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Assessing Alpine Ecosystem Dynamics over the Great Himalayan Mountain Range, Kashmir: Earth Observation and Ecosystem Modeling

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ABSTRACT

The alpine vegetation distribution in the Greater Himalaya, Kashmir is preseted and its projected behavior under changing climate using LANDSAT TM (2002) and LANDSAT-8 (2014) data, mapped at 1:30000 scale and having spatial resolution of 30 m. The alpine vegetation in the region spans ~2990 km^2. SRTM DEM was used to delineate the spatial extents of the alpine landscapes (>2500 m asl). A total of nine land use classes which include Alpine pasture, Alpine scrubs, bare land, dense forest, exposed rocks, lakes, rivers, snow and sparse forest were identified in the area. The results reflect both positive and negative changes in all classes over time. Alpine pastures have increased 60.11 km^2 followed by Alpine scrubs, which have increased by 54.70 km^2. Exposed rocks have reduced to 29.22 km^2, while sparse forests have diminished by 23.62 km^2. Bare land has decreased by 14.64 km^2 and snow has declined by 2.04 km^2. Lakes in the area have shrunk by 0.84 km^2 and river by 0.02 km. The overall observed results revealed that Alpine pastures have increased by 17% followed by Alpine scrubs to 15%. The future climate projections from Worldclim (RCP 8.5) and other environmental data used in the MaxEnt model suggest increase in the suitable habitat for the shrub species by the mid of 21st century.

INTRODUCTION

The term 'alpine' is derivative from the Latin word 'albus' which means white (snow-covered), initially stating to the peaks of Alps in North Italy (Love 1970). Alpine zones are those regions which lie between the altitudinal tree line or its alternatives or the snow line (Kullman 2008). Depending upon the geographical location i.e., distance from the equator, slope, aspect, topography, solar radiation, and patterns of summer and winter precipitation, alpine areas may vary in the physiognomy of vegetation, species configuration and abundance. Not only climate, agronomy and forestry, tourism, nitrogen deposition, but invasive species are also the reasons that disturb alpine ecologies. Earlier studies from the tree-line regions claimed that diverse changes have occurred in vegetation in response to long-term climatic changes. It is believed that the Himalaya has risen by about 2000 m since advent of man (Valdiya 2001). The key habitat factors governing alpine plants are altitude, relief, wind, pressure and exposure to solar radiation (Mani 1978). For predicting the environmental reactions, the terrestrial surface temperature is the key pointer and is widely used as an input data for various ecological models (Rafiq et al.2014, 2016 a Romshoo et al. 2018). The foliage structure in the western Himalayas has been found fertile and rich in biodiversity with some exceptional areas where either the topographic environment is complex or due to human interference (Rashid et al.2013). From the past 158 years, the rise in the concentration of black carbon, temperature and fall in the precipitation rate, results in the reduction of extent of Kashmir Himalayan Glaciers (Rafiq et al. 2016 b, Mishra and Rafiq 2017).

Due to environment obliteration and poaching, worldwide biodiversity is deteriorating at an alarming rate (Archard et al. 2014; Butchart et al. 2010). Ecosystems in the Himalaya have revealed remarkable fluctuations since 1960 (Panigrahy et al. 2015). Flora ingression was observed in complex elevated extents, that were earlier under snow and hoar frost. An apparent change of about 300 m in timberline was witnessed (Panigrahy et al. 2010). The climate is the most probable factor for the expansion of shrubs that have been documented at higher altitudes including radial and vertical growth of shrubs, in northern Sweden (Hallinger et al. 2011). The alpine vegetation of the Himalaya changed only after the final phase of Himalayan uplift (20 – 25 million years ago), following increase in the cold-arid climate and migration of flora from the adjoining regions. However, the forest vegetation at the lower altitudes of the Himalaya was once contiguous with the tropical rain forests and have now been transformed into present condition owing to changes in climate and increased anthropogenic pressures (Vishnu-Mittre 1984). High-latitude ecologies have experienced high temperature in recent decades and are expected to remain warm in the upcoming years (Hinzman et al. 2005).

