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Climate change: An evil or an opportunity-evidence from the Hindu-Kush Mountain system of Pakistan

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Abstract

Swat district falls in the Hindu-Kush mountain system of Pakistan, is considered as one of the most important biodiversity hotspots of the country. To explore the present floristic diversity of the region, vegetation sampling was done and field experiments were carried out using geo-referenced data of various species of eco-geological interest. Field data was merged with remotely sensed data, obtained from Landsat and LDR missions and processed in GIS for various geospatial analyses, i.e. Climate Change modelling, were developed hotspot analysis, Digital Elevation Models. Max Ent niche climate change modelling technique was used to predict the present and future potential distribution of some species. The results were obtained in the form of model outputs and GIS choropleth maps. It is evident from the results that Malakand division general and swat in partial area has microclimatic niches in various pockets of Malakand division i.e. District Swat, Dir and Chitral. Some locations were found to be extremely poor in floristic diversity and are extremely vulnerable to minute climatic changes. We conclude that the inevitable climate change is not necessarily an evil but could be looked at as an opportunity in hand which could be used for the socioeconomic development of the country. We recommend initiatives like introduction of GIS and remote sensing technologies to the Universities' curricula and interdisciplinary adaptation approaches in the form of departmental and inter-universities collaboration.

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Introduction

Conservation ecology requires exploration, identification and quantification of the natural resources. The Hindukush ranges of Pakistan, are considered as one of the most important biodiversity hotspots of the country; being under severe anthropogenic stress. This system of mountains is known for its rich biodiversity (Ali *et al.*, 2013;Rahman *et al.*, 2017)where lies the study area i.e. the Swat Valley, a place of unbelievable natural beauty. Hindu Kush system can be truly dubbed as the only viable timber source for Pakistan and Afghanistan. Administrative division puts the study area in KP (Khyber Pakhtunkhwa) Province of Pakistan geo-referenced as 34° 34'to 35° 55' N and 72° 08' to 72° 50' E (Fig. 1). The valley borders in the north with the Valley of Chitral and Ghizer while Indus Kohistan and district Shanglalies on the east. District Buner, FATA and Malak and Agency lie in the south while Dirdistrict lies in the west of the study area.

Hindu Kush system of mountains is a heaven of natural resources, paying the toll by being exploited severely by the anthropocentrism (Ali *et al.*, 2014; Irshad *et al.*, 2016; Khan *et al.*, 2016). Some of the direct anthropogenic stresses have already been documented (Shinwari *et al.*, 2003; Ali *et al.*, 2013; Khan *et al.*, 2014; Khan *et al.*, 2016) while the unknown or elusive of these threats to the Valley's biodiversity and the whole of the Hindu-Kush system is the global climate change. Very little has been documented and researched about this subject (i.e. Climate Change) in the area.

The diverse flora of the area is playing its role in the economic, medicinal, and ecological arenas of the region (Shinwari *et al.*, 2003; Hussain *et al.*, 2006; Ali *et al.*, 2014; Rahman *et al.*, 2017). The area has an immense water channel system from the glaciers flows to rain fed brooks, (Figure 2) providing an important element for the natural occurrence of MAPs and cultivation of various other economically viable plants. and rain fed well-established network of raw drugs supply originated mostly from the indigenous Medicinal and Aromatic Plant (MAPs), not only serves the national but international markets alike (Shinwari *et al.*, 2003; Ali *et al.*, 2014).

The MAPs use might be very old (Samuelsson, 2004) but the ethnomedical system and herbal remedies still constitute a valid healing industry of the area.

The issue of climate change will not only effect the patterns of seasons but will have significant impact on the socio cultural and financial setup of the area. We are aware that plants interact with their immediate environment, and when the immediate environment has to offer something which is not favoured by the plants, they will have to go through drastic changes in their physiology and ecology (Song *et al.*, 2004). Species respond to these changes (Adnan and Holscher, 2011; Ali *et al.*, 2014;Armsworth *et al.*, 2004;Beigh *et al.*, 2005; Song *et al.*, 2004) either positively or otherwise. Some species are known to be very prone to elfin climate changes e.g. *Aconitum heterophyllum* (Wall) (Beigh *et al.*, 2005)and *Abies Pindrow* (Ali *et al.*, 2014)reported from the complex Hindu-Kush Himalayan systems of mountains.

The natural rule of association and competition is followed by the species, while interacting with their physical environment at the same time (Hirzel and Lay, 2008).Species of significant importance and greater ecological implications are the trees, which form huge strata and could in turn support various understory vegetation. Species demand for the environmental variables to survive and sustain any change in the environmental or edaphic factors may lead to changes in the vegetation structure (Baquar, 1995; Rahman *et al.*, 2014). Tree species shift towards the north in many eco-regions have been noticed and reported (Song *et al.*, 2004). The species growing in association with the trees i.e. the valuable medicinal plants are also under stress either to shift their habitat or die away. This wipe out of species on a large scale with a considerable speed could cause MAPs scarcity which in turn could lead to serious socio-cultural health issues. The study area constitutes the northern part of the country has an immense altitudinal variation (Fig.1). The high altitudes of the areas are significantly colder than the lower parts of the Valley.

These variations are altitude and climatic variables means that there would be a microclimatic shift of a swift nature. Considering a scenario of 1000-meteraltitude having its specific climatic regime swiftly changing to climatic variables of 500-meter altitude can cause a shock effect to the flora. By the end of 2080 the current prevalent environmental variables will not be the same anymore (IPCC, 2007).

A researcher has a free well to choose from a variety of niche predictive modelling (Pulliam *et al.*, 2000; Thomas *et al.*, 2004; Guisan *et al.*, 2005). Our choice was Maximum Entropy (MaxEnt), being reliable and compatible with diverse are as of science i.e. biodiversity, ecology, geography and conservation science etc. (Phillips, 2006; Peterson, 2007; Elith *et al.*, 2011).

There are documentary evidences from the study area that the best niches are provided by the protective cover of the forests for the valuable medicinal plants (Adnan and Holscher, 2011) due to their close affinity with their associated species (Khan *et al.*, 2014). Considering all these changes i.e. the species competition and their interaction with each other, significant changes could be expected in the future distribution and density of the valuable trees and the corresponding sub-flora.

The loss of natural resources doesn't necessary mean loss to the economy, but for this area it would mean a loss to the valuable knowledge of Ethnomedicines. Links between the financial conditions and their preference of traditional medicine use has already been established (Khan, 2002). This valuable knowledge is part of the cultural domain of the communities and is entirely in danger of being lost (Ali *et al.*, 2013; Diallo *et al.*, 1999).

