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Natural resource degradation in three sub-watersheds of river Tons, Uttarakhand, India

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Abstract: The study was conducted in three sub-watersheds (Har-ki-Dun, Tons and Obra Gad) falling in the headwater region of Tons river and located in Govind Wildlife Sanctuary and National Park (Uttarakhand, India) at an altitude ranging from 2000 to 3600 m asl. The paper analyses linkages between natural resource degradation, biodiversity and loss in ecosystem services using Remote Sensing and Geographical Information System. The analysis on forest fragmentation, biodiversity inventories and socio-economic data revealed that biodiversity decreased across disturbance gradient among all the three sub-watersheds and about 12.11 km^2 area was found to be highly fragmented in the study sites. The ecosystem services have been adversely affected in almost all the degraded sites, however, severe effect was observed in naturally degraded site. It is suggested that the development planning of the area should focus on the issue of local people's dependence, and the resultant biotic pressure on the forests.

Resumen: Elestudio se llevó a cabo en tres subcuencas (Har-ki-Dun, Tons y Obra Gad) ubicadas en la región de la cabecera del río Tonsy localizadas en el Santuario para la Vida Silvestre y Parque Nacional Govind(Uttarakhand, India), a altitudesentre 2000 y 3600 m s.n.m. El artículo analiza los nexos que hay entre la degradación de los recursosnaturales, la biodiversidad y la pérdida de servicios ecosistémicospor medio del uso de Percepción Remota y Sistemas de Información Geográfica. Elanálisisde la fragmentacióndel bosque, de los inventarios de biodiversidady de los datos socioeconómicosreveló que labiodiversidad decreció a lo largo del gradiente de disturbio entre las tres subcuencas y se encontró que un área de alrededor de 12.11 km^{2}está muy fragmentadaen lossitios de estudio. Losservicios ecosistémicos han sido afectados de forma adversa en casi todos los sitios degradados, y se observó un efecto severo en el sitio con degradación natural. Se sugiere que la planeación para el desarrollodelárease enfoque en la cuestión de la dependencia en los bosques de la gente local y la presión biótica resultante.

Resumo: O estudo foi realizado em três sub-bacias hidrográficas (Har-ki-Dun, Tons e Obra Gad) desaguando na cabeceira do rio Tons localizado no santuário de vida selvagem de Govind e do Parque Nacional (Uttarakhand, Índia), a uma altitude que varia entre os 2000 a 3600 m de altitude. O artigo analisa as ligações entre a degradação dos recursos naturais, a biodiversidade e a perda de serviços ambientais, utilizando a Detecção Remota e o Sistema de Informação Geográfica. A análise da fragmentação da floresta, dos inventários de biodiversidade e informação socioeconómica revelaram que a biodiversidade diminuiu ao longo do gradiente de perturbação entre todas as três sub-bacias hidrográficas tendo-se encontrado uma área de cerca de 12,11 km^2 altamente fragmentada nos locais de estudo. Os serviços do ecossistema têm sido prejudicados em quase todas as áreas degradadas, no entanto, os efeitos graves foram

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observadosnos locaisdegradados naturalmente. Sugere-se que o planeamento do desenvolvimento da região deve centrar-se sobre a questão da dependência da população local, e da pressão biótica resultante sobre as florestas.

Key words: Biodiversity and ecosystem services, degradation, sub-watersheds.

Introduction

Himalayan ecosystems are unique environments and valuable natural resources; they have particular spatial configurations and values, and offer a wide variety of ecosystem services (Boulinier *et al.* 2001; Forman 1997; Thomas & Sheldon 2000). However, anthropogenic activities, such as agriculture, livestock husbandry, tourism, transportation, and industry, alter and degrade natural resources and environment. Therefore, it is necessary to manage these unique ecosystems through restoration, rehabilitation, or conservation programs (Armando *et al.* 2002; Harper *et al.* 1999). The effect of degradation on ecological processes is not only confined within the Himalayan region but also across the adjoining ecosystems. Degradation can be sub-categorized as biotic and natural, depending upon the causative factors. Natural disturbances strongly influence spatial pattern and dynamics of ecosystems (Landres *et al.* 1999; Turner & Dale 1998). Human induced disturbance differs from natural disturbance especially in extent, severity and frequency. Both natural (landslides, fires, cloud burst, etc.) and human (deforestation, overgrazing, illegal digging of medicinal plants, pollution, etc.) influences are known to cause massive changes in vegetation cover and dynamics.

Disturbance has become a widespread feature all over the Himalayan region (Singh & Singh 1992). It varies in size, frequency and intensity (Romme *et al.* 1998), and the consequences of large, infrequent disturbances are hard to predict. The rate of the loss of the highly diverse ecosystems of Himalayan mountains has also bearing on the loss to the global biodiversity and it is assumed that after several decades only about 10 % of the land area in one of the biodiversity hotspot of India will remain densely forested (Pandit *et al.* 2006). Therefore, the understanding of the ecological processes and biotic and natural pressures can help to know and relate the persistence of plant communities.

