Biodiversity and Conservation (2006) 15:4253–4270
DOI 10.1007/s10531-005-3578-y

Biodiversity characterization in Nubra Valley, Ladakh with special reference to plant resource conservation and bioprospecting

P.K. JOSHI[1,]*, G.S. RAWAT[2], H. PADILYA[1] and P.S. ROY[3]
*[1]Indian Institute of Remote Sensing (NRSA), 4 Kalidas Road, Dehradun 248001, Uttaranchal, India; [2]Wildlife Institute of India, Post Bag #18, Chandrabani, Dehradun 248001, Uttaranchal, India; [3]National Remote Sensing Agency (NRSA), Balanagar, Hyderabad 500 037, Andhra Pradesh, India; *Author for correspondence (e-mail: pkjoshi27@hotmail.com; phone: +91-135-2744518)*

Received 12 October 2004; accepted in revised form 27 September 2005

Key words: Biodiversity, Biopropecting, Nubra valley, Plant resource

Abstract. Trans-Himalayan mountains, owing to harsh climatic conditions and a short growing season support low vegetation cover (<20%), yet it is known to harbour a unique assemblage of flora and fauna which have not been systematically inventoried and documented so far. This paper deals with spatial and non-spatial information on landscape units, vegetation characteristics and plant species diversity of Nubra Valley in Ladakh, India. Based on digital – visual (on screen) interpretation of remote sensing data coupled with knowledge-based classification we delineated 19 cover classes (11 vegetation types and 8 non-vegetation categories). The vascular plants (angiosperms and gymnosperms) were systematically collected using stratified random sampling of different landscape/vegetation to characterize plant communities and assess the distribution patterns of species. The study reveals that nearly 78–80% of plant species in Nubra are restricted to the valley bottoms. In all, 414 species of vascular plants were recorded from the study area. These belongs to 56 families and 202 genera. Of these, 102 species were reported to be used in traditional system of medicine by Amchis over 80 species are largely associated with cultivated fields and human habitation. As many as 49 species were cultivated which include several varieties of crop plants especially those of barley and buckwheat. Aspects of bioprospecting and conservation of valuable species have been discussed.

Introduction

The Convention on Biological Diversity under its article 7 has stressed that the signatories shall, as far as possible and as appropriate, identify components of biodiversity important for conservation and sustainable use, and monitor them. India being the signatory of the convention has taken several initiatives in this direction. Identification of all the components of biodiversity and their quantification, is however, a daunting task and needs enormous effort. Various approaches and strategies have been suggested for the measurement of biodiversity at different levels and scales (Singh et al. 1994). One of the approaches is assessing the pattern diversity and mosaic diversity at landscape level (Scheiner 1992; Roy and Tomar 2000). Landscape complexity can be measured using mosaic diversity which is a function of two properties of species patterns viz., the variation in species richness among the communities and variation in commonness or rarity among species (evenness). It is well established that the patterns of landscape elements can be used effectively in predicting the distribution and abundance of species (Ravan and Roy 1997; Griffiths and Eversham 2000).

The patterns of biodiversity (high or low) determine the state of ecosystem stability and resource use pattern of the local inhabitants. This calls for proper inventory and analysis of broad patterns of species distribution across a wider landscape. It is therefore, imperative to analyze all crucial issues related with biodiversity conservation and management in a holistic manner by considering biodiversity and nature conservation as one of the integral components of overall land use policy, so as to evolve realistic and integrated framework for the management of these regions and biodiversity as well as for sustainable development of communities. This clearly underlines the need for evolving a natural resources information system through scientific and detailed analysis, and mapping of the multiple dimensions of natural resources (Stork et al. 1996).

With the recent advancements in the satellite remote sensing techniques and development of sophisticated tools for the analysis of spatial and non-spatial data our ability to quantify various attributes of biodiversity has increased tremendously (Kasturirangan 2001). The digital nature of land cover information from the satellite imageries allows us to analyze the landscape matrices and provides information at various spatio-temporal scales. Using a combination of spectral features and ground information on species diversity, distribution and dominance it is possible to generate spatial databases on various parameters of biodiversity (e.g., Roy et al. 2001; Porwal et al. 2002; (Anonymous 2002)) in GIS domain. Need for creation of Biodiversity Information System and other databases has also been stressed (Pillai 1994; Saran et al. 2003). Such databases can be of immense help in future monitoring of bioresources as well as for a wide variety of applications.

So far most of the studies have been conducted in the zones of biodiversity hotspots. However, the cold arid areas lying in the Indian Trans-Himalaya have not received adequate attention. This area falls under Zone I of India's biogeographic classification (Rodgers and Panwar 1988). It is characterized by extremely varying day and night temperatures (mean minimum of winter dropping as low as 48 °C), high aridity, thin and nutrient poor soil, and short growing season. The vegetation of this zone is characterized by scattered low bushes, sparsely covered tussock grasslands, herbaceous formations, sedge meadows and stony deserts with cushion like growth forms.

These are not only ecologically sensitive but also economically most backward. There are very few livelihood options available for the local inhabitants. Consequently, the activities of cultivation, grazing and at other resource use patterns have reached to a critical stage. Although this area is considered impoverished in terms of biodiversity compared to the main Himalayan range, it represents characteristic elements from the adjacent biogeographic regions. Therefore, it is pertinent to document the patterns of plant resource distribution and current use patterns so as to evolve suitable land use policies.

Objectives

The objectives of the present study include

i. To generate landscape and vegetation cover map for the Nubra valley using Satellite Remote Sensing data,
ii. To assess the floral diversity including in various landscape units and document the distribution and abundance of medicinal and aromatic plants, and species of other importance for bioprospecting.

