

Assessing Alpine Ecosystem Dynamics over the Greater Himalayas using Moderate Resolution Satellite Data

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ABSTRACT

Like other parts of the globe, the impressions of climate change are very loud and vibrant in Kashmir Himalayas. Unfortunately, the impacts of climate change on Himalayan ecosystems have not been investigated properly although the mountain system is highly vulnerable to changing climate. The study focuses to map the current alpine vegetation distribution in the region using remotely sensed data. In this study, current alpine vegetation distribution across the Greater Himalayan, spanning over ~2989.27 km², was mapped using multi-date images: Landsat TM (2002) and Landsat-8 (2014). During digitization the whole area was classified into nine classes which are Alpine pastures, Alpine scrubs, Bare land, Dense forest, Exposed rocks, lakes etc. Alpine pastures have increased 17% followed by Alpine scrubs which has increased 15% whereas Exposed rocks which has decreased 5.13% and so on.

Key words: *Alpine scrub, Alpine Pastures, Greater Himalaya, Kashmir, Satellite data*

I.INTRODUCTION

Alpine ecosystem is used to represent the area above the natural tree line in the high mountains worldwide, and is no longer constrained to location i.e., distance from the equator, slope, aspect, topography, solar radiation, and patterns of summer and winter precipitation, alpine areas may vary in characteristics of vegetation, species configuration and abundance. Mostly, it is assumed that utmost of the alpine biomes initiates near 10°C summer isotherm with slight difference between areas. Any minor deviations in climate tend to modifies the distribution and dynamics of alpine ecosystem. Global scientists have validated both short and long-term impacts of projected climate change on ecosystem dynamics and distribution. These changes can be best explained with the use of remote sensing and GIS. The simple explanation of remote sensing is the attainment of information about distant object without being in actual contact with that object. It has primarily evolved from the techniques of aerial photography and photo interpretation, a relatively young scientific discipline, and is an area of emerging technology that has undergone remarkable growth during the last nearly three decades. It has dramatically enhanced man's ability for resource exploration and mapping, and monitoring of the earth's environment on local and global scales. In addition to topography, the spatial distribution of factors such as meteorological

conditions, vegetation, and spatial variation in landscape attributes can be examined and mapped from digital imagery (**Lillesand and Kiefer 2008**). Because of the vantage orbital position, the multi-channel design, operational suppleness, and enhanced resolution of many remote sensor systems, this technique is proving to be a lucrative method for collecting a variety of information over large areas of the earth (**Star et al., 1997**). Remote sensing is beneficial in studying flora types. Interpretation of remote sensing images permits geographers, environmentalists, agronomists, and foresters to simply notice what vegetation is present in certain ranges, its growth potential, and sometimes what conditions are favorable to its being there. In the field of vegetation mapping remote sensing offers sufficient information about different classes. Using different band combinations area of interest can be highlighted and delineated accurately (**Morgan et al 2010**). Along with remote sensing, GIS is rapidly becoming a typical tool for management of natural resources. The effective use of huge 3-D data volumes is reliant upon the presence of an efficient geographic handling and processing system to convert this data into usable information. (**Rebelo et al., 2009**). GIS databases comprise of sets of information called Layers. Each layer signifies a specific type of geographic data. For example, one layer may include information on the species in an area. Another layer may contain information on the vegetation in that area, while another records elevation. The GIS can combine these layers into one image, showing how they relate with each other and can contain as many as 100 layers. This capability of GIS makes it a very useful tool in the analysis of change detection. (**Lo 2003**). **Malinova et al., (1999)** made first attempt of mapping and analysis of land use/ vegetation cover dynamics of Russia using a combination of remote sensing and field data of different spatial and temporal resolution. **Rashid et al., (2013)** focused on the integrated use of remote sensing, GIS and simulation modelling to portray the biodiversity arrangements, biodiversity productivity and disturbance regimes in one of the topographically challenging Indian Himalayan regions. The data produced has immense potential for use in various areas associated to policy making and research like forest working plan preparation, protected area management, determining climate change impacts on vegetation, prioritization of habitats, identification of potential ecological corridors, etc. and will help to create conservation plans for sustainable use and management of biodiversity. **Thamm et al., (2001)** investigated the land use changes in the Upper Catchment (Benin) between 1975 and 2000. Two temporal scales one the seasonal vegetation dynamics and the other longer term decennial changes appeared to matter in this study: For that task diverse satellite systems were utilized. The report of the seasonal vegetation dynamics within a period of 18 months was done on the basis of NOAA-AVHRR images. Additional LANDSAT-7 ETM, ENVISAT and MODIS scenes provided information about the land use / land cover in a higher resolution. This analysis of the vegetation dynamics was confirmed by intensive “ground truth” operations during which data about the leaf area index, the biomass and the spectral signatures were collected in the test area.