National Parks and Wildlife Sanctuaries are valuable repositories of biodiversity (Howard *et al.* 1998; Meffe & Carroll 1997; Pressey *et al.* 1993) and it is important to improve the protection of biodiversity in reserve systems (Pressey 1994). This can be achieved by identifying valuable unprotected areas and extending them in a proper way to the reserve system, and by improving areas that are already protected (Howard *et al.* 1998; McNeely 1994; Meffe & Carroll 1997; Pressey *et al.* 1993, 1996). Clearing forested land affects multiple ecosystem services (such as food production, biodiversity, and watershed protection), each of which affects human well-being. Assessing these parameters in the decision-making process requires scientifically based analysis to quantify the responses to different management alternatives. Scientific advances over the past few decades; particularly the remote sensing in combination with the inventory data provides the potential to assess these linkages.

Remotely sensed imagery has long been recognized as a fundamental input data for biodiversity estimate and conservation. In particular, remotely sensed classified data have been used in a number of monitoring tasks such as resource assessment. Satellite remote sensing and GIS has emerged as a vital tool for understanding and monitoring the spatial and structural changes in vegetation and other earth surface features (Pant & Kharkwal 1997; Pant & Singh 1992). But at the same time the vegetation analysis of these degraded forests/grasslands helps in understanding the effects of disturbance on the composition and dynamics of forests/grassland community and also helps in managing the degraded area or secondary forest/vegetation that regenerates after disturbance. Therefore, in the present study we have tried to evaluate the degradation using Remotely sensed data by calculating the landcover change and fragmentation and also studied the ecological parameters of the degraded sites and protected sites in the watersheds. The science of ecology with the use of

remote sensing and GIS tool is highly useful to derive quantitative and qualitative information about ecosystem biodiversity and ecosystem dynamics.

The literature review suggest that there is hardly any major research study conducted in higher altitude of Govind Wildlife Sanctuary and National Park located in the Western Himalayan region, particularly with regard to evaluation of degradation. Some of the relevant investigations on Govind Wildlife Sanctuary and National Park include physical carrying capacity and real carrying capacity (Goyal & Brahma 2001); phytodiversity, vegetation and ethnomedicinal information of 23 medicinal plants (Balodi & Kumar 2002), conservation strategies for some threatened medicinal plants in the study area (Joshi *et al.* 2005) and the baseline studies of Tons river upper catchment (Gopal *et al.* 2007).

The local people in the study area are entirely dependent upon the limited natural resources and much of the recent environmental degradation in the region can be linked to this dependence. This area is highly landslide prone and every year there has been regular phenomenon of landslides and loss of life and property. Thus, not only biodiversity of the region is getting depleted, the natural resource base for sustaining the human population is eroding rapidly that has resulted in degradation of natural resources, loss of biodiversity, ecosystem services and increased geomorphic hazards.

The causes and impact of the natural resource degradation on biodiversity status and ecosystem services of Govind Wildlife Sanctuary and National Park located in the Western Himalayan region is attempted in this study.

Study area

The study was carried out in the three sub-watersheds viz., Har-ki-Dun, Tons, Obra Gad within Govind Wildlife Sanctuary and National Park located in district Uttarkashi, Uttarakhand (Fig. 1). These sub-watersheds constitute the headwater regions of River Tons. This river is formed at the confluence of River Rupin (catchment area almost entirely in Himachal Pradesh) and River Supin at Netwar (1410 m), Utttarkashi. River Supin is formed by the confluence of Supin Gad, Obra Gad and Har-ki-Dun Gad, which arise at the base of Jamdar glacier and adjacent glaciers. More than one third of watershed of River Tons is covered by the Govind Wildlife Sanctuary and National Park which lies almost entirely in the watershed of River Supin. The Tons watershed lies in the middle and greater Himalaya at altitudes ranging from 1400 m to 6323 m above the mean sea level. The three sub-watersheds studied are located at an altitude ranging from 2000 m to 3600 m asl. Fig. 2 presents the detailed map of the three watersheds selected for the present study.

Population and socio-economic condition

There are 42 villages in the upper valley of River Tons (upstream to Netwar). According to 1981 census, the total population of these villages was 12834 persons and a gradual increase is observed in the population from year 1991 (15821 persons) to 2010 (20129 persons). Based on the field survey conducted during 2004 - 2006, the average family size comprised 6 - 7 members. The villages are located in remote areas without connecting motorable roads. Agriculture and animal husbandry is the main source of livelihood and income of the local people. Goats and sheep are maintained for milk, meat and wool. Cropping patterns were built around two seasons locally referred to as Kharif (rainy season) and Rabi (winter season). Cultivation is done on varying degree of slopes and irrespective of soil depth. Fruit cultivation is represented by scattered orchards of apple *(Pyrus malus),* apricots *(Prunus armeniaca),* peaches *(Prunus persica)* in some places near Sankri and Jakhol villages. The literacy rate is very low in almost all villages. Collection of fodder and fuelwood form an important part of the social and cultural life of the women in this area.

