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Analysis of Disturbance Gradient in Tehri Garhwal Region, Uttarakhand, India- A Spatial Landscape Modelling Approach

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Abstract

The analysis was performed taking into account various landscape indices like fragmentation, patchiness, porosity, juxtaposition and interspersion. The disturbance gradient analysis is done using the spatial landscape modelling software (SPLAM). The disturbance index obtained showed that the forest in the area is highly fragmented indicating increased anthropogenic interference in the region. Anthropogenic disturbance was measured as a result of the proximity of landscape to road and settlement. Disturbance gradient analysis has shown that the 29.52% of the area was under low disturbance in 1972, which has gradually decreased to 5.01% in 2006 converting major area to medium or high disturbance. The analysis of disturbance regimes along the altitude, slope and aspect showed that in low lying slopes more area was under low level of disturbance in 1972-1990 which shifted to medium or higher level in 2000-2006. The slopes >30% are highly disturbed slopes. Disturbance along the aspect showed that greater degree of disturbance is in west to east aspect. The study on elevation showed that lower (500 to 1250 m) and higher elevation (2500 to 2791 m) areas show lesser degree of disturbance, in comparison to medium elevation (1500 to 2500 m) areas which shows greater disturbance.

Keywords: Fragmentation, patchiness, porosity, juxtaposition, interspersion

Introduction

Himalayas are massive mountains that occupy over 1 million sq km. Area. The Himalayas also feature a fragile ecosystem. For centuries this ecosystem was the storehouse for tremendous biodiversity in the Himalayas. In the recent years due to processes both man-made and natural this fragile ecosystem has been further deteriorated. Man is mainly responsible to a large extent for some of the environmental problems faced by the mountains. As man urges for industrialization, modernization and various other developmental activities, man has disturbed the natural ecosystem of many parts of the world. The Himalayas have been no exceptions. The Garhwal Himalayas of Uttrakhand spread about 30, 000 sq. km, comes under forests, meadows, marshes, swamps etc., with their characteristic plant composition. Champion and Seth (1968) have described nine forest types in Garhwal Himalayas. However the large tract of forest, which was once flourishing all along, the northern ranges have either been highly degraded or in some cases have been eliminated. In the last few decades these activities in the region are the other major feature of the ecological crisis, which occur due to the construction of roads, and settlement, dam, mining operations and other developmental activities.

Landscape includes all grades of biological hierarchy from ecosystem level to species and genes level. It also includes, agricultural, forested, protected and ecologically sensitive areas, which interact considerably (Forman and Godron, 1986) and upon which humans have major influence (Naveh and Liberman, 1990). The utilization of resources in non-sustainable manner causes the fragmentation of the landscape leading to the disturbance in the ecosystem. These landscapes can be studied regularly and checked for disturbance by using remote sensing. Using maps and remote sensing data, with careful ground truthing, it is possible to derive information about vegetation types (Roy & Raven et al. 1996), and thus remote sensing can be used successfully to identify the frequency, boundaries, sizes and shape of various landscape components (Scott et al., 1993). This has been well studied by Roy *et al*., (1993) in diverse ecological conditions in India. In the global scenario the recent trend in landscape characterization and vegetation studies demonstrates the advancement.

Study Area

Tehri Garhwal is a district that lies in the Uttarakhand state located on the outer ranges of mid Himalayas which extends from the snow covered Himlayan peaks of Thalaiya Sagar, Jonli and the Gangotri group all the way to the foothills near Rishikesh. The Bhaghirathi River divides the district into two, while the Bhilangana, Yamuna, Alaknanda Ganga and Yamuna rivers border it on the east and west. The present study area elaborately describes the part of Tehri Garhwal district of the Uttarakhand state in Northern India. It lies between the latitude 30°14′ N to 30°34′ N and longitude 78°18′ E to 78°34′ E. (figure 1)

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The total area is 875 km^2. Tehri Dam was constructed in this area on river Bhagirathi near its confluence with river Bhilangana , the principle tributary of river Ganga downstream of Tehri town in Garhwal Himalayas, Uttarakhand. Its height is 855 feet (261 m), and ranks 5th on the scale of height among all the dams in the world.

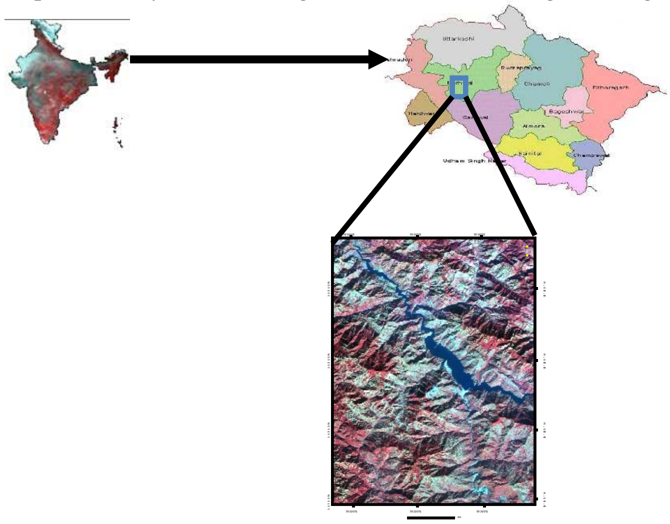

Figure 1. Location of the Study Area.