Study area

The Nubra valley in Ladakh comprises the Valley of Shyok River from its acute-angled bend down to its confluence with Nubra and further towards Indus. This area lies between two great mountain ranges i.e., Ladakh (on the south) and Karakoram (on the north) (approximately 34°15′45″ to 35°30′ N lat. and 76°55′ to 78°05′ E long). The location of study area is shown in Figure 1. The valley portion of Nubra is wide and well vegetated with thickets of seabuckthorn – a thorny shrub which the villagers use for fuel and for fencing their fields compared to mountain slopes and remaining part of Ladakh district. The villages are large and have thick plantations of willow and popular. The cultivated area is spread between 2730 and 3300 m asl. The major food crops grown in the valley are barley (several varieties), wheat, buckwheat, millets, pea, potato, and mustard. In recent years these people have been encouraged to cultivate more vegetables such as onion, cabbage, cauliflower, knol – khol, tomato, radish, turnip, carrot and coriander both for self consumption and for sale to the government employees including the defense personnel. This adds to their cash income. In addition, most of the farmers grow a fodder crop i.e., alfalfa vern *Ol* (*Medicago sativa* and *M. lupulina*) for their livestock and sale. The altitude of the study area ranges approximately between 2700 and 6000 m asl. Climate of the study area is cold arid type with scanty and erratic precipitation (<80 mm per annum) and temperature below zero to as high as 38 °C. It supports an extensive and dense growth of a thorny shrub i.e., seabuckthorn (*Hippophae rhamnoides* subsp. *turkestanica*). Another shrub *Myricaria germanica* grows in profusion along the stream courses of side valleys and is often associated with *Hippophae*.

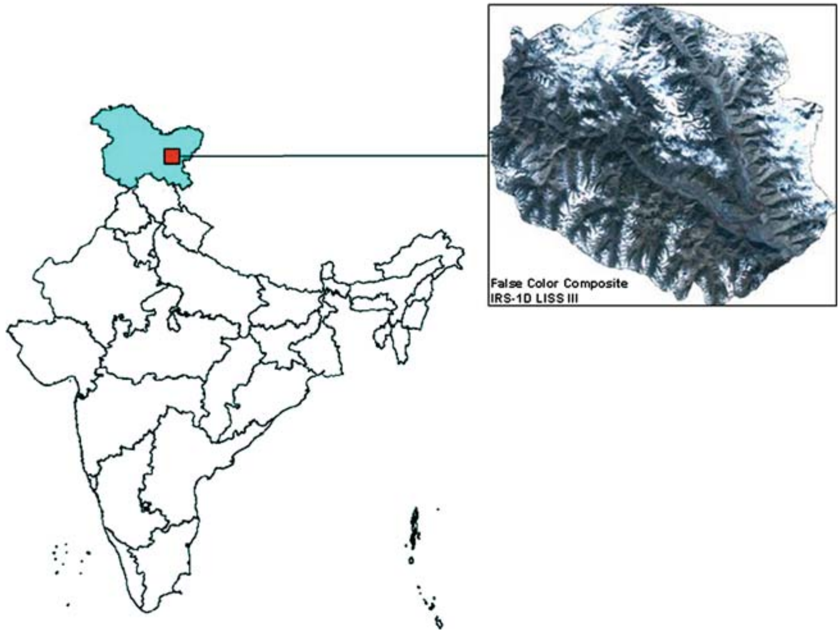

Figure 1. The location of study area and False Colour Composite (FCC) of IRS-1D LISS III.

Material and methods

Remote sensing and ancillary data

The IRS – 1D LISS III digital data set (path/row 96/45) is used in the present study. The sensor provides data in four bands: two bands in visible (green: 0.52–0.59 microns and red: 0.62–0.68 microns), one in near infrared (NIR: 0.77–0.86 microns) with a spatial resolution of 23.5 m and one in short wave infrared (SWIR: 1.55–1.70 microns) with spatial resolution of 70.5 m. The data used were acquired on October 2001. False colour composite (IRS 1D LISS III) of Nubra valley is shown in Figure 1. In addition, the topographic maps were used to generate the ancillary layers and ground work.

Satellite data preprocessing

The radiometric correction was carried out over the raw data sets using the first order dark pixel subtraction technique. The geometric correction was done using topographic maps as reference. The uniformly distributed common Ground Control Points (GCPs) were marked with root mean square error of 0.3 pixel and the image was resampled by cubic convolution method.

Ground truthing

The field survey was undertaken to get acquainted with the general patterns of vegetation and habitat types of the area. Major cover types and few prime localities of the characteristic types were recorded. The image elements were correlated with the ground truth realities and the interpretation key was developed. The variation and tonal patterns were observed on existing maps/ images. Traverse along the major roads, drainage and hilltops were made for collecting ground information. An existing literature survey and interaction with local institutions was also made for collecting the existing knowledge base.

Land cover mapping

In mountain area, especially in the Himalayas due to the terrain complexity, the spectrum signature is influenced by the elevation, the aspect and slope, which might have same objectives showing different reflectance or the different objectives could have the same reflectance. In this situation, using the intensive ground truth, on screen visual interpretation is employed. The interpretation key for the land cover classification is given in Table 1. The enhancement techniques viz., NDVI, PCA and contrast stretching were used to enhance the classes and interpretation. Some of the classes of vegetation, which may be unique to some region and are not deciphered properly, need to be improved by interactive editing through conjunctive use of physiographic data on non-spectral analysis basis. The classification performance was evaluated by field sample points based on the error matrix.