The area experiences regular snow fall interrupted by cloud bursts in winter. Vegetation in the upper Tons river basin changes greatly with the altitude. The major vegetation types found in the area are Himalayan moist temperate forest, sub-alpine forest and alpine scrub. Alpine meadows constitute a very large area above the timberline. Geo-morphologically, the terrain is highly rugged and mountainous, widely intersected by rivers, streams and seasonal *nallahs*.

This region is under intense anthropogenic pressure because local communities are entirely dependent on its natural resources for their survival. Deforestation, forest fire, intensive terrace farming, over grazing and road building activities have increasingly degraded the natural environment of the region. Cultivation on the steep slopes without appropriate terracing, loss of vegetative

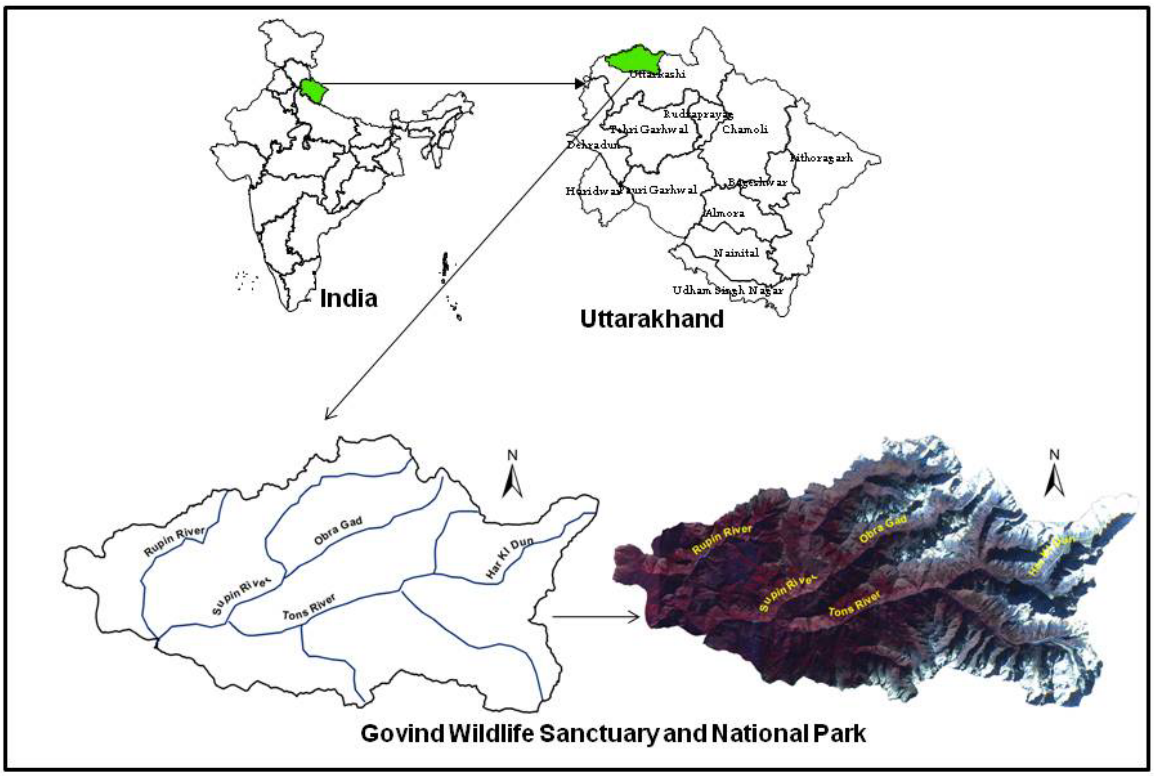

Fig. 1. Location map of the study area.

