Geo-botanical Assessment of Protected Areas of Uttarakhand and Himachal Pradesh

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***Abstract*: In the present study an attempt was made to characterize and explore the relation between different geo-botanical units using RS and GIS. The studies were conducted in the Rajaji National Park (RNP) and Great Himalayan National Park Conservation Area (GHNPCA) in Siwaliks and Higher Himalayas, India respectively.**

The visual interpretation techniques were used for vegetation and geo-morphological mapping from remote sensing data and the spatial data was generated in GIS domain. The species wise distribution of vegetation on various landforms was analyzed. It was observed that in RNP; a particular landform is preferred by specific species, like Sal grows on Heavy Drained Soil, Reverine on Piedmont and Chirpine on Highly Dissected Hills whereas in GHNPCA, the area covered by the vegetation types was different under each terrain parameter. Further, maximum vegetation was found in less complex areas (41%) and minimum vegetation was found in north aspect (3%). It was also analyzed that the effect of microclimate, soil and altitude is unavoidable. The present attempt will be useful, for developing an information base, which will facilitate conservation practices in future.

***Keywords:* Geo-botany, Geo-morphology, Vegetation, Conservation and Landscape.**

1. Introduction

The Geo-botanical study depends on basic understanding of biotic and abiotic components such as vegetation, geology, geo-morphology, water and soil which determines the landscape structure and ecology. The basic aim for considering the case study of Rajaji Naitional Park (RNP and Great Himalayan National Park Conservation Area (GHNPCA) is to cover Himalaya from Siwalik to higher Himalayas in relation to vegetation, land form and geology to define geo-botanical relevance for landscape management.

The RNP forms a part of the north-western range habitat of the Indian elephant (***Elephus maximus***) and also provides habitat to a wide range of the biota of higher altitude and plains. The Siwaliks consists of geologically recent (Pleistocene) formations of unconsolidated materials (boulders, conglomerates, shale and slate) whereas the GHNPCA forms a part of Inner Himalayas. As per the geological map the major rock types in the area are quartzite, phyllite, slate, schist and gneiss along with granite having a regional strike trend of NW-SE with a varying amounts of dip due NE. These rocks have been folded, faulted and thrusted as consequences of different tectonic episodes. The most important causes of damage to natural forest ecosystems in Himalayas are both natural and manmade. The former includes lithology and competency of rocks, inclination and orientation of slopes (aspect), shape of land and surface seismic and other tectonic activities. The human factor includes indiscriminate deforestation through felling, burning, grazing and cultivation (Pandey and Singh 1984; Singh et al. 1994).

In the case of RNP the developmental activities and expending township of Dehradun and Haridwar have reduced the habitat of big animals like Indian elephant (***Elephus maximus***) which in turn affected the habitat of other numerous species. In GHNPCA the human interventions are major threats for the endangered species i.e. Musk deer ***(Moschus chrysogaster)*** and Western Tragopan ***(Tragopan melanocephalus)***. Recently there has been an increasing realization that a tremendous input of science and technology is needed for conservation programmes reaching towards sustainable development. The present study aims to integrate remote sensing data with other multidisciplinary thematic maps in order to study the geo-botanical trends which further can be utilized for wildlife conservation, habitat evaluation and management.

1.2 Geo-botanical Relevance

It has also been reported by earlier studies that vegetation communities are highly influenced by various topographical features (Puri 1950a; Roy and Jugran 1986; Warner 1991). The bases of physiographic and geo-ecological information about the landscape are required for the design and management of National Park and the protected areas (Zomer et al. 2002). Hence the emphasis has been laid on such features in relation to the spatial distribution of vegetation. "In hilly regio ns, variations in the forests are observed with the changes of aspect and configuration of slopes where underlying rocks do not change" (Troup 1921). The rocks and soil affect the vegetation of an area by influencing moisture regime, structure and texture of the soil (Puri1950a). Landform factors that mainly influence vegetation are slope, aspect and inclination. The altitude vegetation relationship and topographical relationship with wildlife species have also been studied (Bunzhuo et. al.1997; Kala et al.2002). After knowing the relationship of these factors the habitat analysis can be made more precise. After knowing the relationship of these factors with elements of landscape the habitat analysis can be made more precise.

The geology of a region affects the vegetation in two ways: - (i) by presence or absence of minerals, and (ii) by structural variations in rocks and nature of the slope, viz. dip versus scarp slopes (Puri1950 a). The effect of geology in local distribution of blue pine and chirpine near Bandal in the Tirthan valley was also observed (Troup1921). The absence of chirpine community in high altitudinal zone from the Beas valley is because of the absence of quartzites. The presence of blue pine at flood plain deposits or on scarp slopes of mica schist or sandstone which is more closely related to rock type than to climate or slope-aspect. The importance of geo-morphology in the distribution of forest communities is now well recognized. Landscape is the mosaic of landform, vegetation and landuse (Urban et al 1987; Noss 1990; Kim and Weaver 1994). Therefore, landscape ecology has emerged as an important discipline to study the landscape structure, its functions and changes. Each landscape is composed of several landscape elements, each of which has its own significance in the ecosystem and is important in evaluating the landscape structure (Oliver and Larson 1990). The objectives mapping of major vegetation communities, Geo-morphological mapping of different landform units, Overlay analysis of landform and vegetation and develop an information base, on habitat components, for analyzing geo-botanical correlations.

2. Methodology

2.1 Study Area: The study has been performed in RNP between 30^0 0' and 30 ^{0} 5' 24'' N Latitudes and 78^0 1' 56'' and 78 ^{0} 8' 4'' E longitudes encompassing an area about 100 sq.km. in toposheet no. 53 J/4. The climate is subtropical; temperature varies from 13.1^0 C (January) to 38.9^0 C (June). The average annual rainfall is about 1270 mm. The torrent beds locally known as Raos, are the distinct features of the area. The ridges at many places are knife-edged and serrated with vertical pinnacles (Fig. 1a). GHNPCA lies in the inner range of Western Himalayas between 31^0 33' 00" N to 31^0 56' 56" N lat. and 77^0 17" 15" E to 77^0 52' 05" E long., and altitude varies from 1344 to 6248 m (Fig.1b). The Rajaji National Park (RNP) lies at the junction of Himalayan foothills and the vast Indo-Gangetic plains and forms a part of the north-western range habitat of the Indian elephant (Elephus maximus) provides habitat to a wide range of the higher altitude and plains biota (Naithani,2013).

