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GEOSPATIAL MONITORING OF FORESTS A CASE STUDY OF PIRPANJAL FOREST DIVISION, J&K

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Abstract

The forests of Jammu & Kashmir are mostly located in inaccessible areas where assessment of its ecological health is very difficult. The conventional surveys become useless for chalking out future management strategies because by the time data becomes available, it no longer represents the ground reality in its entirety. The conservation strategies demand near accurate and near real time spatial data. The remote sensing technique has emerged as a powerful tool to map and monitor the natural resources especially in inaccessible and hilly areas and that too economically, accurately and within a short span of time. The temporal satellite data helps in monitoring the forest cover repetitively. Using remote-sensing data, statistical sampling, and change-detection methods, this research shows how land conversion varies spatially and temporally from 1972–2012. The analysis shows that agricultural land use has continued to increased; however, an important land-cover transition has occurred, from a mode of regional forest-cover gain to one of forest-cover loss caused by timber cutting cycles, urbanization, and other land-use demands. The study area represents the forest division of Pir-Panjal area which is economically growing fast by converting the forest to agricultural, pasture and built-up land for the past few decades. The Landsat images of the year 1972, 1980, 1992, 2001 and IRS LISS-IV imagery of 2012 were analyzed to detect the changes in the land-use / land-cover in the past four decades. The analysis reveals that there has been 4.98% decrease in the forest cover over the past decades and the area is getting degraded in terms of ecological health. The period from 1992 to 2001 witnesses a high annual net rate of deforestation. About 21.32% of pasture and scrub area has increased during this period as per the geospatial analysis.

Key words: Land-use/Land-cover, Change detection, Viewshed, deforestation, Geospatial analysis

Introduction

Remote sensing technique provides valuable land-use/land-cover data at local, regional and global level from the past history till recently [1]. Land cover composition and change are important manners for many scientific research and socioeconomic assessments [2]. Information regarding the land-use/cover types and distributions can be utilized to monitor the status of ecosystems change over desired period and assess landscape condition [3]. Continuous monitoring of the types and locations of land-use/land-cover change gives us an obvious view on change mechanisms and to model impacts on the environment and associated ecosystems [4, 5]. Many studies have been done on the regional land-use/land-cover mapping and it can be used as a guideline for future monitoring and land management by policy-makers or local authorities in order to avoid any environmental change caused by improper planning in land use/land cover [6]. Usually, the process of land cover mapping involves image classification. The Supreme Court of India has banned all kinds of clear felling in the forests of India from 1966 onwards, which has resulted in greater protection and a decreasing trend of deforestation in many parts of the country[7]. But by the time the damages come to fore, it becomes difficult for the authorities to fix responsibility as the field staff decline to take responsibility of the damages and start blaming their predecessors for the loss to forest cover in their jurisdiction. The transfer of field staff also creates confusion while fixing responsibility for the damages to the forest cover. The regional analysis of forest cover reveals that the overall net rate of deforestation is relatively high in the North East region (-0.90 to -5.29) followed by Deccan Peninsula (-0.19 to -3.2) and Western Ghats [8]. The same effect of deforestation is also seen in the North of Himalayan forests particularly in the Pirpanjal Forest Division and Shopian Forest Divisions of Kashmir valley, where large scale damages to the forest cover have been reported and entire compartments were illegally clear felled during the last two decades of turmoil. Forest cover analytical reports by the Forest Survey of India (FSI) using satellite data, defines forest as an area of more than 1 ha and > 10% of tree canopy cover [9]. According to FAO, the global rate of deforestation is reported to be 0.7% per year from 1990to 1995 [10].The net rate of forest loss in the tropics is 21 m ha, which means that about 1.2% of all remaining tropical forests were cleared annually [11]. Nearly 1.8% of the forests is estimated to be degraded every year, the major cause being deforestation [12]. If the current rate of deforestation continues, the world’s tropical forests will vanish within 100 years-causing unknown effects on global climate and eliminating majority of the species [13]. The major drivers of forest cover changes in India are shifting cultivation along with encroachment for agriculture land, mining quarrying, expansion of settlements, dam construction and illegal logging [14, 15]. Absence of reliable spatial datasets on deforestation is a major obstacle for modeling global environmental change [16]. Monitoring of deforestation is perceived as the most important contribution of remote sensing technology to the study of global change [17]. In this back drop, the combination of remote sensing as well as GIS technology with ground surveys has emerged as a powerful tool to closely map and monitor the forest cover of these areas economically, accurately and repetitively within a short period of time. Considerable accuracy can be achieved through the combination of high-resolution satellite data, automated method and high level of human expertise [18].