The influence of climate variation is flamboyant and vibrant over the Himalaya with the Kashmir being no exception. Unfortunately, the impacts of climate variation on Himalayan ecosystems have not been examined as it should be, although the montane system is highly vulnerable to subtle changes in climate. Himalaya is enduring a temperature upsurge that is greater than the global average of ~0.7^o C for the past century (Bhutiyani et al. 2010). A statistically significant rise in the average temperatures by ~1.7^o C has been recorded in Himalayas which has a potential to strongly influence high-elevated montane ecologies particularly changes in the foliage arrangement and associated biodiversity (Aryal et al. 2014). With vast areas covered by the natural vegetation, an appreciable percentage of population is dependent on forest products and services. Hence it becomes imperative to quantify the probable impacts of climate variation on foliage dissemination and composition (Shrestha et al. 2009). In this study, the existing vegetation distribution in Kashmir Greater Himalayas has been delineated and estimated the behavior of shrubs under changing climate using species distribution model (MaxEnt). A varied number of datasets have been used to pursue the study site which includes current vegetation, projected climate (annual temperature and precipitation) downloaded from Worldclim. The maps created in this study site will be beneficial for researchers looking for the high-resolution shrub biomass maps created in this study area. It will serve as valuable reference point that will be advantageous to researchers seeking to interpret tundra ecosystem changes or to

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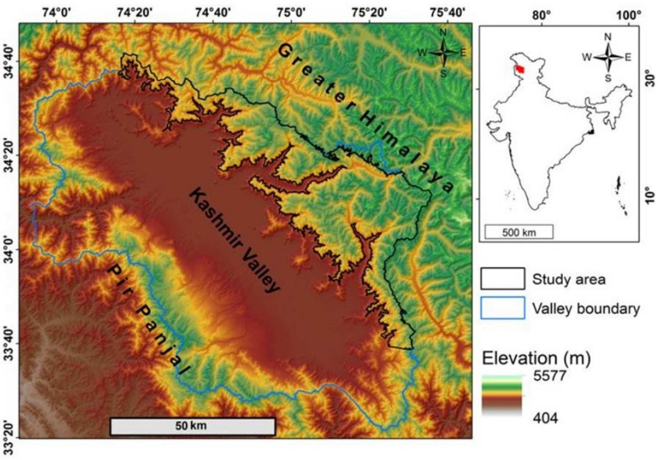

Fig.1. Digital elevation model (DEM) of the study area

progress evaluations of carbon fluctuations, biochemical cycling, fauna habitation in the speedily varying tundra biome.

STUDY AREA

This study was focused on the Great Himalayan range in the Kashmir region (Fig. 1). The Union Territory of Jammu and Kashmir falls in the great north-western complex of the Himalayan ranges with marked topographic fluctuation, snow-laden mountains, ascendent drainage, complex geographic morphology and rich temperate greenery and brute creation (Raza, 1978). The Kashmir valley is an oval shaped intermontane basin surrounded by Pir Panjal towards the south and Zanskar mountain ranges towards the north (Agarwal and Agrawal, 2015). It is 135 km long and 32 km wide basin located between 34° 17'N to 37° 6' N and 73° 6' E to 80° 30' E located at average elevation of 1730 m ASL. The Jhelum river runs along most of its length through middle of the valley.

METHODOLOGY

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 ~2989.27 km^2, was mapped using two moderate resolution satellite images LANDSAT-TM and LANDSAT-8 with a spatial resolution of 30 m on a scale of 1:30000. The false-colour composite band 4:3:2 (IR: R: G) of LANDSAT- TM was used for maximum class identification through visual image interpretation and LANDSAT-8 5:4:3 bands were applied and put to use. These band combinations had importance because it enhances vegetation more promptly in addition to the other classes such as bare rock, settlements etc. SRTM DEM (30 m resolution) has been used to delineate the boundary above 2500 m. ArcMap 10.2, which is the central application in ArcGIS, has been used for database creation and GIS-based analysis. On-screen image interpretation was used for delineation of the land cover types in the area. Further, Google Earth imagery has been used for validation of these land cover classes because of the cloud cover present in the satellite image. Maximum Entropy Species Distribution Modeling, Version 3.4.1 has been used for species distribution modelling and to predict the species suitability on the basis of present occurrence data. The satellite data was obtained from the earth explorer website hosted by U.S. Geological Survey.