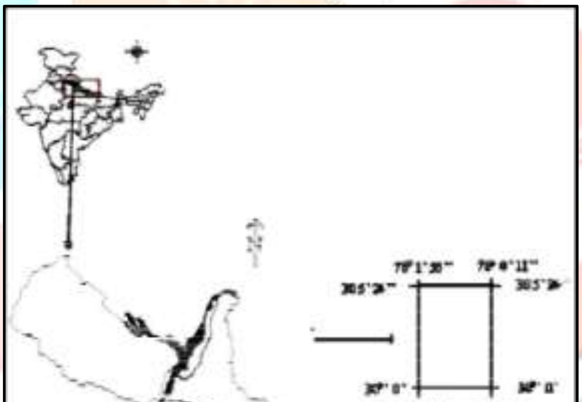

Fig. 1 a. Location Map, Rajaji National Park

Fig. 1b Location Map, Great Himalayan National Park Conserv ation Area

The topography of GHNPCA has also been influenced by avalanches and landslides. Avalanches occur frequently after heavy snow, often originating from steep southern aspect, especially from April to June. Landslides are common features during rainy season. The major tributaries of Beas river *viz.* Tirthan, Sainj, Jiwa and Parvati drain the GHNPCA typically exhibits temperate and alpine climate. Most of the area (approx. 64%) falls above subalpine zone which remains snow covered during winter months. The mean annual rainfall recorded at Niharni 1800 m in GHNPCA for the period 1992-94 was 1155.67 mm while at Sainj 1450 m for 1992-94, it was 1158.26. Temperature is an important factor in determining vegetation types. The mean minimum and mean maximum temperature in Tirthan, Sainj and Jiwanal valleys were 12.65□C, 9.59 □C and 9.69 □C and 16.38□C, 15.03□C and 13.46□C respectively in 1996-97. January was the coldest and June was the hottest months of the year. The temperature in the alpine zone was recorded with the help of the grazers staying there and personal visits during summer months. The mean minimum temperature was 7.73□C and mean maximum temperature was 11.23□C during these months. Based on the physiognomy and dominance of species the vegetation types has been recognized in the study area from temperate broad leaved to alpine pastures . The park is well known for its rich diversity compared to other areas at similar altitudes in the north western Himalaya. It is one of the two National Parks in the world that support a population of endangered Western Tragogan (*Tragopan melanocephalus*) and a large number of rare and threatened plant species, many of which have medicinal values (Gaston and Garson 1992).

2.2 Data products (database used):

2.2.1 RNP; Base map, SOI toposheet (53J/4), satellite data and aerial photographs as stated above along with existing thematic geological maps and management plans.
2.2.2 GHNPCA; Base map, Survey of India topographical maps No. 53 E/5, 53 E/6, 53 E/9, 53 E/10, 53 E/13, and 53 E/14 and satellite data as stated above along with existing thematic geological maps and management plans

2.2.3 GIS Database: Using SPAN and ARC/INFO UNIX based GIS, information was generated for RNP and GHNPCA respectively; with the help of contours, the desired slope map and aspect maps were generated, the terrain complexity map was generated using contour, digitization of thematic layers and labeling/attribute assignments, generation of Digital Elevation Model (DEM) using GIS and analysis of area calculations for management zones using GIS.

2.3 Methodology

2.3.1 RNP: Both aerial photographs and satellite data have been used for the vegetation and geomorphological mapping. The aerial photographs pertaining to December 1959- April 1960 on 1:25000 scale, Satellite images of IRS-1B LISS-II, (FCC 2,3,4 RGB, GEOCODED), of 1993 and of LANDSAT TM, FCC of 1990 were used along with SOI toposheet (53J/4). The season for IRS IB and for LANDSAT was selected March and January respectively.

(a) **Interpretation:** After careful examination of aerial photographs the forest 4 density classes were delineated ;10-20%, 20-40%, and 40-60%, and Density > 60% with 1, 2, 3 and 4 density codes respectively. The entire area could not be mapped using aerial photographs because of non-availability of air photos; however, the total park area was mapped by satellite data. Therefore a comparison had been done between common area mapped during two periods i.e. for photos and satellite data. For comparison of density classes, the class 3-4 and 1-2 of photos was combined to fit into density class 1 (>40%) and 2 (<40 to 10%) of satellite data respectively. The entire site was visited for ground truth. After verification corrections were made to obtain final maps. The vegetation classes having less than 40% canopy density had been classified as open forest, whereas more than 40% was classified as dense forest. Scrub was delineated as a separate class.

2.3.2 GHNPCA

Spatial maps for the entire study area had been prepared on 1:50,000 scale using IRS IB LISS
(False Color Composite) of 1993 with topographic maps 53 E/6, E/9, E/10, E/13 and E/14 on 1:50,000.Some physiographic details were transferred from toposheets (water divide/spurs) to the base map along with the interpreted units through satellite data. The complete specialised and landuse/cover mapping was done using visual interpretation techniques with the help of interpretation key and classification scheme (Naithani and Mathur, 2014; Naithani and Mathur, 2016). The interpretation work and geo-botanical characterization were carried out systematically for geo-morphological mapping; reconnaissance survey, pre-interpretation, parallel ground truth collection, delineation of satellite images, validation, finalization transfer of thematic details along with base map and area calculation on 1:50,000 scale. Likewise for geo-botanical Characterization the input of both the maps i.e. vegetation and geo-morphological in GIS domain along with base map boundary, vector to raster conversion, overlay of Geo-morphological themes like ; drainage density, slope, aspect, terrain complexity and geology with bottom layer i.e. vegetation were performed and geobotaniccal characterization were reported.
Besides geo-morphological map and vegetation map (Fig.4 & Fig.5) other geo-morphological features like Drainage Density, Slope aspects contour shape and DEM had been generated and analyzed through GIS domain. For vegetation mapping two density classes has been attempted. Vegetation with > 40% canopy cover had been delineated as closed forests and < 40% as open forest. 11 forest and 11 non forest classes were delineated like; Conifer forest (Chir Pine Forest),Broadleaf forest (Ban Oak and Kharsu Oak),Broad leaf mixed with conifer (Broadleaf > 60%),Mixed Conifer (Western Mixed Coniferous Forest),Conifer mixed with Broadleaf (Conifers > 60%),Secondary Scrub (Chirpine and Berberis),Alpine Scrub (Rhododendron and Betula),Slope Grasses, Grasslands and Forest Blanks (Both temperate, sub-alpine and alpine pastures),Riverain, Plantations and Non forest; Non-forest-Agriculture/Settlement/Orchards, Exposed rock with slope grasses, Escarpment, Alpine Exposed Rocks with Slope Grasses, Landslide, Morainic Island, Glacier, Moraine, Permanent Snow, Lakes and River.