Quantification of vegetation and floral diversity

Systematic survey of vegetation across various landscape units was conducted in the study area covering a wide altitudinal range (2800–5400 m) along the valleys of Nubra, Shyok, Hunder Dok and Sumoor Fu as well as adjacent slopes. The plant species were recorded systematically and vouchers collected from all the habitats and landforms during May–August 2002 with the help of a local field assistant. Pertinent literature viz., Kachroo et al. (1977); Polunin and Stainton (1990); Aswal and Mehrotra (1997) and Murty (2001) were used for identification of plants. Voucher specimens were confirmed with regional herbaria at Dehradun. Plants collected from the area (herbarium sheets) were also shown to the local *Amchis* to get information on the medicinal use, medical names and availability of the species in the study area.

Distinct landscape units identified based on remote sensing data were used as primary and secondary strata. Within each landscape unit random quadrates of 1 m^2 (10 at each site) were laid to quantify herbaceous vegetation following standard methods (Mueller-Dombois and Ellenberg 1974; Kent and Coker

Table 1. Interpretation key for the land cover mapping in Nubra Valley.

Class	Tone	Texture	Shape	Association	Phenology
Hippophae scrub	Blood red	Coarse	Irregular	River bed	Green/flowering
Hippophae–Myricaria (mixed scrub)	Reddish/orange	Coarse	Irregular	River bed	Green/flowering
Myricaria scrub	Red light	Coarse	Irregular	River bed	Green
Ephedra scrub	Reddish	Medium coarse	Irregular patches	Alluvial fans/rocky slopes	Green/flowering
Lycium–Tamarix scrub			Irregular patches	Alluvial fans/rocky slopes	Green/flowering
Herbaceous meadows	Light red	Smooth	Geometrical polygon	High altitudes	Green
Sedge meadows	Greenish smooth	Smooth	Geometrical polygon	Valley bottoms/river beds	Green
Plantation (willow poplar)	Orange	Medium smooth	Rectangular	Habitation	Green
Agriculture/plantation	Red	Coarse	Rectangular	Habitation	Ploughed/green
Agriculture	Pink–red	Smooth	Rectangular	Habitation	Green
Rocky slopes	Creamy-white	Coarse	Irregular	High altitudes	×
Hard rocky slopes	Black–brown	Smooth	Irregular	Very high altitudes	×
Scree slopes	Slaty-brown	Coarse smooth	Irregular	Hills near valleys	×
Alluvial fans *(Lycium/Epherdra)*	Creamy	Medium smooth	Conic structure	Near valley bottom/river beds	×/Green/flowering
Snow/glaciers	White–Cyan	Smooth	Irregular	High ridges	×
River bed	Cyan	Smooth	Linear	Valley bottom	×
Water body	Blue–Black	Smooth	Linear	Valley bottom	×
Cloud	Clear white	Smooth	Irregular	High hills/hills near	×

1992). For the riverine scrub circular plots of 5 m radius (78.5 m^2 area) were laid randomly (10 at each site). At each sample site altitude, geographical coordinates using Global Positioning System (GPS), aspect, terrain, soil type, and vegetation cover information were recorded. The data on the abundance (number) of individual species were recorded within each quadrate along with their approximate % cover. Percent cover of mosses, lichens, rocks and soil was also recorded within the quadrates (Table 2).

Species diversity was calculated using Shannon–Wiener index (H'). Total number of species recorded within 10 quadrates/circular plots at each site was taken as richness. Evenness of the stand (relative proportion of species) was estimated following Maguran (1988), using an index J ($J = H'/\log S$), where $S =$ total number of species in a stand. Availability of medicinal plants in various landscape units was compared using Prominence Value Index (Dinerstein 1979) as Prominence Value = % Cover × √% Frequency. Prominence Value Index allows comparison of relative importance of species in a stand similar to Importance Value Index, which is used to compare the dominance of tree species in forest vegetation.

Results

Land cover

The visual interpretation of the satellite data with the strong ground truth was used to map the different land cover classes. The land use land cover map is shown in Figure 2. For some of the classes *a priori* knowledge was used to delineate the different landscape units. At this resolution many of the land cover features encountered in field could not be mapped. A brief description of the land cover features mapped is given in Table 3. For the delineation of the above classes altitudinal gradient and aspect was used. All the habitats observed during the field visit could not mapped because of complex topography and limited resolution of the satellite data. Summer camping sites of local herders, who exploit the higher altitude herbaceous medows, could not be

Table 2. The number of sites sampled under each landscape unit and number of quadrates/plots.

S.No.	Landscape units	No. of Sites	No. of quadrates/plots
1.	Fell fields	2	20
2.	Herbaceous meadows	9	90
3.	Dry scrub on the plateau	16	160
4.	Scrub on alluvial fans	10	100
5.	Riverrine scrub	7	70
6.	Marsh meadow	3	30
7.	Plantations	3	30
8.	Other area	6	60
	Total	56	560

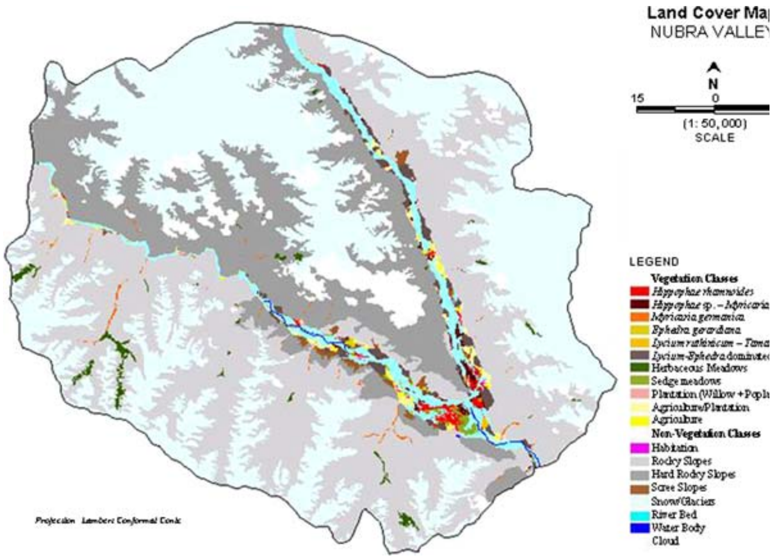

Figure 2. The land use land cover map of Nubra Valley (IRS – 1D LISS III ~ October 2001).

mapped because was resolution limit. Moreover, the patches are highly diluted and scattered to provide any unique reflectance other than rocky slopes. The drainage pattern was helpful in delineating different categories of vegetation. The high-resolution satellite data along with the topographic information and geological control can be used for detailed inventory using remote sensing data.

