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Interaction of Biodiversity and Economic Welfare – A Case Study from the Himalayas of India

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ABSTRACT. In any area to achieve the goal of biodiversity conservation, the existing resources must be strengthened, which are helpful to provide the alternate livelihood or income to the local people. However, although various programmes/policies are being set up over the world for conservation of biodiversity, a variety of factors are hurdles to achieve the expected goals. Particularly in developing countries the sustainable livelihood of the local perople is difficult if restrictions are imposed on their traditional usufruct rights over the natural resources. Based on the extensive field work and analysis of satellite imagery in the selected localities of the Indian Himalaya, we found that if the people are having the alternate avenue (profitable options) for earning, their dependencies on the existing resources (only to meet the subsistence needs, not for commercial purpose) will become much lower. Therefore, the biodiversity in these areas is conserved and managed in a healthy way. In this paper, the interactions of biodiversity and economic welfare of local people are discussed in view of understanding that the economic security is more important than pure enforcement of policies for biodiversity conservation.

Keywords: Biodiversity, conservation, Himalaya, medicinal and aromatic plants, *NDVI*, policies, protected areas, remote sensing

1. Introduction

In India, the Himalaya occupies 18% of the total geographical area and 6% of the total population and spans over 12 states of the country. It is broadly categorized into Northern Himalaya, Western Himalaya, Central Himalaya and North-eastern Himalaya. Uttaranchal is centrally located in the Indian Himalayan mountain chain. It is the youngest and the 27th state of the Indian Republic, with a geographical area of 53,453 km^2. The state is famous for its biodiversity, where conservation efforts have been undertaken for a long time. The world famous CHIPKO (hug the tree) movement for environmental conservation was started from a remote village of Uttaranchal about three decades ago. In order to conserve biological resources, more than 22% of the total geographical area of state is currently protected. As a result, one Himalayan Biosphere Reserve (Nanda Devi), four National Parks and six Sanctuaries have been established. The local people are having agriculture–forest based economy. The whole state is categorized into three agro-climatic zones, i.e. lower elevation (< 1000 m asl), middle elevation (1000-1800 m asl), and high elevation (> 1800 m asl - 7817 m "Nanda Devi peak" the second highest peak of India). The elevation of human settlement is below 3600 m asl in the region (Maikhuri et al., 1996; Nautiyal et al., 1998a, 2002, 2003).

Due to inaccessibility to the nearby market centers, motorable roads, and a variety of factors, the agricultural sector could not provide sufficient remuneration to the locals at high elevations. Normally, a major share of income, which is earned by villagers from agriculture, is spent on carrying their agricultural products from their villages/settlements to the nearby market centers. The high-elevation areas of the Uttaranchal Himalaya are reservoirs for a variety of medicinal and aromatic plants (MAPs) and wild edibles.

The local people in Uttaranchal rely on natural resources to sustain their subsistences and ensure contributions to their economies/incomes. The dependency of the local people over the natural resources is coupled with a variety of factors such as population pressure, needless disturbances to ecosystems, and unsustainable harvesting/overexploitation on natural resources by various pharmaceutical and aroma-chemical industries (Maikhuri et al., 1998; Nautiyal et al., 2001). Consequently, there is little room left to naturally regenerate the endangered flora and fauna (Rao et al., 2000).

A number of studies were conducted by researchers in Uttaranchal Himalaya regarding human plant interactions, resource utilization patterns, and traditional knowledge pertaining to biodiversity conservations (Bhatt et al., 2000; Nautiyal et al., 2001, 2002; Kala, 2003; Kala et al., 2003; Maikhuri et al., 1996). Currently, many policies and strategies have been promugated for protecting and conserving the ecosystems and environment. However, due to a variety of factors, these regulations have not been taken into consideration by the policy makers or government for effective implementation in this region. The main reason is that there are still few in-depth studies that investigated the population of a variety of medicinal and aromatic plants in their natural