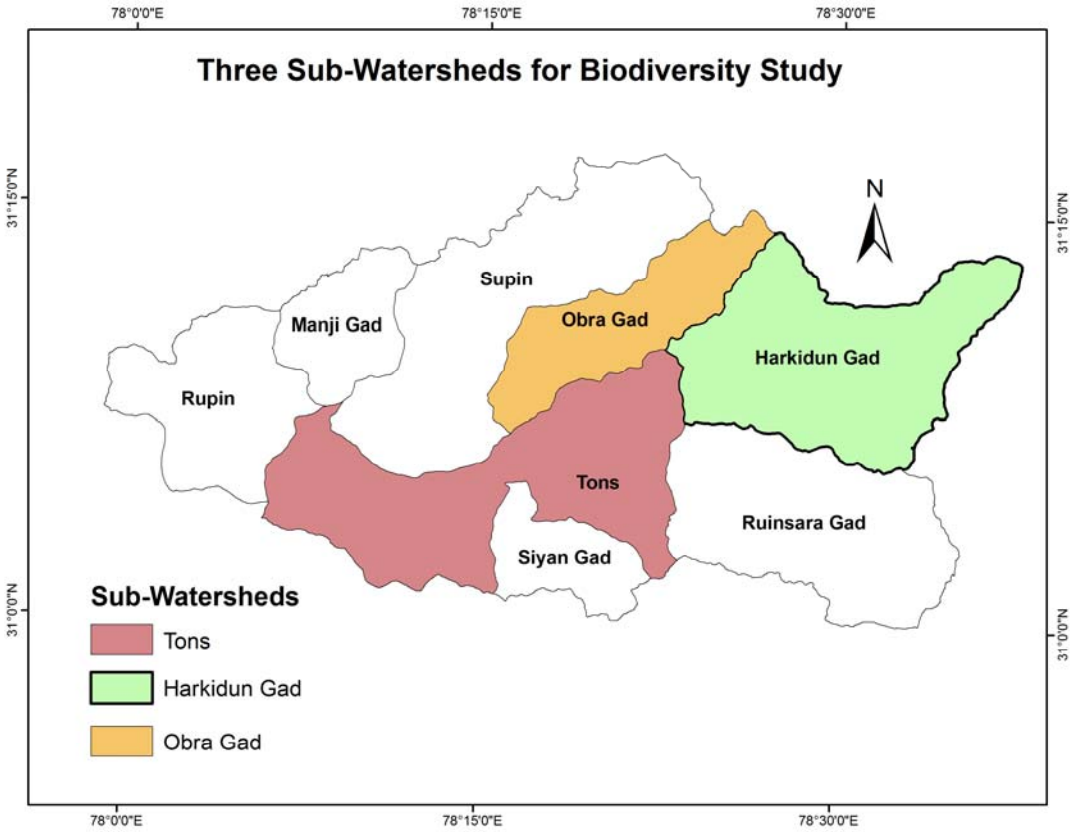

Fig. 2. Three sub-watersheds selected for the evaluation of ecological parameters.

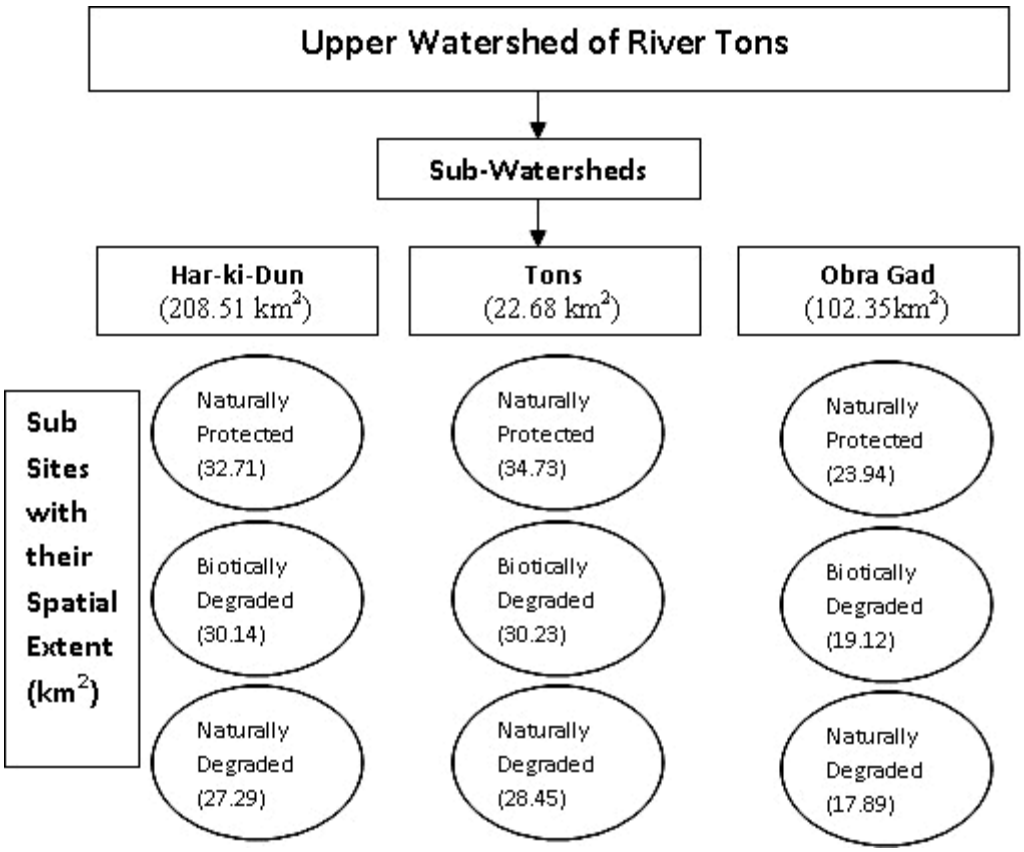

Fig. 3. Number of study sites and their spatial extent.

cover and absence of soil conservation measures and over grazing on the forest and meadow areas are the main reasons for soil erosion in this area.