II.STUDY AREA

The study was conducted in the Great Himalayan range which lies in the Kashmir region. The State of Jammu and Kashmir falls in the great north-western, complex of the Himalayan ranges with marked relief variation, snow- capped peaks, antecedent drainage, multifaceted geological structure and rich temperate flora and fauna.

Kashmir lies between the coordinates $34^{\circ} 17' N$ to $37^{\circ} 6' N$ latitude and $73^{\circ} 6' E$ to $80^{\circ} 30' E$, it is around 135 km long and 32 km wide formed by the Jhelum River. It is approximately located 1730 m above the sea level. Location map of the study area is shown in the Fig. 1.1

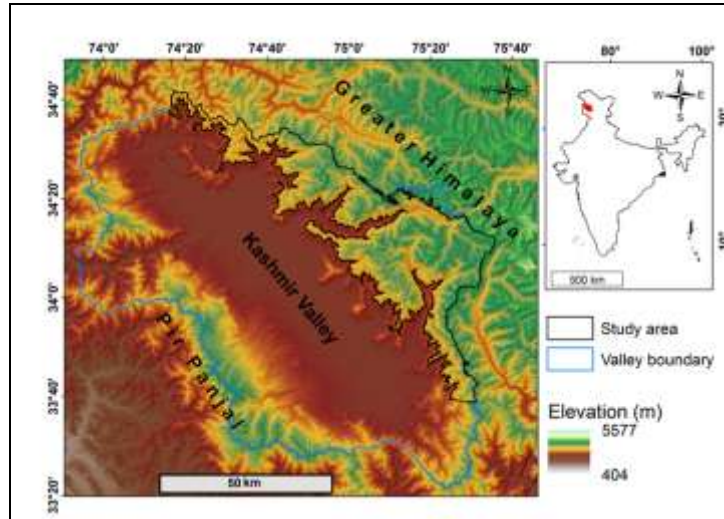


Fig.1.1: Location map of the study area

III. DATASETS AND METHODS

3.1 Satellite imagery preprocessing and classification

In the present study a number of remote sensing data processing techniques and GIS applications were exercised. Current alpine vegetation distribution across the Greater Himalayas, spanning over $\sim 2989.27 \text{ km}^2$, was mapped using two moderate resolution satellite images Landsat-TM and Landsat-8 with spatial resolution of 30 m on a scale of 1:30000. The false color composite band 4:3:2 (IR: R: G) was used for maximum class identification through visual image interpretation in case of LANDSAT- TM and LANDSAT-8 5:4:3 bands were applied and put to use. These band combinations had an import and importance because it enhances vegetation more promptly in addition to the other classes such as bare rock, settlements etc. SRTM DEM has been used to delineate the boundary above 2500 m. ArcMap 10.1 which is the central application in ArcGIS, has been used for database creation and GIS based analysis. The Google Earth had been used for validation because of the cloud cover present in the satellite image.