Forest type

The forest type of the area is mainly divided into four main divisions (1) the chir forest, (2) the oak forests, and (3) the deodar forest (4) the sal forest.

Chir forest

This forest ordinarily extends on the southern aspects from 1,000 m to 2,150 m altitude and on the northern aspects from 900 m to 2,000 m altitude throughout the area. These forests are more prominent in the Bhilangana valley. In all chir forests, the pine (*Pinus roxburghii)* is the dominant tree species present throughout. The chir forests are seldom very dense. The ground is covered with grass, sometimes dense, and there is discontinuous undergrowth of shrubs, often so widely scattered that even from a short distance their presence is scarcely noticeable. The open nature of these forests, the absence of other tree species and poverty of the undergrowth are attributable to fires which have in past swept annually throughout the area. Towards its lower limit, Chir gets mixed with trees of miscellaneous species and, less frequently, with Sal forests. Towards its upper limits and in moist and shady ravines, it gradually gives place to oak.

Deodar forest

Deodar (*Cedrus deodara)* forests occur in the northern part of the area in tahsil Pratapnagar in a small area between the altitudes of 1,520 m, and 2,150 m above the sea level. The forests are open and the trees do not attain great height.

Oak forest

The three principal oak are *Quercus incana* (banj), *Quercus semicarpifolia* (kharsu) and *Quercus lamellosa* (moru). Banj forests are ordinarily found between the heights of 1,800 m. and 2,150 m., above the mean sea level but they occupy moist ravines running down into the chir zone where they reach level as low as 1,050 m. Those present on the northern aspect are much dense, while on the southern aspect the ground is covered with dense grass. The Oak has a large number of shrubs associated with it. Moru forest is found between 1,980 m and 2,750 m above the mean sea level. It occupy intermediate zone between *Quercus incana* (banj) and *Quercus semicarpifolia* (Kharsu) . Kharsu forests occur at the higher tracts, at heights between 2,350 m and 3,500 m in the Pratapnagar area. At its lower limit, Kharsu often passes into banj forests. Kharsu forests are normally dense.

Sal forest

The Sal *(Shorea robusta)* forests occur at some localised patches and occupy mostly lower elevation. Wherever they are present in Tehri region, they have mostly medium to low density.

Materials and Methods

The materials used for the analysis mainly include satellite images LISS 3, landsat, ETM, TM, MSS (Table 1)and ancillary data namely SOI Toposheet (50 K) and Forest record. Software was applied for Image processing (ERDAS 9.1), GIS analysis (ARC GIS 9.1) and modelling (SPLAM).

Analysis of Landscape

Spatial Landscape Analysis Model (SPLAM) developed at Indian Institute of Remote Sensing, Dehradun (Roy et al., 1999). It is a program generated for the analysis of fragmentation, patchiness, porosity, interspersion, juxtaposition and disturbance index. SPLAM software uses a generic binary image as the input and the output is also written in the same format. For the landscape analysis, all the vegetation type maps of different time periods were converted into grid format, as input data. This is used in the calculation of all the landscape indices and finally shows the disturbance index.

The landscape parameters used for the assessment of disturbance are fragmentation, patchiness, porosity, interspersion, and juxtaposition (Table 2).

Table 1. List of Satellite data used.

Data Used	Path/Row	Date of Pass
IRS P6 LISS III	96/49	21 Dec 2006
LANDSAT ETM	146/39	25 Nov 2000
LANDSAT TM	146/39	21 Oct 1990
LANDSAT MSS	157/39	14 Nov 1972

Table 2. Landscape Matrices.

Parameters	**Formula**
Porosity	$PO=\sum_{i=1}^{n} CPi$ Where: CPi= Number of closed patches of i^{th} cover class. Forman and Godron(1986)
Patchiness	$P= \sum_{i=1}^{n} CPi$ Where: P= Patchiness. Di= Dissimilarity value for the i^{th} boundary between adjacent cells. N= Number of boundaries between adjacent cells. Romme (1982)
Interspersion	$I = \sum_{i=1}^{n} SFi$ Where: SFi = shape factor $i= \frac{1}{N}$, $SFi \; \frac{Edge}{2\sqrt{\pi} * Area\ j}$ Where: Edge = The length of edge, in both x and y directions Area j= Area of j^{th} polygon formed by groups I^{th} cover class. Lyon(1983)
Juxtaposition	$J= \sum_{i=1}^{n} Di(JUXi)$ Where: JUXmax = The average total weighted edge per habitat unit of good habitat. $i= \frac{1}{JUmax}$ Di= The edge desirability weight for each cover types combination, based on field data. JUXi = The length of edge between combination of cover types on either side of an edge. Lyon(1983)
Fragmentation	Fragmentation is number of patches of forest and non-forest type in per unit area.
$DI =\sum^{n}(Fragi * Wtj1 + Porji * Wtj2 + Inti * Wti3 + Juxi * Wtj5$ Where: DI= Disturbance Index, Frag= Fragmentation, P= porosity, Int= Interspersion, Jux= Juxtaposition, Wt= Weightages. Joshi et al., 2003	

Fragmentation

Fragmentation describes the distributional pattern of a land use class in the entire landscape. It signifies the interference of biotic or abiotic component on the landscape. Fragmentation of a landscape increases the threat to vulnerability of the landscape patches to external disturbance with threat to their survival and also on the supporting biodiversity (Nilsson and

Grelsson, 1995). It reduces the quality of habitat over a period. As habitat fragmentation increase, the disturbed habitat dominates in the landscape and original habitat occurs in isolated patches. Vegetation type map was simplified as forest and non-forest areas. Fragmentation is the number of forest and non-forest patches per unit area. Higher value of fragmentation indicates higher level of disturbance in the area.