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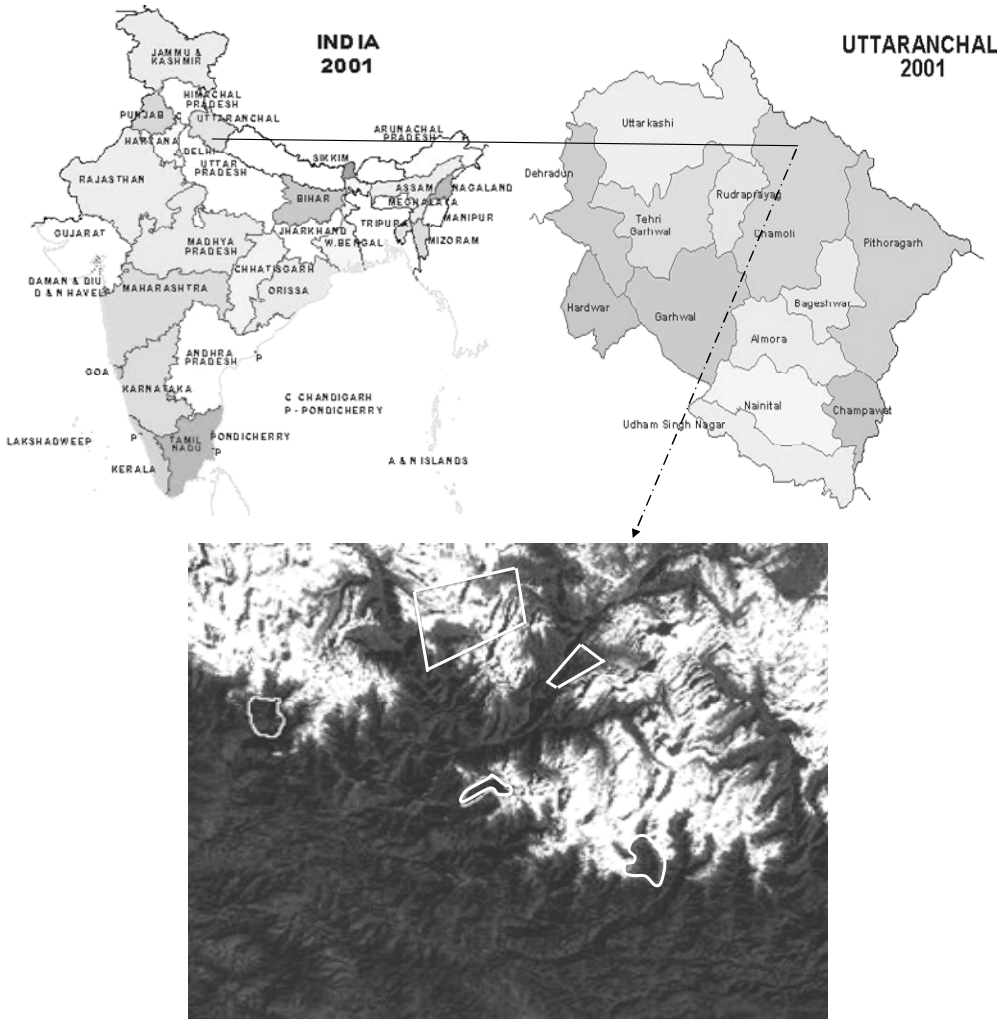

Figure 1. Location of study area in the Indian Himalaya (Landsat-7 ETM+ image of the area).

habitat and the impact of local economy on their conservation and management. To fill this gap, this paper aims to enhance studies in this area with the help of remote sensing techniques in view of understanding the conservation of biodiversity and improving the economic condition of the local people. Five valleys (*viz.,* Bahgirathi Valley, Uttarkashi district; Mandakini Valley, Rudraprayag district; Sundardhunga Valley, Bageshwar district; Roopkund Valley and Niti Valley (Nanda Devi Biosphere Reserve), Chamoli district) in this region will be explored which are reservoirs of a variety of medicinal and aromatic plants.

2. Methodology

The Himalaya is the reservoir of a variety of important plant species that produces secondary metabolites under environmental stress. As a result, the plants have both medicinal and aromatic properties. Medicinal and aromatic plants (MAPs) found in the Himalayan region include species of high ecological and economic potential and were known as high-value low-volume crops (Maikhuri et al., 2005). Therefore, the rural households living in the region collect them for commercial purposes in order to increase their household incomes (Olsen and Larsen, 2003). The commercial demands for MAPs in various pharmaceutical and aroma-chemical industries are expediting the depletion of these plants from their natural habitat (Nautiyal et al., 2001; Maikhuri et al., 2005). The overall circumstances are posing severe threats to the diversity of MAPs at local, regional, national and global levels. Based on the extensive study in above mentioned valleys of Uttaranchal Himalayan region of India, this paper tries to examine the relationship between economic welfare and biodiversity in the context of the mountainous conditions. The period of study for different valleys of the region was from April 1999 to November 2002. Three field trips were made in each valley in each year: i) first in the summer season (April and May) when medicinal herbs in the high elevation region sprout (to mark the localities/ habitat of plant species), ii)

Table 1. Monetary Value of Medicinal and Aromatic Plants Selected for the Population Study and Traditional Food Crops / Cash Crops of the Region