SRTM DEM

Global SRTM Digital Elevation Model is probably the most well-known global environmental dataset. The Shuttle Radar Topography Mission was launched on 11th February 2000 on-board space shuttle Endeavour. Here SRTM 30 m has been used for delineating the area above 2500m. Fig. 1.2 shows the Digital Elevation Model of Study area.

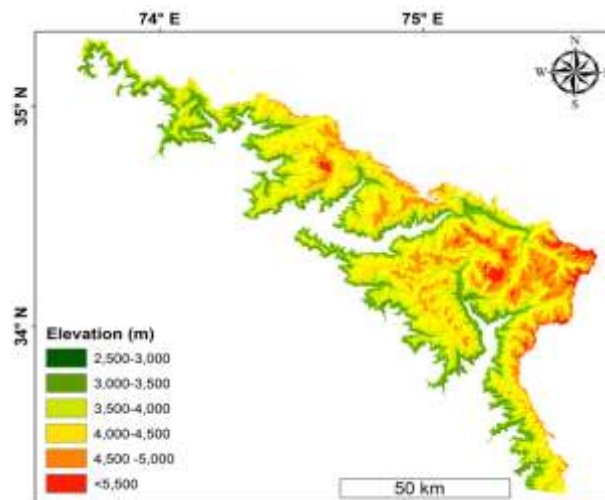


Fig.1.2.: DEM of the Study area

Slope

The incline, or steepness, of a surface. It is the rate of maximum change in z-value from each cell. The range of slope values in degrees is 0 to 90. For percent rise, the range is 0 for near infinity. A flat surface is 0 percent, a 45-degree surface is 100 percent, and as the surface becomes more vertical, the percent rise becomes increasingly large.

Aspect

Aspect is the compass direction that a slope faces. It recognizes the downslope direction of the maximum rate of change in value from each cell to its neighbors. It is the direction of the maximum rate of change in the z-value from each cell in a raster surface.

Aspect is expressed in positive degrees from 0 to 359.9, measured clockwise from north.

Fig. 1.3 and 1.4 shows the slope and aspect map of study area which has been extracted from SRTM DEM with the help of “Spatial Analyst Tool” function in ArcMap 10.1.