Patchiness

Patchiness is the measure of the density of patches of all types or numbers of clusters in a given landscape. It is also described as the measure of the number of polygons over a particular area. As the patchiness increases in a forest the degree of disturbance also increases.

Porosity

Porosity is the measure of the number of patches or density of patches within a particular type, irrespective of patch size (Forman and Godron, 1986). Porosity is calculated only for a particular forest type or ecologically unique ecosystems. It provides all the information regarding the change of species isolation and genetic variability present within them in a landscape. Lower value of porosity indicates lower interaction among the landscape elements, i.e. homogeneity and less fragmented area and considerable remote area. Higher value of porosity indicates greater interaction among the landscape elements, i.e. heterogeneous and highly fragmented habitats.

Interspersion

Interspersion is the count of dissimilar neighbours with respect to central pixel. It measures the spatial intermixing of different patch types. Interspersion value gives us information on the resistance of the central pixel or class with respect to its surrounding neighbours. Higher value of interspersion indicates more disturbances in the landscape. This also indicates that the ability of the central class will be lowered or influence of the resistance by surrounding class may lead to the loss of the central class. The input layer taken was vegetation type map and the measurement of interspersion was done by assigning the relative weightages depending on the adjacency of the two cover types to meet the objective of the study. For determining the interspersion, a convolution window of

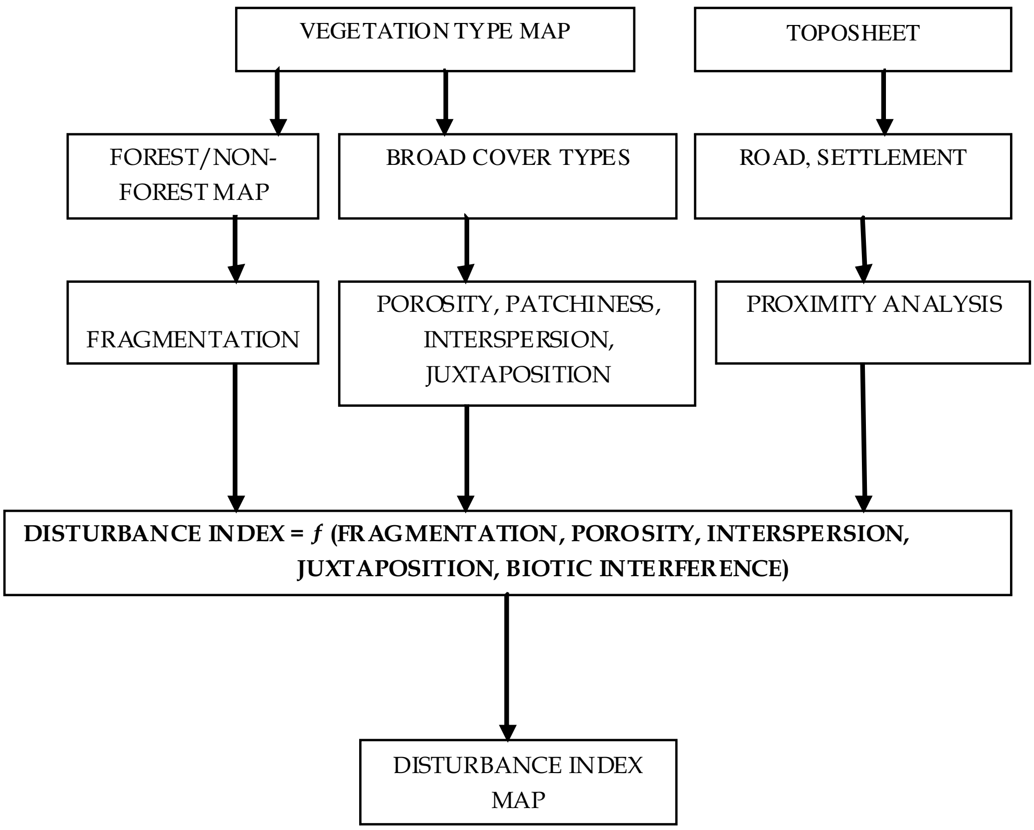

Figure 2. Methodology of SPLAM (Spatial Landscape Modelling).

3 x 3 pixels was used with a vegetation type map in order to compute the number of dissimilar pixels in the nearest neighbourhood. The computation was performed in an interactive mode through the entire spatial layer and an interspersion layer was derived as output. A normalized LUT was made in the range of 1-10.

Juxtaposition

Juxtaposition is the measure of proximity of the vegetation. It mostly measures the relative weightages assigned by the importance of the adjacency of two cover types for the species in the studied area. This parameter particularly helps in characterizing the parameter porosity with respect to natural and non-natural vegetation. Juxtaposition was calculated by comparing the class of central pixel with adjacent pixel depending upon the preferred weights assigned to the different forest types and other features in the area. The location of the adjacent pixel with respect to central pixel carries a weightage.

Analysis of Disturbance Gradient

The disturbance thus obtained by assigning the weights to all the landscape parameters was divided into three categories (high, medium and low) in forest class and agriculture, water and settlement. Each class was analysed separately. In analysing the disturbance index, more emphasis was given to the proximity of the forest to the road and settlement as they contribute more towards disturbance.