The present research work was to explore the present floristic diversity and agro-economic potential of the region, vegetation sampling and field experiments were carried out using geo-referenced data of various species of interest. We have deigned the current study to assess the actual impact of climate change on the current indigenous flora, especially the trees and their ultimate impact on the associated species.

Materials and methods

We have systematically selected tree species using modern robust hardware. The tree species of ecological or ethnomedicinal were selected. As per example, *Acacia modesta* was selected as it is commonly used as fodder, fuel wood and has many ethnomedicinal remedies (Bashir *et al.*, 2012). Other three species selected belong to Gymnosperms and commonly used for timber wood, fuel wood, scents, resin etc.

Max Ent Modelling

We have used Max Entmodelling technique using presence-only data of the selected species. Species data was randomly collected from 23 different localities of the Hindu-Kush mountain system of the district Swat. A reliable and robust method was set to collect geo-referenced data of the species. We used RedHen DX-GPS system connected to Garmin GPS and a Nikon D300 camera.

The data was captured in the form of images with metadata recorded in the background of the images. BR's EXIF extractor was used to extract the metadata quickly and efficiently.

Climate models

The CSV comma delimited text files were used as input data for the Maximum Entropy (MaxEnt) software (Phillips *et al.*, 2004). We have followed the protocols of (Phillips, 2007).

The UK Meteorological model, HADCM3 (Hadley Centre Coupled Model) was used with 19-bioclimatic layers (Worldclim, 2017) (Table 1). We chose A2a scenario of the climate model (Collins *et al.*, 2001).

We chose Maximum Entropy (MaxEnt) change model for the modeling operation over the other modeling software packages as it uses" presence only" data and is known to be one of the high lyprecise predictive modeling methods (Elith *et al.*, 2011).

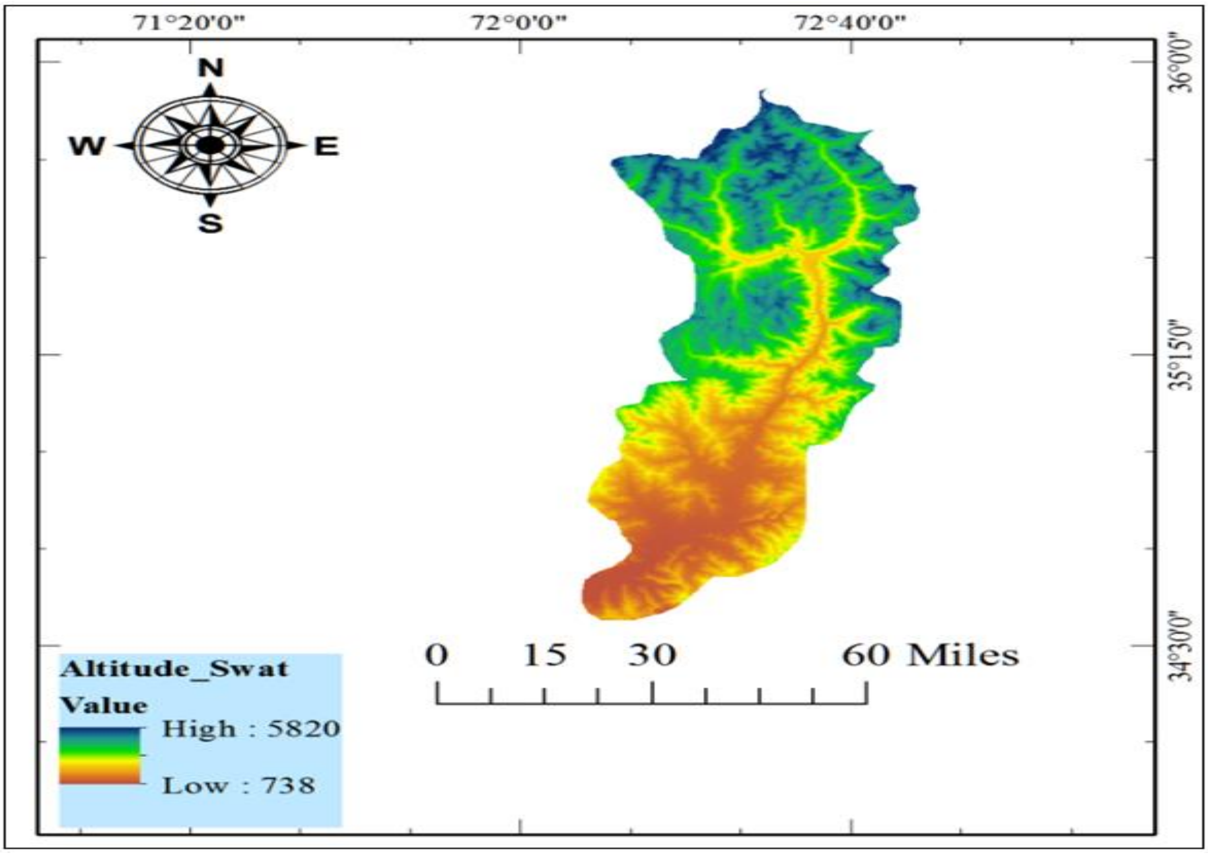

Fig. 1. Altitudinal variation in Swat district, a Shuttle Remote Terrain Model (SRTM).