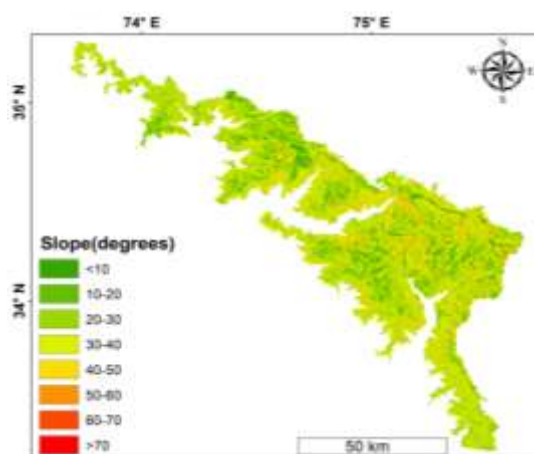


Fig.1.3: Slope map of the study area

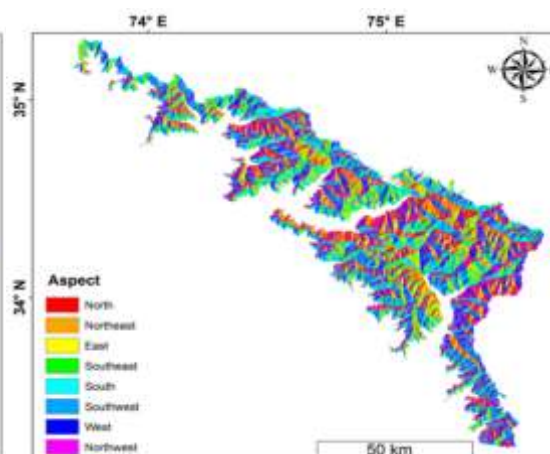


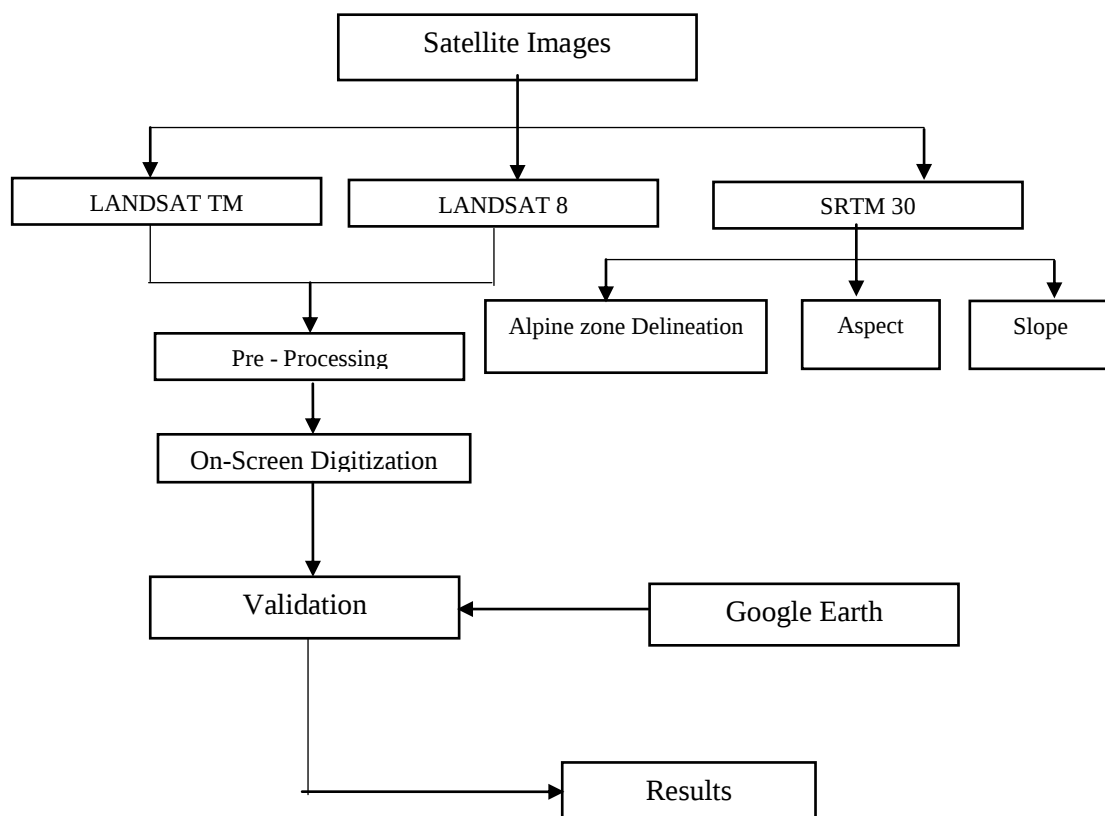
Fig.1.4: Aspect map of the study area

3.2 Methodology adopted

Following software was used for satellite data processing and analysis:

1. ArcGIS 10.1 for database creation and GIS based analysis.
2. Google Earth for validation because of the presence of cloud cover in the multi-date Satellite Images.
3. MS Office 2013 for data analysis and report writing. MS-Excel and MS-word has been primarily used.

Satellite data	Resolution
Landsat TM	30 m
Landsat 8	30 m
SRTM DEM	30 m



Flow chart showing the methodology adopted

IV.RESULTS AND DISCUSSIONS

4.1 Alpine vegetation dynamics over the study region

Nine land use land cover types were delineated in the present study. It is evident from the figure that 67.50% of the area is covered by vegetation while as the non-vegetated areas (snow-covered areas, bare land, exposed

rocks and water-bodies) cover 32.49% of the area. Vegetation types were checked and validated with Google Earth. Another important aspect of the study was to compare the land cover types as delineated from Landsat TM with land cover delineated from Landsat 2014 to measure the changes in the study area. Fig. 1.5 shows the vegetation map of study area of the year 2002 delineated from the Landsat TM whereas Fig. 1.6 shows the vegetation map of the said area of the year 2014 delineated from the Landsat 8.