The aim of this study was to explore the possibility of monitoring forest cover repetitively using low, moderate to high resolution images so that ultimately, a mechanism is evolved where responsibility of any damages that take place over time can be fixed on the field staff posted during that period. The temporal high resolution imageries may be used periodically to detect changes in the forest cover in such areas. In Pirpanjal forest division, historical land-use trends have been dominated by an increase in agriculture and subsequent reforestation as cropland, pasture, and other cleared lands were abandoned. The forests in Pirpanjal Forest Division are not only one of the important habitats for wildlife, but also the home for many other rare and endangered species. Deforestation was realized as a critical threat to the existence of endangered species while Endangered Species Act of 1973 was being drafted [19]. However, the vegetation which constitutes the home for rare and endangered species, are experiencing various pressures [20] and a large scale felling and smuggling of forest is going on in the division. The land-use/land-cover pattern of the region is an outcome of natural and socio–economic factors and their utilization by man in time and space. Land-use has a significant impact on forest characteristics, potentially causing large-scale changes in the extent of forest cover in the Kashmir Himalayas and elsewhere. Quantification of such changes is possible through GIS techniques even if the resultant spatial datasets are of different scales/resolutions [21]. Such studies have helped in understanding the dynamics of human activities. The present study has been taken up to explore the possibility of spatial monitoring of the forests using space technology.

Methodology

A. STUDY AREA

The study area is located in the Inner Himalayan region, running from east southeast to west northwest parts of Jammu Kashmir State. The area covered in this investigation is about 475 sq.km lying in between 74°-25´ to 74°-45´ East longitude and 33°-45´ and 33° -55´ North latitude (Figure 1), where the average elevation varies from 1824 m to 4783 m. The present study area (Pir-Panjal forest division) comprises of three forest ranges, viz.

i. Dudganga Range
ii. Raithan Range
iii. S.P.S.P Range

The forest division is bounded by the cultivation of "Kandi illaqa" in North-East while the alpine blanks of Pir-Panjal mountain range from its boundary in the South-west. The forests of this division are spread over the administrative districts of Pulwama and Budgam.

Figure1:- Location of Study Area

B. TOPOGRAPHY

The topographical setting of the division shows that the Eastern regions are gently sloped while as the North and North West regions are precipitous. A large number of lofty peaks exist on this mountain range, the most impressing of which are , Tatakuti peak(4745m) , facing Magru sar 4704m, Shilmahinu (4612M) , Budangan (4247m) etc. Some of the important meadows of the tract are Yusmarg, Danwas, Tosamaidan, Bargamaidan etc. The above given maps (Figure 2) show the elevation ranges of the study area where elevation varies from 1824 m to 4783 m. Though the general topography varies from gentle to moderate, yet some steep and precipitous slopes do also occur (Figure 3). Towards the foot of mountains, fan like projection with flat tops; run at a very gentle angle towards the valley.

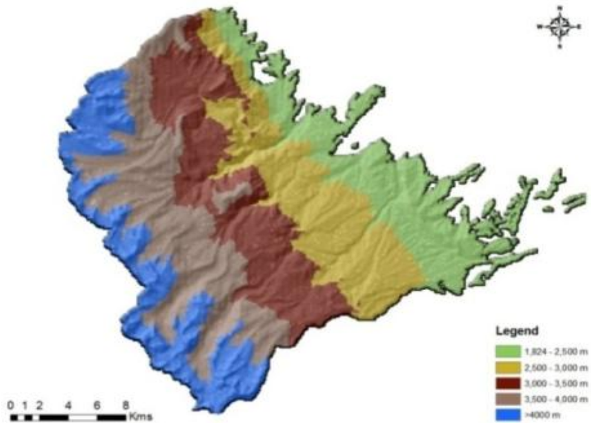

Figure2: Digital Elevation Map

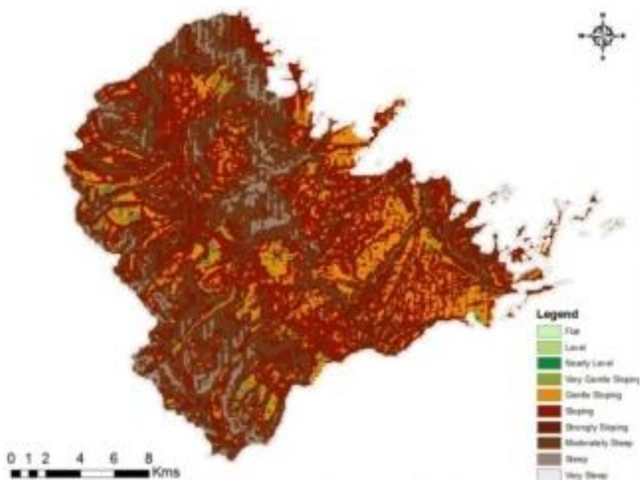

Figure3: Slope Map

These are known as "karewa". These karewa are pierced by mountain torrents and seamed with ravines. These are subject to heavy erosion due to their loose, friable and clayey nature, besides being the victims of faulty agricultural practices.