Analysis of the vegetation and floral diversity

Extensive collection of plants during May–August, and systematic enumeration during intensive sampling of various landscape units yielded 414 species of vascular plants (angiosperms and gymnosperms) in the study area that belonged to 56 families and 202 genera. The number of species in dicots, monocots and gymnosperms were 297, 115 and 2, respectively (Table 4).

The largest families of flowering plants in the study area include Poaceae (58 species), Asteraceae (44), Cyperaceae (28), Brassicaceae (26), Rosaceae (21), Fabaceae (17) and Polygonaceae (14). The families with single genus and species in Nubra Valley include Plumbaginaceae, Capparidaceae, Santalaceae, Ephedraceae, Cupressaceae, Iridaceae, Orobanchaceae, Parnassiaceae, Grossulariaceae, Lentibulariaceae, Ulmaceae, and Zanichelliaceae. *Carex, Potentilla, Kobresia, Oxytropis, Poa, Polygonum, Saxifraga, Saussurea*, *Salix* and *Ranunculus* are the common genera having >5 species each. Categorized by habits 261 species belonged herbs, 33 shrubs, 2 climbers, 87 graminoids

Table 3. Area covered under different land cover type in Nubra Valley.

S.No.	Land use/land cover classes	Description
Vegetation class		
1	*Hippophae rhamnoides* (0.34)	It forms the riverine scrub and occupies wide river bed areas with good growth at the confluence zone of rivers
2	*Hippophae–Myricaria* mixed Scrub (0.19)	This type is characterized by mixed formations of *Hippophae rhamnoides* and *Myricaria germanica*. Other species viz. *Tamarix gallica* and *Phragmites australis* are found as the associates in some areas
3	*Myricaria germanical* (0.17)	It is found growing mainly along the water courses. Thus forming pure population in river bed as well as climbs up to altitude of 4000 m where it follows the course of small rivulets.
4	*Ephedra gerardiana* (0.03)	It forms one of the categories of dry scrub vegetation and found in the alluvial fans at the valley bottom and the dry plateau in high altitude
5	Alluvial forms with sparse vegetation (0.84)	This plant community occupies the undulating areas in the valley bottom along the gradients of dry sand dunes to flat, seasonally inundated sand beds
6	*Lycium–Ephedra* scrub (0.03)	This community is largely found along the alluvial fans, especially along the deposits of sand and weathered rocks indicating the well drained soils
7	Herbaceous meadows (0.30)	This category is largely found at the higher altitudes between 4000 and 4500 m asl. These are the areas invariably occupied by herders to graze livestock during summer
8	Sedge meadows (0.21)	These are found in the flat valley bottoms adjacent to river courses. These area are used as the grazing lands by the local communities and are often protected using throny bushes of *Hippophae* during summer
9	Plantation (willows + poplar) (0.07)	Mixture of two widely grown species of plantation in Nubra valley reflects orange red tone and course texture. The plantations are generally found in the valleys and river bottoms. Some associate species along with the plantations are *Myricaria* and *Hippophae*
10	Agriculture/plantation (0.48)	Plantation patches in valley are not very regular in shape and found intermixed with agriculture. To overcome this intermixing one combined class of plantation and agriculture has been made and delineated on the basis of intermixing tone of agriculture and plantation
11	Agriculture (0.14)	This class comes in dull grey color tone due to the off season, and has been associated with habitation mainly and near the water courses on the alluvial fans
Non-vegetation classes		
12	Habitation (0.02)	Distribution of settlement in valley landscape is scattered and only few polygon of crowded settlements has been mapped based on cyan tone and rough texture

Table 3. (Continued.)

S.No.	Land use/land cover classes	Description
13	Rock genera (34.45)	General rock type reflects light gray to slightly darker shade due to variations aspect, geological formations and widespread erosion pattern. Further delineation in this class has not been attempted
14	Hard rocks (18.04)	Valley facing slopes of hard rock has been mapped based on their dark salty color and smooth texture
15	Scree slopes (0.25)	It is found facing the valley side and reflects creamy-white tone
16	Snow/glacier (38.29)	It is found above 5000 m asl and reflects white tone with smooth texture. The moraines and freshly fallen snow could be demarcated. But keeping the minimum mapable unit in consideration certain features clearly accounted during field were merged with this class.
17	Riverbed (boulder + sand) (3.08)	It reflects cyan color tone with smooth texture in sandy areas while coarse texture in pebbly or boulder areas
18	River	It reflects blue tone with smooth texture. The major drainage of the Shyok and Nubra could only be delineated. Though the different orders of the drainage are clearly visible on the satellite data but the areas under the minimum mapable unit has been shown in the land cover map
19	Cloud (3.06)	The low altitude clouds are the general problems in the valley areas. The Nubra valley is covered with the fragmented could patches in the entire area

Percentage area in parenthesis.

Table 4. Analysis of the vascular flora recorded from Nubra Valley, Ladakh.