Methodology

The land cover changes and fragmentation were calculated for the total area of Govind Wildlife Sanctuary and National Park but for the evaluation of ecological parameters, the field work was done in three watersheds only. To study the biodiversity status and the extent of degradation, we selected sub-sites i.e., two degraded and one intact site in each of the three selected sub-watersheds (SWS). The degraded sites were classified into the naturally degraded and biotically degraded due to natural disturbances and grazing, respectively. The two levels of degradation were selected on the basis of exhaustive survey and visual interpretation. The 'biotically degraded' site experienced grazing pressure and hectic tourist activities besides illegal extraction of medicinal and aromatic plants; the degradation was moderate. The 'naturally degraded' site experienced natural stress in the form of cloud burst, landslides with a high level of degradation. The relatively intact site due to inaccessibility and its remoteness was recognized as 'naturally protected'. Natural and biotically degraded sites identified in each SWS were investigated for their biodiversity status and ecosystem services and compared with relatively intact sites in respective SWS. Thus a total of nine sites were selected for this study (Fig. 3).

Vegetational analysis in various sub-sites selected within three SWS was carried out in the years 2004 to 2006 using 10 × 10 m quadrats for tree layer, 5 × 5 m quadrats for shrubs and 1 × 1 m quadrats for herbs following Misra (1968). Plant specimens were carefully collected, numbered and preserved in the field for each quadrat. Identification was done with the help of departmental herbarium as well as by consulting the herbarium of Botanical Survey of India, Northern Circle Herbarium**,** Dehradun and the Herbarium of Forest Research Institute, Dehradun. The vegetation data were used to determine the Shannon-Wiener diversity index (Shannon & Wiener 1963), Simpson Index of Dominance (Simpson 1949) and Species Evenness (Pielou 1966) of the plant communities by standard formulae.

Table 1. General Information about the three micro-watersheds (NP=Naturally Protected; ND=Naturally Degraded; BD=Biotically Degraded).

Sub-watersheds	Har-ki-Dun			Tons			Obra Gad		
	NP	ND	BD	NP	ND	BD	NP	ND	BD
Site Category/ Locations	31° 08' 57.9"N 78° 26' 03.4"E	31° 08' 37.1"N 78° 26' 45.7"E	3° 08' 59.6"N 78° 25' 46.1"E	31° 06' 59.4"N 78° 21' 05.5"E	31°0 06' 33.7"N 78° 19' 35.0"E	31° 06' 34.4"N 78° 19' 2.71"E	31° 08' 11.8"N 78°15' 11.8"E	31° 08' 37.1"N 78°15' 34.1"E	31° 06' 51.9"N 78°13' 51.9"E
	3496 m	3561 m	3519 m	2683 m	2483 m	2348 m	2657 m	2508 m	2627 m
Number of species	Tree- 00 Shrub-00 Herb-93	Tree-00 Shrub-00 Herb-72	Tree-00 Shrub-00 Herb-74	Tree-04 Shrub-04 Herb-42	Tree-07 Shrub-08 Herb-19	Tree-05 Shrub-04 Herb-35	Tree-05 Shrub-03 Herb-48	Tree-05 Shrub-03 Herb-00	Tree-02 Shrub-03 Herb-44
Dominant Taxa	*Pedicularis puncata, Phleum alpinum, Persicaria polystachya*	*Rumex acetosa, Myriactis wallichii, Geum elatum*	*Circium verutum, Impatiens racemosa, Rumex nepalensis*	*Quercus semicarpifolia, Rosa webbiana, Anaphalis triplinervis*	*Acer villosum, Rosa webbina, Fragaria vesca*	*Quercus dilatata, Viburnum nervosum, Poa annua*	*Alnus nepalensis, Hippophae salicifolia, Chareophyllum villosum*	*Alnus nepalensis, Rhododendron arboreum, Rosa webbiana*	*Acer villosum, Neolitsea umbrosa, Erigeron canadensis*
Canopy cover (%)	90	30	60	90	30	60	90	30	60
Disturbance level	Low	Very High	High	Low	Very High	High	Low	Very High	High

Table 2. Plant diversity, dominance and evenness data of the three SWS.

SWS	Protected			Naturally Degraded			Biotically Degraded		
	Tree	Shrub	Herb	Tree	Shrub	Herb	Tree	Shrub	Herb
Har-ki-Dun									
Shannon-Weiner's index of diversity	NR	NR	2.32 to 2.85	NR	NR	2.14 to 3.33	NR	NR	2.16 to 3.07
Simpson's index of dominance	NR	NR	0.09 to 0.28	NR	NR	0.04 to 0.21	NR	NR	0.07 to 0.11
Pielou's index of evenness	NR	NR	0.65 to 0.75	NR	NR	0.61 to 0.89	NR	NR	0.71 to 0.87
Tons									
Shannon-Weiner's index of diversity	0.61	1.12	3.04	0.66	1.62	2.45	0.95	2.02	1.75
Simpson's index of dominance	0.06	0.37	0.05	0.14	0.23	0.16	0.06	0.17	0.29
Pielou's index of evenness	0.44	0.81	0.87	0.60	0.91	0.69	0.59	0.84	0.59
Obra Gad									
Shannon-Weiner's index of diversity	0.94	0.59	2.53 to 3.29	0.55	1.08	NR	0.64	0.35	1.9 to 0.25
Simpson's index of dominance	0.47	0.62	0.03 to 0.08	0.36	0.35	NR	0.22	0.96	0.14 to 0.25
Pielou's index of evenness	0.59	0.54	0.93 to 0.94	1.12	0.98	NR	0.98	0.72	0.59 to 0.67