Climate Data

Climate data was retrieved from http://www.worldclim.org/. The present and future climatic datasets were used. The minimum temperature, maximum temperature and precipitation layers were clipped and resampled with the required area of interest. Also, the Bioclimatic variables were obtained from the monthly temperature and precipitation values in order to produce more biologically significant variables. These are frequently used in species distribution

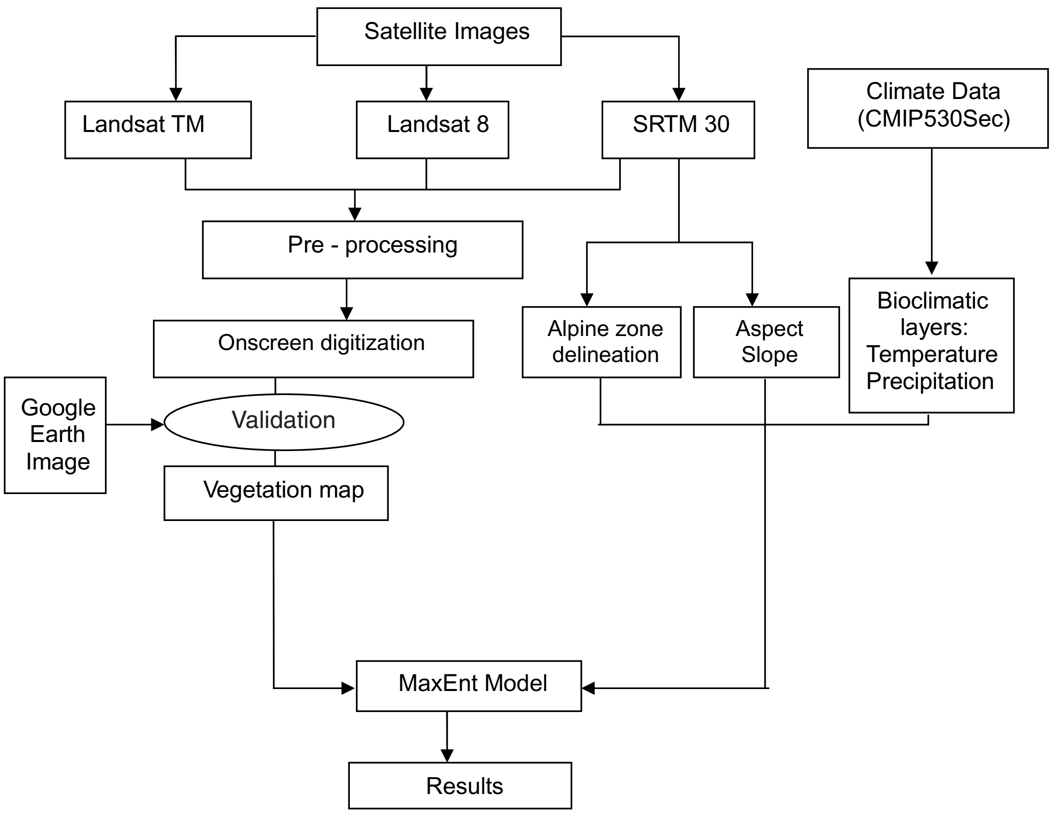

Fig.2. Flow chart showing the methodology adopted for this study

modelling and associated environmental modelling approaches. The bioclimatic variables symbolize yearly tendencies, seasonality and extreme or restrictive ecological dynamics. Out of the 19 bioclimatic variables, of both present and future, BIO1 which is Annual Mean Temperature and BIO12 which is Annual Precipitation were clipped with the study area which was used as inputs for the MaxEnt model. Apart from these layers, altitude layer was also derived, clipped and resampled with the study area.

MaxEnt Model

A computer based learning software package that guesses the possibility distribution for a species existence based on environmental variables. The maximum entropy modelling or MaxEnt setup has been used for predicting the dispersal of shrubs. The principle of maximum entropy methodology is to provide assurance that estimation satisfies any restraints on the unfamiliar spots, meaning that the projected possibility of unknown distribution consist of a reduced number of limitations but more choices (Jaynes, 1957). An imperative module of MaxEnt modelling is the data construction, which involves the understanding of several other operating system and file formats comprising Microsoft Excel, ESRI ArcGIS and Notepad. The model provides hindmost answer as ecological circumstances underneath which the species should be able to uphold inhabitants. The MaxEnt yields numerous output documents, of which the most significant for evaluating the model is the hypertext markup language record called "shrubs.html".

