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Stratification and mapping of *Ephedra gerardiana* Wall. in Poh (Lahul and Spiti) using remote sensing and GIS

M. C. Porwal*, Lalit Sharma and P. S. Roy

Indian Institute of Remote Sensing, National Remote Sensing Agency, 4, Kalidas Road, P.B. No. 135, Dehra Dun 248 001, India

The somlata plant (*Ephedra gerardiana* Wall.) has acquired importance in Indian medicine because it yields alkaloids that are effective in the treatment of asthma and hay fever. Tincture of *Ephedra* is used for cardiac and circulatory stimulation. Its demand as medicine has intensified the pressure on landscapes bearing this species. This has necessitated bioprospection and active planning to ensure safe conservation of the existing gene pool and sustainable utilization of this land resource. On account of its importance, an attempt has been made, using remote sensing and geographical information system to identify and map *Ephedra*-dominated sites. IRS 1C/1D LISS-III false colour composite has been used for stratification of *E. gerardiana* bearing landscape in the present study. Test sites were used to evaluate the mapping results and promising accuracy has been achieved. The study highlights the possibility of mapping *E. gerardiana* in complex terrain conditions. Through this study it is also emphasized that the methodology can be used for bioprospection of species in the whole Lahul and Spiti district.

ENVIRONMENTALLY sensitive areas, such as cold deserts, form an important element in the ecology of the Himalayas. Within these regions, there is considerable variation in ground cover, ranging from barren, deserted mounds of mud to a mosaic of sparsely vegetated areas[1]. Dry alpine scrub vegetation is found predominantly in the cold desert areas of Lahul and Spiti, Kinnaur and Chamba above 3600 m elevation ranging up to 5500 m, i.e. the last vegetation limit[2]. Cold desert vegetation is low in productivity with sparse distribution. Stress-tolerant plants are a characteristic feature of cold deserts. The climatic limitations allow these plants to flower, fruit and complete the life cycle within a short span under favourable conditions. Climate, geology and soil structure in conjunction are responsible for the presence of sparse and herbaceous vegetation characterized by the total absence of tree growth.

The environment and ecology of cold deserts have endowed certain plant species with the capability to produce certain chemical ingredients or alkaloids, which bear high medicinal value. Therefore, such plant species are of specific and significant interest to mankind. Certain plant species which attract nomadic graziers from hundreds of kilometre are also present. Above all, nature has been kind enough to bless such regions with very scanty, but useful vegetation.

Due to increasing pressure on these pasturelands from the local people, nomadic graziers of lower altitude and drug manufacturers, there is a gradual depletion of the great medicinal wealth. The rich repositories in the past have been over exploited with ruthless greed, and several species of drug-plants like *Dioscorea, Jurnea*, *Orachis*, *Aconitum*, *Polygonatum*, *Angelica*, *Nardostachys*, *Valerina*, *Arnebia* and even *Berberis* are facing threat to their survival[2]. These zones dominated by stress-tolerant medicinal plant species facing extinction need critical examination. Therefore, areas dominated by medicinally important plant species must be identified for active planning, management and conservation. To achieve this it is important to maintain accurate current information on their condition and extent.

Detailed ground-based surveys in large, relatively inaccessible and ecologically complex areas are generally difficult and expensive. Remote sensing (RS) offers a seemingly ideal tool for the mapping and monitoring of such areas, particularly to complement or update the conventional data-gathering techniques[3,4]. The launch of IRS 1C/1D satellite with the on-board LISS III sensor is an important step forward in the use of remotely sensed image for land-cover studies. Data sets from IRS 1C/1D LISS III have been used effectively in mapping the pure plant colonies of *Hippophae rhamnoides* in the Spiti region and stratify *Taxus* in the northeastern regions of India with prior knowledge of their occurrence and vegetation types of the area using remote sensing technique[5,6].

Satellite remote sensing images have also been used as a multitemporal data source, combined with existing base

*For correspondence. (e-mail: mcporwal@iirs.gov.in)

maps and maps derived from field research, for determining management regimes in Mercantour National Park, France[7]. Geographical information system (GIS) has been widely used as a tool to aid the design, management and monitoring of national parks and other protected areas[8]. Many case studies reveal the benefit of applying the technology for both policy and research.