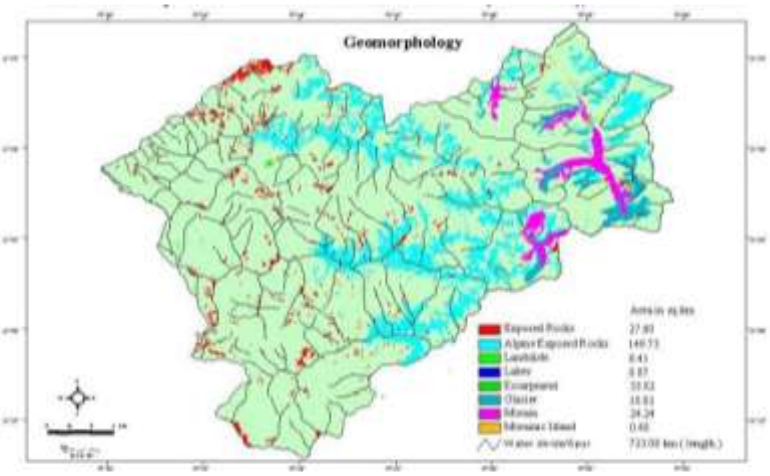

Fig. 4 Geo-morphology, Great Himalayan National Park Conservation Area

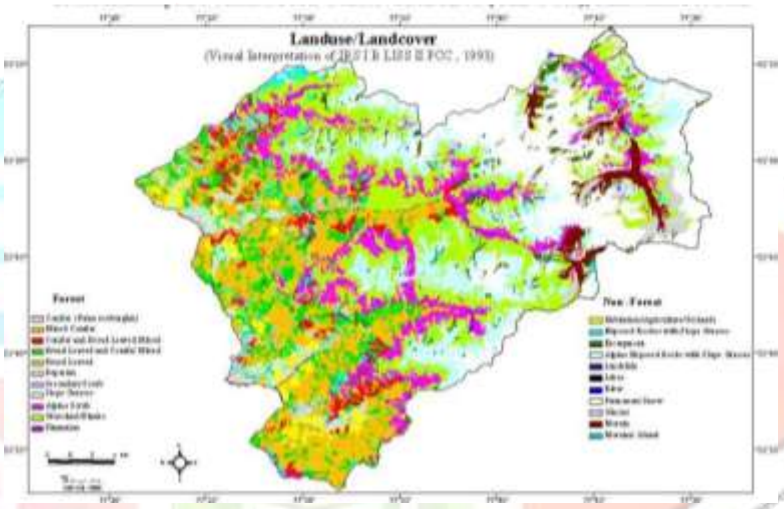

Fig. 5 Landuse/landcover, Great Himalayan National Park Conservation Area

3. Results and Discussions

The vegetation classes were delineated on the basis of dominant species, species association and vegetation density (Fig.6).The geomorphic units were classified on the basis of photo-characters topography and relief (Fig.7).

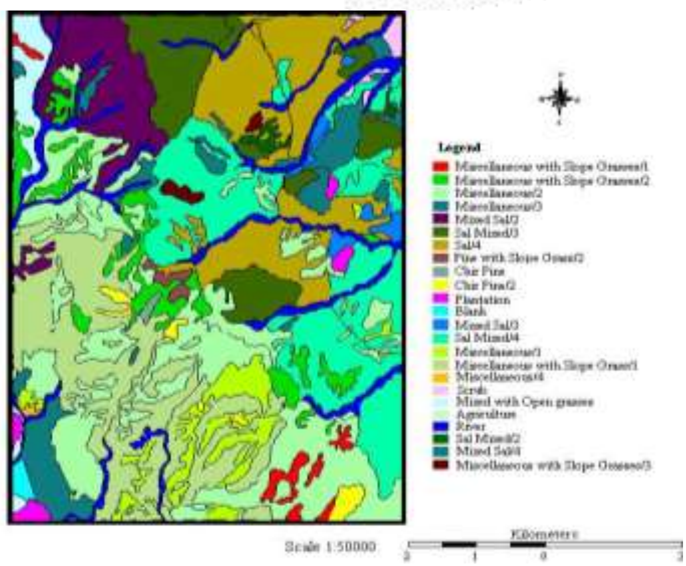

Fig. 6. Landuse/landcover, Core Study Area (RNP)

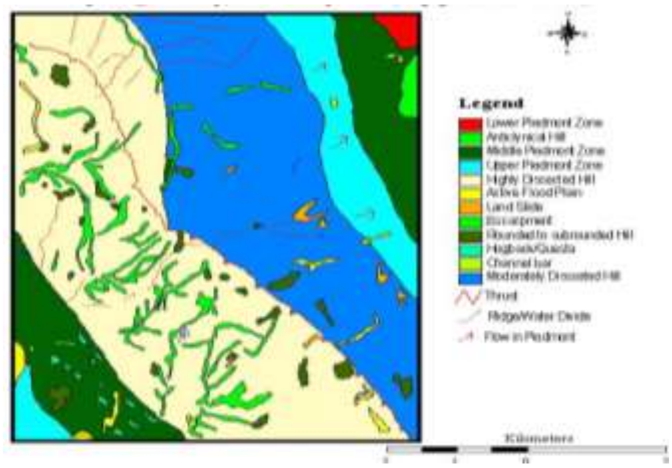

Fig. 7. Geo-morphological Map, Core Study Area (RNP)

Generally the southern slopes are warmer than northern parts, which may also influence the vegetation growth variations. Landforms i.e., highly dissected hills falls within the 5^0 to 14^0 slopes having maximum percentage of chirpine and maximum percentage of sal found in upper piedmont zone between 1^0 to 5^0 (Fig.8). (Cannone et al 2004) studied that plant cover varied according to the patter originated by periglacial processes. The distributional patterns of vascular plants, lichens and bryophytes were primarily affected by complex responses to substrate texture, soil moisture content and substrate disturbance.

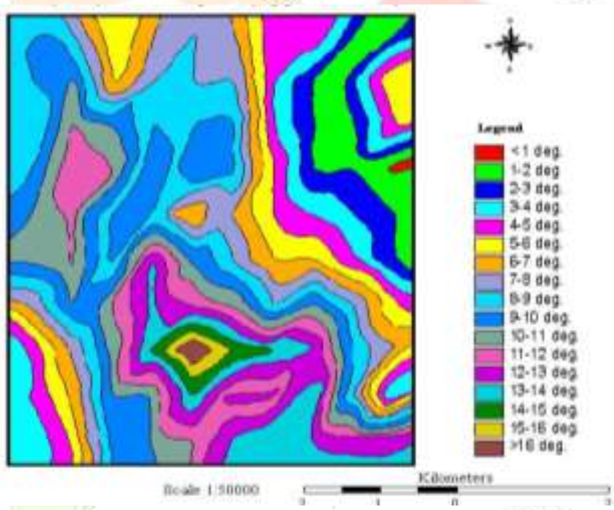

Fig. 8. Slope Map, Core Study Area (RNP)

The maximum percentage of scrub is found in NE and SE aspect, whereas the maximum dense forest falls within NW and W aspect. The NE followed by SE aspect is full of open forest (Fig.9). Mediterranean mountain forests of southern Anatolia, consisting of species cover and environmental measures in 99 sample plots. Results illustrated two vegetation gradients related to factor complexes of altitude-landform and parent material-land surface smoothness (Ozkan 2009).