C. VEGETATION TYPES

The division is well endowed with natural flora. A large number of plant species are found in the division. Natural vegetation of the division is diverse and ranges from lush green grass belts called Margs to evergreen forests of coniferous on the mountain slopes. This great diversity of the flora is due to great heterogeneity in ecological and climatic conditions. Temperate forests are extensively distributed over the division. Such forests are dominated by coniferous vegetation and commonly found trees are *Cedrus deodara* (Deodar), *Pinus wallichiana* (Kail), *Abies pondrow* (Silver Fir), *Piecia simithiana* (Spruce) and *Taxus baccata* (Yew). The broad leaved trees species like Horse chestnut, Maple, Ash, Hazul nut, Bird cherry, Popular, Willow, Birch and Walnut are also represented in the division. The lower sloppy area of the Pirpanjal Forest division is very rich in Kail forest whereas the Deodar forest is very poor in the division. Some small patches of broad leaved deciduous species are also seen in the division. Altitude and aspect has a great role on the crop type. The crop varies according to its height and slope where the gentle sloppy areas have a good crop and high riches have scanty crop due to the impact of adverse ecological factors.

D. CLIMATE

The altitudinal variation and the differing topographical features are the two main factors responsible for the variation in microclimate. It is temperate in lower elevations but very cold in the higher up with the everlasting snow. Four distinct seasons viz spring, summer, autumn and winter are well represented. The spring, which is cool with light showers, starts in March and ends up in May. Summer month falls between June to August and are hottest and partially dry. Autumn months falls between September to November and are bright and pleasant with a little cold and practically dry. Winter months of December, January and February are extremely cold and experience heavy snow fall. Frost is experienced from middle of November on wards.

E. DATA USED

For monitoring the changes in land use/land cover, Landsat- 1 digital data of 1972, landsat-3 of 1980, landsat-5 digital data of 1992, landsat-7 ETM+ digital data of 2001 and IRS LISS-IV of 2012 have been used. Landsat imagery held in the USGS (United State Geological Survey) archives can be searched and downloaded freely. IRS LISS-IV satellite images of the study area have been procured from National Remote Sensing Centre (NRSC), Hyderabad, after browsing the NRSC website for the availability of satellite data for required sensor/date/area and verifying for minimum cloud cover. The Survey of India (SOI) topographical maps of the series 43K/13, 43K/10, 43K/5, 43K/9 published on a scale 1:50,000 have been used along with working plan map of Pir-Panjal forest division that procured from the forest department for generating the compartment layers.

F. WORKING PLAN MAP PREPARATION

Working plan maps procured from forest department were scanned and geo-rectified with the satellite data. The working plan maps prepared were used for generating compartment layers and divisional boundary of the Pir-Panjal forest division.

G. METHOD

Several steps were followed for the land-use classification and mapping. Firstly the specific feature classes have been identified based on the visual interpretation of the satellite imagery and then digital data analysis was carried out using ERDAS IMAGINE software. Land-use maps of 1972, 1980, 1992, 2001 and 2012 have been prepared by employing supervised classification using maximum likelihood algorithm and parallelepiped nonparametric rule method. The land use/land cover classes include Agriculture land, Forest, Settlements, Rivers, Pastures, Scrub, Rocky, Snow, Built-up, etc. and a thorough field survey of the area was conducted to collect information about the land-use types prevailing in the area. Much information related to the Agriculture, forest area, Built-up and other land-use practices have been obtained during the field visit. Global Position System (GPS) was used to conduct ground verification. Later, change detection was done for the images to find out the changes that have taken place in the study

H. DEFORESTATION EVALUATION

Satellite imagery and spatial analysis play an important role in measuring the forest loss. The annual net rate of change is calculated by comparing the area under forest cover in the same region at two different times. To assess the annual rate of forest change, the compound interest formula was used due to its explicit biological meaning [22]. This is as follows

$$r = (1/(t2-t1) \times \ln(a2/a1)) \times 100$$

Where r is the percentage of forest cover loss (annual rate of change), a2 is the area cover in current year, a1 is area in base year, t2 is the current year, t1 is the base year and ln is natural logarithm

I. VIEWSHED ANALYSIS

A viewshed is an area that is visible from a specific location. Viewshed analysis is a common function of most GIS software. The analysis uses the elevation value of each cell of the DEM to determine visibility to or from a particular cell. For example, a Viewshed analysis is commonly used to locate communication tower. Viewshed identifies the cells in an input raster that can be seen from one or more observation points or lines. Each cell in the output raster receives a value that indicates how many observer points can be seen from each location. If you have only one observer point, each cell that can see that observer point is given a value of one. All cells that cannot see the observer points are given a value of zero [23]. To determine the visibility of a target cell, each cell between the viewpoint cell and target cell is examined for line of sight. Where cells of higher value are between the viewpoints and target cells the line of sight is blocked. If the line of sight is blocked then the target cell is determined to not be part of the viewshed. If it is not blocked then it is included in the viewshed [24].