Considering, the importance of *Ephedra gerardiana* in Indian medicine, an attempt has been made to map the areas dominated by this plant. Hence, the objective of the study includes the creation of a database of medicinally important species at 1 : 50,000 scale with respect to mapping of *E. gerardiana* using RS and GIS.

E. gerardiana is a plant species of the cold desert (family: Ephedraceae), with sporadic distribution in arid regions of the tropics and subtropics of both the hemispheres. It is a low-growing, rigid, tufted shrub, 30–60 cm in height, with numerous clustered, erect, slender, smooth, green, jointed branches, arising from a branched woody base. The shrublets with closely clustered branches bear deciduous brown scales, arising at the joints. Male cones are ovate 6–8 mm, solitary or 2–3, with 4–8 flowers each with 5–8 anthers with fused filaments and rounded fused bracts. Female cones are solitary. Fruit is ovoid 7–10 mm, with fleshy red succulent bracts enclosing 1–2 seeds[9].

The genus *Ephedra* spreading worldwide, is found in Europe, temperate Asia, South America and Afghanistan to Bhutan (2400–5000 m). However, the plant species *E. gerardiana* in India is found in drier regions of temperate and alpine Himalaya from Kashmir to Sikkim, Chamba, Lahul, Spiti and Ladakh[2,9].

The uses of this plant and its parts are varied. Goats and yaks feed on its branches during winter. Its dried twigs yield alkaloids (ephedrine and pseudo-ephedrine) which are used in drugs to treat asthma, hay fever and rashes of allergic origin. Tincture of *Ephedra* is used for cardiac and circulatory stimulation. Decoction of stems and roots is the remedy for rheumatism and syphilis in Russia[2]. With many versatile uses of the various plant parts in medicine, its demand among the pharmaceutical groups has increased, becoming a serious issue with regard to its conservation and protection.

The presence of high alkaloid content in the plant is related to the prevailing moisture level in the area. Rainfall has adverse effect on its alkaloid content because of which the alkaloid content keeps decreasing from May to August and thereafter gradually starts increasing from September, reaching a maximum in October and November when the moisture level is minimum. The alkaloid content is also related to the age of the plant and the best time for collection is when the plants attain the age of at least four years. The alkaloid content in Indian *Ephedra* varies between 0.28 and 2.79% (refs 2, 9).

The geographical position of the study area is about 32°2′–32°6′N and 78°15′–78°22′E in Lahul and Spiti districts of Himachal Pradesh. The climatic set-up of the state is so complex that it ranges from hot tropical to dry-cool temperate[10].

Along the Spiti river an intricate fabric of valleys and spurs can be seen. Most of the valley is made up of loose sedimentary rocks, which are completely pervious. The morphology of the valley is a result of the combined action of glaciers and rivers.

The inhospitable terrain represents a barren and bewildering landscape. Some of the higher glens and valleys are covered with alpine pastures. Some cultivable spots are also present along the course of adjunct feeders of Spiti river, or in open hollows facing the sun. The mountains of Spiti are loftier than those of Lahul, with an average elevation of 6000 m or more[10].

In Spiti, spring arrives late, while the winter spell lasts for a longer duration. Snowfall begins in December and it remains on the ground till the end of April. Annual snowfall is around 72 mm. Cloudy days in one year account for nearly 60 days. Owing to the high elevation of the Spiti Valley and slight rainfall, vegetation is scanty. Rainfall is insufficient to have any significant effect on the production of crops or grasses. The annual rainfall in Spiti region is around 5 mm. The maximum and minimum temperature is around 30.5 and –19.5°C respectively[11].

Lithologically, rocks are composed of diverse coloured sandstone, shale, limestone, etc. due to which the water of the rivers remains heavily charged with silt and appears yellow. The dwarf willows, which grow wild on the river bank, are mere bushes. It is only in the lower villages of Poh and Tabo that willows and poplars thrive. Good grass grows only in a few hollows where snow has laid long and saturated the ground with moisture[12]. In Lahul and Spiti, there is a steppe-like vegetation, with *Caragana*, *Artemisia, Hippophae*, *Ephedra* and *Arenaria*.