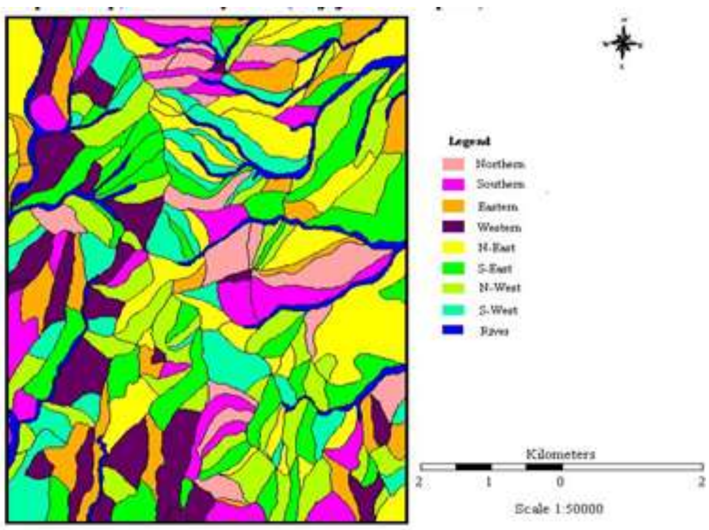

Fig. 9. Aspect Map, Core Study Area (RNP)

In relation to physiography and slope, pure scrub (7.36%) is found on active flood plain areas with varying slopes within1^0 to 7^0. A spatial structure of landforms and vegetation patterns was also studied by (Kikuchi and Miura 1993). It was found that variations in plant communities in accordance with landform between upper and lower hill slopes. The Escarpment is dominated by miscellaneous with Slope grasses (11.39%) followed by Bahonia species (*Bauhnia vahlii*). Moderately dissected hills (Upper Siwaliks) supported the maximum percent (62.17%) of Sal (*Shoria robusta)*, may be because of large unit comprising other landscape feature (1^{0}to 10^{0}of slopes). The maximum percentage of Chirpine and Slope grasses (73.10%) are confined to highly dissected hill with 5^0 to 14^0 slopes.
The Upper Piedmont zone was full of Sal (21.925%) within 1^0 to 5^0 of slopes. It is noticed that Sal grows on heavy and well-drained soil (Puri1949). Piedmont zone is made up of derived material mainly from Upper Siwaliks. Middle piedmont zone (where river is mostly braided) supports Reverine forest (69.44%) within 1^{0}to 6^0 slopes. The Scrub is dominant (5.20%) on Lower piedmont zone within 1^{0}to 2^{0}slopes, whereas Anticlinal hill contains mixed Sal (2.45%) within 5^0 to 7^0 slopes. (Gerhardt et al 2002) has also measured the abundances of all vascular plants in the over story and understory and nine physiographical and historical variables. Results Species richness was primarily related to landform: species-rich communities occurred in poorly drained basins and species-poor communities occurred on well-drained glacial outwash. Many species were restricted to specific physiographical conditions.

As far as geology is concerned the miscellaneous vegetation with Slope grasses (98.29%) was found in Middle Siwalik in which highly dissected zone falls, which also shows the same relation with vegetation. The maximum percentage of Scrub (70.53%) is found in the in Upper Siwalik. The maximum percentage of Riverine forest (73.77%) was observed on the Piedmont zone. Miscellaneous vegetation with Slope grasses was observed to be maximum (83.55%) in highly dissected hill. This shows that grasslands cover large portion in the study area especially on Middle Siwaliks.

The GHNPCA reveals an interesting altitudinal pattern of vegetation types. *Pinus roxburghii* forest is found to be influenced by moderate slopes having concave form on southern and western facing aspects. They were generally observed over Rampur and Bandal formations with a low to medium drainage density, approximately 0.29% of the total area with moderate complexity. While, conifer mixed with broad leaved forest occupies an area of 4.61% (33.21 km^2) of the total vegetation cover. The vegetation is growing predominantly over convex and concave forms (6.05% and 3.63%) respectively, influenced by the medium slopes. These are facing mostly east and north-eastern aspects. This vegetation is generally observed over Bandal and Rampur formations in moderately to less complexity with a medium to low drainage density covering approximately 4.61% of the total area. Broad leaved Mixed with Conifer Forest is widely distributed in the study area especially on less to moderate complexity approximately 11.58% of the total area.
In the study site the area of about 11.58% (83.44 km^2) of the total vegetation cover having convex and concave slopes in which they are dominantly spread on west and south-western aspect. This vegetation is generally observed over Rampur and Bandal formations with medium to low drainage density. Riparian Forest is generally observed in valleys. RF is occupying an area of about 0.02% of the total area. Low slopes having concave to convex form over southern and south-western aspects influence them. This vegetation is observed over Bandal granites with a less complexity over medium to high drainage density. Secondary Scrub is occupying an area of approximately 22.26 km^2. Steep slopes having concave forms on south-western and southern aspects influence these. They are observed mostly over Bandal granite and Rampur formations with medium to low drainage density, covering approximately 3.09% of the total area, with moderate to high complexity.

Alpine Scrub is occupying about 16.34% of the total vegetative area. They are mostly restricted to concave and convex slopes 10.68 and 11.58 km^2 respectively. They are profound over south-western and southern aspects and generally observed on Vaikrita and Jutogh group of rocks covering an area of 16.34% of the total area of vegetation with a medium to low drainage density, covering approximately 117.71 km^2 of the total area with moderate complexity whereas Habitation/Agriculture/Orchard falls under non-forest type but because of the resolution constraints in the data, the habitation could not be delineated as a separate unit. It is noticeable that the study area is having dominantly orchards with agriculture in the surroundings of habitation intermingling with natural vegetation (trees of fuel and fodder). This type is covering an area of about 3.54% of the total vegetation cover over dominant concave forms with east and northeast aspects. It is observed on Bandal granite followed by Rampur formation covering 3.54% of the total area with medium to low drainage density having less complexity. Plantation, mostly blupine is occupying an area of about 0.02% of the total area mainly over moderate slopes with concave form in north-western aspect.

Plantation is observed over Bandal granite, approximately 0.16 km^2 of the total area with less complexity and medium drainage density. Temperate Broad Leaved Forest are observed along valley/khadd/nalah influenced by drainage density that is why they are occupying areas with low, medium and up to the high drainage densities, approximately 10.27, 17.03 and 12.93 km^2 respectively. Moderate slopes also influence them; mostly the area is about 5.96% of the total vegetation. This type is occurring over predominantly concave form on south-western and south-eastern aspects. They are generally observed on Bandal and Rampur formations with moderate to less complexity.

Kharsu Forest are high altitude broad-leaved forests occupying an area of about 3.29%, and found to be restricted over concave and convex slopes covering approximately 23.7 km^2 having medium slopes on south-western and south-eastern aspects. They are observed on Rampur formation and Bandal granite approximately 16.76 and 6.39 km^2 respectively, with a medium to low drainage density approximately 3.29% of the total area with a less complexity. Temperate Mixed Conifers Forest is occupying an area of about 11.43% of the total area, and is influenced by moderate slopes having dominantly concave form on north-west and north-east aspect. The type is mainly observed on Rampur and Bandal formations with low to medium drainage density, covering approximately 82.39 km^2 of the total area with less complexity.

The Temperate Grasslands is observed having an area of about 4.40% of the total area. They are more restricted to medium slopes with concave form on south and south-eastern aspect approximately covering an area of about 31.7 km^2. They are observed over Bandal granites followed by Rampur formation with low to medium drainage densities in moderately complex areas. Sub-Alpine Mixed Conifer Forest occupying about 5.43% of the total area, having moderate slopes followed by lower slopes on dominantly convex forms followed by concave areas. They are observed pre-dominantly on north-western and western aspects. They is generally observed over Rampur formation followed by Bandal granite approximately covering an area of about 39.11 km^2 of the total area with low to medium drainage density in less to moderate complexity.

Sub-Alpine Grasslands are occupying an area of about 3.09% of the total area, dominant over moderate slopes followed by concave form and convex form approximately the area of about 22.25 km^2. They are generally observed on south-western and southern aspects. They are observed mainly over Rampur formation followed by Bandal granite with medium to low drainage densities, and moderate complexity. Alpine Grasslands are the dominant grasslands in the study area. The total area covered by this type is about 26.91% of the total area and is mainly influenced by concave form of slopes covering followed by convex form of slope approximately 139.94 and 53.95 km^2 area. The type is observed mostly on south-western aspect followed by north-eastern aspect. They are observed mainly over Rampur formation followed by Bandal granite with a low to medium drainage density and less complexity.