Scientific name	Local name	Part used	Cure for / Used for	Local price Rs/kg
Medicinal and aromatic plants				
Podophyllum hexandrum	Ban kakri	Root	Stomach-ache, wounds and cuts	60
Pleurospermum angelicoides	Chippi	Root	Fever, stomach-ache	150
Saussurea costus	Kut	Root	Stomach-ache, typhoid fever	95
Angelica glauca	Choru	Root	Dysentery, body pain	150
Dactylorhiza hatagirea	Hatazari	Tuber	Wounds and cuts, health tonic	600
Paeonia emodi	Chandra	Leaves	Dysentery, Colic	50
Tanacetum longifolium	Dhoop	Whole plant	Cold and cough	50
Traditional/ Cash crops				
Amaranthus paniculatus	Chaulai	Seed/Leaves	Edible and medicinal	12
Fagopyrum esculentum	Oggal	Seed/Leaves	Edible and medicinal	20
Fagopyrum tataricum	Phaphar	Seed	Edible and medicinal	15
Macrotyloma uniflorum	Gahat	Seed	Edible and medicinal	20
Hordeum himalayens	Uwa	Seed	Edible and medicinal	05
Brassica compestris	Sarson	Seed/ Leaves	Edible and medicinal	15
Eleusine coracana	Finger millet	Seed	Edible and medicinal	05

second in rainy season (July to August) when most of the high altitudinal plants attain luxuriant growth (for photosociological study), and iii) third at the beginning of the winter (October last to mid November) when plants reach maturities (to monitor the habitat of each species).

We have reported 250 plant species that have certain socio-economic and medicinal values from the region. These species are also identified by the local people as they have been using them for a variety of purposes. However, seven species, *viz.* (1) *Podophyllum hexandrum,* (2) *Pleurospermum angelicoides,* (3) *Anglica glauca,* (4) *Saussurea costus,* (5) *Dactylorhiza hatagirea,* (6) *Paeonia emodi,* and (7) *Tanacetum longifolium,* are identified for the population study. The emphasis was given to theses species as they are presently in the category of rare, endangered and threatened, and having huge economic potential along with high social value. For the population study, we have identified 10 different habitats of the selected species in all valleys; they have variations in aspect, slope, and soil condition. Subsequently 20 quadrates (2 m × 2 m) were laid down in each of these habitats to enumerate the plant species. The mean density (individual of species per unit area) of each species was calculated within its habitat type.

After completion of the field observations, the remote sensing imagery was used for vegetation-cover analysis in each of the studied valleys. We used Landsat-7 ETM+ satellite image (path/row, 145/39; 146/39) to cover the study area (Figure 1). Thereafter we used the geometric correction to calculate the Normalized Difference Vegetation Index (*NDVI*). *NDVI* is a model for converting satellite based measurement into surface vegetation types. The *NDVI* is calculated by the following formula (Rouse, 1974):

$$NDVI = \frac{NIR - Red}{NIR + Red} \quad (1)$$

where "*NIR*" is the near-infrared radiation from a pixel. The information generated here is interpreted with Ground Control Points (GCPs), field data, field observation, and in-depth knowledge of the area and plant communities.

3. Results

The people of the region identified over 250 wild plant species for different uses, i.e. medicinal, aromatic, edible, religious and other miscellaneous purposes. Many of these wild plant species were commonly used by the people of this region for a variety of purposes. The detailed description (such as local name, used for and use method) of these wild species can be found in Nautiyal et al. (2003).

Thirty five species, which belong to 25 families of the plant kingdom, are generally known to all the knowledgeable persons or traditional healer locally known as "Vaidhya" in the studied valleys. By and large, the used method is based on the traditional knowledge and cultural preferences of people of the region.

The density (per hectare) of MAPs is presented in Figure 2. But it is important to mention here that all key medicinal and aromatic plant species which were selected for the population study (viz., *Podophyllum hexandrum, Pleurospermum angelicoides, Anglica glauca, Saussurea costus, Dactylorhiza hatagirea, Paeonia emodi* and *Tanacetum longifolium* etc.) have found densely populated in the Mandakini Valley followed by Roopkund Valley as compared to other studied valleys of the regions (viz., Niti, Sundardhunga and Bhagirathi Valleys). The five species, namely *P. hexandrum, P. angelicoides, A. glauca, S. costus and D. hatagirea*, were presently under the rare and endangered categories. The *P. emodi* and *T. longifolium* are not in peril; however, every year, the people of the region harvest them in huge quantities from the nature for vegetable, religious and medicinal purposes.