The MaxEnt takes the input as .csv record from species occurrent and in ASCII format only. In this study, I created a comma-separated value (.csv) record from meridian and parallel coordinates of shrubs from MS Excel database. A .csv record is the mandatory format for the input samples in MaxEnt. Environmental layers were modified in ArcMap 10.2 so that all the three-dimensional data (i.e. independent or predictor variables) have the same radius (same geographic bounds and cell size).Hence, all the input layers were projected to GCS WGS84.

There are two types of datasets required in MaxEnt; the species occurrence records and environmental covariates. Occurrence records are geographic points (i.e. coordinates) of species observation while environmental covariates are a set of data that contains continuous or categorical values such as temperature; precipitation and land cover (Pearson, 2007). To perform the modelling in MaxEnt, species occurrence should be in comma separated values (CSV) and covariates should be in raster Arc/Info ASCII Grid format. In order to run MaxEnt, all environmental layers must be in ASCII format.

At initiation, Image Acquisition, and layer staking to digitize vegetation boundary was generated for a given area. It was proceeded with the Onscreen digitization to map vegetation (forests, shrubs, pastures). Projection of SRTM and Landsat images from Global coordinate system was converted to GCS WGS84. Also, downloaded climate data was projected to GCS WGS84. Environmental layers and climatic variables were generated for MaxEnt model. The results obtained were finally analyzed by MaxEnt model.

RESULTS AND DISCUSSION

Alpine Vegetation Dynamics over the Study Region

Nine land use/land cover types were demarcated in the current study. It is discernible that 67.50% of the region is enclosed by foliage whereas the devegetated areas (including snow-covered, bare land, exposed rocks and water-bodies) cover 32.49% of the area (Fig. 3). Foliage categories were crisscrossed and confirmed with Google Earth Imagery. Another important aspect of the study was to compare the land cover types as delineated from LANDSAT TM 2002 with land cover delineated from LANDSAT 8 of 2014 to measure the changes in the study area.

From the data in Table 1, i can conclude that 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. The decrease in bare land and exposed rock is mainly due to growth of mosses and lichens which appears as pastures and scrubs on the satellite imagery. Exposed rocks are decreased to -5.13% while in the case of bare land it is -31.50%. The reason for shrinking of water bodies is mainly due to the fluctuations in the climate setup.

MaxEnt Model

The MaxEnt yields numerous output records, of which the utmost essential for evaluating the model is a hyper text markup language file called "shrubs.html". This record comprises evidence on the inclusive averaging of all model runs that were quantified with arithmetical examination, charts and graphs, model pictures, and links to the other files and runs. This file also holds the control settings and parameters that were used to execute the model, and the code to run the MaxEnt model from the command line. The foremost graph perceived is the Analysis of Omission/ Commission. The next graph is Sensitivity vs 1 –Specificity for scrub. This is a graph of the area under the Receiver Operating Characteristic (ROC) Curve or AUC. The AUC values permit