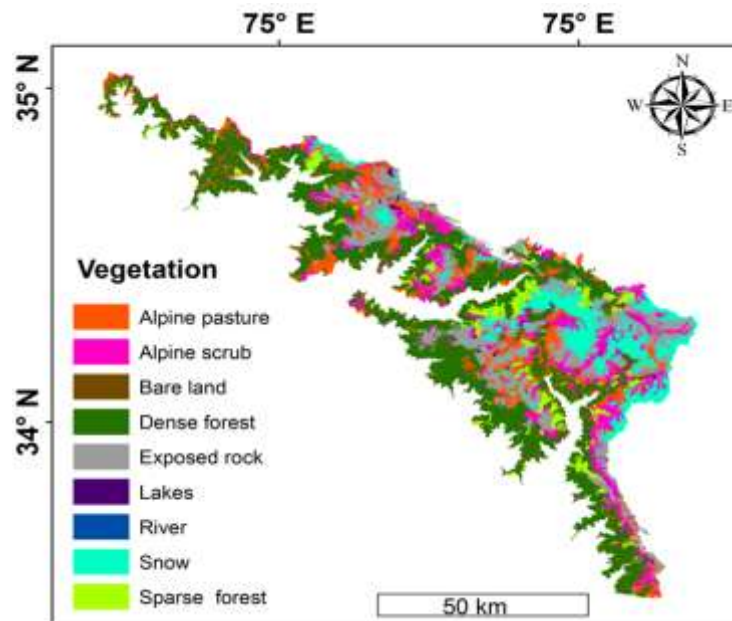


Fig 1.5: Vegetation map (2002)

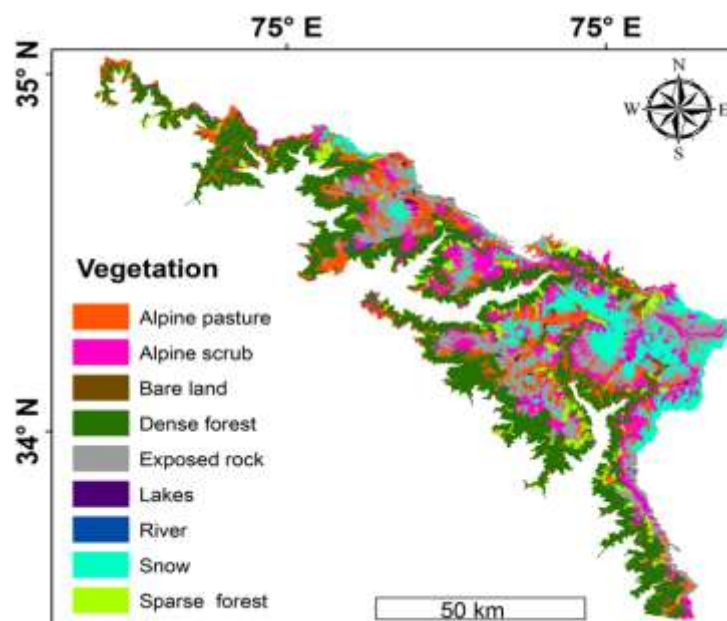


Fig 1.6: Vegetation map (2014)