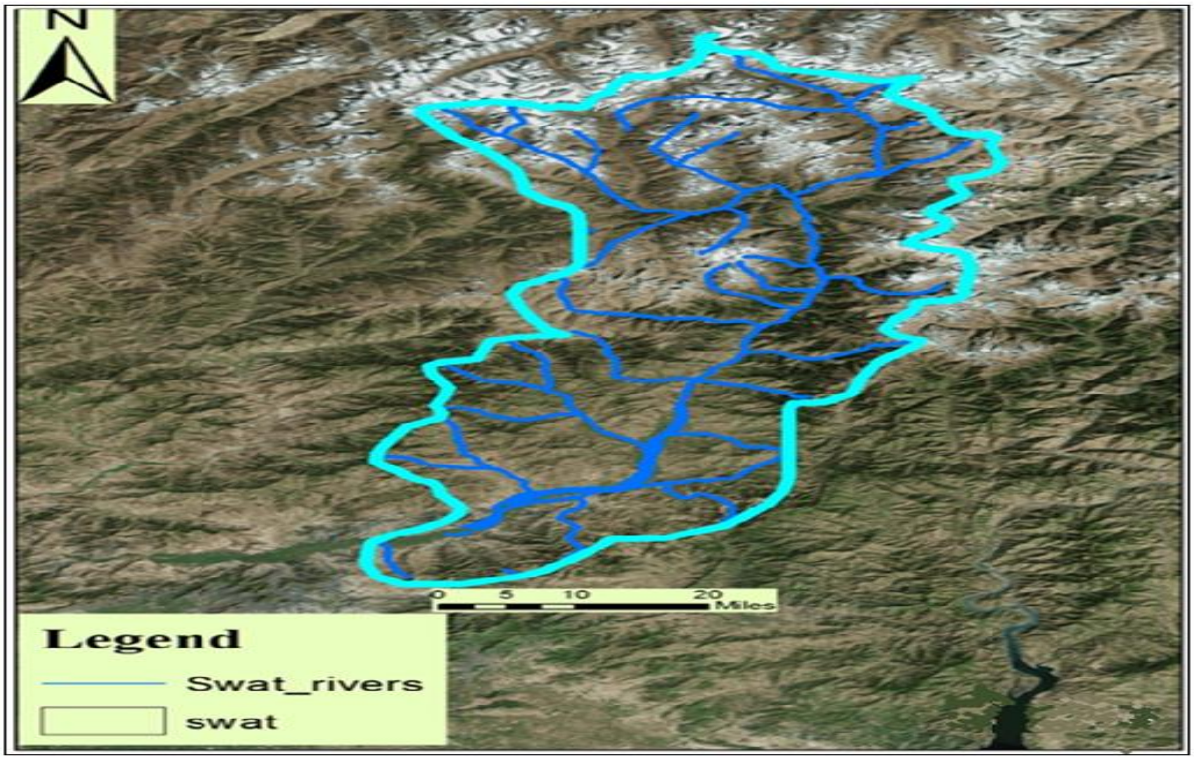

Fig. 2. Administrative boundaries of the Swat district and its main river system clipped and extrapolated in Arc GIS 10.3.1. The image shows a true colour composite Land sat 7 image of the study area with an overlay of administrative boundaries and water layers.

To interpret the results, the AUC values obtained were used a measure (Table 2). The models were evaluated on the measured values of the receiver operating characteristic curve (ROC) where the areaof1 represents a perfect test; a0.5or below represents a worth less test. The consensus of on the use of AUC value is that the model with a value of 0.8 is considered "good" while the value of over0.9isconsideredhighlyaccurate (Luoto *et al.*, 2005).

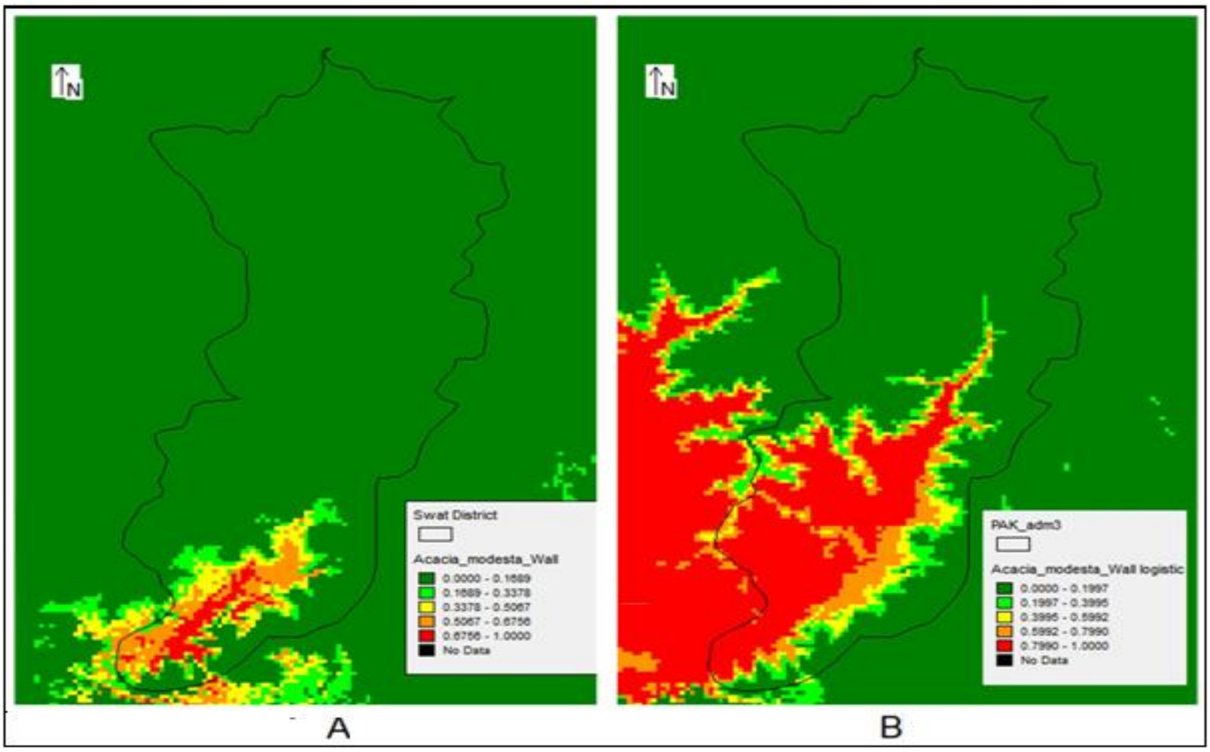

Fig. 3. A. Predicted Present distribution of *Acacia modesta*; B. Future projected distribution of *Acacia modesta*.