Results and Discussion

This research deals with the disturbance gradient analysis and characterisation of disturbance regimes in different physiographic conditions. This was done using various landscape indices like fragmentation, patchiness, porosity, juxtaposition and interspersion is made. Then after finding out the disturbance index, disturbance gradient in the area was also analysed for the time period from 1972 to 2006.

Analysis of disturbance gradient

The landscape analysis was done with two primary land use classes viz., forest and non-forest. This analysis indicates that the fragmentation in the landscape exists even at very lower area scales and effect of this fragmentation on forests appears throughout the studied area. This fragmentation is mainly due to the interaction and expansion of human activities over the natural landscape. The fragmentation is more concentrated within the densely populated areas. The non-fragmented area as homogenous areas represent either the natural vegetation, which are mostly forests saved due to the legal restrictions or rough inaccessible terrain, or modified landscape like village or non-forest area.

The total patchiness of the landscape with respect to all land cover classes indicates almost similar trend as emerged from fragmentation analysis, and shows the presence of heterogeneous patches within the landscape of the Tehri Garhwal region. These heterogeneous patches are reflected as an output of activities and interaction of human settlement, dam construction and people rehabilitation to different areas with the surrounding nature. This has led to adverse effect on the survival of natural vegetation. Oak and Chir pine, Deodar and mixed conifers are the four important forest types of Tehri Garhwal region. The number of these forest patches over the years from 1972 to 2006 has increased significantly owing to the disturbance in the surrounding ecosystem.

Porosity analysis of these four prominent forest types' viz., Oak, Chir pine, Deodar and mixed conifers indicates that these forests have a very close interaction with other land cover classes along the edge. This interaction of forests increases with the passage of time from 1972 to 2006 and the number of patch increasing and penetrating into a forest type, lowering the density of the forest and making it more susceptible to destruction.

Interspersion was calculated to analyze the diversity within the landscape. The analysis showed that most of the area is surrounded by different land use / land cover types which represents heterogeneous nature in constructional and other human activities within the studied area. For example, in a village area the agricultural fields are not continuous but they are surrounded by fallow land or with forests. Similarly the old Tehri region before the dam construction in 1972 was later utilized for dam construction site leading to the change in surrounding land use / land cover types. Thus it is causing heterogeneity in the forest types.

The results of fragmentation and heterogeneous within the landscape, proximity analysis for vegetation to vegetation was carried out and is represented as juxtaposition. The relative weightage was assigned keeping in view of the importance of adjacency of two forest types.

Finally a disturbance index was calculated on the basis of all the parameters studied in the landscape analysis. This disturbance index was calculated for all the years 1972, 1990, 2000 and 2006. The map showing the disturbance in the Tehri Garhwal region are given in figures 4 to 20 and distribution of area under different disturbance classes is given in from tables 3 to 7. A mathematical model was run after considering the weightages of all the landscape characters (input) with

Table 3. Developed juxtaposition table.

	18	**23**	**41**	**44**	**45**	**53**	**106**	**121**	**141**	**170**	**180**	**190**	**200**
18	8	2	6	5	4	2	2	2	1	1	1	1	1
23	2	8	4	3	1	5	6	6	2	1	1	1	1
41	6	4	9	4	4	3	3	2	1	1	1	1	1
44	5	3	4	9	6	2	2	1	2	1	1	1	1
45	4	1	4	6	9	1	2	2	1	1	1	1	1
53	2	5	3	2	1	8	6	4	2	1	1	1	1
106	2	6	3	2	2	6	8	6	2	1	1	1	
121	2	6	2	1	2	4	6	8	2	1	1	1	1
141	1	2	1	2	1	2	2	2	9	1	1	1	1
170	1	1	1	1	1	1	1	1	1	1	1	1	1
180	1	1	1	1	1	1	1	1	1	1	1	1	1
190	1	1	1	1	1	1	1	1	1	1	1	1	1
200	1	1	1	1	1	1	1	1	1	1	1	1	1

Where:

Class	**SPLAM Code**
Mixed Conifer	18
Miscellaneous forest	23
Chir pine	41
Oak	44
Deodar	45
Khair mixed	53
Degraded Forest	106
Scrub	121
Grass	141
Agriculture	170
Barren	180
Water	190
Settlement	200

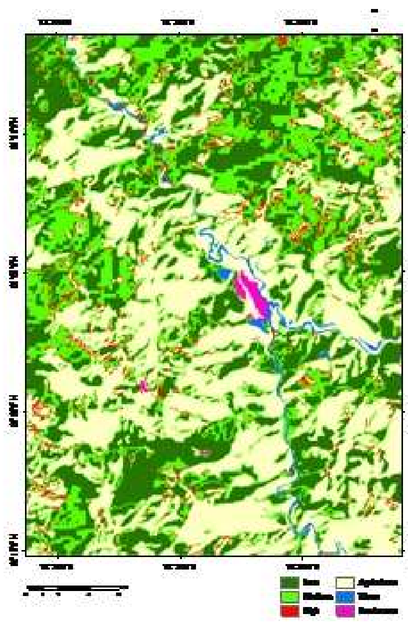

Figure 4. Disturbance index map of Tehri Garhwal region, 1972.

respect to their contribution towards the magnitude of disturbance. The result of the model indicates that Tehri Garhwal region is disturbed due to human settlement. However dam construction and road counts for maximum disturbance in the studied area. Destruction of the landscape due to the constructional activity causing heavy troll of vehicular movements and submergence of the surrounding forests in water due to the filling of the reservoir also contributes towards the disturbance in the area. A juxtaposition table was developed considering neighbourhood of different vegetation and other land cover types (Table 3). Appropriate SPLAM codes have been given for further analysis.