Slope versus vegetation are generally classified into four categories i.e. low, medium, steep and very steep. The dominance of vegetation over particular slope categories are observed and it is found that in lower slope category the maximum area covered by alpine grasslands is 32.40% followed by alpine scrub (14.48%), temperate mixed conifer (11.45%) and broad-leaved mixed with conifer (9.30%). On the moderate slope, alpine grasslands (26.19%) covered maximum area whereas riparian forests covered minimum area. Likewise in steep slopes again alpine grasslands are dominated (20.48%) and the plantation is minimum (0.01%). In the same way broad-leaved with conifers (31.70%) are found dominant on very steep slopes whereas riparian forest are found minimum (0.67%) on these slopes. Overall maximum area lying under moderate slopes is approximately 444.45 km^2, whereas the minimum area observed on lower slope category is approximately 181 .67 km^2. 19% of vegetative cover is on lower slopes out of total area covered by vegetation (721km^2). The landuse/cover covered by lower slopes is 25%. In the same way maximum area over moderate slope cover is 38% of the total area, of which 62% is covered by vegetation and landuse type out of the total vegetation area. On the other hand under very steep category are only 0.38% of the total area in which only 0.62% is covered by vegetation out of the total vegetation cover i.e. (721sq km^2). According to (Hara 1996), the relationship between micro-landform and vegetation structure a slope from the ridge to the valley bottom in evergreen broad- leaved forest on S-W Japan a well-developed forest stand, whose dominant species were *Castanopsis sie boldii*, *lutchuensis* and *Schima wallichii*, wa s seen on the upper slope, whereas only a poorly developed stand was seen on the lower slope (Fig. 10).

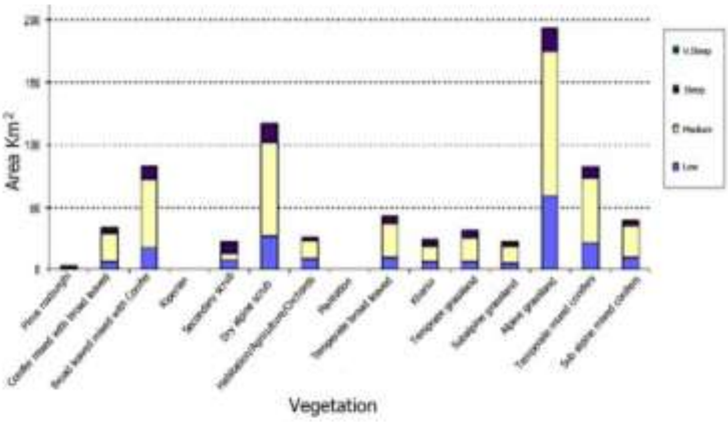

Fig. 10. Area under Slope Categories in Various Vegetation/lan d use Types

Shape (form) versus Vegetation was observed that the maximum area covered by vegetation falls under concave form of slope i.e. by alpine grasslands (approximately 31.62%) followed by alpine scrub (15.09%) and temperate mixed conifer (13.84%). On the convex form, maximum area is covered by alpine grasslands (18.53%) followed by dry alpine scrub and broad-leaved mixed with conifer (14.62%). As a whole the minimum area covered by the riparian forest was 0.01% on the convex form. Likewise, in flat category only sub-alpine mixed conifer forests are found covering an area of about 0.04 km^2 which is 100% within the flat form of slope. Overall maximum area lies in concave category covering vegetation approximately (38%) within the total area in which 60% of vegetation has been covered by the slopes out of the total vegetative cover i.e. 721 km^2 whereas the minimum area found under flat category is approximately 0.4 km^2, (Fig.11).

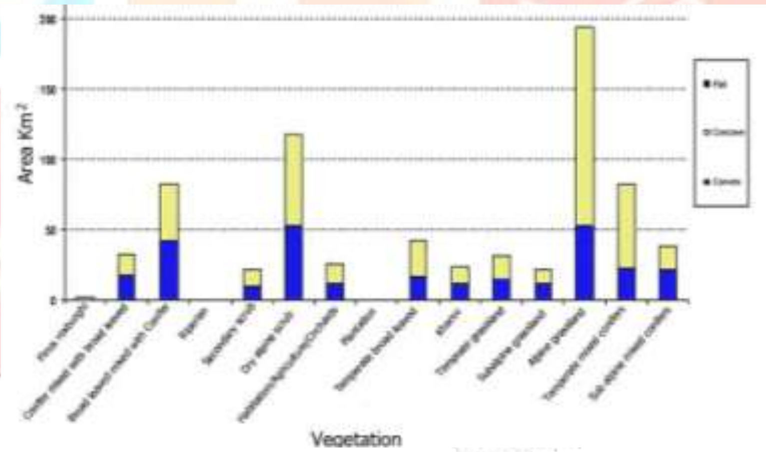

Fig. 11. Area under Shape Categories in Various Vegetation/land use Types

Aspect versus Vegetation was categorized into eight categories/ directions. The maximum vegetation type is influenced by south-western aspect covering approximately 119.16 km^2, whereas the minimum area covered by the vegetation i.e. *Pinus roxburghii* (0.3%) on northern aspect. The overall minimum area is found under total vegetation in north aspect (3%) approximately 32.2 km ^{2}. The maximum area covered by alpine grassland is (30%) followed by alpine scrub in SW aspect. On the eastern aspect maximum vegetation found on alpine grassland followed by broad-leaved mixed with conifer and tem perate mixed with conifer whereas on south-ea stern aspect, maximum area is covered by alpine grassland followed by dry alpine scrub. On southern aspect the alpine grasslands are dominant. On western aspect the same alpine grassland are dominating followed by alpine scrub. The northwest aspect is dominated by temperate mixed conifer (24.49%) followed by alpine grassland (19.50%). According to Chang et al. (2003) that Tundra was almost evenly present in various aspects. Most larch forest was in favor of northeastern direction with small amount facing eastern and northern way (Fig.12).