Results and Discussion

The satellite images of Landsat-1 of the 1972, Landsat-3 of 1980, Landsat-5 of 1992, Landsat-7 ETM+ of 2001 and IRS of 2012 were rectified in ERDAS IMAGINE by Geo-referencing the satellite data with the help of already rectified Survey of India Topo maps. After Geo-referencing the satellite data, the images were mosaiced and the area of interest was subsetted using ERDAS Imagine tools. Various classes were identified and then classified using the supervised classification technique and produce a detailed land use/land cover map for all the digital data sets of the study area (Figure 4, Figure 5 & Figure 6).

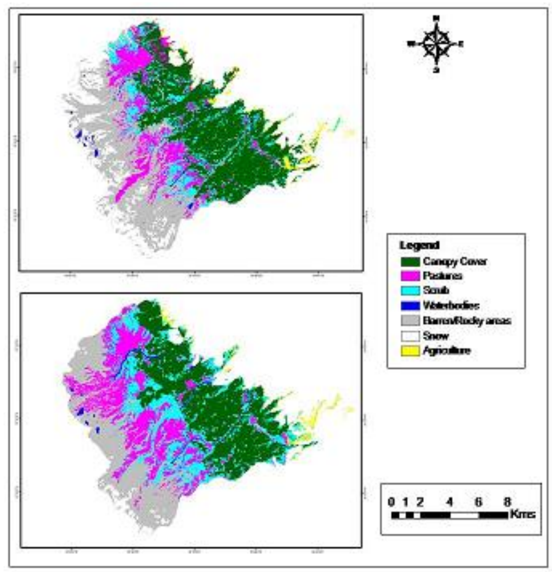

Figure 4: Land-use/Land-cover map of 1972 and 1980

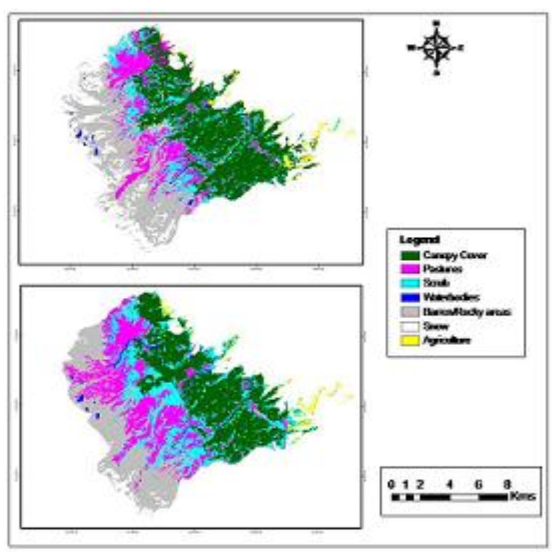

Figure 5: Land-use/Land-cover map of 1992 and 2001

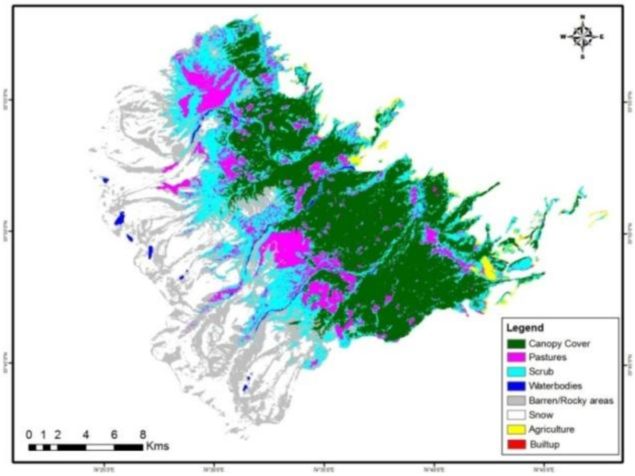

Figure 6: Land-use/Land-cover map of 2012

Attribute information was also obtained (Table.1), i.e. the area and percentage occupied by different classes for all the data sets of the study area. Based on this the changes that have taken place between the four decade data sets and have been presented in pictorial representation (Figure 7).