Fieldwork was carried out on a monthly basis from June to September 2001. Intensive ground truth was collected to verify the spectral and spatial variation among different classes. Reconnaissance survey of the entire area and ground truth collection were done to correlate the ground objects with the signature of image features on satellite data[13]. The *Ephedra*-dominated areas were first located on ground and later the delineation was performed for classification and mapping. Spectral signatures of different land features were studied to prepare an interpretation key (Table 1). Fifteen ground control points (GCPs) were collected in all using global positioning system (GPS) in the field. Three sites were checked to validate the mapping of *E. gerardiana*. Use of GPS enabled building of strong correlation of features on ground with the satellite image, thus making it easier to locate important places and *Ephedra* outburst on ground.

The plant samples collected from the study region during June and August 2001 have been sent to Institute of Himalayan Bio-resource and Technology (IHBT),

Table 1. Interpretation key

Landcover/ land use	Tone	Texture	Shape	Associated physiography	Phenology
Ephedra gerardiana	Red	Coarse	Irregular	Along riverbed	Flowering and fruiting
Ephedra mixed with grasses	Dusty red	Coarse	Irregular	Along riverbed	Fruiting and green
Dry alpine grassland	Reddish-orange	Coarse	Irregular	Steep to gentle slopes	Flowering and green
Alpine desert	Greyish-blue	Smooth	Irregular	Steep to gentle slopes	Partially green
Shrubs/scrub	Light-greyish	Smooth	Irregular	Along riverside	Green
Agriculture	Dark-orange	Smooth	Irregular	Along riverside	Crops in green
Rockout*	Bluish	Coarse	Irregular	Low–high elevation	–
River*	Blue	Smooth	Irregular	Low–high elevation	–
Snow*	White	Smooth	Irregular	Higher elevation	–

Classes marked with asterisk (*) have no relation with phenology.

Palampur and Central Institute for Medicinal and Aromatic Plants (CIMAP), Lucknow for chemical analysis to investigate the ephedrine content in the plant species encountered along Spiti riverbed.

Geo-coded false colour composite (FCC, band 432) hardcopy output of IRS-1C/1D LISS III (Path 96 and Row 48) with 23.5 m resolution at 1 :50,000 scale of 25 June 1999 has been used for the specific study (Figure 1). Satellite data of the corresponding season eased the job of species colony identification on FCC. Spectral variability is attributed to the geological set-up of the terrain, as the background offers no complexity due to intermittent and sparsely vegetated arid environment of Spiti. Ground reference data for the geographical information were obtained from the Survey of India toposheet no. 52 L/08 at 1 :50,000 scale, GPS and actual ground surveys.

Visual interpretation technique coupled with extensive ground check method and sampling was adopted to tap the maximum spectral variation. The image classification is based on the spectral response of reflectance of the elements contained in the terrain surface corresponding to the eight classes. Analysis of vegetation using remote sensing is quite significant, based on spectral signatures for different land use/cover classes. Probably the most frequently used parameter in analysing vegetation from RS data is the image tone of the vegetation in one or more spectral bands[14]. Stratification of *E. gerardiana*-dominated areas was done based on image recognition elements, (shape, size, tone, texture, association, etc.) and also taking into consideration the physiography, slope, aspect and other physical environments of the area.

The class dry alpine desert, rockout/dry alpine grassland were treated in a special way. Since unvegetated areas above a certain altitude can be classified to a high accuracy, a distinction could be made between tones made up of 100% bare rocks and soils, and those containing at least 75%. The threshold tone and texture used for delineating these surface covers were determined from satellite image and ground surveys.

After this, only vegetated areas and their various degrees of mixing with bare rocks and soil are left for further classification. The classification procedure is a sort of hierarchical analysis, in which one or more classes are resolved and masked at each step[15]. In practice, at each step, the classes extracted are those which can be identified with greatest accuracy and least effort. The last classes to be resolved were *Ephedra* as pure patches and *Ephedra* mixed, which are more complex to define and classify since shaded or slightly shaded *Ephedra* regions have reflectance values similar to those of grasses and other herbaceous vegetation.