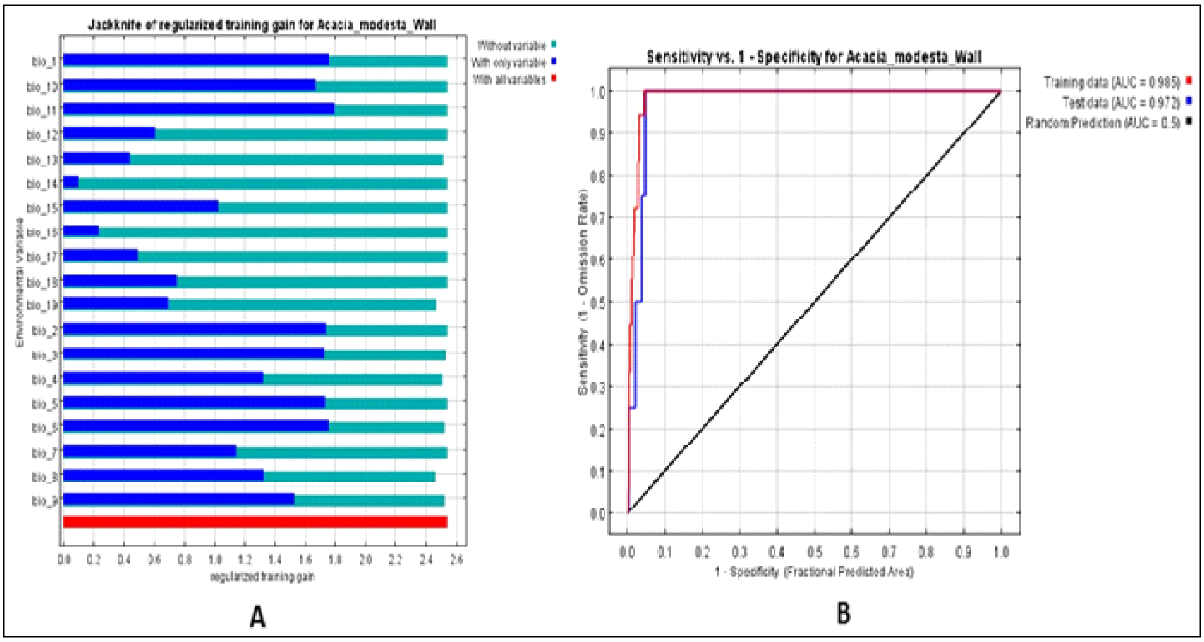

Fig. 4. A. Sensitivity vs. 1-Specificitygraph; Jackknife of AUC for *Acacia modesta*, **B.** Jackknife of AUC for *Acacia modesta*, future prediction model; results obtained using A2ascenario, all presence data of the species and19bioclimaticvariables (22).

Bioclimatic layers

Field data was merged with remotely sensed data, obtained from Landsat and LDR missions and processed in Maxent, TERSET and GIS for various geospatial analyses, i.e. Climate Change modelling, hotspot analysis, NDVI, NDBI, Digital Elevation Models. ArcGIS version 10.3.1 (ArcMap) licensed by ESRI (2016) was used for geoprocessing of the bioclimatic layers and cartographical operations for better interpretation of the Max Entraster results.

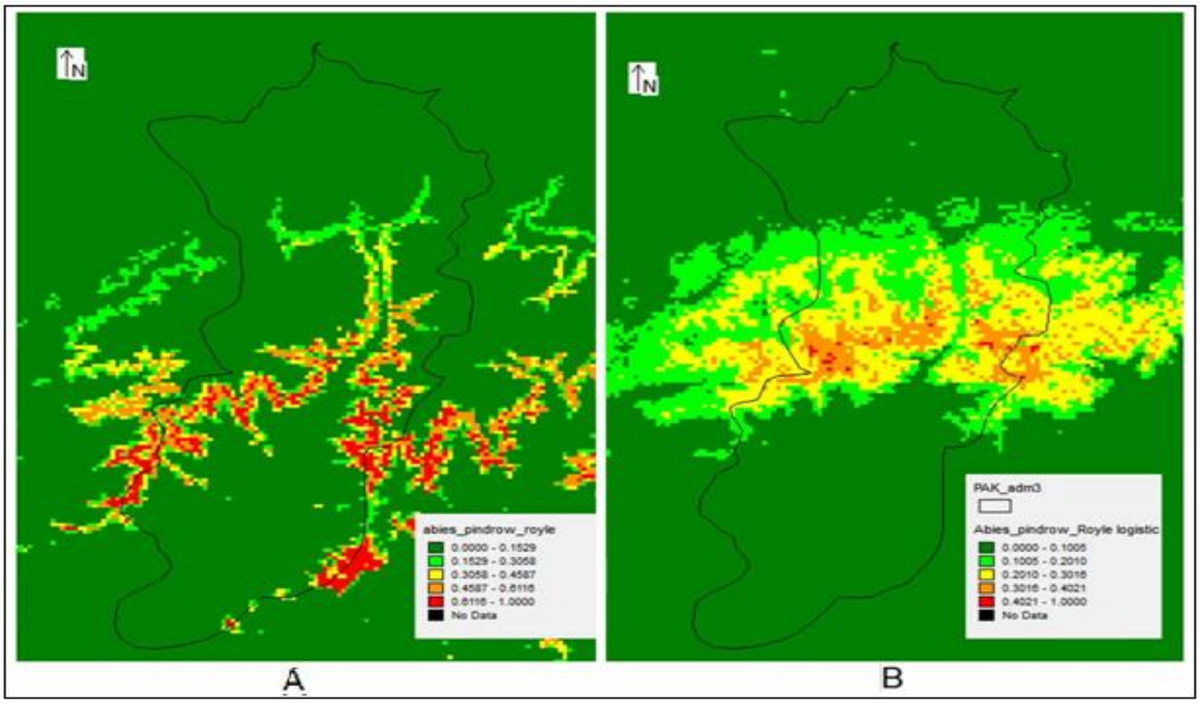

Fig. 5. A. Present distribution of *Abies pindrow*; B. Future projected distribution of *A. pindrow*.