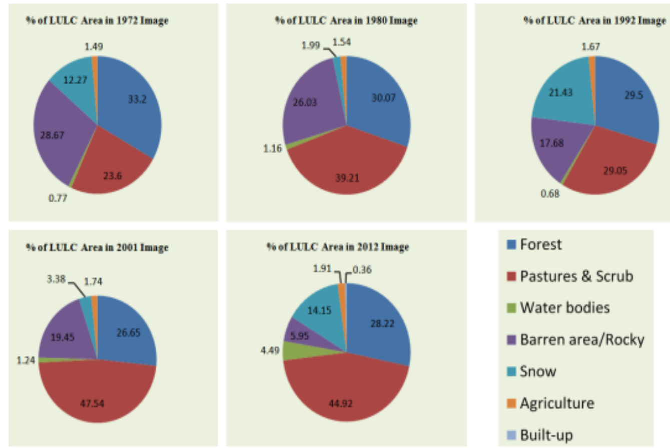

Figure 7: Spatial Extent of various Land-use/Land-cover from 1972 to 2012

Table 1: Statistics of changes in LULC of PP forest division

CATEGORIES	Area (Km^2) (1972)	%	Area (Km^2) (1980)	%	Area (Km^2) (1992)	%	Area (Km^2) (2001)	%	Area (Km^2) (2012)	%
Forest	157.92	33.2	143.06	30.07	140.34	29.5	126.8	26.65	134.25	28.22
Pastures & Scrub	112.28	23.6	186.51	39.21	138.2	29.05	226.16	47.54	213.68	44.92
Built-up*	NV	NV	NV	NV	NV	NV	NV	NV	1.71	0.36
Water bodies **	3.68	0.77	5.51	1.16	3.22	0.68	5.89	1.24	21.36	4.49
Barren/Rocky***	136.38	28.67	123.81	26.03	84.09	17.68	92.54	19.45	28.31	5.95
Snow	58.37	12.27	9.49	1.99	101.93	21.43	16.06	3.38	67.32	14.15
Agriculture	7.1	1.49	7.35	1.54	7.95	1.67	8.28	1.74	9.1	1.91

*Because of poor resolution, streams could not be identified earlier but these where accurately mapped using IRS LISS-IV of 2012.
**Due to poor resolution of Landsat images most of the pastures land had been clubbed with barren/rocky but the same is easily identified on IRS LISS-IV image of 2012.
*** Statistical values varying due to different spatial resolutions of multi-temporal datasets.
****NV: Not Visible

DETECTION OF DAMAGED AREAS

The satellite images contain different bands in different wavelengths. Every image has its own band such as Blue band, Green band, Red Band, Infrared band etc. To see the maximum vegetation from these images one is to make these images in False Color Composition. In false color composition the green band take red one and the red take infrared. From the FCC images of 1972 to 2012, the damage area of PP division is interpreted and detected in the ERDAS Imagine by using different enhancement techniques. Some of the compartments in forest fringes are heavily damaged and these areas are easily visible on the recent high resolution satellite images. As seen in the compartment 16 of the SPSP range of PP division, the red tone in 1992 image showing the rich forest keeps degrading with every decade. The image of IRS LISS-IV 2012 showing the maximum area of compartment 16 of SPSP range is degraded due to felling and smuggling of forest (Figure 8). The same example is also seen in the second figure where in 1980 image the area is fully red and in 2012 image it is converted into scrub/pasture and agriculture land. Another example (Figure 8) is shown below which give us the same area of SPSP range after supervised classification where the green color shows the forest area and pink area shows the pasture. The classified image of 1972 shows the maximum area of compartment is forest cover but the same area is converted into pasture in 2012 classified image.

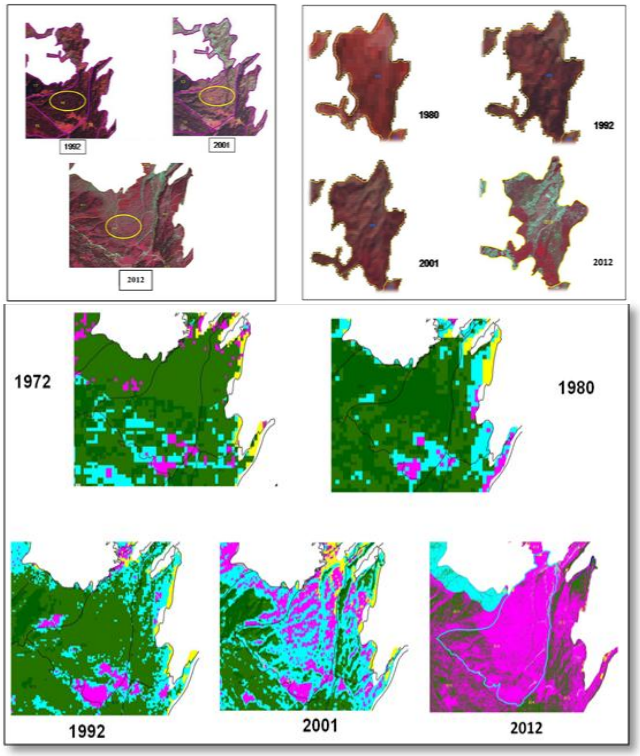

Figure 8: Changes in Compartment 16 of SPSP Range (On-screen visual interpretation) and after Supervised Classification

CHANGE DETECTION ANALYSIS

Change detection is an important application of Remote Sensing technology. This gives us the changes of specific features within a certain time interval. After obtaining detailed land use/land cover information, change detection analysis is done by using five data sets to find out the changes that have taken place between the years 1972 to year 2012 in the study area. The detailed overview of change in different land use/land cover categories over the decades is given in Table: 2. and represented in bar chart (Figure 9) as wel.