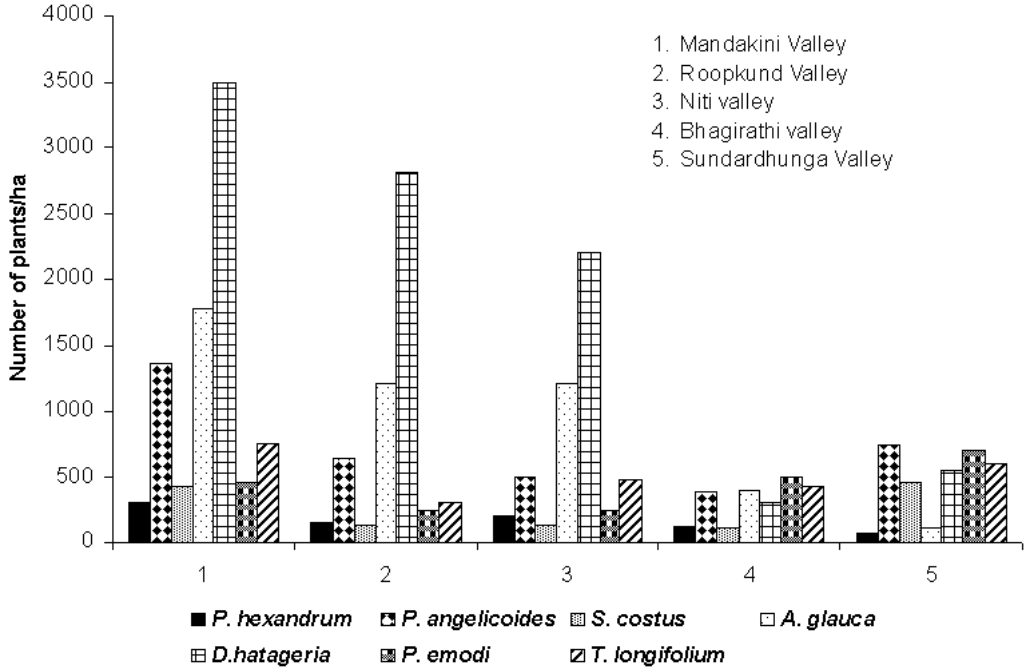

Figure 2. Number of plant species/ha in their natural habitats.

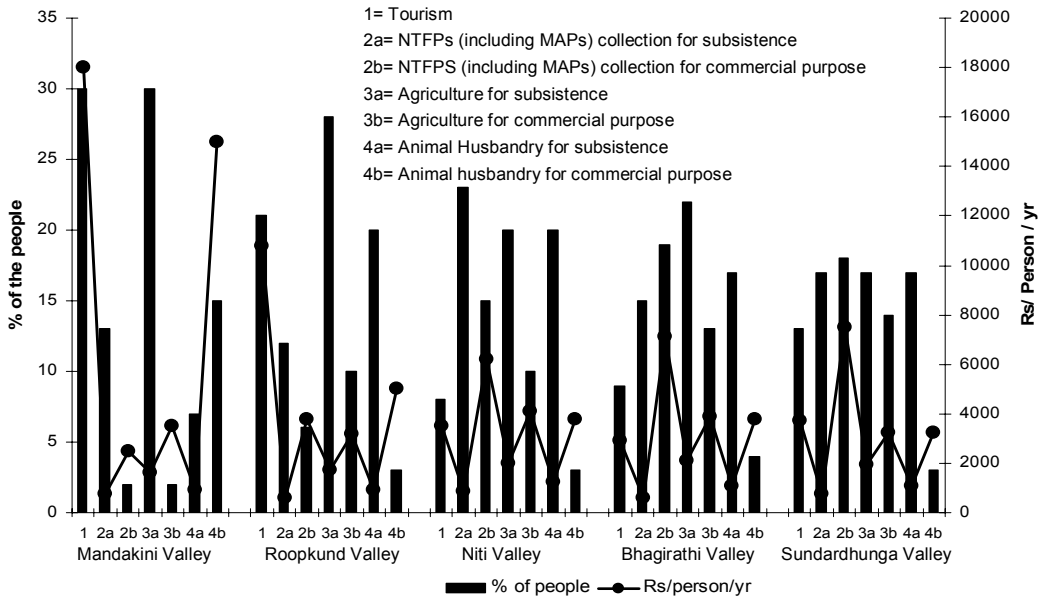

Figure 3. Percentage of people engaged in different activities and their earning per year from different activities in the explored valleys of the Uttaranchal Himalaya, India (number of people n = 1500).