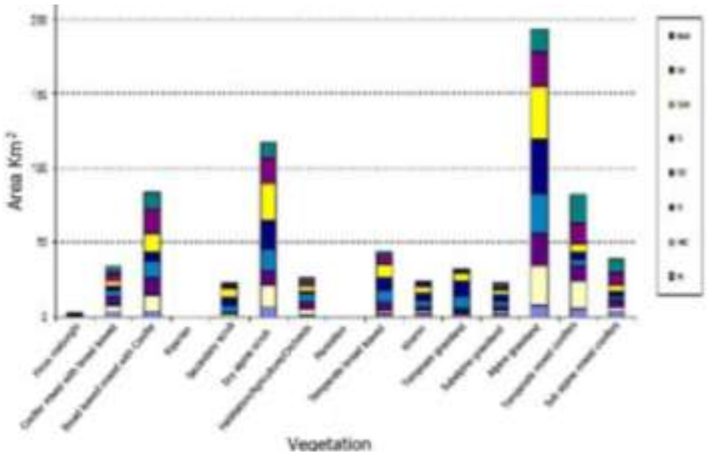

Fig. 12. Area under Aspects in Various Vegetation/land use Types

Drainage density versus vegetation is classified into four categories i.e. low, moderate, high and very high. The dominance of vegetation type is observed in each category. On lower density the maximum area is covered by alpine grassland (approx. 29.91 %) followed by the alpine scrub and temperate mixed conifer. The minimum area is covered by the *Pinus roxburghii* (0.38%). Under the moderate drainage density, the maximum area is covered by the alpine scrub (25.54%) followed by the alpine scrub (15.70%), whereas the minimum area is covered by the vegetation in this category is riparian (0.03%). On the higher drainage density the maximum area is covered by alpine grassland (25%) followed by the alpine scrub (20%), whereas the minimum is covered by riparian (0.02%). Under the very high category the alpine scrub (28%) are dominated followed by the alpine grassland (2 5%). The minimum area covered by riparian forest is 0.12%. The correlation between vegetation and drainage density indicated that the alpine scrub has highest drainage density (27%) and riparian forest (0.02%) has the lowest drainage density. Generally the maximum ar ea covered by the vegetation found over lower drainage density i.e. approximately 277.76 km^2, which is 38% of the total vegetation i.e. (721 km^2) whereas the minimum area lies in the riparian forest (0.12%). According to (Wondzell et al 1996), the Sharp ecotones occurred at the transition from depositional to erosion al landforms where little material was transferred and steep environmental gradients are maintained, Gradual ecotones occurred at the transition from erosional to depositional landforms where large quantities of material were transferred leading to the development of a gradual environmental gradient (Fig.13).

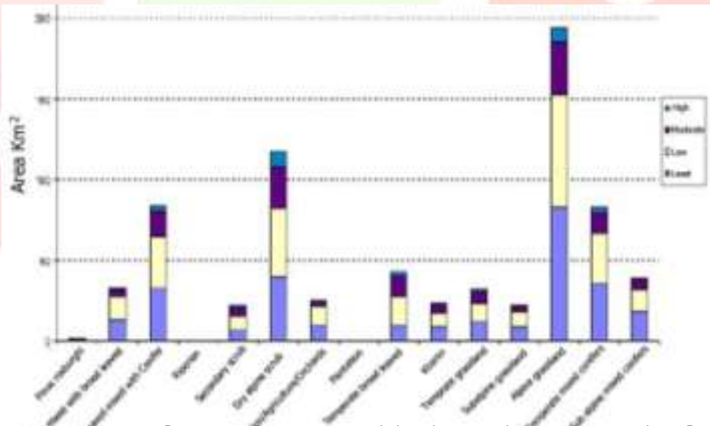

Fig. 13. Area under Dr ainage Densities in Various Vegetation/la nd use Types

Terrain complexity versus vegetation is divided into three categories for the study of complexity, namely low, moderate and highly complex terrain. In the l ess complex terrain the maximum area of vegetation (41%), of which alpine grassland are (32%) followed by alpine scrub and temperate mixed conifer. The minimum area of vegetation is found in highly complex areas (19%) in which riparian is (0.01%). Under the moderate complex zone, the maximum area is of alpine grasslands (25.79%), whereas the minimum area of vegetation found in riparian forest (0.01 %). The alpine grassland (25.41%) followed by the alpine scrub (16.14%) dominates the hig hly complex zone. Overall Maximum are a found under less complex zone i.e. (approximately 41%) of the total vegetation cover and 2 5% of the total area i.e. 1171 km^2), whereas mini mum area observed in highly complex zone i.e. 19% of the total vegetation cover (Fig.14).

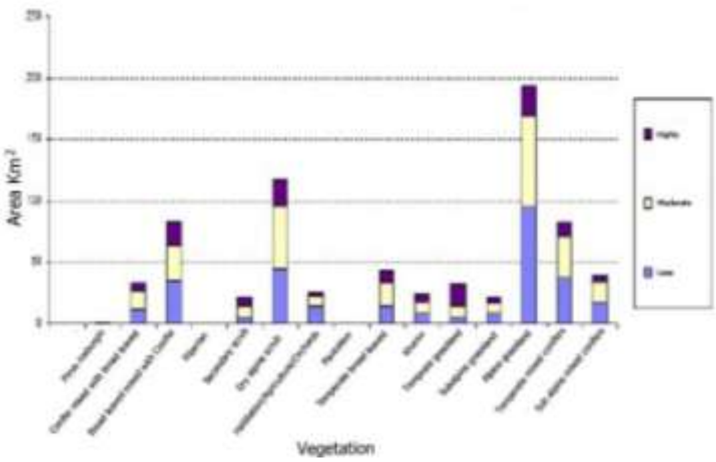

Fig. 14. Area under Te rrain Categories in Various Vegetation/la nd use Types

Geology versus vegetation is mainly consist of following formations/groups, which are exposed on the study sites viz. Rampur formation, Bandal Granite, Chail Group, Jutogh Group, Vaikrita Group and Haimanta Group. Rampur formation has maximum exposures and covers the most of the area by vegetation, which is about 312.61 km^2. The maximum area under the vegetation on this formation is alpine grasslands (27.39%) followed by the broad-leafed mixed with conifer. The Bandal granites are the second largest formation covering most of the vegetation. The maximum vegetation in this is covered by broad-leafed mixed with conifer approximately 18.96% followed by the temperate mixed conifer. The riparian forest (approx. 0.07%) covered the minimum area. On Chail group the maximum area found under alpine grassland is 49.47% followed by the alpine scrub (36.48%). The minimum area covered by the vegetation in this group is temperate broad-leaved forest (0.07%). Under the Jutogh group the maximum area covered by alpine grassland is 57.98% and the minimum area covered by the subalpine grasslands, whereas under Vaikrita group. Alpine grassland are covering most of the area and minimum area covered by the alpine scrub. The Haimanta group finds above 5000m altitude that is why no vegetation is observed in this group. The maximum area of vegetation found in Rampur formation, whereas minimum area of vegetation finds under Vaikrita group (Fig.15).