Table 2: Attribute data of supervised classification of change detection images

CATEGORIES	1972 (%)	2012 (%)	Difference (%)
Forest	33.2	28.22	-4.98
Pastures & Scrub	23.6	44.92	21.32
Built-up	NV	0.36	0.36
Water bodies	0.77	4.49	3.72
Barren area/Rocky	28.67	5.96	-22.71
Snow	12.27	14.15	1.88
Agriculture	1.49	1.91	0.42

The attribute data of land use/land cover from the study area between years 1972 and 2012 with regard to various features indicated significant changes in feature classes and mostly in forest area. Maximum area of dense forest is depleted due to encroachment and degradation in the division from 1972 to 2001 as per the statistical values of feature class, but a gain in forest is also seen from 2001 to 2012. The above statistical data indicates that area under agriculture in 1972 is 7.1 km^2 and 9.1 km^2 in 2012. About 0.42% of agricultural area has increased from 1972 to 2012 and this could be due to slow and steady illegal conversion of forest land.. Whereas the area under pasture and scrub land has increased from 28.22% in the year 1972 to 44.92% in the year 2012, an increase of 21.32% is seen over a period of 40 years. This increase can be attributed to the fact that due to various social and financial reasons, villagers are degrading the forest and also due to different season data. The area under forest has shown a drastic change which can be considered a negative sign for the wildlife animals and also for the environment. The forest area which is decreased in every dataset from 1972 to 2001 but the span of 2001 to 2012 shows a positive sign due to increase in forest canopy (Figure 10). The classified forest area in 1972 image is 33.20%, in 1980 there is a dip in percentage and the calculated area is 30.07% and this process is continue in the next two data sets where the forest area percentage is 29.5% & 26.65% (Shown in Table 1). This decrease is due to the encroachment in forest area and degradation of forest area for their livelihood and also the reason is why there is an increase in pasture and scrub area. But there is increase in forest area in recent decade from 2001 to 2012 and this increase is due to several forest protection related schemes. The built-up area which is not visible in the landsat because of low resolution can be easily interpreted in the IRS data. The total built-up area in the forest division is 0.36% and is a violation of law because of illegal encroachment and also loss of natural property. Because of high altitude area the data mostly available is snow covered, a class of snow is also generated which is varying in statistical values in multi-temporal data sets.