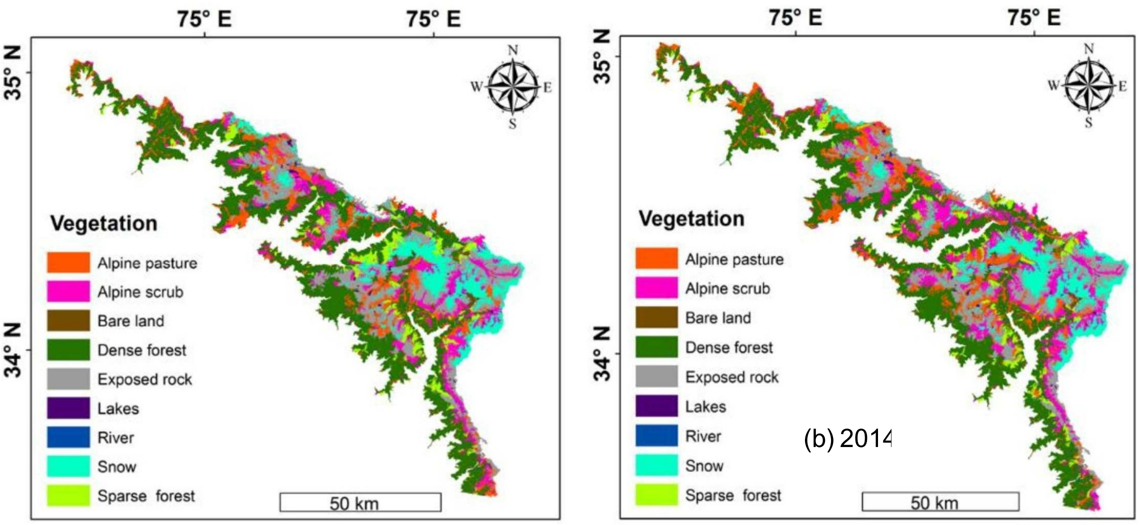

Fig.3. Vegetation maps of the study area (a.) 2002, (b.) 2014

Table 1. Vegetation changes in Greater Himalayas

Vegetation	Area (km²)		Area change (km²)	Percentage 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		

us to easily compare performance of one model with alternative, and are suitable in assessing manifold MaxEnt models. An AUC value of 0.5 designates that the demonstration of the model is no better than random, while values nearer to 1.0 indicate better model performance. Further a picture of the model can be seen. Moreover the picture can be viewed in the Plots folder in the outputs as a Portable Network Graphic (.png) file.

Figure 4 shows the omission rate and predicted area at different thresholds. The orange and blue shading adjacent the lines on the graph signify variability. Figure 5 shows the range under the Receiver