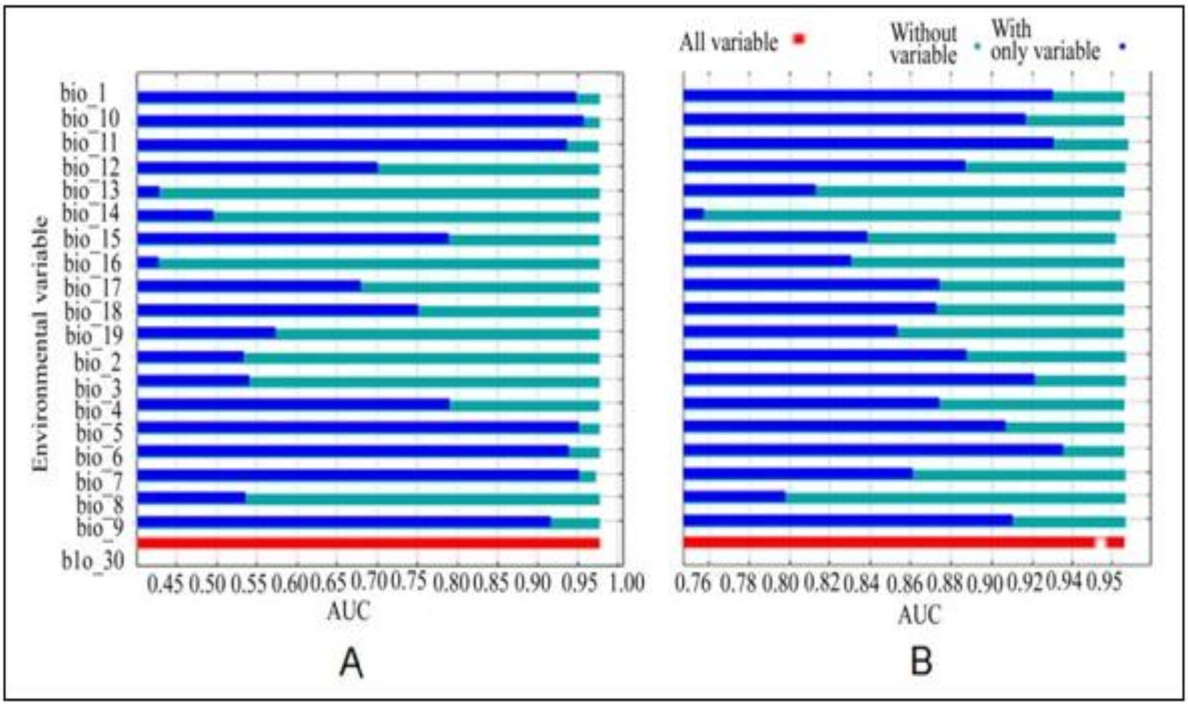

Fig. 6. A. Jackknife of AUC (area under the curve) for *Abies pindrow*, present prediction model; B. Jackknife Of AUC for *Abies pindrow*, future prediction model; results of a Jackknife AUC of variable importance for *Abiespindrow*intheA2ascenariousingallpointlocalities and19bioclimaticvariables (22).

Results

Maxent produced some interesting results regarding the selected species models which are individually described below:

Acacia modesta model

The results of the present predictive model for *Acacia modesta* indicates that the species has significantly restricted present distribution in the low altitudinal regions of Swat Valley of the Hindukush system.

Only the lower areas of the Valley have the suitable niches available with the presence of the required bioclimatic variables for the species and have been there for probably hundreds of years.

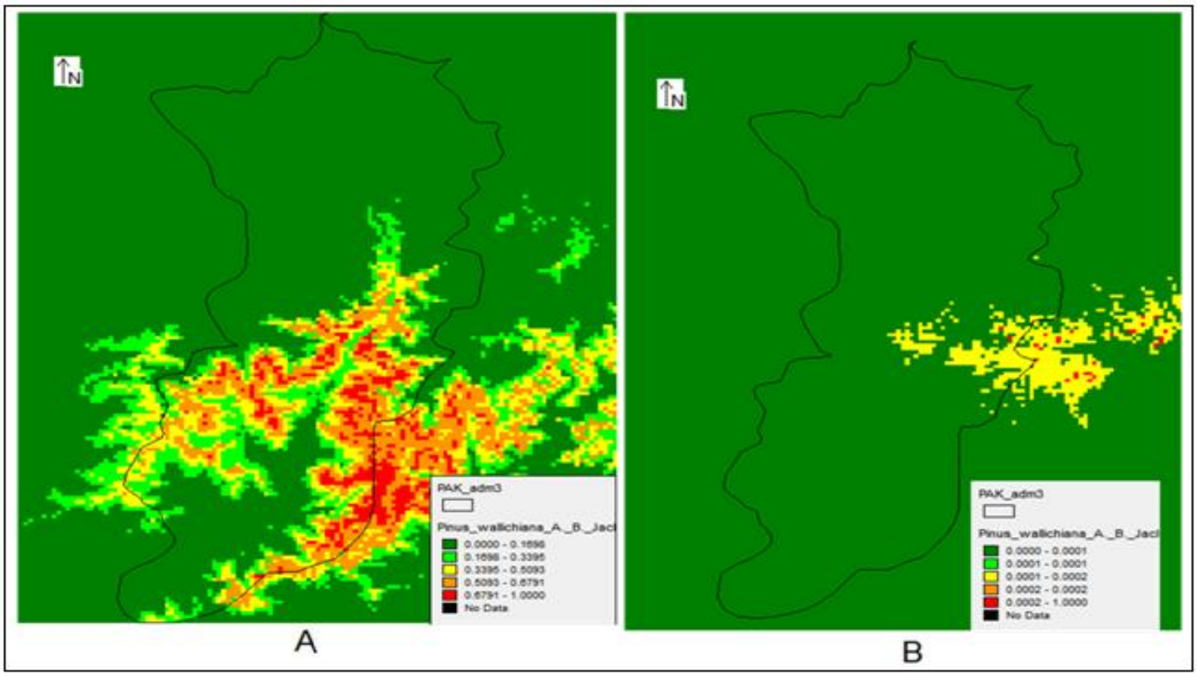

Fig. 7. A. Present predicted distribution of *Pinus wallichiana*; B. Future predicted distribution of *Pinus wallichiana*.