Group	# Families	# Genera	# Species
Dicotyledons	45	155	297
Monocotyledons	9	45	115
Gymnosperms	2	2	2
Total	56	202	414

(grasses, sedges and rushes) and 13 trees. Almost all the tree species (13) have been planted around cultivated fields and along irrigated channels in the valley bottom (below 3300 m a.s.l).

The following species are 'endemic' or 'near endemic' to Nubra and adjacent ranges of Ladakh: *Corydalis adiantifolia, Astragalus oxydon, A. tribulifolius, Inula rhizocephala, Saussurea thomsonii, Senecio tibeticus, Braya aenea, Waldhemia vestita* and *Acantholimon lycopodioides*. The following species have affinity with the hot deserts of western India: *Peganum harmala, Tribulus terrestris, Capparis himalayensis, Ephedra gerardiana, Eragrostis pilosa, Kochia* spp. A large number (nearly 30%) of species are confined to agricultural fields in the valley bottom and represent recently introduced flora. Several species exhibit stronger affinity with the flora of Pamirs and Afghanistan rather than rest of the Himalayan mountains, e.g., *Berberis ulicina, B. zabeliana, Clematis orientalis, Matthiola odoratissima, Nepeta floccosa, Atriplex hortensis, Hippophae rhamnoides* ssp. *turkestanica*, and *Kochia* spp. Similarly, a majority of species show close affinity with the flora of Tibet, e.g., *Stachys tibetica, Elsholtzia desna, Lindelofia anchusoides, Tanacetum tibeticum, Hippuris vulgaris, Ranunculus pulchellus, Artemisia gmelinii, A. maritima, Stipa jacquemontii*, and *S. splendens* to name a few.

Species diversity, richness and evenness of major vegetation classes are given in Table 5. Herbaceous meadows (HM) on the gentle slopes had higher species diversity (1.2–2.29) and richness (14–21) compared to all other vegetation classes. Highest diversity ($H' = 2.29$) was recorded in a HM near North Polu

Table 5. Diversity, evenness and richness of major vegetation classes in Nubra Valley.

Vegetation type	% Ground cover	Diversity (H')	Evenness	Richness
FF	10–26	2.08–2.23	0.77–0.83	13–18
HM	35–75	1.2–2.29	0.48–0.75	14–21
DSP	6–90	1.1–2.19	0.43–0.80	5–15
AFS	2–48	0.11–1.34	0.17–0.62	2–12
RSH	18–90	0.30–0.90	0.21–0.80	3–5
RSM	22–49	0.55–0.68	0.50–0.99	2–4
SM	27–86	0.72–1.92	0.32–0.72	5–16
PL	23–68	0.06–0.66	0.05–0.86	2–4
EDS	5–13	0.0–0.68	0.0–0.74	1–4

Vegetation types: FF, fell fields; HM, herbaceous meadows; DSP, dry scrub on plateau; AFS, alluvial fan with sparse scrub; RSM, riverine scrub – *Myricaria*; SM, sedge meadows; PL, plantations; EDS, dry scrub on eroded slope.

at an altitude of 4770 m asl on a gentle (15°) North-west facing slope. Interestingly, the fell fields (FF) adjacent to the herbaceous meadows had second highest range of species diversity (2.08–2.23) and richness (13–18). Least diversity was observed on scree slopes and on lower eroded slopes (0.0–0.68). Riverine scrub – *Myricaria*, plantations and FF exhibited higher evenness compared to all other vegetation classes. Highest cover of vegetation (18–90%) was observed in riverine scrub – *Hippophae* followed by sedge meadows (27–86%) and HM (35–75%). Stream/river courses and areas adjacent to snow banks harbour considerable ground cover. Dry scrub on the plateau had higher species richness compared to riverine scrub. Eroded dry slopes close to valley bottoms and alluvial fans without irrigation channels supported lowest cover of vegetation, species diversity and richness.

Herbaceous meadows closer to snow banks also supported higher moss and lichen cover compared to all other vegetation types. Mosses and lichens were completely absent in alluvial fans, dry scrub on the plateau, and riverbeds. It is noteworthy that the agricultural fields and herbaceous meadows combined together supported nearly 50% of the total flora reported from the study area. Dry scrub on the plateau, fell fields, sedge meadows, and riverine mixed scrub were other areas of high species richness. Thus, altitude determines the growth forms, soil moisture and soil depth played major role in determining the species diversity and richness.

Bioprospecting and conservation of floral diversity

The major plant resources in the study area are medicinal and aromatic plants (MAPs), native crop varieties and their wild relatives, species of horticultural importance, fodder grasses and sedges, and several species of ethno-botanical importance. Despite an extremely harsh and arid environment the study area has a relatively rich diversity of wild and domesticated plants that would need long-term plan for conservation.

Medicinal plants for bioprospecting

At present there are just 6–7 practicing *Amchis* in the valley. Of the 414 species of vascular plants recorded from the study area during 4 months (May–August), 102 species were used in traditional system of medicine. Major plant parts used in the preparation of medicine and treatment were leaves (28), young shoots (20), roots (15), rhizomes and tubers (8), seeds and fruits (11), flowers (9), whole plant (8) and stem (2). It was found that *Amchis* used combination of several species for the treatment of single ailment. As many as 17 species were used (in various combinations) in the treatment of fever. Number of species used in septics, cough and cold and indigestion were 15, 11 and 10, respectively. Two species each were used in the treatment of heart disease, diarrhoea, headache, skin diseases, arthritis and eye diseases. One species each was used to cure the ailments related to ear, liver, burns, piles, chickenpox and back-ache.