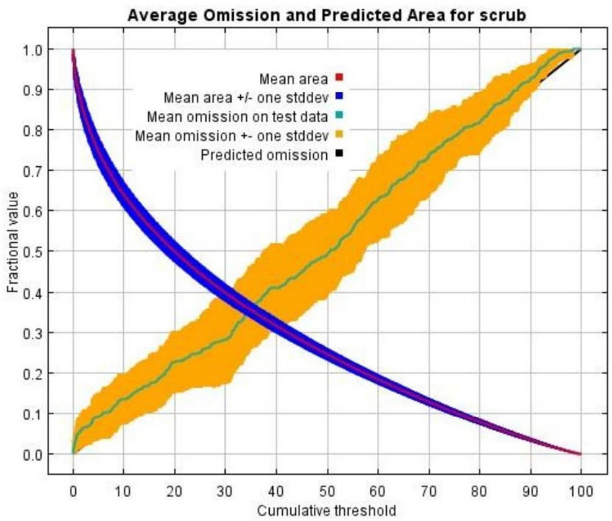

Fig.4. Analysis of Omission/ Commission

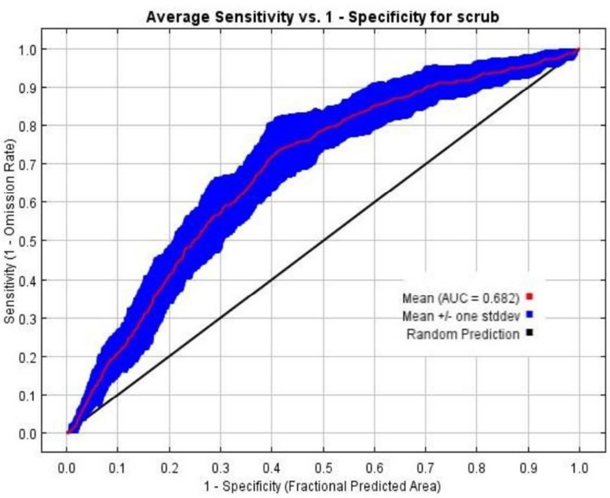

Fig.5. Sensitivity vs 1 –Specificity for scrub

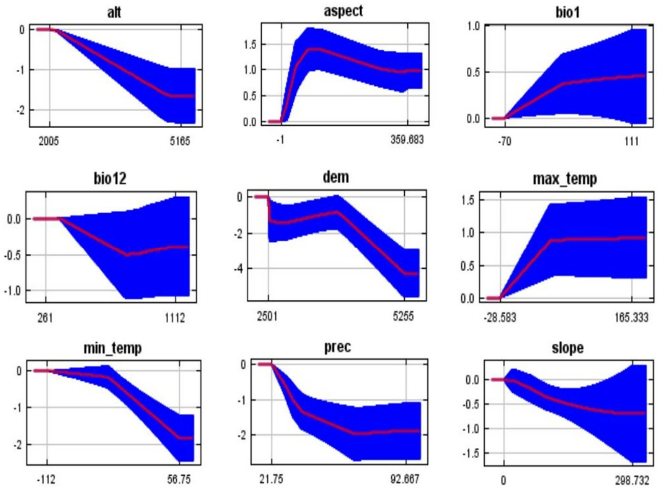

Fig.6(a. Response curves with all the variables

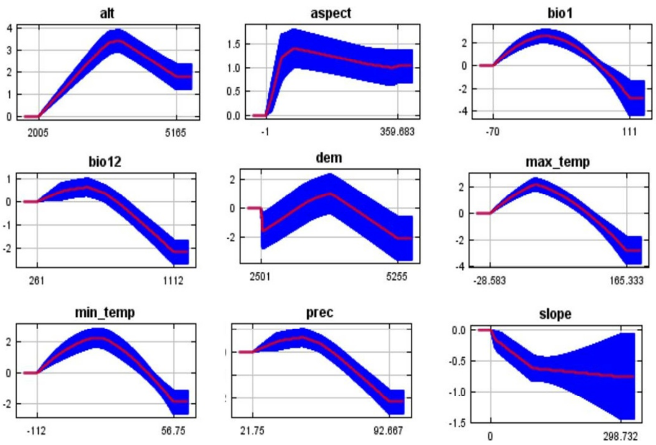

Fig.6b. Response curves with only one variable

Operating Characteristic (ROC) Curve or AUC. The AUC values permit us to simply relate presentation of one model with other, and are worthwhile in calculating manifold MaxEnt models. The average test AUC for the replicate runs is 0.682, and the standard deviation is 0.041.

Charts are delivered for each specific bioclimatic variable that was used in the model (Fig. 6). The initial set of charts denotes the variation in each variable with all others held constant (Fig.6a) and the second set displays the scenario if a model were run via only the charted variable (Fig.6b). Red lines signify the mean response and the blue lines represent the ± standard deviation.

The model also provides a word table that shows the analysis of variable contributions. This table shows the ecological parameters used in the model and their percentage predictive involvement of each variable. The greater the involvement, the more influence that particular variable has on forecasting the existence of that species.

To ascertain the initial estimate, in each repetition of the training procedure, the growth in regularized gain is counted to the involvement of the relative variable or deducted from it if the change to the absolute value of lambda is negative. For the succeeding estimate, for each ecological parameter, in turn, the values of that variable on training presence and background data are arbitrarily arranged. The model is reexamined on the arranged data, and the consequential drop in training AUC is presented in the table, regularized to percentages. As with the variable jackknife, variable aids should be interpreted with care when the predictor variables are interrelated. Values displayed are averages over replicate runs.

Table 2. Analysis of variable contribution

Variable	Percent contribution	Permutation importance
dem	60	17.3
prec	13.7	16.7
aspect	11.1	20.9
slope	4.1	4.1
min_temp	4	20.1
bio1	2.3	1.7
max_temp	2.3	5
alt	1.3	7
bio12	1.3	7.2

Table 2 displays the outcomes of the jackknife test of variable significance. The ecological parameter with the maximum gain, when used in isolation, is dem, which as a result seems to have the most valuable evidence by itself. The ecological parameter that declines the gain the maximum when it is omitted is aspect, which therefore seems to have the most information that isn't available in the other variables. Values displayed are averages over replicate runs.

The Jackknifing displays the training gain for each variable if the model was executed in isolation, besides relating it to the training gain with entire variables (Fig.7). This is advantageous to recognize which variables contribute the most independently.

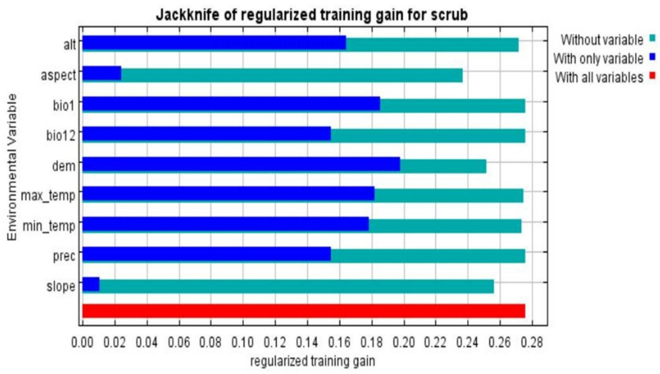

Fig.7. Graph of the Jackknife of regularized training gain for scrub.