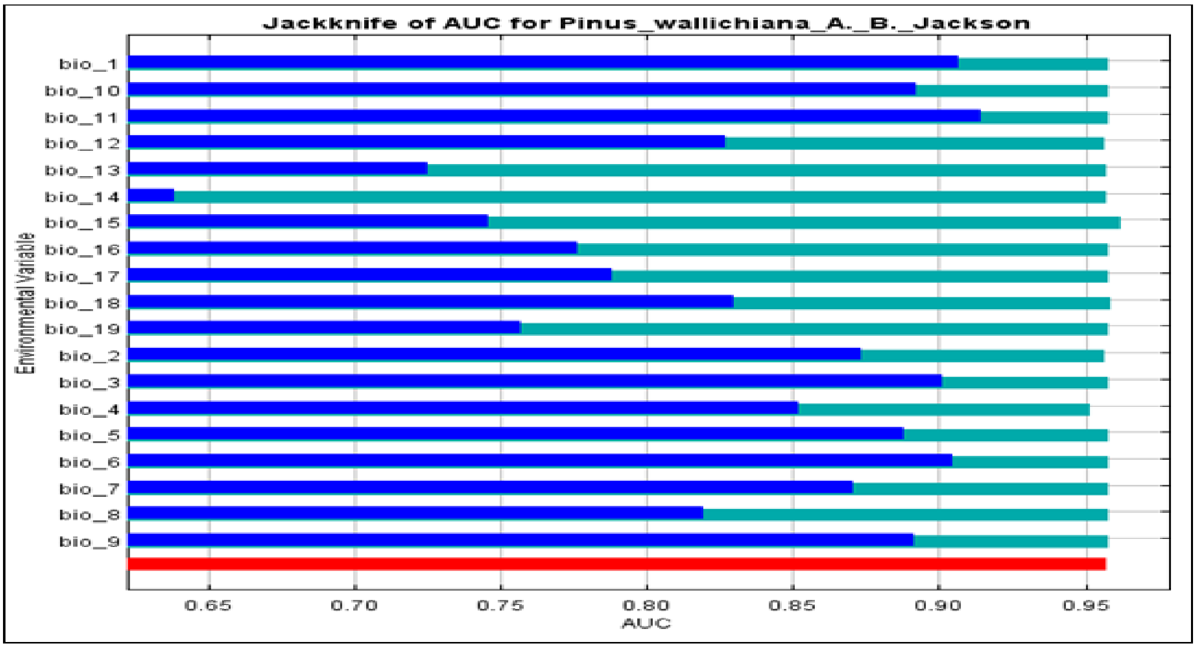

Fig. 8. Jackknife of AUC for *Pinus wallichiana*, present predictive model.

The Southern borders of the Valley were recorded to have the highest probability of occurrence (Fig. 3 A), which was confirmed by a systematic ground truth analysis.

The results of the future prediction model of *Acacia modesta* showed a significantly higher occurrence probability in the core of the Valley and South-western areas of the Valley extending as far as the neighbouring district Dir (Fig. 3 B). The change is in the distribution pattern is obvious for *Acacia modesta* (Fig. 3 B). We have recorded that certain bioclimatic variables have contributed more than the others, i.e. bio_11 was one of the most important contributor in affecting the distribution and occurrence density of the species.

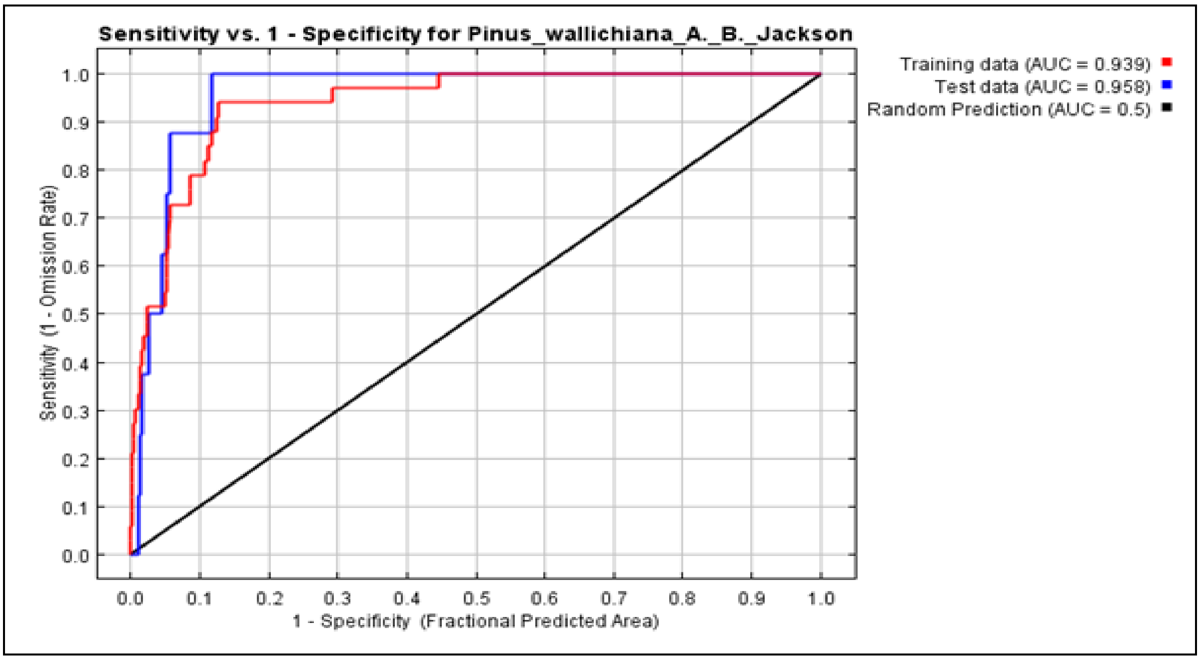

Fig. 9. Sensitivityvs.1-specificity for *Pinus wallichiana*, present prediction distribution model.