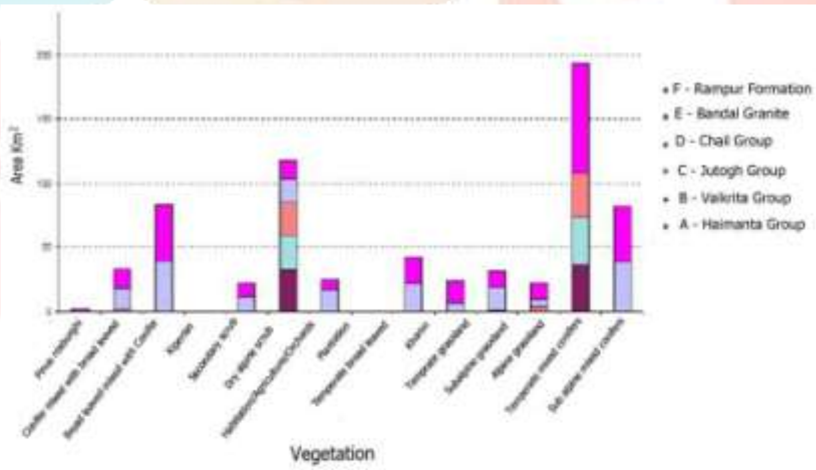

Fig. 15. Area under Geological Formations/Group in Various Vegetation/land use Types

In geo-botanical studies the relation between lithology and vegetation is observed through overlay analysis and it is found that the minimum vegetation growth is over Jutogh formation. It is noticeable that overlay analysis considers the spatial extant and areal estimation within the overlays. The minimum percentage of vegetation is in sub alpine about (0.28%) on Jutogh group. The group is composed of garnet-biotite, schist and gneisses along with quartzite**.** Whereas, the maximum vegetation cover is found on the Rampur formation composed of quartzite and metavolcanics i.e. alpine grasslands cover about 27.39% of the total area. It is observed that the maximum percentage of Chirpine is found in the Rampur formation with influence of southern aspect and lower altitudes. Other studies have also reported these observations. For example, (Dhar and Jha 1978) found chirpine on terraces/piedmont deposits derived from sandstone and shale, while studying geology and distribution of plant communities in Dharamsala area of Himachal Pradesh.
The importance of geology in the study of forest vegetation in India was recognized as early as 1921 by Troup who recorded that the effect of geological formations in determining the local distribution of the blue pine on mica schist and chirpine on quartzite, below Bandal in the Tirthan valley. A spatio-geoecological framework based on geographic information systems (GIS) and a vegetation survey were also developed by (Hong et al 2004) for wildlife habitat evaluation of national parks in Korea. On the

basis of an ecotope (spatial eco-space) map combining biological and geophysical variables the geoecological factors were determined relating to the spatial pattern of plant community.

In this study the Kharsu forest and subalpine mixed conifer (fir and spruce) is found maximum in the upper reaches of the Rampur and Bandai formations composed of Quartzite with metavolcanics and Granites. Here soil is fertile with higher humus. While studying in Dhuladhar range (Dhar and Jha 1978) observed that this range was composed of gneissose granite in maximum altitude, on weathering because of kaolinisation of the orthoclase, the rock becomes soft, deep fertile with high humus soil which supports the Kharsu oak, spruce and fir. Riparian forest is also found especially distributed only on the Bandai granite but certainly it is not only influenced by the lithology but also because of drainage and transported material. Non-forest class i.e. habitation/agriculture/orchards are considered for analysis because of intermingling of the vegetal cover with the habitation. Though habitation is not directly related to the litho units, but slope, aspect, drainage and shape might play important role in distribution of this non-forest category. Though no marked relationship is observed while correlating geology with vegetation, but through this study it is realized that there are also other factors controlling the vegetation growth in the forms of topographic features (slope, aspect, shape, drainage density, terrain complexity etc.). This fact was observed while analyzing remote sensing geobotanical trends in Quctico Provincial Park, Ontario, Canada, using Digital Elevation Data (Warner et al 1991). They found an increase in the deciduous species growing on mafic lithologies. They also found that north facing, cool sites underlain by mafic lithologies have the highest conifer components. The mafic lithologies were found to support vegetation similar to that growing over granite for north facing slopes steeper than three degrees. They also observed that aspect, drainage and the lithology; all influence the forest cover in Quantico. Aspect was an important parameter, while determining the geo-botanical relationship.

According to Mohan and Puri (1956) there was a striking habitat difference on scarp and dip slopes. The *Pinus roxburghii* is found stable over scarp slopes, which are steep and precipitous while on the dip slopes, the other conifers with broad-leaved communities were found, which are gentle and topographically stable sites. This relation may be understood in the context of aspect. In the study area although the rocks have many folds and are tectonically aligned but the general alignment of the ranges is NW-SE (Puri 1950a). It is observed in field that maximum percentage of *Pinus roxburghii* is in the southern and western aspects along with maximum percentage of temperate, sub alpine and alpine grasslands. It may be because the sun illuminates the scarp slope portion, as the rocks of the study area generally dip towards ENE/NE. The NE & E aspect had the maximum vegetation composed of conifer and broad leaved forest vegetation possessed.

The growth of vegetation on NW aspect may be because all the river systems are flowing from NE/E to SE/S direction except Parvati (which flows initially towards north then turns towards west and afterwards south). Generally, they are making NW aspect with combination of north, north-east by erosion in the valley portions in the study area, which may further be influenced by the microclimatic factors as far as vegetation growth is concerned. Moderate slopes are observed on the most preferable sites for the vegetation growth with concave shape and its forms. Most of the flat areas are under snow and the absence of vegetation indirectly reflects that the flat/rounded/sub rounded topography might be under glaciations.

Slope studies are generally quantitative thus to define the slope in the form of concavity, convexity and flat areas, softwares are available in GIS domain for characterizing the topographic surfaces (Savigear, 1956 and Young, 1964). This has also been reported by the (Falcidieno et al 1990) and (Lin and Perry 1982). While seeking relation between drainage density and vegetation, it is observed that the alpine scrub are on higher drainage density (DD), which may be because of the nature of catchment area and lower DD is found in the riparian forest. The moderate slopes (21^0-50^0) are having the maximum vegetation followed by lower angle slopes, while correlating with vegetation.

In the less complex areas, alpine grasslands are dominant which may be due to modification in topography during glaciations. Wherever in the study area on lower altitude, terrain is found less complex it is realized that the area is covered with forest. On the other hand, there is less vegetation on highly complex convex form, as far as the spatial distribution of vegetation is concerned. In geo-botanical studies soil play important roles (Puri, 1950a and Mohan and Puri, 1955). In the Himalayas soil are *in-situ* in nature, wherever the landform elements are covered by the secondary soil as stated by (Puri 1955), and their physical and chemical nature varies greatly with original rock material and nitrogen. It is observed in the study area, wherever the soil are sandy the succession of chirpine and blue pine community were observed. On more fertile soil over little higher ridges, the Blue pine, Deodar, Abies with *Piecia smithiana* communities are present. On fresh alluvium, there were riparian patches of *Alnus nitida* at Bathad, which grow up to 50 meters along nalas because of the same fresh alluvium. Near Shakti, patches of *Hippophae* sp., and *Myicaris* sp. are found comparatively at higher altitudes, may be because of climatic variations with altitude and different soil materials deposited by the river.

The chirpine is found on the rock scree in the study area near Sairopa in Tirthan valley and near Seund in Sainj valley. Through visual interpretation of satellite images, it is observed that the alpine scrub was widespread in the Parvati valley along stream on the both sides (Rawat 1999 personal communication). In the study area, the conifers are also related to altitudinal zones. This fact is also supported by Puri (1950b) that *Pinus roxburghii* occurs at low altitude zone and on upper limits the silver fir is found, and in the intermediate altitude *Cedrus deodara*, *Abies pindro*, *Picea smithiana* occur, supported by data of foliar ash and CaO (Calcium Oxide) of tree species.The study reveals that in the case of Himalayas the vegetation is not only dependent on geology and landform with soil but is also controlled by the climate and altitude.

4. Conclusions

Much of the observations in this study are based on visual interpretation with convergence of evidences. It also includes the opinions of experts. For the study of vegetation distribution with reference to the landscape can be used as one of the most important parameters, because various landforms are the results of interaction of natural forces with land. For example, wildlife species make use of wide range of habitats; with varying topography and vegetation.