Forest fragmentation and degradation have been identified as fundamental causes for bio-diversity loss. Fragmentation of the forests was estimated by calculating the amount of forest patches occurring in a landscape with respect to non-forest patches using SPLAM software in Landsat TM image at 30 m spatial resolution. SPLAM is a semi-expert software developed by IIRS. It describes a set of GIS-based (Arc/Info) procedures, aimed at the estimate and analysis of areas, which were subjected to environmental dynamics, by computing landscape indices. The fragmentation image obtained was recoded to four levels of fragmentation as low, medium, high and very high excluding non-forest and snow classes and the area under respective level was calculated.

The ecosystem condition and services were assessed through the data (ecological and socio-economic parameters) collected during 2005 - 2007. The land - cover conversion was assessed using two-time satellite imagery of the landuse and land cover maps for 1994 and 2004 classified from Landsat TM images with 30 m spatial resolution of the study area. For classification of complex terrain, such as mountainous regions, with varied spectral response, independent supervised or unsupervised classification have their own limitations. In such conditions the combined use of supervised and unsupervised classification methods was used for proper landuse/ land cover classification (Alberti *et al*. 2004).

The floristic data collected was evaluated with the help of field study, literature and herbaria. The criterion for categorization of threatened species was based on the IUCN. Three disturbance levels, viz., low, high and very high were based on visual estimation. The threatened plants were confirmed after they were matched with 2008 IUCN Red List and Red Data Book. Door-to-door survey was carried out in seven villages (viz., Osla, Taluka, Datmer, Jakhol, Dhara and Sakri) falling in three SWS. People of these seven villages were interviewed using questionnaires to examine the resource availability and utilization and their views towards conservation. A list of NTFP found and used in the region was prepared by collecting the information from these surveys and consultations with forest officials.

Results

In Har-ki-Dun SWS a total of 93 plant species was reported in naturally protected sites. In this SWS no woody species was recorded, however, 74 and 72 herbaceous species were recorded in intact and biotically degraded sites, respectively. In Tons SWS, which is at a relatively lower altitude, 50 species in all were recorded in protected site, whereas 34 species in naturally degraded and 44 in biotically degraded site. In the naturally protected sites of Obra Gad SWS 56 species were recorded with 44 herb species in biotically degraded site and 48 herbaceous species in naturally protected sites (Table 1). No herb species was recorded in naturally degraded site of Obra Gad SWS.

Table 2 depicts the range of the species diversity, dominance and evenness of tree, shrubs and herbs. It has been observed that during succession species diversity increases, but towards maturity, or at a relatively stable state of the community, a few species assume dominance (McNaughton 1967). In the present study area, in naturally and biotically degraded sites at Har-ki-Dun SWS the diversity of herbs is more as compared to the naturally protected site in the same SWS. The diversity index values thus fall within the range reported for temperate forests (Risser & Rice 1971). The range of diversity was high on the disturbed sites due to disturbance and invasion by new species. Pandey & Singh (1985) have also reported increasing species diversity in disturbed ecosystem of Kumaon Himalaya. Tree species diversity within a habitat commonly decreases with altitude (Gentry 1988). In the present study also the tree diversity was found decreasing with altitude.

Disturbance and fragmentation are two strongly related processes. The fragmentation image obtained was classified into four levels for understanding the forested landscape pattern i.e., Low, Medium, High and Very High. Higher the numbers of forest and non-forest mosaic, higher are the levels of fragmentation. Among the forest classes the intact or low fragmented area constitutes about 538.12 km^2. The high fragmentation area accounted for 50.25 km^2 followed by very high fragmentation 12.11 km^2 and medium fragmentation 159.55 km^2. The image statistics shows that the non-forest area which included of agriculture snow, glacier, rock-outcrop and river was 411.67 km^2. The fragmentation map is shown in Fig. 4.