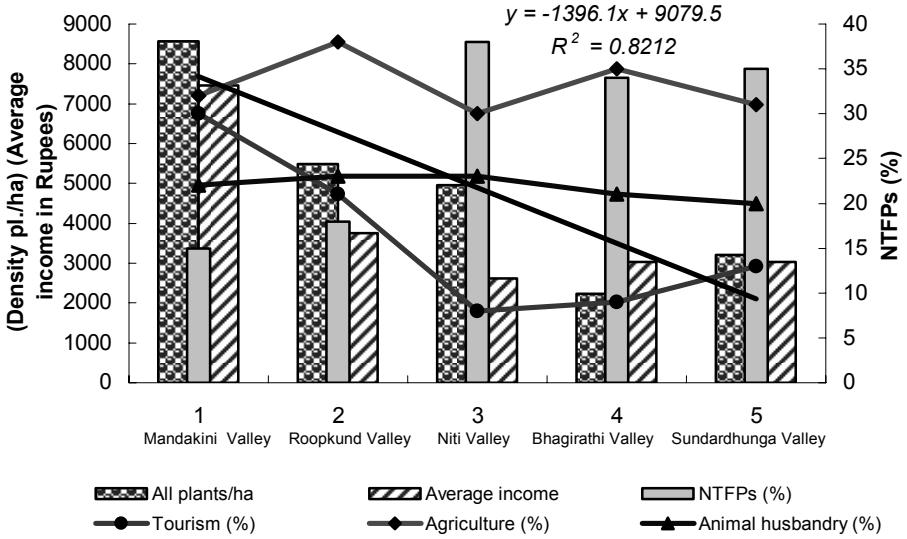

Figure 4. The relationship among the drivers (income, income generating activities) and biodiversity of the studied valleys.

The monetary values (Rs./kg) at local market, in addition to the local name, parts to be used and ailments to be cured, of the selected medicinal and aromatic plant species is given in Table 1. In this table the same information is provided for those important traditional/cash crops of the region. The monetary values of the wild species are several times higher than those of the traditional food crops of the region.

Fortunately, the density of *Dactylorhiza hatagirea*, a critical endangered medicinal plant was the highest among all other rare medicinal plant species on various localities. This species was the highest in density towards Mandakini Valley followed by Roopkund and Niti Valleys (as shown in Figure 2). Nonetheless, in spite of the strict ban on its collection, this tuberous plant is heavily exploited from both protected and unprotected areas for its use as a health tonic. *Angelica glauca* was next to *D. hatagirea* in terms of density. However, a few rare medicinal plant species, such as *Saussurea costus* and *Podophyllum hexandrum*, exibited lower densities due to over exploitation and poor regeneration. The densities of all rare plants were found lowest in Bhagirathi Valley.

In the studied region, four major activities (viz., tourism, non-timber forest products (NTFPs)/MAPs collection, agriculture and animal husbandry) are identified as the primary components of the local economy. Except for tourism, other activities (viz., NTFPs/MAPs collection, agriculture and animal husbandry) are traditional since generations. People in this region prefer these activities for subsistence (category a) and/or commercial (category b) purposes in order to secure their livelihoods (Figure 3).

In Mandakini Valley, more than 30% people are actively engaged in tourism, followed by Roopkund Valley (21%). People from these two valleys are earning about 18,000 and 11,000 rupees per capita per year, respectively. People of all the valleys are involved in agriculture and animal husbandry mainly for subsistences and, to some extent, for commercial purposes. In Mandakini Valley, where the tourism potential is much higher, more than 15% people are rearing animals for commercial purposes (viz. carrying luggage, goods or tourists etc.). But it is noteworthy to mention here that the NTFPs collections for economic gains are high in the Niti, Bhagirathi and Sundardhunga Valleys; and about 15 to 23% people have been found engaged in this activity. However, only 2 to 7% people of the Roopkund and Mandakini Valleys are involved in NTFPs for economic incomes; the others collect these products for their own consumptions only (Figure 3).

Figure 4 presents a conclusive look on the field study that was undertaken in various localities/valleys of the region. It is indicated that the plant density is proportional to the average income of the people. For example, the density level is high in the areas where the average income is also eminent; the plant density reduces as the average income is decreasing. Based on the observations, we found that tourism is a lucrative option which attracts local people to use it as a good source for their income increment. The options and opportunities for activities of agriculture and animal husbandry are almost similar in all valleys. This implies that there is an urgent need to strengthen those sectors for promoting the income-generation activities of the local people (Figure 4).

The Normalized Difference Vegetation Indexes (*NDVIs*) of all studied valleys are presented in Figure 5. The *NDVI* levels indicated a high vegetation density in Mandakini Valley, followed by Roopkund and Sundardhunga Valleys. However, the vegetation index shows a low vegetation density in alpine pastures of the Bhagirathi and Niti Valleys of the region (Figure 5).