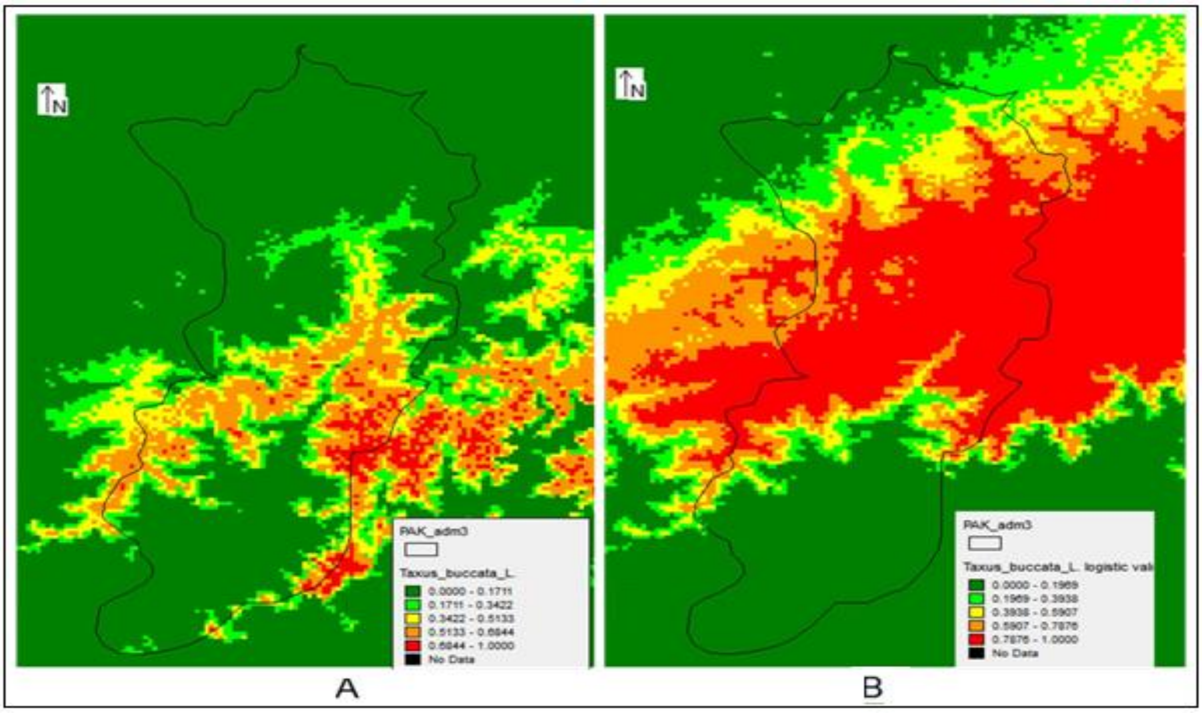

Fig. 10. A. Present distribution of *Taxus baccata;* B. Future projection of *T. baccata*.

Bio_19 showed the least gain of AUC when used individually thus proved to be the least important bioclimatic variable in predicting the species distribution (Fig. 4 A and B). To validate the statistical significance of the models, the AUC value was recorded from Max Ent.

Abies pindrow

The MaxEnt model recorded that the *Abies pindrow's* population has the potential to expand to the neighboring districts in thee a stand west with significantly sparse population. Some of the key areas identified were namely, Sulatanr and Mankialsub-valleys (Fig. 5A-B). Here too, a ground truth operation has confirmed the present predicted results of the model.

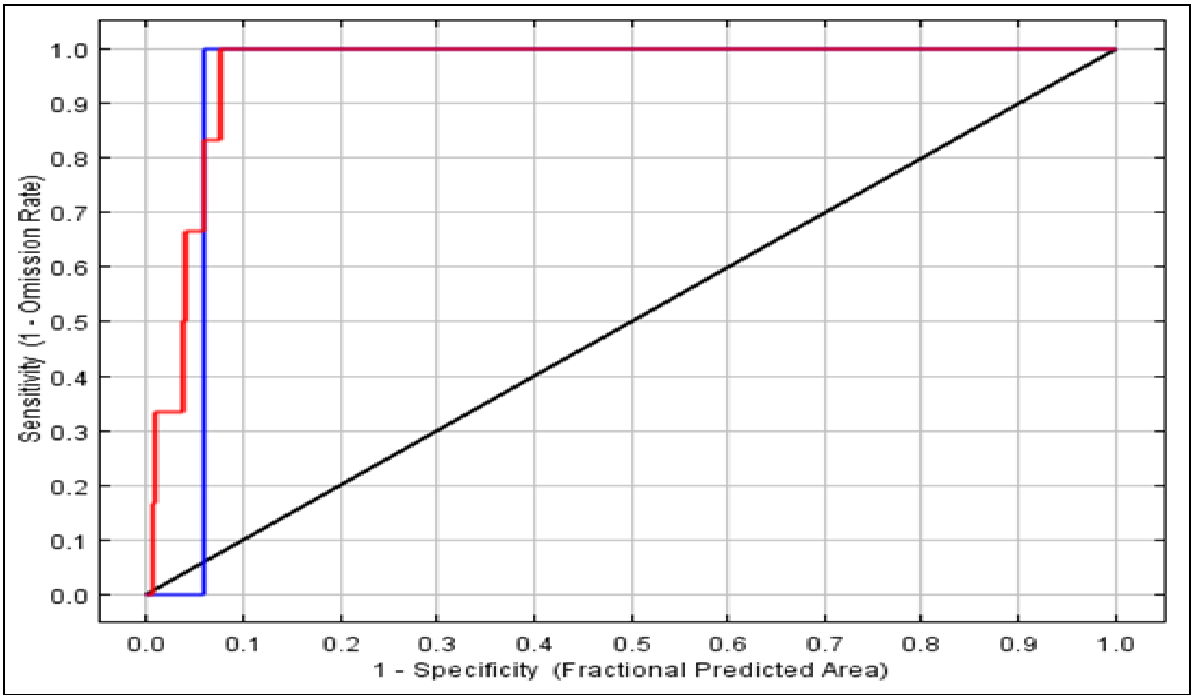

Fig. 11. Sensitivity vs. 1-specificity for *Taxus baccata*. In the present model.

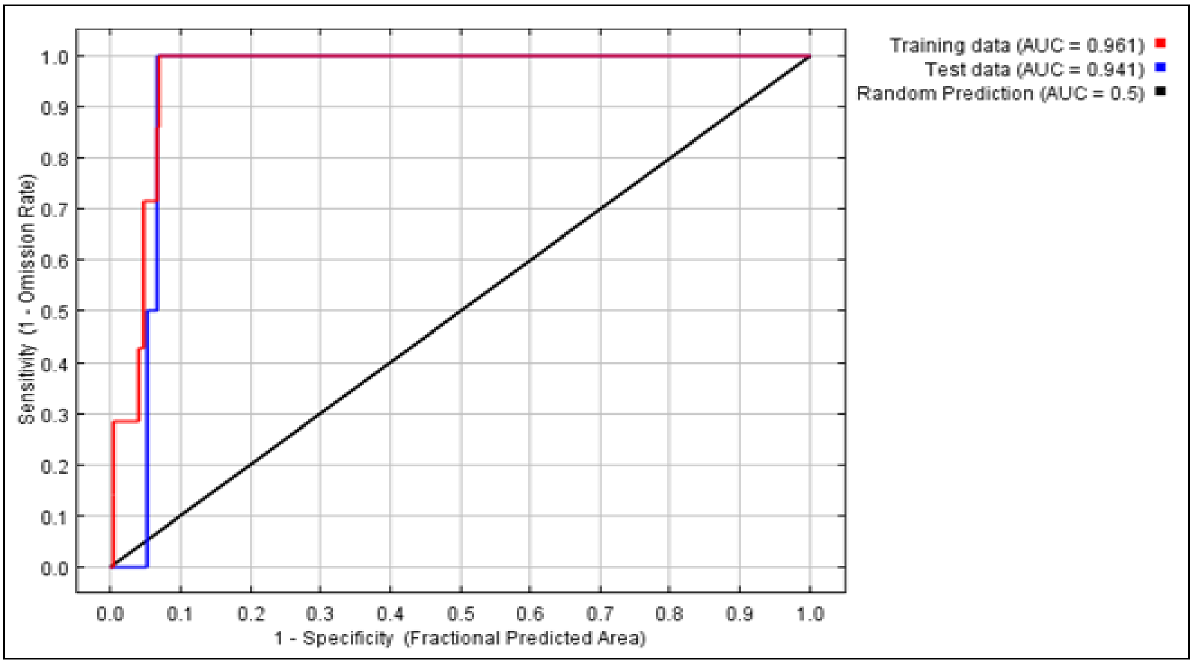

Fig. 12. Sensitivityvs.1-specificity for *Taxus baccata*; future prediction model.