The changes of LUCC classes during the 1994 and 2004 are shown in Table 3. It is clear that there has been a considerable change during the 10 year period. The area under moderate dense forest and dense forest has decreased by 14.95 km^2

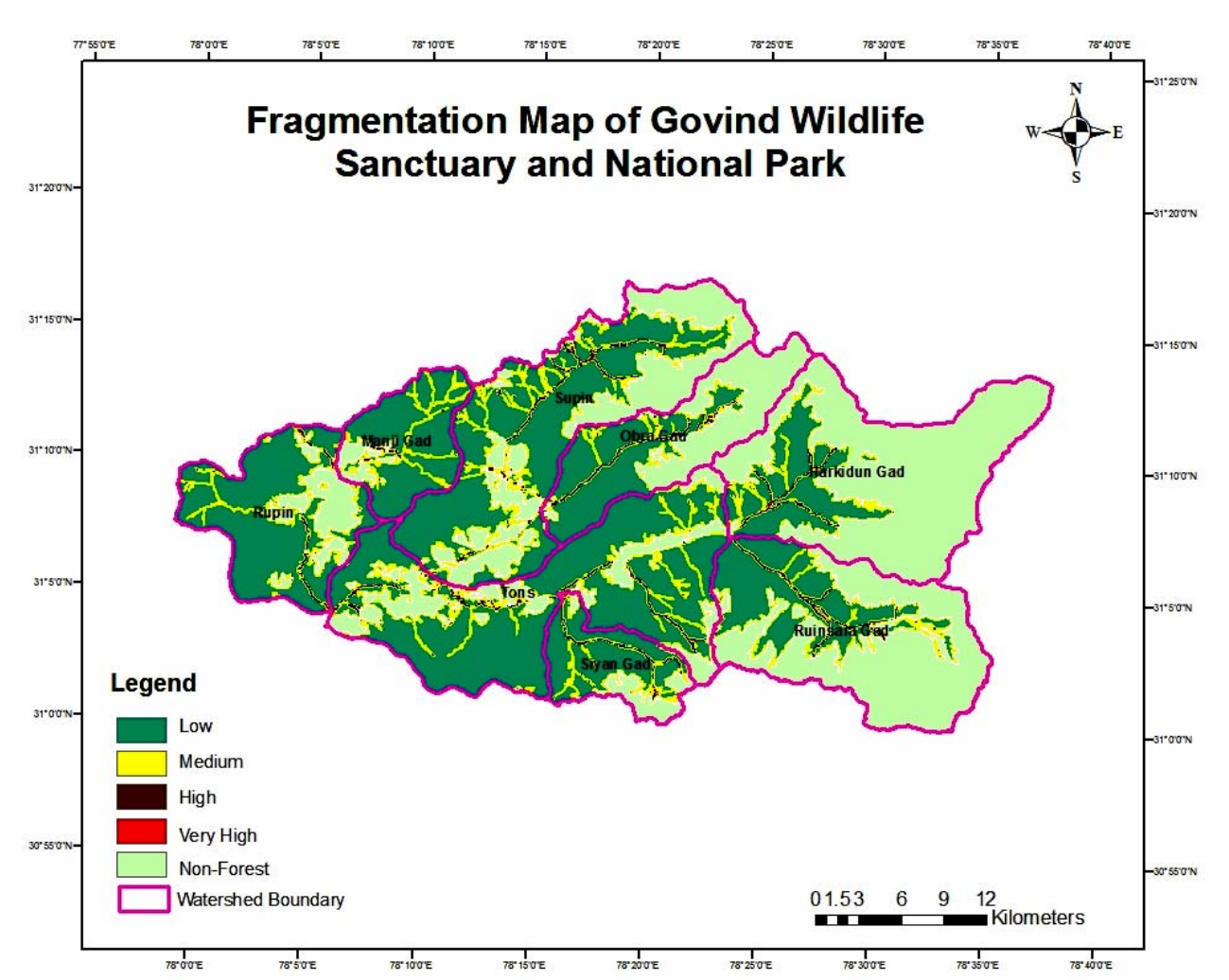

Fig. 4. Fragmentation image of the study area.

Table 3. Landuse/landcover classes change between 1994 and 2004 (area km²).

Class	Area (km²) 1994	Area (km²) 2004	Landuse/Landcover Change (km²)
Moderate dense forest	45.51	30.56	-14.95
Open forests	64.33	53.26	-11.07
Scrubs	13.73	26.94	+13.21
Dense forest	347.04	305.74	-41.3
Agriculture	71.02	93.14	+22.12
Snow	351.9	349.45	-2.45
River	12.63	13.11	+0.48
Rock outcrop	45.81	48.89	+3.08
Undisturbed grassland	157.27	147.84	-9.43
Moderately disturbed grassland	25.35	29.71	+4.36
Degraded grassland	15.97	33.72	+17.75
Severely degraded grassland	21.14	39.34	+18.20

Table 4. Threatened plant species of the study area.