Remotely sensed image is a major source of data for environmental applications. These sources of data have, perhaps, a greater value in mountain environment, where traditional ground-based surveying techniques are restricted by the nature of the terrain. Therefore, dealing with geometric distortions due to high variability in relief is a major factor in making sensible use of remotely sensed data in mountain regions[16]. Hence, the geometric corrections of the image were done using Erdas Imagine 8.4 software.

Area of interest of 50.46 km^2, covering Poh and adjoining areas, was extracted and scanned from a geo-coded FCC on 1 :50,000 scale for further analysis. The scanned portion of FCC was interpreted on a glass light table for the extraction of eight classes. Digitization of the interpreted vector layer and base-map details was carried out using ArcView 3.2a software. The classes were assigned suitable colours and a colour-coded map was obtained (Figure 2).

The results of the study are summarized in Table 2. Areas covered by *E. gerardiana* as a pure class, constitute 3.61% of the classes (*E. gerardiana*, *Ephedra* mixed, Dry alpine grassland and shrubs/scrub), i.e. 1.16 km^2. Another class of significant interest is Ephedra mixed, with other herbaceous plants occupying nearly 4.63 km^2 and representing 9.2% share of the total. However, dry alpine grassland covers 37.49% of the total which is highest, occupying 18.92 km^2. The category of shrubs occupies 14.58% of the total and is third highest after dry alpine desert, i.e. 7.36 km^2. The rest of the area has a sparse vegetation cover or consists of bare soil, rocks and glaciers.

There is also a strong tendency for *Ephedra* outburst to be found on gravel terraces with relatively gentle slopes (5–15 degrees), adjacent to the riverbed at Spiti. Its presence could be attributed to relatively high water/moisture content and its preference to conquer lands rich in sandy soils adjacent to the riverbed. Its presence in the higher reaches of hills may be restricted due to low moisture-retaining capacity of the loose sandy soil on steep slopes. Plants thrive well from May to August due to high moisture regime from the melting snow in April–May and light showers in June–July. The climatic break followed by snowmelt in May witnesses the *Ephedra* outburst on gentle slopes along the riverbed at Spiti. Plants can be seen in flowering and fruiting stage in late June and July (Figures 3 and 4).

The vegetation is mainly dominated by the species of *Ephedra*, *Myricaria*, *Rhododendron* supported by *Rosa webbiana*, *Capparis spinosa*, *Hippophae rhamnoides* and others. Grasses are represented by the species of *Agrostis*, *Agropyron*, *Bromus*, *Deyeuxia*, *Dactylis*, *Festuca*, *Phleum*, *Poa*, etc. The denuded, rugged and treeless tract of Spiti needs intensive afforestation with grass species like rye grass (*Lolium perenne*), orchard grass (*Bromus inermis*), clover (*Trifolium pratense*) and lucerne (*Medicago sativa*)[10].

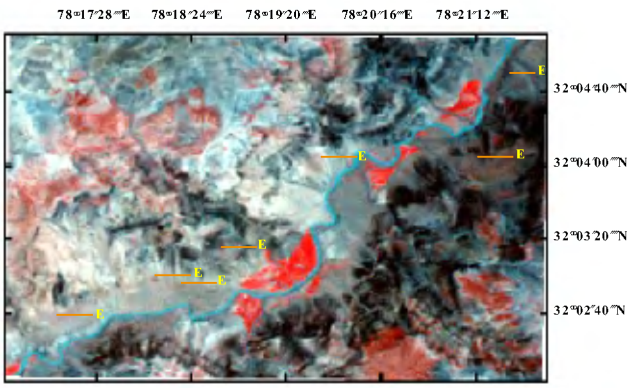

Figure 1. False colour composite on 1 : 50,000 showing distribution of *E. gerardiana* (E) vegetation along Spiti river in the adjoining areas of Poh.

