complex Himalayan environment which need to handled in an integrated interdisciplinary way.

4.4. (b) Implications on forest ecosystems due to increase demand for resource input in agriculture

The effects farmers' decision on land use change showed the results on overall landscape development in particular on forests ecosystems. We have used remote sensing data to understand scenario results at microscopic level in multi-temporal dimensions. The analysis showed that in 2002 only 9.16% of this vegetation class remained dense, however it was once about 36.61% in the forests of the study region (Nautiyal and Kaechele 2007c). Consequently, the spatial extent of the vegetation is dominated by conifers in this area and is increasing. Studies have reported the degradation of broad-leaved forests due to variety of factors (Wakeel et al.,2005) and unfortunately the rate of forest loss and fragmentation in the Himalayas of India is very high (Pandit et al.,2007). Thus the conservation of the Himalayan landscape is a major concern in view of the national as well as the global context (Singh, 2002; Saxena et al., 2005). The study on land use is crucial that determine the way for further landscape ecological research (Schroeder and Seppelt, 2006). The amount, the rate and the intensity of land use and land cover change are very high in developing countries (Rao and Pant, 2001) and assessment of causes and consequences are the first step in developing a successful conservation and management scheme (Brandt and Townsend, 2006). Therefore, there is an urgent need to understand the future scenario development of the whole landscape in the mountains of the Indian Himalayan region. At the core of such analysis is the development of the theory which enables us to understand the link between the ecosystem processes, composition and functions with output of the goods and services from the ecosystems and which can be assigned with economic importance as well with ecological values. This study is one such efforts which facilitated us to develop the theoretical model and concurrently for the conceptual model development for integrated interdisciplinary landscape research in the Himalayan region (Nautiyal and Kaechele 2007a; Nautiyal et al., 2007b).

5. Conclusion

The research approach we have followed such as long term empirical studies and using satellite data has main advantage which tries to simplify the complex human ecosystem interactions while analyzing and evaluating the whole system. The conservation and management of the ecosystems/landscape and development of the local economy are interwoven. The complexity of the system is a major hurdle in achieving the goal-“conservation and compensation.” However, the long-term study of the representative sites of the rural ecosystems and landscape is key factor in understanding the system functioning and designing the appropriate strategies for sustainable development of the region. Conservation and economic security are important at the same spatial and temporal dimension. The following points are suggested based on this study: (1) rather than a strict ban in the name of conservation, the appropriate design and framework should be developed for sustainable utilization of the resources. This should be based on the scientific study undertaken in any area. The increment in resource collection to sustain the livelihood of the local people and the land-use intensification are example of negative external effects of the “conservation” approach of most of the developmental models in the Himalayan region. However, the sustainable management of the resources and development would be possible at same time if the way chalk out for better economic development from the better ecological performance (Jianchu et.al., 2005). (2) The real world is complex and to handle the real world complexities science has to develop adequate methods. In our opinion scientific methods should be able to bring the multidisciplinary science in to an integrated interdisciplinary research. There are so far a few approaches available that needs to take-up for the Himalayas of India (Nautiyal et al., 2007b).

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