Table 1.1: Vegetation changes in Greater Himalayas

Vegetation	Area(km ²)		Area Change	% difference
	2002	2014		
Alpine pasture	352.80	412.91	60.11	17.04
Alpine scrub	344.68	399.38	54.70	15.87
Bare land	46.47	31.84	-14.64	-31.50
Dense forest	1150.14	1105.76	-44.39	-3.86
Exposed rock	569.02	539.80	-29.22	-5.13
Lakes	11.58	10.71	-0.87	-7.51
River	33.06	33.04	-0.02	-0.07
Snow	311.09	309.05	-2.04	-0.66
Sparse forest	170.40	146.79	-23.62	-13.86
TOTAL	2989.25	2989.27		

From the above table we can conclude that during the span of 12 years the vegetation classes have shown extreme changes. Alpine pastures have increased 17% followed by alpine scrubs to 15% while as other vegetative classes like Dense forests and sparse forests have decreased to -3.86% and -13.86% respectively.

The decrease in bare land and exposed rock is mainly due to growth of mosses and lichens which appear to be pastures and scrubs on the satellite images. Exposed rocks are decreased to -5.13% while in case of bare land it is -31.50%.

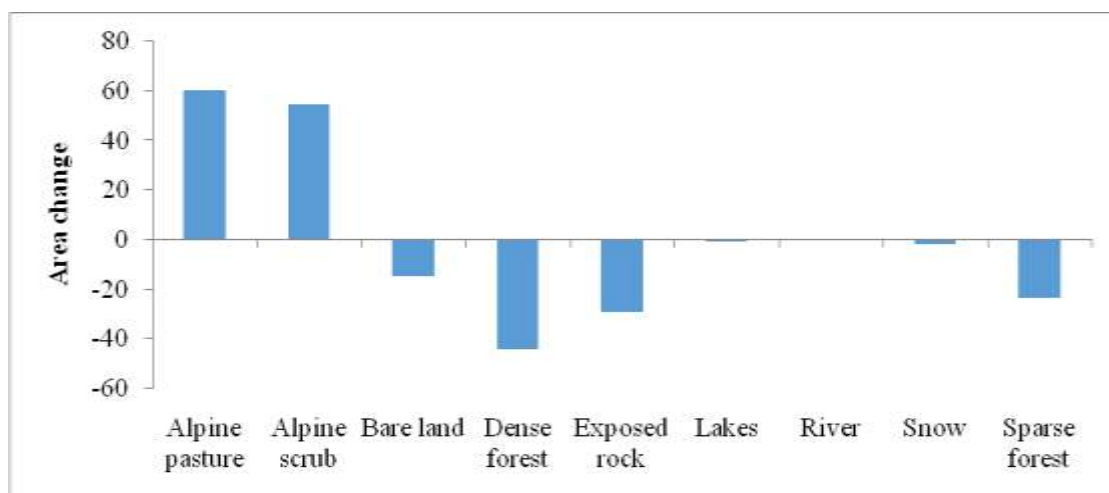


Fig 1.7: Area change in the Greater Himalayas

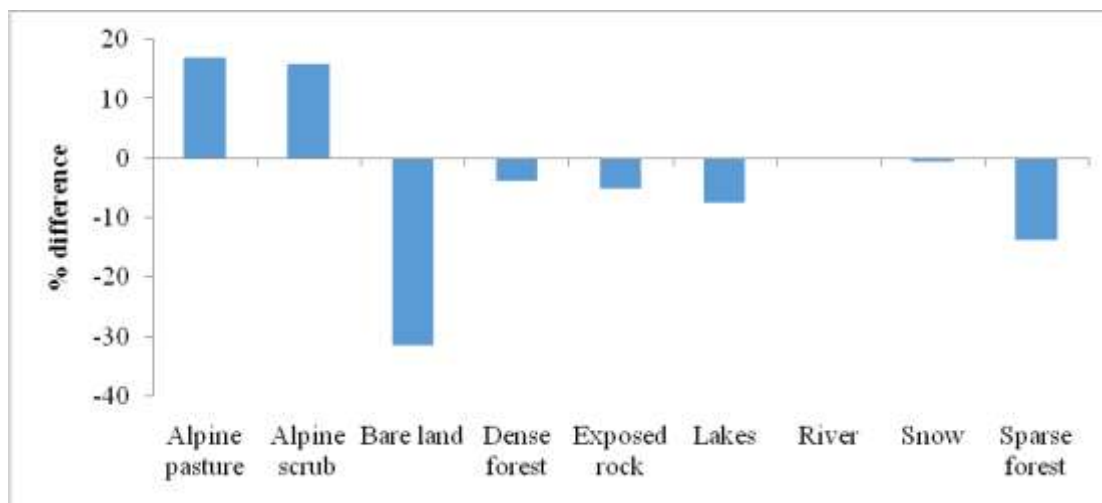


Fig 1.8: Percentage difference of vegetation classes in the Greater Himalayas

During the duration of 12 years the vegetation classes have shown harsh changes. Alpine pastures have increased 17% trailed by alpine scrubs to 15% while as other vegetative classes like Dense forests and sparse forests have decreased to -3.86% and -13.86% respectively.

The decrease in bare land and exposed rock is mainly due to growth of mosses and lichens which seem to be pastures and scrubs on the satellite images. Exposed rocks are reduced to -5.13% while in case of bare land it is -31.50%. the above graphs shows the area change (fig.1.7) and percentage difference (fig.1.8) of vegetation classes in the Greater Himalayas, Kashmir.

4.2 Discussion

Scrub expansion

Studies indicate that due to high temperature, changes in cryosphere, diverse disturbance regimes as a result of permafrost thaw, tundra fires, and anthropogenic activities or variations in herbivory concentration are all contributing to observed changes in plant wealth. Numerous current studies have recognized major positive correlations between ring widths or shoot lengths and early and mid-growing season temperatures for some of the most common giant and dwarf plant species found in tundra ecosystems. (Rayback et al., 2011). In some studies, winter temperatures and snow have been found to correlate with growth in the following summer (Rixen et al., 2010)