Plant species	Family	Common name	Life-form	Plant part used	Status as per IUCN
Corydalis govaniana Wall.	Fumariaceae	Balsam jar	Herb	Root	Endangered
Nardostachys jatamansi D.Don Dc.	Valerianaceae	Jatamasi	Herb	Rhizome	Endangered
Podophyllum hexandrum Royle	Podophyllaceae	Vankakari	Herb	Root	Endangered
Aconitum heterophyllum Wall. ex Royle	Ranunculaceae	Atis	Herb	Root	Vulnerable
Delphinium brunonianum Royle	Ranunculaceae	Ativisha	Herb	Root	Vulnerable
Picrorrhiza kurrooa Royle ex Benth	Scrophulariaceae	Kutki	Herb	Root	Vulnerable
Astragalus chlorostachys Lindley	Fabaceae	Milk vetch	Herb	Root	Rare
Taxus baccata Linn. sub. sp. *wallichiana* (Zucc.) Pilger	Taxaceae	Birmi	Tree	Barks and Leaves	Rare
Galium acutum Edgen.	Rubiaceae	Kura	Herb	Plant extract	Rare
Jurinea dolomiaea Boiss	Asteraceae	Guggal	Herb	Root and leaves	Rare

and 41.3 km^2 respectively in year 2004, whereas a visible increase in agriculture and scrub areas i.e. 22.12 km^2 and 13.21 km^2, respectively is observed in year 2004.

The study area is biologically rich and it offers unique habitats to sustain several endemic and rare plant taxa. Their number is shrinking, due to grazing and illegal harvesting of medicinal plants, over-exploitation, informal supply chain, population pressure and absence of scientific system of collection, various plants have come under the threatened category of IUCN. Table 4 presents information on 3 endangered, 3 vulnerable and 4 rare plant species listed from the study site. Their exploitation level was evaluated on the basis of field visits and discussion with locals. All the threatened species are restricted to narrow altitudinal ranges.

It can be stated that in the study area the moderate rate of change in the land cover categories as depicted in the two time satellite imagery data analysis for a difference of ten years has certain bearing on the ecosystem services. The native flora is being intensively replaced at a high rate by invasive species of *Impatiens* and *Rumex*, as inferred through the regular field visits in the study area. 12.11 km^2 area was under very high level of forest fragmentation and 538.12 km^2 under low fragmentation. This analysis depicts that the rate of vegetation change is medium. Various species have come under threatened categories at an alarming rate. A number of timber species and NTFP species were recorded at the study sites (a total of 173 NTFP species), among them 112 species were found at Har-ki-Dun (including all species collected during the field survey), 30 species at Tons and 17 species at Obra Gad SWS. The results indicate that the study area provides valuable ecosystem services and is rich in biodiversity but at the same time, it is under stress due to various pressures, and immediate feasible conservation plans are required to save this fragile ecosystem. The occurrence of rainfall has decreased in the area in last five years and frequency of landslide has increased in last ten years as inferred during the socio economic survey. The ecosystem services are affected in almost all the degraded sites, however, severe effect was observed in naturally degraded sites. Invasive, opportunistic and non-palatable plant species have replaced the local floristic elements greatly.

Discussion

In the study area the loss of biodiversity has resulted both due to natural factors and changes in land use patterns and overexploitation of natural resources, which has ultimately resulted in the invasion by weeds replacing native flora. Local people depend mostly on agriculture and animal

husbandry and the agricultural activities occur up to about 2700 m altitude. Large part of their livelihood depends upon the pastoral activity for which they utilize the natural resources for their livestock grazing and thus add to the degradation. The alpine meadows in watershed have extensively been used for grazing. Moreover the loss of flora due to biotic and abiotic pressures has enhanced soil degradation. The biotic degradation in all the three SWS has accelerated with the change in landuse and increase in the intensity of biotic pressure. Human disturbances have greatly influenced and increased the rhythms of natural disturbances in the study area. Results of this study indicated that during the last 10 years, the vegetal cover has undergone significant changes with increasing population pressure (both human and animal), increase in agricultural land and over exploitation of forest resources that has altered the natural landscape to a great extent. This in turn has led to increased incidents of hazards such as mass movement and soil erosion in the Tons valley.

Reforestation and reclamation of degraded areas with appropriate vegetative cover can reduce loss of biodiversity and ecosystem services. There is a need to characterize the livelihood strategies and to provide governance support to many low-income forest-dependent rural communities in the area. The diversity of income-generating activities should be designed to cover various types of needs like engaging in tree planting and forest management to compensate for the loss of biodiversity and degradation of natural forests and help in achieving the ecosystem balance. Degradation can be managed by caring, managing and improving the natural resources (Hudson 1995). To conserve the biodiversity and ecosystem services, the management of human interactions with the variety of life forms has to be done on sustainable basis to maximize the benefits they provide today and maintain their potential needs for future generations. The study area is suitable habitat for various NTFPs. The potential taxa, such as species of *Aconitum, Delphinium, Jurinea, Juniperus*, *Berberis, Corydalis, Gentiana, Hippophae* and *Rhododendron* can be commercialized under scientific guidance. Products can be marketed with a premium on the prices for biodiversity conservation. Therefore, sustainable management practices with the alternatives for livelihoods of the villagers residing in the area should be given a considerate thought, and to include them in several management schemes to provide the social protection which will certainly help the resilience of ecosystem and will save the potential ecosystem goods as well as the services for the region.

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