The study shows that a particular landform is preferred by specific species. For instance, Sal grows on heavy well drained soil, maximum vegetation area under less complex zone and Chirpine on lower slopes of hill. As far as conservation is concerned, the landslides and erosion have a negative impact because of their destructive nature. The results from the study can be used to develop better conservation strategies for utilizing resources in a way that future generation can utilize it properly. This may be further useful in sustainable development planning and conservation programmes as for instance, planning of protected areas, habitat suitability analysis, waste land development, reforestation, aforestation, watershed development and resource utilization.

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REFERENCES:

[1] Bunzhuo, P., Lijie, P., Haosheng, B. & Higgitt, D.L. 1997. Vertical zonation of landscape characteristics in the Namjagbarwa massif of Tibet, China. Mount. Res. Devel. 17:43-48.

[2] Cannone N., Guglielmin, M., Gerdol, R. 2004. Relationships between vegetation patterns and periglacial landforms in northwestern Svalbard, Polar Biology, 27(9), 562-571.

[3] Chang,Yu., Bu, R., Hu, Y., Xu, C., & Wang, Q. 2003. GIS and RS determination of abiotic range of forest landscape distribution in Changbai Mountain Natural Reserve, the Journal of Applied Ecology, (2003),14(5), 671-675.

[4] Dhar, B.L. and Jha, M.N. 1978. Geology and distribution of plant communities in Dharamsala area. Himachal Himalayas. *Himalayan Geology* 8: 54-60.

[5] Falcideno, B. and Spagnuolo, M. 1990. Automatic recognition of topographic features for digital terrain modeling. In: K. Brassel and H. Kishimoto (eds.) Proceedings of spatial data handling, Department of Geography, University of Zurich. 35-44.

[6] Gaston, A.J. and Garson, P.J.1992. *A re-appraisal of the Great Himalayan National Park, Himachal Wildlife Project III. Himachal Pradesh Department of Forest Farming and Conservation*, International Trust for Nature Conservation, World Wide Fund for Nature, India and Oriental Bird Club. 80.

[7] Gerhardt, F., and Foster, D. R. 2002. Physiographical and historical effects on forest vegetation in central New England, USA, Journal of Biogeography, 29(10-11), 1421-1437.

[8] Hara M., Hirata, K., Fujihara, M., and Oono, K. 1996. Vegetation structure in relation to micro-landform in an evergreen broad-leaved forest on Amami Ohshima Island, south-west Japan, Ecological Research, 11(3), 325-337.

[9] Hong, S,K., Kim, S., Cho, K., Kim, J., Kang, S., and Lee, D. 2004. Ecotope mapping for landscape ecological assessment of habitat and ecosystem, Ecological Research, 19(1), 131-139.

[10] Kala, C.P. and Mathur, V. B. 2002. Patterns of plant species distribution in the Trans Himalayan region of Ladakh, India. Journal of Vegetation Science, 13: 751-754.

[12] Kikuchi., T. and Miura, O. 1993. Vegetation patterns in relation to micro-scale landforms in hilly land regions, Plant Ecology, 106 (2), 147-154.

[13] Kim, K.C. and Weaver, R.D. 1994. *Biodiversity and landscapes,* A paradox of humanity. Cambridge University Press. 431.

[14] Lin, C. and Perry, M.J. 1982. Shape description using surface triangulation proceedings of the workshop in computer vision: Representation and control. New York: Computer Society Press. 38-45.

[15] N.P. Mohan and G.S.,Puri 1956. The Himalayan Conifers. The succession in Chir forest of the Punjab and Himachal Pradesh. Indian Forester. 82(7).

[15] Naithani, S. 2013. Interpretation and Analysis of Habitat Parameters in Rajaji National Park, Uttarakhand, Journal of International Academic Research For Multidisciplinary, Vol. 1 Issue 10 November,302-308.

[17] Naithani, S. Mathur V.B. 2014. Specialized Mapping using Climatic Zones for Habitat Conservation, International Journal of Advanced Remote Sensing and GIS 2014, Volume 3, Issue 1, pp. 660-668.

[18] Naithani , S. and V.B. Mathur 2016. Comparative Analysis of Eco-zone; Great Himalayan National Park, India, Indian Journal of Ecology (2016) 43 (1).

[19] Noss, R. F.1990. Indicators for monitoring biodiversity: hierarchical approach. *Conservation Biology* 4:355-364.

[20] Oliver, C.D. and Larson, B.C. 1990. *Forest stand dynamics. Biological Resource Management Series*. Mc Graw Hill, New York. 467.

[21] Ozkan K. 2009. Environmental factors as influencing vegetation communities in Acipayam district of Turkey, Journal of environmental biology Academy of Environmental Biology India, 30(5), 741-746.

[22] Pandey, U. and Singh, J.S. 1984. Energy flow relationship between agro and forest ecosystem in central Himalaya. *Environmental conservation* 11(2): 45-53.

[23] Puri, G.S. 1949. Physical geology and forest distribution. *Science and Culture* 15:183-186.

[24] Puri, G.S 1950a. *The importance of geology in the study of vegetation.* Proceeding I.S.C. part III abstract. 37: 63-64.

[25] Puri, G.S. 1950a. Soil PH and forest communities in the sal forest of the Dun valley, U.P., India, *Indian Forester* 76: 292-309.

[26] Puri, G.S. 1950b. The distribution of conifers in Kullu Himalayas with special relation to geology. *Indian Forester* 76: 144-153.

[27] Rawat, 1999. Personal communication.

[28] Roy, A.K. and Jugran, D.K.1986. Remote sensing for geology and geo-morphology of Kanha wildlife habitat, M.P. *Seminar on wildlife habitat*. Held at Wildlife Institute of India from October 22-23, 1986, 137-145.

[29] Savigear, R.A.G. 1956. *Technique and terminology in the investigation of slope forms,* Premier raport de la commission pour 1etude des versants, international geographical congress, Reo de Janeiro, 66-75.

[30] Troup, R.S. 1921. The silviculture of Indian trees. International Book Distributors, Dehradun. I-III.989.

[31] Urban, D.L., O'Neill, R.V., and Shugart, H.H. 1987. Landscape ecology. *Bioscience* 37: 119-227.

[32] Warner, T.A., David, J., S., Evans, C., Levandowski, D.N., and Cetin, H. 1991.
Analyzing remote sensing geobotanical trends in Quetico Provential Park, Ontario, Canada, using digital elevation data. *Photogram. Engg, and Remote Sensing* 57(9): 1179-1183.

[33] Wondzell, S. M., Cunningham, [33] G.L. and Bachelet, D.1996. Relationships between landforms, geomorphic processes, and plant communities on a watershed in the northern Chihuahuan Desert, Landscape Ecology, Volume: 11, Issue: 6, Publisher: Springer, 351-362.

[34] Zomer, R., Ustin, S. and Ives, J. (2002). Using satellite remote sensing for DEM extraction in complex mountain terrain: Landscape analysis of the Makalu Barun National Park of eastern Nepal. INT. J. remote sensing, 2002, Vol. 23, (1): 125-143.