Extensive degeneration in prairie area exposed tremendous pressures on the ecologically and socioeconomically vital land cover attributed to the biotic intervention in and around the Dachigam National Park including clearing of the grasslands at the low altitudes for farming, exploitation for medicinal plants and other activities. Several decades of grazing and that too beyond the carrying capacity have resulted in the creation of denuded and semi-denuded patches in these grasslands (Shameem et al., 2010). (Wookey P A et al., 2009) validated that changes to tundra vegetation structure, such as an upsurge in tall shrub species, may either mitigate or exacerbate warming in tundra ecosystems.

Reason for Bare land degradation

Bare class includes the bare exposed rocks, along with some extracting sites. In the year 1980 the total area under this class was 5.39 Km² which decreased to 4.80 km², losing 5.9 km² (Amin and Fazal 2012).

Reason for Deforestation

Highland deforestation due to built-up expansion increases soil erosion within catchments and thus, upsurges the sediment load entering waterways leading to wetlands (Lee et al., 2006). In the year 1980, the total area under this class was 3.46 Km² which decreased to 1.53 km² (0.65% of the total study area) in 2010, decreased by 1.93 Km² (Amin and Fazal 2012). Change detection analysis of LULC comprising of eight vegetation and five non - vegetation types indicated that 74.5km² of dense evergreen forest has degraded (Rashid et al., 2016)

V.CONCLUSION

In this study, current alpine vegetation distribution across the Greater Himalayas, spanning over ~2989.27 km², was mapped using two moderate resolution satellite images Landsat-TM and Landsat-8 with spatial resolution of 30 m on a scale of 1: 30000. SRTM DEM has been used to delineate the boundary above 2500 m. ArcMap 10.1, which is the central application in ArcGIS, has been used for database creation and GIS based analysis. The Google Earth had been used for validation because of the cloud cover present in the satellite images.