Table 4. Distribution of area under different disturbance classes, 1972.

Class	Area(km^2)	Area (%)
Low	258.35	29.53
Medium	217.12	24.81
High	34.18	3.91
Agriculture	352.54	40.29
Water	9.41	1.08
Settlement	3.40	0.39
Total	**875.00**	**100.00**

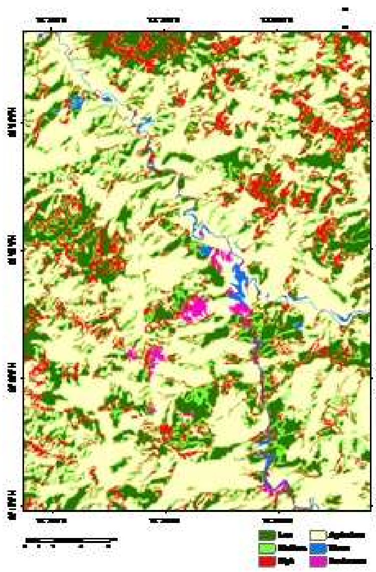

Figure 5. Disturbance index map of Tehri-Garhwal region, 1990.

Table 5. Distribution of area under different disturbance classes, 1990.

Class Name	Area(km^2)	Area (%)
Low	144.41	16.50
Medium	140.34	16.04
High	103.24	11.80
Agriculture	471.07	53.84
Water	9.59	1.10
Settlement	6.35	0.73
Total	**875.00**	**100.00**

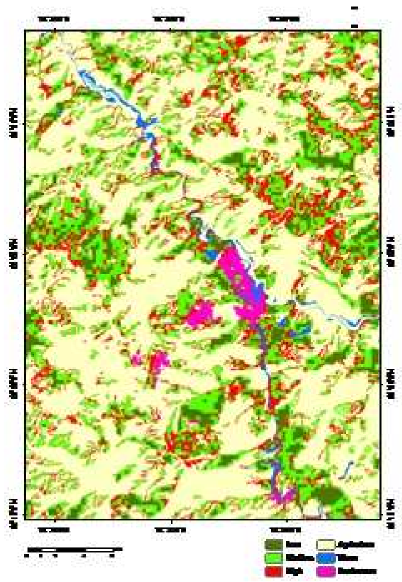

Figure 6. Disturbance index map of TehriGarhwal region, 2000.

Table 6. Distribution of area under different disturbance classes, 2000.

Class Name	Area(km^2)	Area (%)
Low	62.47	7.14
Medium	193.10	22.07
High	110.89	12.67
Agriculture	486.32	55.58
Water	11.32	1.29
Settlement	10.90	1.25
Total	**875.00**	**100.00**

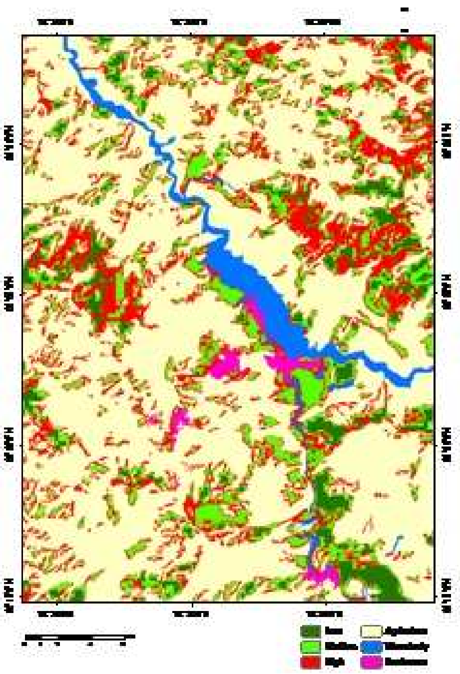

Figure 7. Disturbance index map of TehriGarhwal region, 2006.

Table 7. Distribution of area under different disturbance classes, 2006.

Class	Area (km^2)	Area (%)
Low	43.87	5.01
Medium	103.13	11.79
High	157.91	18.05
Agriculture	531.64	60.76
Waterbody	30.18	3.45
Settlement	8.28	0.95
Total	**875.00**	**100.00**

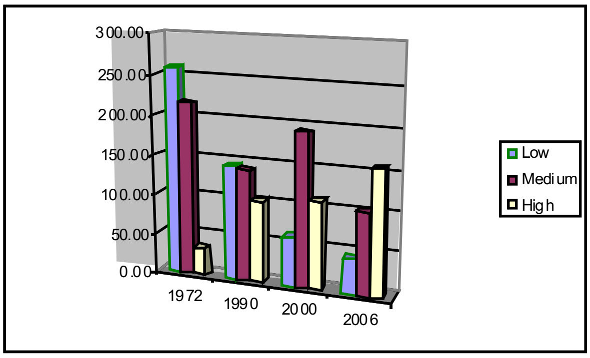

Figure 8. Distribution of area disturbed under different disturbance classes, 1972-2006.