Some of the rare and threatened species of medicinal plants (listed in various threat categories of Indian Red Data Book) used by *Amchis* in Nubra area include *Aconitum violaceum* (Critically Endangered – CR), *Arnebia euchroma* (Endangered – E), *Artemisia maritima* (E), *Dactylorhiza hatagirea* (CR), *Hippophae rhamnoides* (Low risk, not threatened; LR-NT), *Hyoscyamus niger* (LR-NT), *Juniperus recurva* (Rare – R), *Lancea tibetica* (R), *Meconopsis aculeata* (CR), *Physochlaina praealta* (Vulnerable – Vu), *Rheum speciforme* (Vu), *Saussurea bracteata* (R), *Saussurea gnaphaloides* (R), and *Saussurea obvallata* (Vu). Of the 102 species of medicinal plants recorded in the study area only 25 species could be obtained within the sampling plots. The vegetation types, mean cover of these species within the sample plots and their prominence value at various sites are given in Table 6. The higher prominence value of the species indicates greater cover and availability. Of all the species, *Ephedra gerardiana* had highest frequency and prominence value (0.2–92) within the study locations. Herbaceous species such as *Aster flaccidus, Dracocephalum heterophyllum, Gentiana carinata, Lancea tibetica, Lloydea serotina, Plantago depressa, Rhodiola heterodonta* and *Taraxacum officinale* had relatively low cover and prominence value. Most frequently used species viz., *Dactylorhiza hatagirea, Scrophularia scabiosaefolia, Aconitum violaceum, Inula rhizocephala* and *Hyoscyamus niger* were not encountered within the sample plots.

Agribiodiversity

Owing to harsh climatic conditions and lack of irrigation facilities it is possible to cultivate only one crop in a year. At present over 50 species and several varieties of a few species are under cultivation in the study area. Traditional food crops in the valley include buckwheat (*Fagopyrum tataricum* and *F. esculentum*), millet (*Panicum miliaceum*), several varieties of naked barley or grim (*Hordeum aegiceras*), barley (*Hordeum vulgare*), and oat (*Avena sativa*). The Government of Jammu & Kashmir, especially Department of Agriculture Development and Field Research Laboratory (FRL) of Defence Research and Development Organization have recently (after 1980) introduced a large number of vegetable and other species of horticultural and ornamental values. The species commonly cultivated in the valley at present include: *Allium cepa, Allium stracheyi, Coriandrum sativum, Carum carvii* (spices); *Althea rosea, Rosa indica, Rosa* spp. *Amaranthus caudatus, Dahlia variabilis, Digitalis purpurea, Solidago canadensis, Tagetes erecta, Zinnia elegans, Rudbeckia hirta, Aster* sp., *Cosmos bipinnatus, Viola* sp., *Antirhinum majus, Calendula* (ornamental); *Brassica rappa, B. oleracea* (both cauliflower and cabbage), *B. nigra, B. caulo-rapa, Chenopodium album, Cucurbita maxima, Cucumis melo, Lycopersicon esculentum, Solanum melongena, Solanum tuberosum* (vegetables); *Humulus*

Table 6. Mean cover and prominence value of various medicinal plants recorded in various vegetation types of of Nubra Valley, Ladakh.

Species	Site #	Vegetation type	% Cover of species	Prominence value
1. *Acantholimon lycopodioides* (Gir.)Boiss.	P4	DSP	12	121
2. *Aster flaccidus* Bunge	P2	HM	1.5	6.70
3. *Bistorta vivipara* (L.) Gray	P2	HM	4.8	37.92
	KV4	HM	16.5	165
4. *Carum carvii* L.	PN4	RSH	0.3	0.94
5. *Cichorium intybus* L.	SF2	RSM	1.1	4.91
	L7	SM	1.1	6.95
6. *Dracocephalum*	P4	DSP	0.6	2.68
Heterophyllum Benth	SF9	HM	1.5	8.20
7. *Ephedra gerardiana* Wall.	P4	DSP	0.4	2.18
	P5	DSP	0.3	1.26
	PN1	AFS	6.3	63
	PN2	AFS	1.7	14.20
	PN3	AFS	1.3	12.32
	PN5	AFS	0.5	3.87
	D5	AFS	2.0	12.64
	SF1	EDS	0.2	0.89
	SF8	DSP	3.0	21.90
	SF13	DSP	0.1	0.30
	HD3	DSP	5.5	30.08
	TU3	AFS	8.1	72.17
	KV2	DSP	9.7	91.95
	KV3	DSP	9.2	92
8. *Gentiana carinata* Griseb	PN4	RSH	0.1	0.31
9. *Gentianella moorcroftina* Wall ex G.	KV4	HM	1.7	15.19
10. *Hippophae rhamnoides* L.	PN4	RSH	23	230
	D6	SM	1.0	3.16
	D7	RSH	0.8	4.37
	SF6	MO	3.1	21.91
	LK1	PL	0.3	0.94
11. *Lancea tibetica* Hk.f. & T.	PN4	RSH	8.0	80
	SF2	RSH	0.3	0.94
12. *Llyodea serotina* (L.) Reich.	K4	FF	4.0	33.44
	PI	HM	0.3	1.64
13. *Lycium ruthinicum* Murr.	PN5	AFS	5.1	51
	Dl	RB	16.4	164
14 *Nepeta longibracteata* Benth	K2	FF	0.8	3.57
	K3	FF	0.2	0.63
15. *Perovskia abrotanoides* Kar.	PN3	AFS	12.0	11.37
	PN5	AFS	0.4	1.26
	HD4	DSP	1.3	7.11
16. *Physoclaina praealta* (Walp.) Miers.	SF2	RSM	11.0	60.17
	SF6	MO	0.2	0.63
17. *Plantago depressa* Willd.	KV4	HM	0.1	0.31
18. *Potentilla fulgens* Wall.	SF2	HM	0.6	1.89
19. *Primula macrophylla* Don	K3	FF	1	3.16
20. *Psychrogeton*	P2	HM	2.5	11.17

Table 6. (Continued.)