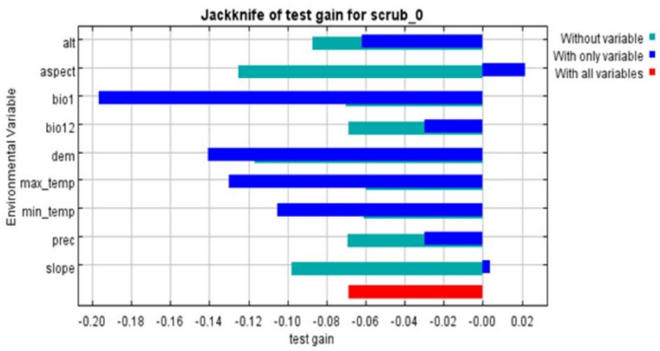

Fig.8. Graph of the Jackknife of test gain for scrub.

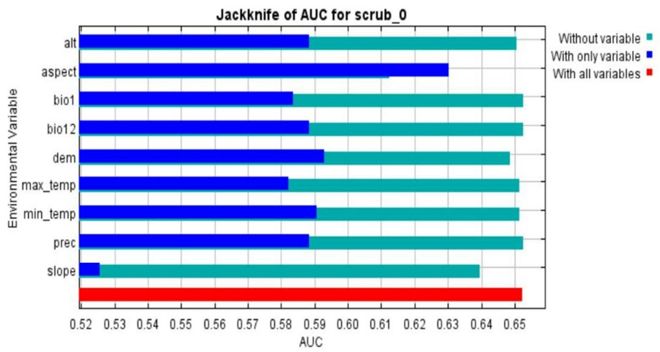

Fig.9. Graph of the Jackknife of AUC for scrub.

Figure 8 displays the identical jackknife test, using test gain as an alternative of training gain (). The inferences about which variables are most important can change, that is why there is a need of looking at test data. To sum up, there is same jackknife test, via AUC on test data. (Fig.9)

The MaxEnt model provides two sets of images: the present image which displays the current scrub and future image that characterizes the model of species dissemination estimated to the approaching climate data (2050). The future image which the model provides depicts that in future (2050) there will be a drastic change in temperature and precipitation which results in the expansion of scrubs over the Greater Himalayas. The changes could be better predicted through graphs which shows the omission rate plus predicted zone at distinct thresholds. The two ASCII files of scrubs were converted into raster format and were projected to GCS coordinate projection. The two images which were obtained from the MaxEnt model depicts that which area is more suitable for a particular species on the basis of values (Figs. 10 and 11). Here the value 0.01-0.1 is unsuitable for shrubs

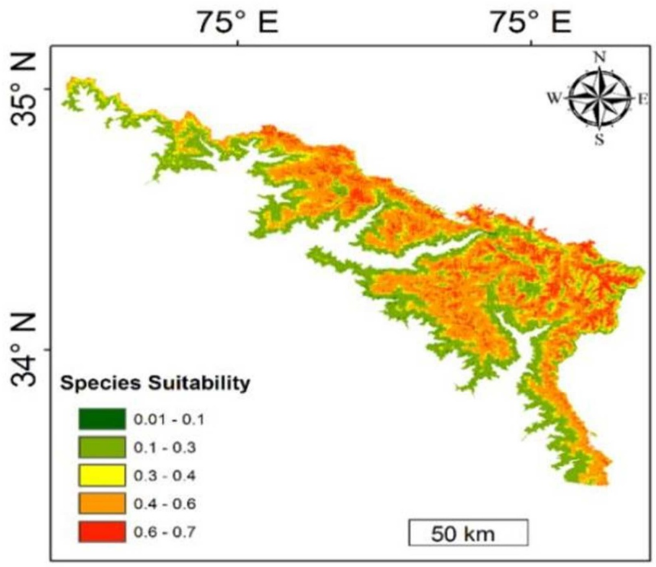

Fig.10. Present suitability for scrub (2014)