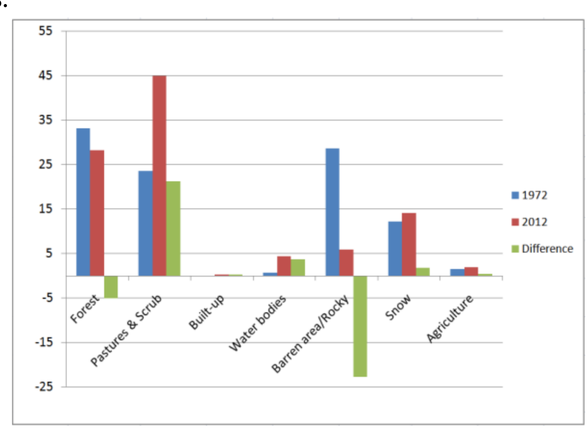

Figure 9: Percentage Distribution of LU/LC during years 1972-2012

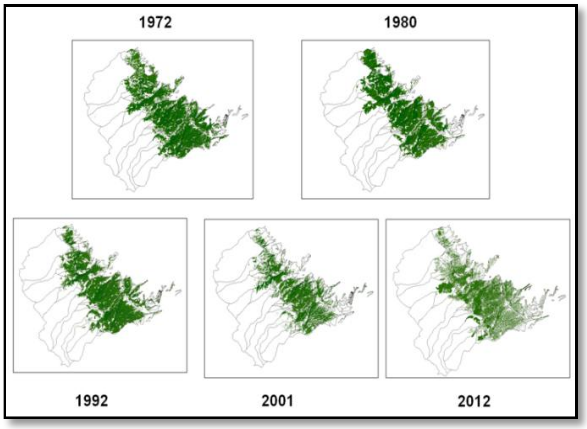

Figure 10: Temporal Forest Canopy Cover Change in PP division

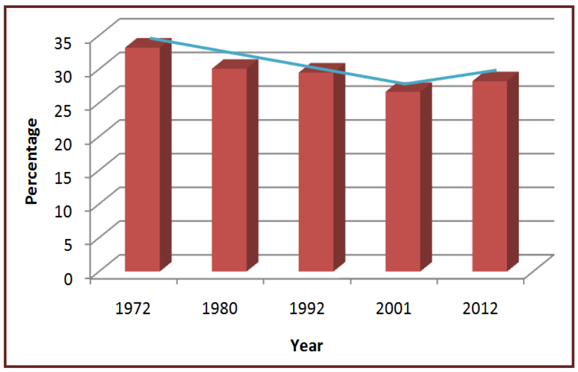

Figure 11: Percentage Area of Forest Canopy Cover

ANNUAL RATE OF DEFORESTATION

Forest cover loss assessment was carried out in the Pir-Panjal division, which revealed the net rate of deforestation as -0.13 from 1972 to 2012, the change being mainly due to existing anthropogenic pressure. The rate of deforestation was most evident during the period 1992-2001. The highest loss of forest was noticed with -14.86 km^2 during 1972-1980 followed by 13.54 km^2 during 1992-2001 and -2.72 km^2 during 1980-1992. The period of 2001-2012 shows a gain of 7.45 km^2 in forest area. Figure 12 showing the net loss and gain in forest area during last few decades.

Table3: Net area loss/gain

S.No.	t_1	t_2	a_1 (km^2)	a_2 (km^2)	Net area Loss/gain
1	1972	1980	157.92	143.06	-14.86
2	1980	1992	143.06	140.34	-2.72
3	1992	2001	140.34	126.8	-13.54
4	2001	2012	126.8	134.25	7.45

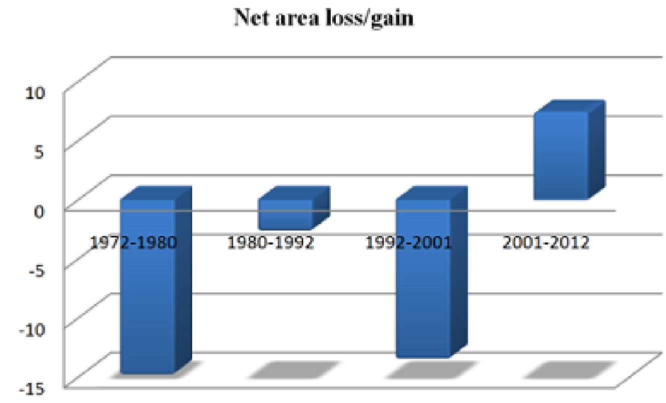

Figure 12: Net area of forest (loss/gain in Sq.Km)

Table 4: Annual rate of Net Deforestation

S. No.	t_1/t_2	1980	1992	2001	2012
1	1972	-1.24	-0.59	-0.76	-0.41
2	1980		-0.16	-0.57	-0.20
3	1992			-1.13	-0.22
4	2001				0.52

Due to various ongoing programs, there is a decline in the net rate of annual deforestation from 2001 to 2012. Analysis of annual rate of deforestation indicates net loss of 1.24% during 1972-1980. The highest net annual rate of deforestation is 1.24% during 1972-1980 and the lowest net loss is 0.16% & 0.20% during 1980-1992 and 1980-2012 respectively. Analysis of the trend in net rate of deforestation of Pir Panjal division, J&K (Figure 13) showing a decline of 0.41% from 1972-2012. But the duration of 2001-2012 shows a lowest deforestation in the study area as compared to previous time. This is only the decade where net rate of deforestation is minimum. The particular compartment of SPSP range where the elevation value ranges from 2211-3017m and having a very gentle to moderate slope is degraded very badly. One factor for deforestation in that compartment is also due to low altitude and gentle to moderate slope where smugglers can have easy access.

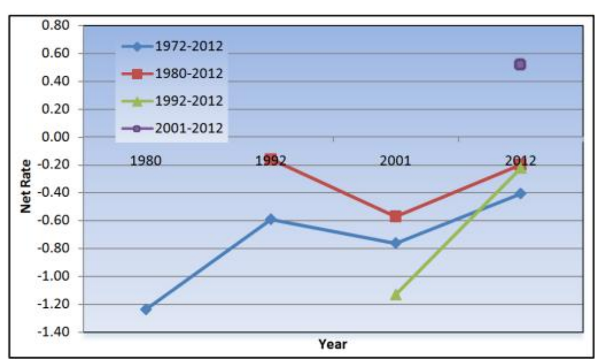

Figure 13: Trend of annual rate of net deforestation in Pir-Panjal Division.

In the Pirpanjal division, large area of forest is degraded by illegal smuggling. The path is easily detected on the high resolution image (Figure 14) from where the timber is smuggled and to check and control the smuggling a bird eye view is needed in the area.