Species	Site #	Vegetation type	% Cover of species	Prominence value
Andryaloides (DC) Nov.	P6	DSP	0.4	2.52
	P7	DSP	0.1	0.31
21. *Rhodiola heterodonta Boris.*	K2	FF	2.0	15.08
	K3	FF	2.5	23.70
	K4	FF	8.36	9.19
22. *Rosa webbiana* Wall. ex Royle	PN4	RSH	5	41.80
23. *Saxifraga flagellaris* Willd. ex Sternb.	K2	FF	0.6	3.8
	K3	FF	0.05	0.16
24. *Taraxacum officinale* Wigg.	PN4	RSH	0.2	0.89
	D2	RSH	0.4	2.52
	D3	SM	0.3	1.64
	SF2	RSM	0.5	2.73
25. *Waldhemia glabra* (Decne) Regel.	K1	SS	7.5	47.40
	K2	FF	4.4	36.81
	K3	FF	3.8	36.08
	K4	FF	0.8	5.65
	K5	HM	3.5	27.11

Vegetation/habitat types: SS, scree slopes; MO, moraines; AFS, alluvial fan with sparse scrub; RB, river beds; SM, sedge meadow (flat water logged areas); HM, herbaceous meadows; RSH, riverine scrub – *Hippophae*; RSM, riverine scrub – *Myrcaria*; RSW, riverine scrub – willow/mixed; EDS, scattered scrub on the eroded slope; DSP, dry scrub on the plateau; FF, fell fields (Moss–Lichen formations); PL, Plantations; AG, Agriculture.

lupulus (cash crop); *Medicago lupulina, Melilotus alba, M. indica, M. officinalis* (fodder); *Morus alba, Prunus armeniaca, P. persica, Pyrus malus, Juglans regia* (fruit trees); *Avena sativa, Hordeum vulgare, Pisum sativum* and *Fagopyrum tataricum* (food crop).

Associated with agriculture are a large number of fuel, fodder and multipurpose species. Such species, generally associated with agricultural crops, are usually wild relatives of crop plants which could be used for various purposes and have immense conservation significance. Some of the wild food plants in the area include *Amaranthus spinosus* Willd., *Capsella thomsonii, Allium thomsonii, Lactuca dolichophylla, Chenopodium foliolosum, Lepidium latifolium, Orobanche hansii* and *Polygonum aviculare* which are used as vegetables. In addition, a large number of legumes associated with agricultural crops act as a valuable sources of fodder and soil enrichment.

Other species of conservation significance

The local inhabitants make best use of all plant biomass produced in the area. Species commonly used as fodder include *Artemisia dracunculus, Astragalus adesmifolius, A. confertus, A. oxydon, Bromus inermis, B. oxydon, Calamogrostis emodensis, Eragrostis pilosa, Festuca kashmeriana, Heracleum pinnatum,* *Lactuca tatarica, Lindelofia anchusoides, L. stylosa, Oxytropis cahsemiriana, O. tatarica, Poa bulbosa, P. falconeri, P. stapfiana, Stipa sibirica* and *Ulmus wallichiana*. Species of *Delphinium, Aquilegia fragrans, Aster flaccidus, Lychnis nutans, Malva verticellata, Dianthus angulatus, Epilobium angustifolium, Potentilla curviseta, Rosa webbiana, Primula macrophylla, Perovskia abrotanoides, Rheum speciforme* and *Tanacetum tibeticum* have good potential to serve as ornamental as well as medicinal plants.

Almost all the woody species are used as a source of fuel wood in the valley. Prominent species used as a fuel include *Atriplex hortensis, Ephedra gerardiana, Hippophae rhamnoides, Sophora moorcroftiana, Tanacetum tibeticum, Rosa webbiana, Berberis ulicina, Myricaria germanica, Tamarix gallica*, and various species of *Salix* and *Populus*. *Morus alba* and several other fruit trees have potential to improve the economy of the local people.

Multipurpose species, found in low abundance and having restricted distribution, must rank highest in terms of conservation priority. Among the rare medicinal and aromatic plants *Aconitum violaceum, Allium* species, *Dactylorhiza hatagirea, Geranium sibiricum, Herminium monorchis, Inula rhizocephala* var. *rhizocephaloides, Lloydea serotina* and *Ulmus wallichiana* are most important. *Hippophae rhamnoides* ssp. *turkestanica* (Seabuck thorn) is a multi-purpose species. It is used as a medicine, fruits are used locally as well as could be sold in the local cooperative stores for the preparation of drink. Its branches are used as fuel wood and fodder. It is estimated that at least 20 other species have two or more than two uses. Such species would require more attention of conservationists.

Discussion and conclusions

Compared to other parts of Indian Trans-Himalaya, Nubra valley exhibits much wider altitudinal and topographic variation. While low-lying wider river valleys harbour a rich array of flora distributed within marsh meadows, riverine scrub and adjacent alluvial fans, the other areas follow different trends. A few stretches of river courses support hardly any vegetation owing to wide sand dunes and dry boulders. The upper eroded slopes and rocky outcrops had least vegetation cover and species diversity. The stream courses along the higher altitudes and moist herbaceous meadows, though limited in extent, supported greater species richness. This explains that soil moisture and soil depth influence the species diversity and richness rather than altitude. Compared to western parts of Karakoram and eastern flanks of Nubra viz., Aksai Chin and north-western parts of Tibetan Plateau (Miehe et al. 2002), the present study area seems to be higher in overall species richness. A detailed analysis of phytogeographic affinities and micro-habitat requirements of rare endemic species will reveal insights on the biodiversity values of the study area. Nubra valley represents best formations of *Hippophae–Myricaria* scrub and large alluvial fans which make it unique in the entire trans-Himalaya.