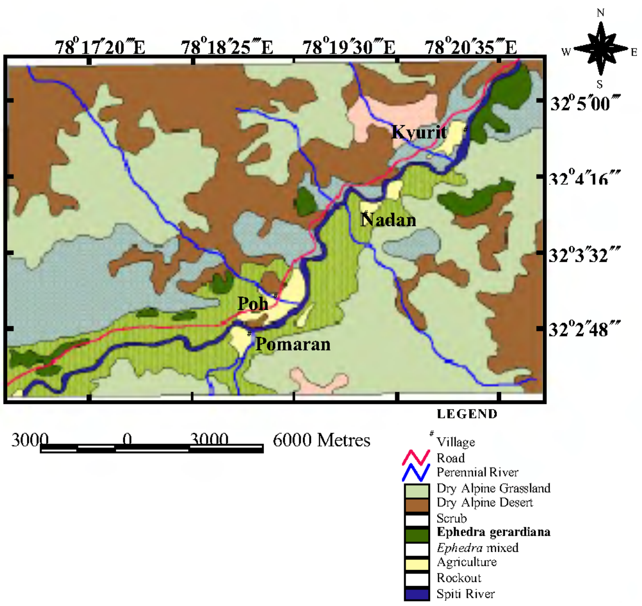

Figure 2. Classified image of Poh and adjoining areas on 1 : 50,000 showing distribution of *E. gerardiana*.

Table 2. Mapping results

Class	Area (km^2)	Percentage
Ephedra gerardiana	1.16	2.29
Ephedra mixed	4.63	9.20
Dry alpine grassland	18.92	37.49
Dry alpine desert	14.72	29.17
Shrubs/scrub	7.36	14.58
Agriculture	1.36	2.69
Rockout	1.26	2.49
Snow	1.05	2.08

Figure 3. Distribution of *E. gerardiana* on gentle slopes found adjacent to Spiti river near Poh.

Figure 4. *E. gerardiana* in fruiting stage on gentle terraces adjacent to Spiti river.

The analysis carried out by IHBT Palampur and CIMAP, Lucknow indicates that the ephedrine content in the plant samples varies between 0.70 and 0.82%.

The GPS technology offers effective alternative to ground-survey methods for the capture of breakline information. One essential prerequisite for the use of a GPS system is a clear field of view. The situation is conveniently met with in the Spiti valley on account of the valley being broad U-shaped. Further, absence of higher tree formations serves as an added advantage. This situation ensures that both geographic location and height are fixed to the best accuracy[16].

It is often difficult to find useful images for vegetation classification due to heavy cloud cover in mountain areas. Furthermore, the period suited for vegetation studies is restricted to the summer months because of the presence of snow until late spring or early summer[15]. Analysis of availability of images from IRS 1C/1D LISS III revealed that the presently used image is potentially useful and free of heavy cloud or snow cover. This is a typical situation in data availability for much of the Himalaya.

The use of GIS in the present study was limited to geometric correction of the image with respect to SOI topomap, digitization and area calculation of the *Ephedra*-dominated areas and the associated land cover classes on satellite data.

Commercialization of plants for the extraction of drug molecules has inadvertently put pressure on medicinal plant wealth in Upper and Trans Himalayan zones. The unsystematic over exploitation of *E. gerardiana* may lead to a change in its status from threatened to rare, if any measures to protect this plant are not taken in time.

Although stratification has been done in parts of the Spiti region, RS technology can be effectively utilized in the bioprospection of *E. gerardiana* and other important medicinal plants in the Lahul and Spiti district, which have unique geological, physiographic and climatic conditions. The methodology can be used in other cold deserts. The pilot study will make significant contribution in bioprospection of other species as well.

This study on the inventory of *Ephedra* vegetation could prove highly beneficial for two groups, i.e. drug manufacturers and conservationists, besides planners and foresters. Once the mapping of this medicinal wealth is complete, conservation plans can be drawn for future sustainable use. RS technique is user-friendly, relatively inexpensive and has the potential to generate results for large sites in a short period.

Since conservation of this medicinally important species is of prime concern, the areas identified as rich repositories of *E. gerardiana* should be made protected habitats for *in situ* conservation and preservation as gene sanctuaries. Secondly, a separate management plan for the conservation of this high-altitude medicinal plant wealth in the Spiti valley is strongly recommended. Thirdly, the forest and wildlife administration in the state may be requested to check its illegal exploitation. Strict regulation and control of trade should be imposed on these species.

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