4. Discussion

The Himalayan region of India, distinguished by global biodiversity, is an area where ecological and evolutionary factors favored development of a huge diversity of species and where the remoteness of the area prevented many large scale exploitations on natural ecosystems (Myers, 1990). The inaccessibility of the region fostered local inhabitants to depend on local available resources for survival (Nautiyal et al., 2001).

Investigations conducted in the valleys of the Uttaranchal Himalaya suggested that the forest and alpine pasture are holding diverse resources, particularly NTFPs (Maikhuri et al., 1998; Nautiyal et al., 1998b; Nautiyal et al., 2001). The MAPs extraction was a common practice in the Uttaranchal hills since a long ago. Till 1957, the local people directly collect and sold MAPs as well as state use to get in the form of toll tex/royalty etc. From 1957 to 1977, the collection of MAPs in this region was undertaken on contract basis. However, in the absence of any price policy, exploitation activities of local traders remain unchecked. Thereafter (in 1977), the state government set up a sale-purchase cooperative (Bhesaj Sang) for protecting the interest of local villagers. This cooperative did not earn sufficient confidence in remote villagers due to a variety of reasons (Purohit, 1997).

The trade of Himalayan MAPs is frequent across the region because of their high medicinal and aromatic values

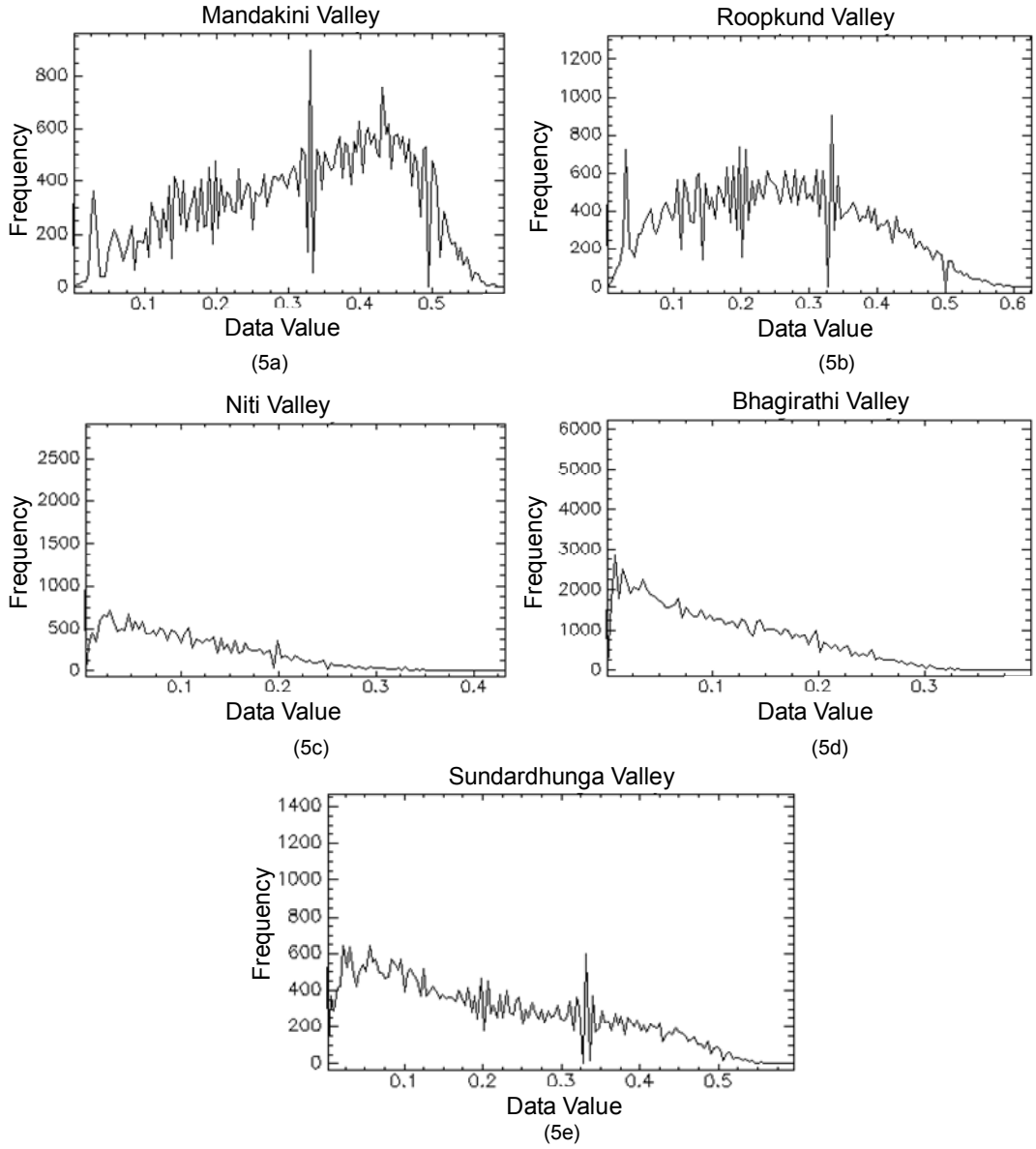

Figure 5. Vegetation index (NDVI) of the study valleys in the Uttaranchal Himalaya.