The study area has very short growing season and land available for cultivation is limited. As a result, local people subsist on limited crops and a large number of wild plants for fuel, fodder, and medicine for their survival. With the changing socio-economic scenario there is a rush for the cultivable land and cash income. This is likely to result in the fragmentation of land and competition for the common property resources such as pastures and medicinal plants. There are indications that these resources are becoming scarce year by year (personal communication). Since local people depend heavily on the traditional healers for their day to day treatment, there is a need to revitalize the sense of conservation of wild medicinal herbs among them. Due to low availability of certain wild medicinal herbs in the study area Amchis have to travel far and wide outside Nubra in search of such species. It would, therefore, be desirable to establish herbal gardens in each village for the propagation of valuable herbs. Economic potential of these species need to be assessed for bioprospecting and their sustainable utilization need to be enhanced so that the local people respect the native species rather than depending entirely on the recently introduced cultigens. Intensification of agriculture and recent introduction of several horticultural species have, no doubt, benefited a few farmers but long-term ecological implications of such practices need to be understood. The native crop varieties, especially drought and disease resistant land races need to be given highest priority in terms of conservation.

The study area differs from rest of the Indian biomes in terms of vegetation cover and species composition. Nearly 70% of plant species are restricted to the valley bottoms and stream courses which are also utilized by humans and livestock. Such areas are extremely important from conservation point of view and can be regarded as highly sensitive landscape units. Future studies in Nubra valley should therefore focus on the ecology and patterns of biodiversity in such areas using high resolution satellite data with a separate set of environmental variables. Key parameters such as relative area under various landscape units and vegetation classes, species richness and prominence values of highly important medicinal plants will need regular monitoring for which baseline data have been generated through this study.

Acknowledgement

The financial assistance from Department of Biotechnology and the Department of Space, Government of India in the form of a research project on Biodiversity Characterization at Landscape Level is thankfully acknowledged. We are extremely thankful to the anonymous reviewer, who provided us useful comments to the early version of this manuscript.

References

Anonymous. 2002. Biodiversity Characterization at Landscape Level in Western Himalaya Using Satellite Remote Sensing and Geographical Information System. Indian Institute Remote Sensing, Dehradun, India.

Aswal B.S. and Mehrotra B.N. 1997. Flora of Lahaul – Spiti. Bishen Singh Mahendra Pal Singh, Dehradun, India.

Dinerstein E. 1979. An ecological survey of Royal Karnali-Bardia wildlife reserve, Nepal. Part K: vegetation, modifying factors and successional relationship. Biol. Conserv. 15: 127–150.

Griffiths G.H. and Eversham B. 2000. Landscape pattern and species richness: regional scale analysis from remote sensing. Int. J. Remote Sens. 21: 2685–2704.

Kachroo P., Sapru B.L. and Dhar U. 1977. Flora of Ladakh: An Ecological and Taxonomic Appraisal. Bishen Singh Mahendra Pal Singh, Dehradun, India.

Kasturirangan K. 2001. Foreword. In: Anonymous (ed.), North-East India Using Satellite Remote Sensing and Geographical Information System. Indian Institute Remote Sensing, Dehradun, India, iii p.

Kent M. and Coker P. 1992. Vegetation Description and Analysis – A Practical Approach. Belhaven Press, London.

Maguran A.E. 1988. Ecological Diversity and its Measurement. Croom Helm.

Miehe G., Miehe S., and Dickore W.B. 2002. Alpine deserts in high Asia. In: Yang Xiaping (ed.), Desert and Alpine Environments – Advances in Geomorphology and Palaeoclimatology. China Ocean Press, pp.59–79.

Mueller-Dombois D. and Ellenberg H. 1974. Aims and Methods of Vegetation Ecology. John Wiley & Sons.

Murty S.K. 2001. Flora of Cold Deserts of Western Himalaya, Vol. 1. (Monocotyledons). Botanical Survey of India, Dehradun, India.

Pillai J. 1994. Developing a biodiversity information system. Curr. Sci. 66: 892–893.

Polunin O. and Stainton A. 1990. Concise Flowers of the Himalaya. Oxford University Press.

Rodgers W.A. and Panwar H.S. 1988. Planning a Protected Area Network for India, Vols. 1 & 2. Wildlife Institute of India, Dehradun, India.

Ravan S.A. and Roy P.S. 1997. Satellite remote sensing for ecological analysis of forested landscape. Plant Ecol. 131: 124–141.

Roy P.S. and Tomar S. 2000. Biodiversity characterisation at landscape level using geospatial modelling technique. Biol. Conserv. 95: 95–109.

Roy P.S., Porwal M.C. and Sharma L. 2001. Mapping of *Hippophae rhamnoides* Linn. in the adjoining areas of Kaza in Lahul and Spiti using remote sensing and GIS. Curr. Sci. 80: 1107–1111.

Porwal M.C., Sharma L. and Roy P.S. 2002. Stratification and mapping of *Ephedra gerardiana* Wall. in Poh (Lahul and Spiti) using remote sensing and GIS. Curr. Sci. 84: 208–212.

Saran S., Gosh S., Srivastava G., Roy P.S., Talukdar G. and Prasad N. 2003. Spatial decision support system for biodiversity conservation prioritization: web based approach. Asian J. Geoinformatics 4: 21–30.

Scheiner S.M. 1992. Assessing pattern diversity at landscape level. Ecology 73: 1860–1867.

Singh J.S., Raghubanshi A.S. and Varshney C.K. 1994. Integrated biodiversity research for India. Curr. Sci. 66: 109–112.

Stork N.E., Samways M.J. and Eeley H.A.C. 1996. Inventorying and monitoring biodiversity. Trends in Ecology and Evolution 11: 39–40.