Table 8. Distribution of area under different disturbance classes, 1972-2006.

Year	**1972**		**1990**		**2000**		**2006**	
Class	**Area (km^2)**	**Area(%)**	**Area (km^2)**	**Area(%)**	**Area (km^2)**	**Area(%)**	**Area (km^2)**	**Area(%)**
Low	258.35	29.53	144.41	16.50	62.47	7.14	43.87	5.01
Medium	217.12	24.81	140.34	16.04	193.10	22.07	103.13	11.79
High	34.18	3.91	103.24	11.80	110.89	12.67	157.91	18.05
Agriculture	352.54	40.29	471.07	53.84	486.32	55.58	531.64	60.76
Water	9.41	1.08	9.59	1.10	11.32	1.29	30.18	3.45
Settlement	3.40	0.39	6.35	0.73	10.90	1.25	8.28	0.95
	875.00	**100.00**	**875.00**	**100.00**	**875.00**	**100.00**	**875.00**	**100.00**

In 1972, 29.53 % of the forest area was under low disturbance, this has gradually decreased during the years 1990, 2000 and 2006 converting the major area to medium or high disturbance range. The area under medium disturbance also shows a decrease in trend from 24.81% in 1972 to 11.79% in 2006, converting the major area under high disturbance regime. The highly disturbed area has shown an increase in trend during the successive years from 1972, 1990, 2000 and 2006 as the dam construction has been started in the year 1972 and during the subsequent years i.e. 2000 to 2006 filling of reservoir with water took place thus submerging major portion of the forest. Also due to the dam constructed a large amount of the area has turned barren thus adding to the disturbance. The agriculture showed an increasing trend due to rapid urbanization of the region. Similarly water also shows an increase in the area and in 2006 the area has been increased up to 3.45% as compared to 1.07% in 1972. This has occurred mainly due to water filling after the dam construction. The settlement in the region shows an increase in trend from 1972 to 1990 but afterwards in 2000 and 2006 it shows a decreasing trend because after the dam construction large numbers of peoples are shifted from the dam site leading to fewer disturbances to settlement area during that period (Tables 3-8).The temporal disturbance gradients obtained are much alarming and shows that the area is highly disturbed due to the anthropogenic activities in the name of development and urbanization. The distribution of area under different disturbance classes is in gradient in table 7.

Analysis of Disturbance Regime along Different Physiographic Conditions

Dividing the disturbance in to three categories i.e., high, medium and low disturbance, further analysis was done. Each class was studied separately with respect to topographic parameters viz., slope, aspect and altitude.

Disturbance regime along the elevation

The study indicates that during the years 1972 and 1990, mainly 1250 to 2000 m elevation areas were disturbed. While in 2000, 1500 to 2500 m elevation area were disturbed. This trend remained the same in 2006 where 1750 to 2000 m have been found disturbed. This suggests that during the early periods, lower elevation areas were more disturbed while in 2000 to 2006, lower(500 to 1250 m) and higher elevated areas(2500 to 2791 m) were less disturbed as compared to the middle elevation area (1500 to 2500 m). This region is also very fragile due to the dam construction and construction of new Tehri town. This has made this area more vulnerable to disturbance. The detailed study of disturbance along the elevation for all four years is given in figure. 9 to 12.

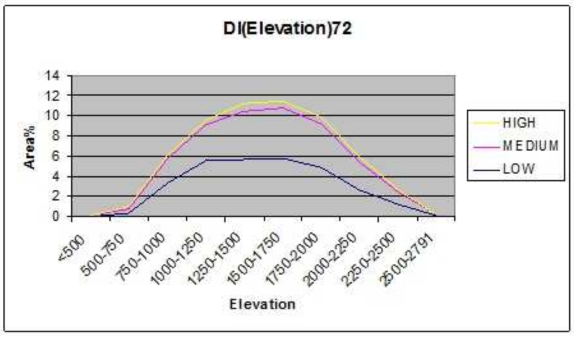

Figure 9. DI along the elevation, 1972.

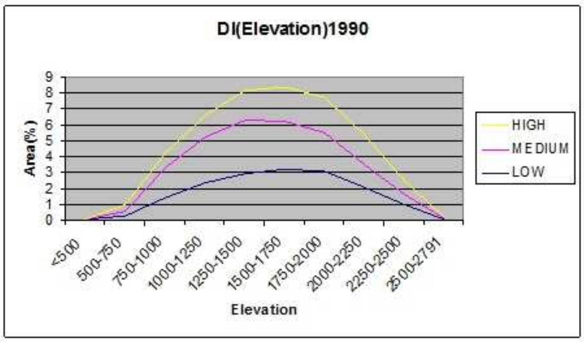

Figure 10. DI along the elevation, 1990.

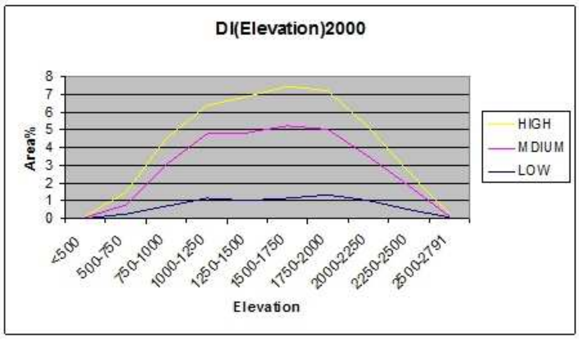

Figure 11. DI along the elevation, 2000.