Table 2. Monetary Input, Output and Output/Input Ratio of Cultivation of Medicinal and Aromatic Plants in the High Altitude of the Uttaranchal Himalaya (after *Nautiyal et al., 1998; Maikhuri et al, 2002)

Scientific name	Local name	Output (Rs/ha/yr)	Output/ input ratio
Aconitum heterophyllum	Atis	78750	22
**Allium humile*	Ladum	37620	13
**Allium stracheyi*	Jimbu	29220	11
**Angelica glauca*	Choru	27750	9
Arnebia benthamii	Balchhari	54000	11
**Carum carvi*	Kala jeera	40000	25
**Dactylorhiza hatagirea*	Hathazari	33750	12.5
**Megacarpaea polyandra*	Barmao	12750	6
Nardostachys grandiflora	Jatamashi	48500	19.2
Picrorhiza kurooa	Katuki	27500	8.7
Plantago ovata	Isabgol	12000	4
**Pleurospermum angelicoides*	Chippi	27750	9
Polygonatum verticillatum	Salammisri	66150	17
Potentilla fulgens	Bajradanti	55250	12
Rheum australe	Dolu	47000	12.7
**Saussurea costus*	Kut	30625	9
Selinum wallichianum	Bhoot kesh	35400	12.3

(Olsen and Larsen, 2003). Many studies have documented the mode of collection of medicinal plant and trade in Himalayan region (e.g. Dobriyal et al., 1997; Farooquee and Saxena, 1996; Olsen, 1998; Nautiyal et al., 2001; Olsen and Larsen, 2003; Maikhuri et al., 2005). Based on field studies and explorations, it was noticed that, in the areas where people have profitable earning sources such as tourism, the density of economically and socially important medicinal and aromatic plant species is higher than those in other areas, where people do not have profitable options to earn money. Furthermore, low densities of the medicinal and aromatic plants were found in the areas where policy has also been implemented for a long time for ecosystem conservation. In such cases, dependence of the people over the natural resources may increase several times higher to meet their requirements. In general, the endangered medicinal and aromatic plant species are densely populated in the alpine pastures of Mandakini Valley because the pilgrimage season provides significant seasonal employment opportunities to the people in the region. Thus, they do not spend much time on collecting NTFPs/MAPs, which are not as remunerative as other routine income earning activities. The Niti Valley, which falls in Nanda Devi Biosphere Reserve (NDBR), has low MAPs densities. However, the traditional rights of resource use (including collection of MAPs) are lost after implementation of conservation policies. Illicit collections from the wild in those areas, however, continued because of ineffective enforcement of the policy; consequently, the biodiversity is in jeopardy (Rao and Saxena, 1996; Nautiyal, 1998; Nautiyal et al., 1998b; Nautiyal et al., 2001; Maikhuri et al., 2000a, b; Rao et al., 2000; Rao et al. 2002; Silori and Badola, 2000). Meanwhile, we analysed the satellite image (Landsat-7 ETM+) of the area and developed a vegetation index map following the methods of Rouse et al. (1974). The *NDVI* is the representative index and is suitable for the studied area. Based on the satellite image analysis, we also found that, if the vegetation density in the local area is high, the dependency of the local people on the surrounding resources is low, for the purpose of earning their incomes.