During the span of 12 years the vegetation classes have shown drastic changes. Alpine pastures have increased 17% followed by alpine scrubs to 15% while as other vegetative classes like Dense forests and sparse forests have decreased to -3.86% and -13.86% respectively. Exposed rocks have decreased to -5.13% while in case of bare land it is -31.50%. The decrease in bare land and exposed rock is mainly due to growth of mosses and lichens which appear to be pastures and scrubs on the satellite images.

REFERENCES

Books:

- [1] Lillesand, T. M., Kiefer, R. W., & Chipman, J. W. (2008). Digital image interpretation and analysis. *Remote sensing and image interpretation*, 6, 545-81.
- [2] Lo, C. P., & Yeung, A. K. (2003). *Concepts and Techniques in Geographic Information Systems: Laboratory Manual*. Pearson Prentice Hall.

Journal Papers:

- [1] Star, J. L., Estes, J. E., & McGwire, K. C. (Eds.). (1997). *Integration of geographic information systems and remote sensing (Vol. 5)*. Cambridge University Press.
- [2] Morgan, J. L., Gergel, S. E., & Coops, N. C. (2010). *Aerial photography: a rapidly evolving tool for ecological management*. *BioScience*, 60(1), 47-59.

- [3] Rebelo, L. M., Finlayson, C. M., & Nagabhatla, N. (2009). *Remote sensing and GIS for wetland inventory, mapping and change analysis. Journal of environmental management*, 90(7), 2144-2153.
- [4] Milanova, E. V., Lioubimtseva, E. Y., Tcherkashin, P. A., and Yanvareva, L. F. (1999). *Land use/cover change in Russia: mapping and GIS. Land Use Policy*, 16(3), 153-159.
- [5] Rashid, I., Romshoo, S. A., and Vijayalakshmi, T. 2013. *Geospatial modelling approach for identifying disturbance regimes and biodiversity rich areas in North Western Himalayas, India. Biodiversity and conservation. Vol .22No.11, pp. 2537-2566.*
- [6] Thamm, H. P., Menz, G., and Kissiyar, O. 2001. *Investigation of the land use/land cover change in the Upper Oue' me' Catchment, Benin (West-Africa) for the setup of a coherent development plan. In Geoscience and Remote Sensing Symposium. IGARSS'01. Vol 7. pp. 3209-3211). IEEE.*
- [7] Rayback, S. A., Lini, A., and Henry, G. H. 2011. *Spatial variability of the dominant climate signal in Cassiope tetragona from sites in Arctic Canada. Arctic.pp. 98-114.*
- [8] Rixen, C., Schwoerer, C., and Wipf, S. 2010. *Winter climate change at different temporal scales in Vaccinium myrtillus, an Arctic and alpine dwarf shrub. Polar Research, Vol .29No.1, pp.85-94.*
- [9] Shameem, S. A., Soni, P., & Bhat, G. A. (2010). *Comparative study of herbaceous vegetation in lower Dachigam National Park, Kashmir Himalaya, India. Asian Journal of Plant Sciences*, 9(6), 329-336.
- [10] Sjögersten, S., and Wookey, P. A. (2009). *The impact of climate change on ecosystem carbon dynamics at the Scandinavian mountain birch forest–tundra heath ecotone. AMBIO: A Journal of the Human Environment*, 38(1), 2-10.
- [11] Amin, A., and Fazal, S. (2012). *Land transformation analysis using remote sensing and GIS techniques (a case study). Journal of Geographic Information System*, 4(3), 229.
- [12] Lee, S. Y., Dunn, R. J. K., Young, R. A., Connolly, R. M., Dale, P. E. R., Dehayr, R., ... and Welsh, D. T. (2006). *Impact of urbanization on coastal wetland structure and function. Austral Ecology*, 31(2), 149-163.
- [13] Rashid, I., Bhat, M. A., and Romshoo, S. A. 2016. *Assessing Changes in the Above Ground Biomass and Carbon Stocks of Lidder Valley, Kashmir Himalaya, India. Geocarto International, (just-accepted), pp 1- 41.*