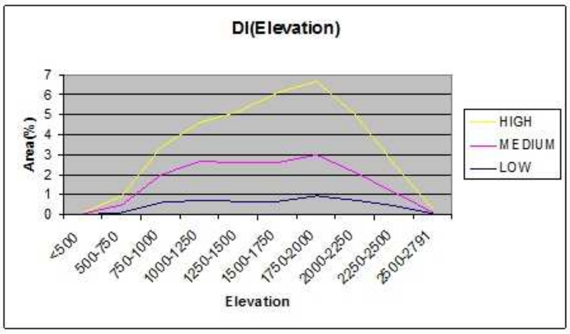

Figure 12. DI along the elevation, 2006.

Disturbance regime along the slope

Inverse relationship was found. In 1972, more area was under low disturbance and lesser area was under medium or high disturbance. This trend was reversed in successive years, 1990, 2000 and 2006 with greater area of disturbance coming under higher level and lesser area coming under lower level. The study also indicates that lower slopes, 0-2%, 2-8% and 8-16% were less disturbed. In slope 16-30%, there is slight increase in the degree of disturbance while in slopes >30%, there is highest level of disturbance. The detailed study on the disturbance regime along the slopes for four years is given in figure 13 to 16 (Source FAO, 1990).

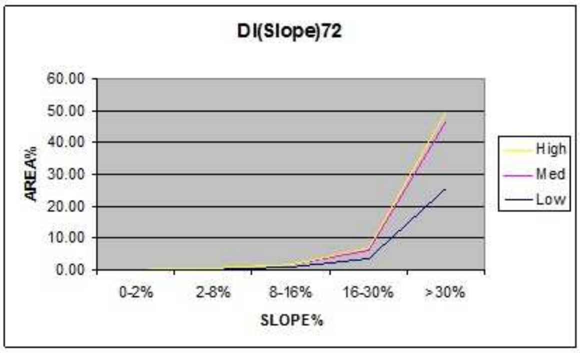

Figure 13. DI along the slope, 1972.

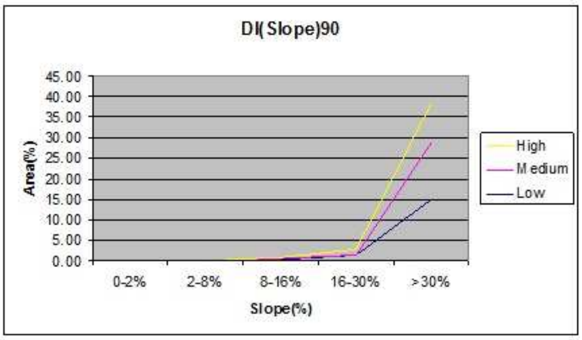

Figure 14. DI along the slope, 1990.

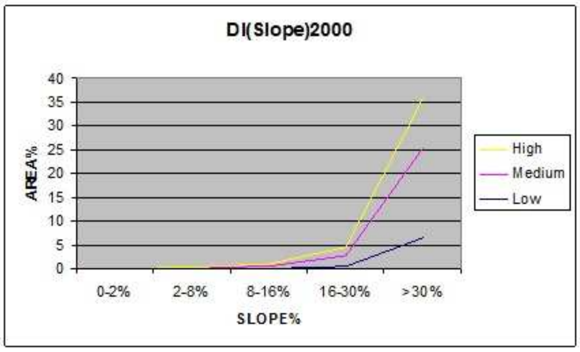

Figure 15. DI along the slope, 2000.

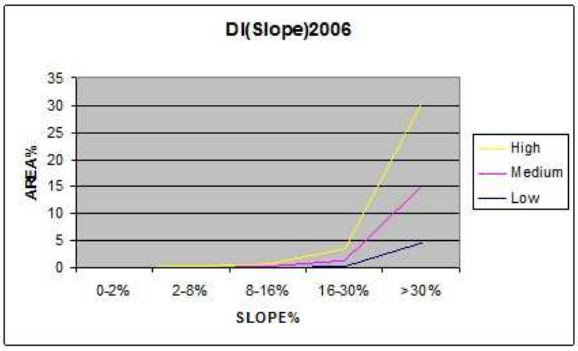

Figure 16. DI along the slope, 2006.

Disturbance regime along the aspect

Aspect, is an important topographic characteristic affecting species distribution and productivity in many forests. Aspect largely controls the amount of sunlight that the forest receives; it also affects the soil properties which contribute to the growth and productivity of different forests. All the three classes of the disturbance were studied along the eight aspects (NE, E, SE, S, SW, W, NW, and N). In 1972, more disturbance area was in N, NE, E, SW and W aspects which shifted towards N, NE and E aspects in 1990. This trend changed in 2000 when more disturbed area was in aspects W, NW, N, NE and E aspects and in 2006 also greater disturbance remained in these aspects with prominent impact on N, NE and E aspects. The detailed study of disturbance along the eight aspects for all the four years is given in figure17 to 20.

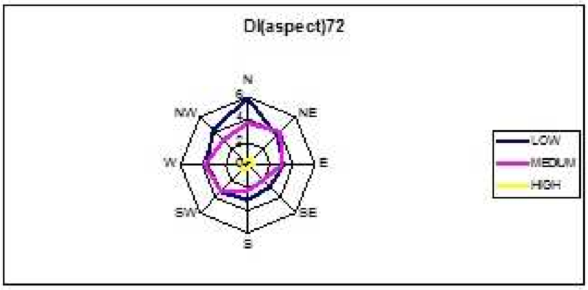

Figure 17. DI along the aspects, 1972.