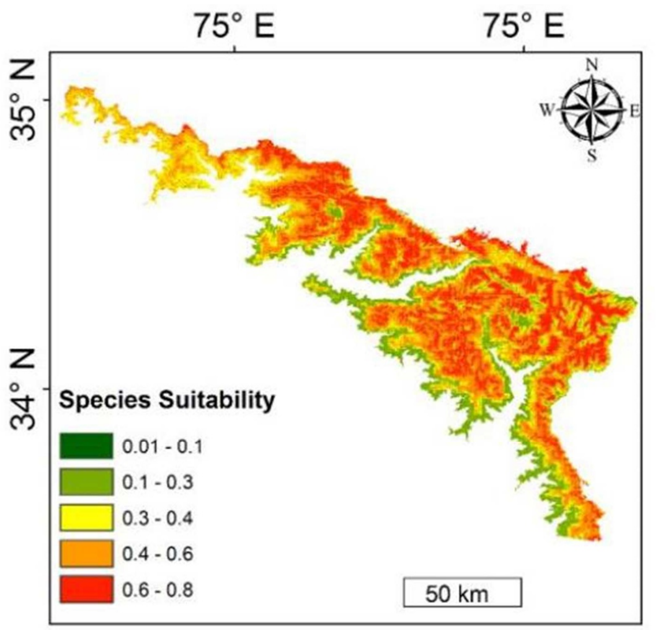

Fig.11. Future suitability for scrub (2050).

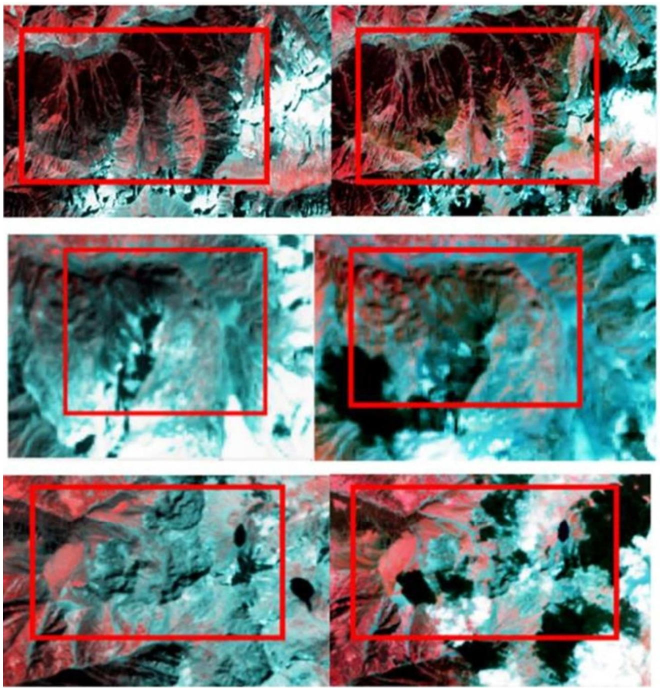

Fig.12. Landsat TM (2002) Landsat 8 (2014).

followed by higher values. The higher the value the more is the species suitability.

Figure 12 shows the screenshots taken from the two Landsat TM and Landsat 8, which depict the scrub expansion over the Greater Himalayan Region. 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%.

Due to the massive increase in the number of population, the need of land increased simultaneously. (Amin and Fazal, 2012). Besides this, the inter conversion of agriculture to horticulture and bare land for commercial purposes are the basic reasons for the degradation. The shrub expansion in summer's upsurges but in autumn and arid winter, it steps down due to minimal growth rate and other climatic factors (Shameem at el. 2010). The changeover of paddy fields and degraded forest land into orchards is mainly because of the less tributary movement and pecuniary emergency (Rashid et al. 2016).

CONCLUSION

From the above results, it can be concluded that the applied climatic scenario shows increasing suitable environment, meant for the species in the forthcoming years, with the shrubs moving up and down in the mountains. The reason is simply, the climate change which is most probably depicted by the model. Besides this, the factors which led to the shrinking of dense and sparse forest is the natural phenomena like forest fires. It can be anthropogenic activities as well. The hazardous effects witnessing in the Alpine region, is the drifting of the tree line upwards. The detected fluctuations over the Kashmir glacial alpine Himalayas, if proceeds and is expected that it will have an adverse effect (Murtaza et al. 2017). The foliage including curative plants found in the Kashmir Himalayan range is sensitive and prone to climate dynamics and can result into the death of myriad species (Rashid et al. 2015).

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