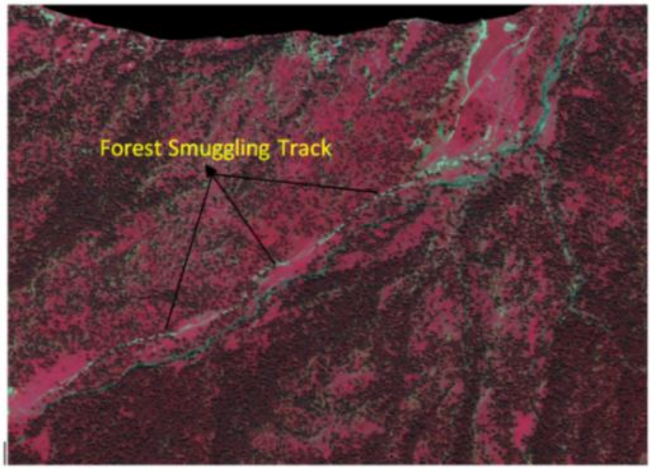

Figure 14: Forest smuggling Track

Viewshed analysis plays a major role for proposing a tower to watch the remained vegetated area and to control the forest smuggling. In the example below, the viewshed from an observation tower is identified. The elevation raster displays the height of the land (darker locations represent lower elevations), and the observation tower is marked as Pink and white tower. The height of the observation tower can be specified in the analysis. Cells in green are visible from the observation tower, while cells in red are not (Figure 15).

Not only you can determine which cells can be seen from the observation tower, if you have several observation points, you can also determine which observers can see each observed location.

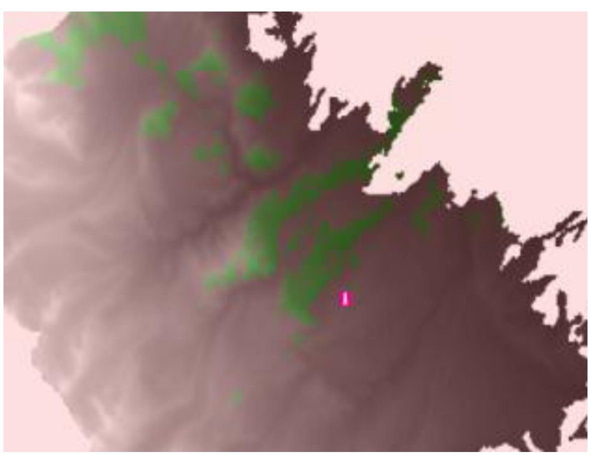

Figure 15: Viewshed from one Tower

Table 5: Location of Proposed Watch Towers

S.No	Watch Towers	Longitude	Latitude	Elevation (m)	Compartment
1	T-1	74°31´38´´	33°55´17´´	3332	S19
2	T-2	74°36´54´´	33°50´11´´	2705	D22
3	T-3	74°35´47´´	33°50´07´´	2830	D25

To cover the maximum accessible area of the Pirpanjal division, three different watch towers have been proposed at three different locations and elevation. The first watch tower is proposed at longitude 74°31´38´´ and latitude 33°55´17´´ having an attitude of 3332 m from mean sea level, the second tower is at longitude 74°36´54´´ and latitude 33°50´11´´ with elevation of 2705 m and third one is at longitude 74°35´47´´ and latitude 33°50´07´´ with elevation of 2830 meter (Table 5). The figure 16 showing the area comes under surveillance from these three proposed towers.

Figure 16: Viewshed from Different Towers

Conclusions

The study was carried out in the Pirpanjal forest division of Kashmir Himalayas. The study clearly established that the temporal data from satellite remote sensing coupled with GIS can be a powerful tool for monitoring forest cover changes of a given area. The significant changes in the land use/land cover during the study period between the years 1972 to 2012 recorded some interesting observations. The forest area is degraded continuously from 1972-2001 as per classified temporal images but the change is also seen in the recent time from 2001-2012 where deforestation is low. The net rate of deforestation is minimum in 2001-2012 but interval of 1992-2001 is one of the worst times for biodiversity of division where the net rate of deforestation is 1.13%. Compartment 16 of the SPSP range of PP division is an example of deforestation in Pir Panjal division and change is easily seen on the multi-temporal images. Forest land showing a decreasing trend where as the features like agriculture, Scrub & pasture etc indicating an increasing trend. The reasons attributed for this are due to the changes in the pattern of agricultural activity and increased activity of human in the forest area. A number of forest employs are deployed to make a check on the forest but still the smuggling is occurring in that area. In order to maximize vigil in the disturbed zones, watch towers have been proposed using Viewshed analysis. However, these trends need to be closely monitored for the sustainability of environment and for preserving the forest in future.

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