The Jack Knife analysis has confirmed that the main contributors to (AUC) value werebio_10andbio_7 (Table 2). In the future projected model for Abies, bio_6 was contributing more along with bio_1andbio_11. In this model, bio_14washaving the least contribution to the AUC value (Fig. 6A,B).

Pinus wallichiana

The raster results of the current distribution model suggest that *Pinus wallichiana* being a pervasive species in the study area with specific growing pockets. The Max Ent results for the present model suggests that the plant is highly concentrated is the eastern, western and some central part of the valley (Fig. 7A and B).

Table 1. Bioclimatic variables and their description.

No	Bioclimatic Variable	Description
1	bio_1	Annual mean temperature
2	bio_2	Mean diurnal range (mean of monthly (max temp-min temp)
3	bio_3	Iso thermality (100*mean diurnal range/annual temperature range)or (bio_2/bio_7*100)
4	bio_4	Temperature seasonality (standard deviation*100)
5	bio_5	Max temperature of warmest month
6	bio_6	Min temperature of coldest month
7	bio_7	Temperature annual range (bio_5-bio_6)
8	bio_8	Mean temperature of wettest quarter
9	bio_9	Mean temperature of driest quarter
10	bio_10	Mean temperature of warmest quarter
11	bio_11	Mean temperature of coldest quarter
12	bio_12	Annual precipitation
13	bio_13	Precipitation of wettest month
14	bio_14	Precipitationofdriestmonth
15	bio_15	Precipitation seasonality (coefficient of variation)
16	bio_16	Precipitation of wettest quarter
17	bio_17	Precipitation of driest quarter
18	bio_18	Precipitation of warmest quarter
19	bio_19	Precipitation of coldest quarter

The future model of the species show a significant change in habitat, a shift towards North east with a considerably lower probability. The graphical scheme of Jackknife (Fig.8, 9) of AUC shows an overall gain of 0.95 with the highest gain achieved by bio_11. This gain of AUC puts the model in a highly reliable category.

Taxus baccata

Taxus baccata/*Taxus* fauna's model clearly predicts the current possible distribution in a small region with very low density (Fig. 10. A. B). The future predicted distribution of the species in the raster output of MaxEnt is very promising, a highly probability with wider area of occupancy especially in the north (Fig.10. A. B). A training data of the species have recorded a highly significant AUC value of 0.962 (Fig.11 and 12).

Discussion

Evil or opportunity

All organisms should live in association with their biotic components i.e. other species and interact with their immediate environment (Hirzel and Lay, 2008). This perfect balance of interaction gives a species a place to live (niche). Some species respond to minute changes in their surroundings and could react in various ways, i.e. reproductive cycle change, morphological change in vegetative part or seeds dispersion etc. For example, for *Aconitum* heterophyllum the change in climate means changein their habitat towards the north in the Himalayan ranges of Pakistan (Beigh *et al.*, 2005). We can confidently predict that the species under consideration in the study will not completely wipe out of the study area. Some species will find it as an "evil" for them to be severely affected by losing their suitable habitats while for others it will be an "opportunity" to expand in their distribution and density.

Table 2. Regularized Training AUC values and important variables for *Acacia modesta, Abies pindrow, Pinus wallichiana* and *Taxus baccata* in the present and future predictive models.

Plant species	Present model Important variables	Future model Important variables
Abies pindrow	bio_10	bio_6
Acacia modesta	bio_11,bio_3,bio_2	bio_11,bio_3,bio_19
Pinus wallichiana	bio_3,bio_6	bio_11
Taxus baccata	bio_15,bio_7	bio_15,bio_7

Hindu-Kush Himalayas

A common response recorded in the Hindu-Kush–Himalayas is the movement of species to higher altitudes as these altitudes provide colder climatic regimes at the moment and will be suitable by 2080 for their growth and development (Song *et al.*, 2004). We have corroborative results to that of Song *et al.* (2004) as our species of interest also show the same pattern in their future model. In Swat Valley, the steep northern areas of valley provides completely different microclimatic zones with cooler temperatures and precipitation regimes; but, by the year 2080theseareas could be compared with the currently prevailing climatic conditions of the South.

Climate change

Taking the other ecological prospect of species dependence on other species, most of the MAPs of the area are naturally found under the natural forest canopies (Adnan *et al.*, 2011; Khan *et al.*, 2014). These canopies are formed by the few important trees, i.e. *Abies pindrow*, *Pinus wallichiana* and *Acacia modesta*. Taking this fact into account, most of the MAPs and valuable non-timber forest products (NTFPs) will be negatively affected from this climate change. Any major depletion event would mean loss to the invaluable flora resulting in a possible socio-economic and sociocultural catastrophe on a regional scale (Ali *et al.*, 2014). As already been proven by various scientific studies that there exists a strong positive correlation between the financial situation of the local communities' preferential use of the traditional medicines (Khan *et al.*, 2002). ethnomedicinal knowledge of the communities (Diallo *et al.*, 1999; Ali *et al.*, 2013) which could ultimately result in food and medicine scarcity.

We can draw some common conclusions as; all the species assessed for the climate change effects how a significant change in their distribution which includes movement to the northern regions of the Hindu Kush system. We conclude that for some species the climate change means an opportunity while for others it's an evil. In 2080 A. modesta's population will be seen everywhere warranting that all other human interferences being checked.

The population density of some important species like A. *pindrow* will decrease and *Taxus baccata* could flourish in the northern parts if allowed to be grown and taken care of. Recommendation We recommended large scale climate change assessments over the entire Hindu Kush Himalayas while educating the laymen regarding the consequences of the unavoidable change We urge the government and the local authorities of the area to address the climate change issue effectively and adopt a better mitigation policy. We also recommend initiatives like introduction of GIS and remote sensing technologies to our Universities' curricula and interdisciplinary approaches in the form of departmental and inter-universities collaboration.

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