Therefore, to achieve the conservation goal, appropriate mechanism need to be devised based on the existing resources through which people can be benefited from the monetary point of view. In this regard, Sharma et al. (2000) described that the local mountain niche can be exploited sustainably for sustainable development of the area. The cultivation of a cash crop "Large Cardamom" (*Amomum subulatum Roxb*.) family Zingiberaceae, beneath the forest cover in Sikkim Himalaya, is an example that how avenues can be developed for the earnings of the local people in mountainous areas. Various studies done by Nautiyal (1998), Maikhuri, et al. (1998), Rao et al. (2000); Nautiyal et al. (2001, 2002, and 2003) in one of the Himalayan biosphere reserves "Nanda Devi" suggested many approaches for biodiversity conservation and economic upliftment of the local people through strengthening the existing resources. In this paper, we found that the interest and income of the local people from the agriculture and animal husbandry sectors are showing similar trend in all the valleys. These sectors need to be strengthened in a way from which the local people can be benefited economically instead of relying on these sectors only for food for a couple of months in a year. The traditional crop cultivars and landraces, having potentials to produce good outputs along with manifold uses besides staple food, need policy supports for their conservations and wild uses in the Himalayan region (Maikhuri et al., 1997). A participatory approach through institutional and policy support is required for developing new strategies and approaches for sustainable agriculture development in the region, adding new dimensions to its enhancement efforts, including the promotion of value addition of traditional crops and enhanced production on the basis of growing urban consumption needs (Bisht et al., 2005). Urban demand for Himalayan crops would provide market incentives for farmers to produce more outputs beyond the subsistence level. This will be helpful to

originate the strong base line for biodiversity conservation in Himalayan region. However, similar studies conducted by Nautiyal et al. (1998b) and Maikhuri et al. (1998, 2002) in high elevations of Uttaranchal on MAPs cultivation suggested that there is an urgent need to develop MAP-based cultivation sector in the region as such a crop shows good properties of low volume and high value and can provide 9 to 15 times higher economic benefit to the locals than those provided by traditional crops or cash crops. Besides, the local environment is favorable for MAPs cultivation. Based on the findings, the expenditure, income and expenditure/ income ratio (per ha per year) of seventeen species of MAPs are summarized in Table 2. They suggested that the cultivation of medicinal and aromatic plants can not only facilitate the conservation program in the Himalayan region, but also provide better opportunities for the local people of the region to increase their household incomes.

In the Uttaranchal Himalayan region there exist immense opportunities for economic development of local people. For examples, the traditional crops of the region have medicinal properties, which is critical for food and nutritional security while making value addition. With planned cultivation of low volume high value crops (such as MAPs), the socio-economic conditions of the local people may be improved; meanwhile, the goal of biodiversity conservation can be achieved in the large area of new state "Uttaranchal" (Nautiyal et al., 2002, 2003). Private sectors need to be involved in this region in the programmes particularly in bioprospecting of MAPs and traditional crops by people who would be benefited directly and then be ensured to participate in the developmental programme. Since the inhabitants are the focal point of every conservation effort, attempt should be made to strive for a balance between conservation and development. To keep the environmental settings of the area, social and economic status of the local people in view and availability of the existing resources (i.e. traditional crops, natural resources and MAPs) efforts need to be initiated by all the institutions (such as governmental and non-governmental organizations, local instituteions).

Moreover, this study indicated that the people of the region are having close affinity with the surrounding vegetation. The ethnobotanical knowledge is rich in the studied area and it is being transferreded from one generation to the next. The indigenous knowledge base that is related to ethnobotany of the people in any area is important for keeping the present Intellectual Property Rights (IPR) regime in view and also preventing such knowledge from losing in the communities, as a result of rapid socio-economic and cultural changes. Similar information related to human plant interactions have been reported by many researchers over the world (Fanshawe, 1948a, b; Danks, 1945; Farnsworth et al., 1988; Johnston and Colquhoun, 1996; Hafeel and Shankar, 1999; Sajeev and Sashidharan, 1996; Rao, 1995; Caniago and Siebert, 1998; Olsen, 1998). Other studies from the Himalayan region also described the dependencies of the rural people on wild plants for subsistence needs (Maikhuri and Ramakrishnan, 1992; Farooquee and Saxena, 1996; Farooquee and Rao, 1998; Bhatt et al., 2000). In addition, many researchers have pointed out that there is still a commercial exploitation on many rare, threatened and endangered MAPs species from the nature (Jain and Sastry, 1979; Nautiyal, 1998; Nautiyal et al., 2001; Kala, 1998; 1999; Kala et al., 2003).

5. Conclusions

Through field investigations and remote sensing image analysis, this paper indicated that high densities of many important medicinal and aromatic plants would present in those areas where people have lucrative options to earn money. As described in the case study, the plant density is high in Mandakini Valley and Roopkund Valley, as compared to other valleys, even if the policies are implemented in some areas for a long time for biodiversity conservation. Therefore, in any area, the biodiversity conservation and economic security are both important to local people. We concluded the following three points based on this study: a) if the incomes of the local perople were generated from non-vegetation related activities, conservation will happen; b) if a decrease of income from vegetation related activities can be compensated with other activities, conservation is possible; and c) peope with low incomes are trying to maximize their income from the existing forest resources, leading to severe environmental degradation. A documentation of such knowledge is also important as rapid socio-economic and cultural changes are taking place in the societies.

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