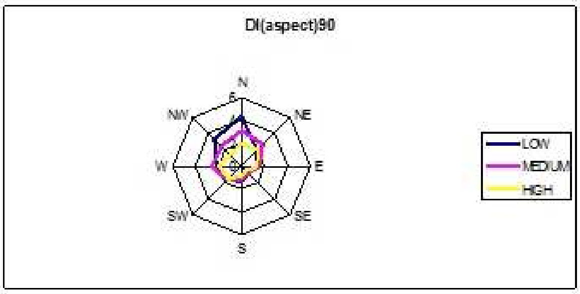

Figure 18. DI along the aspects, 1990.

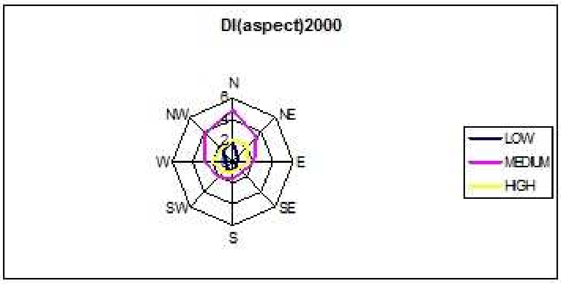

Figure 19. DI along the aspects, 2000.

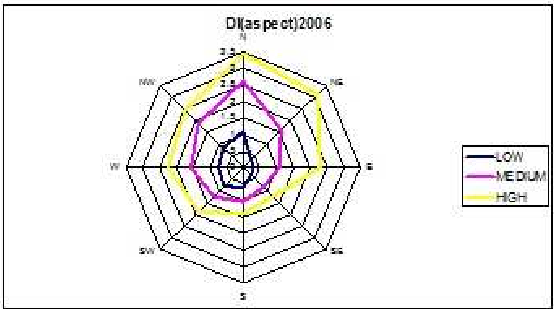

Figure 20. DI along the aspects, 2006.

Conclusions

The analysis of disturbance along different land cover types in successive periods from 1972 to 2006 shows an increasing trend in the disturbance gradient analysis. It shows that during the successive years after 1972, the forest area characterised under low disturbed forest has been changed to medium or highly disturbed forest. The agriculture showed an increasing trend from low to high disturbance. The disturbance along the slope showed that mainly area beyond 30 % slope are highly disturbed and less degree of disturbance occurred in areas lying in the lower slopes. The disturbance along the aspects shows that more degree of disturbance occurred from west to east aspect and in elevation; it showed that areas lying under lower and higher elevation show less disturbance in comparison to areas lying in the middle elevation. Thus showing that mainly Chir pine forests are worst affected then miscellaneous forest to some extent and Deodar forest and mixed conifers were among the least affected ones.

References

Champion, H. G. and Seth, S. K. (1968). A revised survey of the forest types of India. Government of India publication, Delhi.

FAO (1990). Guidelines for Soil Profile Description. Third edition (revised). Soil Resources, Management and Conservation Service, Land and Water Development Division, FAO, Rome.

Forman, R. T. T. and Godron, M. (1986). Landscape Ecology. John Wiley & Sons, New York.

Joshi, P. K., Yang, X., Agarwal, S.P., Das,K.K. and Roy, P.S. (2003). Impact of resource utilization in Himalayan watershed a landscape ecological approach for watershed development and planning. *Asian Journal of Geoinformatics,* 3(4): 1-9.

Naveh, Z. and Lieberman, A. S. (1990*). Landscape Ecology:theory and applicatios.* Springer-Verlag, New York.

Nilsson,C.N. and Grelsson,G (1995).The fragility of ecosystems :a review.*J.Appl.Eco*.,32,677-692

Romme, W. (1982). Fire and Landscape diversity in sub alpine forest of Yellowstone National Park. *Bioscience*, 32: 664-670.

Roy, P. S. and Ravan, S. (1996). Biomass estimation using satellite remote sensing data- an investigation on possible approaches for natural forest. *Journal of Biosciences* 21(4):535-561.

Roy, P.S., Singh, Sarnam and Porwal. M. C. (1993). Characterization of ecological parameters in tropical forest communities- A remote sensing approach. *Journal of the Indian society of remote sensing*,21(3): 127-149pp

Roy, P.S., Tomar, S. and Jeganathan, C. (1997). Biodiversity characterization at landscape level using remote sensing. *NNRMS Bulletin* B (21): 12-18.

Roy, P.S.,Singh,S.,Dutt,C.B.,Jeganathan,C.,Jadav,R.N. and Ravan,S.A.(1999). Biodiversity characterisation at landscape level using satellite remote sensing and Geographical Information System. DOS-DBT User Manual, Indian Institute of Remote Sensing (NRSA), Dehradun.

Scott J.Michael., Davis, Frank., Csuti, Blair., Noss, Reed., Butterfield, Bart., Craig, Groves., Anderson, Hal., Caicco, Steve., D'Erchia, Frank., Edwards, Thomas, C., Jr., Ulliman, Joe and Wright, R. Gerald (1993). Gap analysis: A geographical approach for protection of biological diversity. *Wildlife monograph*, 123: 1-41pp.