EXCELLENT PUBLISHERS

International Journal of Current Research and Academic Review

ISSN: 2347-3215 Special Issue-1 (October-2014) pp. 58-65

www.ijcrar.com

Climate change and the fate of *Picea smithiana* in Swat District, Northern Pakistan

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KEYWORDS

Climate change, *Picea smithiana*, Predictive modelling, MaxEnt, Swat Valley, Pakistan

A B S T R A C T

The effect of the global climate change was assessed in the Swat Valley of Northern Pakistan, to understand the future of one of the important tree species i.e. *Picea smithiana (Wall.) Boiss. Picea smithiana* is of a significant ecological and ethnomedicinal importance to the area. The Maximum entropy (MaxEnt) modelling technique of species prediction and distribution was applied, using HADCM3 A2a global climate change scenario. It was concluded that by the 2080 there will be a significant change in the distribution and density of the species. The results obtained show a "good model" for both present and future models, gaining the AUC values of 0.972 and 0.977respectively. The results indicate that mean temperature of coldest quarter (bio_11) and temperature of the warmest month (bio_5) climatic variables have the highest contribution to the AUC values in the present model, while the mean temperature of warmest quarter (bio_10) and bio_3 have significant contribution to the future prediction model of the species and thus positively correlated with the distribution and density of the species. The predicted changes in the distribution and density of the species in the future prediction model can have immense ecological and socioeconomic impact.

Introduction

The Swat Valley**,** which is well known for its biodiversity, is situated in the Khyber Pukhtunkhwa Province of Pakistan and can be traced on the globe at 34° 34' to 35° 55' N and 72° 08' to 72° 50' E (Shinwari et al., 2003). The valley has borders in the north with Chitral and Ghizer, Indus Kohistan and Shangla to the east, Bunir and FATA, Malakand Agency on the south, and district Dir on the west (GPO, 1998). The floral diversity in the Swat District, especially, tree flora is threatened with severe extinction from global climate change. Most of the naturally occurring flora of the valley is of immense economic, medicinal, and ecological value, giving the district a key role in the medicinal and aromatic plant (MAPs) markets of not only in the region but in the international arena (Ali et.al., 2014; Shinwari et al., 2003).

Plants, especially, MAPs have been known to be used for thousands of years in human history (Samuelsson, 2004), by different civilizations and for all different sorts of ailments. These plants have particular growing requirements to grow in and if not fulfilled, they would vanish. Man-made, Anthropogenic changes are the most prominent changes of all, observed recently on regional and global scale, effecting natural vegetation (Song et al., 2004). Some species are susceptible to minute changes in the climate as Beigh et al. (2005) and Ali et al (2014) have pointed out for *Aconitum heterophyllum* (Wall) and for Abies Pindrow, respectively, in the complex Himalayan region. The current study was carried out to model the impact of changing climate on the distribution of the forest trees of the Swat Valley, especially *Picea smithiana (Wall.) Boiss*, which together with a few other species provide a lifeline for the subflora, especially, MAPs of the area.

Predictive modelling techniques of species are useful for the understanding of conservation issues as they can provide valid estimates on the possible extinction probabilities of biota due to climate change and thereby aid future conservation planners. In the present study, the current and future distribution of *Picea smithiana* will be modelled using these tools in order to obtain a better understanding of climate change affect on the vegetation dynamics of the area and help the planners to plan ahead of any permanent damage to the precious flora of this area.

Picea smithiana was selected for the study as it is a native plant of the valley, grows at altitudinal range of around 2000-4000m. It typically grows in moisture rich and cold area reaching the height of 40-60m and a diameter of 2-2.5m. It is very well known for its ethnomedicinal, ecological and economic values and is one of the most expensive plants used in the timber and construction industry. The plant's tincture or decoction is used in coughs, phthisis, asthma, and catarrh of the bladder (Hussain et. al., 2006). Its fresh juice is given to infants in fever chest afflictions. The powder of leaves is given with the addition of *Adhatoda vasica* L. leaves powder and honey in haemoptysis (Nadkarni, 1927). The tree is also a common ornamental plant in the area (Baquar, 1995) while the wood is used for construction purpose–e.g., doors, windows, houses, and furniture— and the tree branches are used as fuel wood.

The presence data of *Picea smithiana* was drawn from randomly selected plots belonging to 23 different localities of the Swat District between 2007-2008 and 2010-2011. To ensure robust and accurate data collection, the RedHen DX-GPS system was used. The hardware was a Garmin GPS and Nikon D300 camera connected together to capture and store all the background information with the picture as metadata. Over 2,000 photographs of different plant communities were captured and the metadata was extracted with the help of BR's EXIF extractor, a freeware available online [http://www.br-software.com/ extracter.html; visited 07/08/2011]. The software transforms metadata into CSV comma-delimited text file format that can then be used in the Maximum Entropy (MaxEnt) software (Phillips et al. 2004). The MaxEnt method of predictive modelling was followed step by step as given in Phillips (2006). The HADCM3 A2a climate-change scenario (Collins et al., 2001) was used, which predicts a decrease in precipitation [- 20mm /year] with an increase in temperature of around 4 degree Celsius, up to the year 2080. The bioclimatic layers (see Table 1) in GIS compatible format were downloaded from the Worldclim website (WorldClim, 2011).

The predictive modelling approach is a common practice in different areas of science, used to address ecological, bio-geographical, and conservation issues of species (Peterson, 2007). There are a variety of species distribution models available (Guisan and Thuiller, 2005), some of which need species presence-absence data while others are known which only use the "presence only data" and do not require "absence data" or they assume pseudo-absence (e.g., Soberón and Peterson, 2005; Phillips et al. 2006; Chefaoui and Lobo, 2008; Hirzel and Le Lay, 2008; Jiménez-Valverde et al. 2008; Soberón and Nakamura, 2009; Lobo et al. 2010). Predictive models are regarded as useful tools for the conservation of species by estimating the extinction probabilities of species due to the climate change (Thomas et al. 2004). These kind of integrative programs connect the geospatial data with species-based information and help to us to identify priorities for conservation actions (Scott et al. 1996).

The MaxEnt modelling technique was applied to the study because it uses "presence only" data and is known to be a highly precise predictive method (Elith et al. 2011). The AUC values obtained for the species for present distribution models indicate highly significant results (see Table 2). The general agreement on the AUC value is that the model is "good" if the value is over 0.8, while the value of over 0.9 is considered highly accurate (Luoto et al. 2005). For the current project, all of the software packages mentioned above were utilized along with some help from ArcGIS version10 (ArcMap) licensed by ESRI 2011 in map development.

Table.1 Bioclimatic variables and their description (Source: WorldClim, 2011)

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	Isothermality (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	Precipitation of driest month
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

Table.2 Training AUC values, important variables and percentage contribution of *Picea smithiana* for the present and future predictive models

Plant Species	Present distribution model			Future distribution model		
	Training AUC	**Important variables**	**Contribution (%)**	**Training AUC**	**Important variables**	**Contribution (%)**
Picea smithiana (Wall.) Boiss.	0.972	bio_11	69.2	0.977	bio_15	24.5
		bio_7	16.4		bio_12	17.8
		bio_15	14		bio_11	16.9

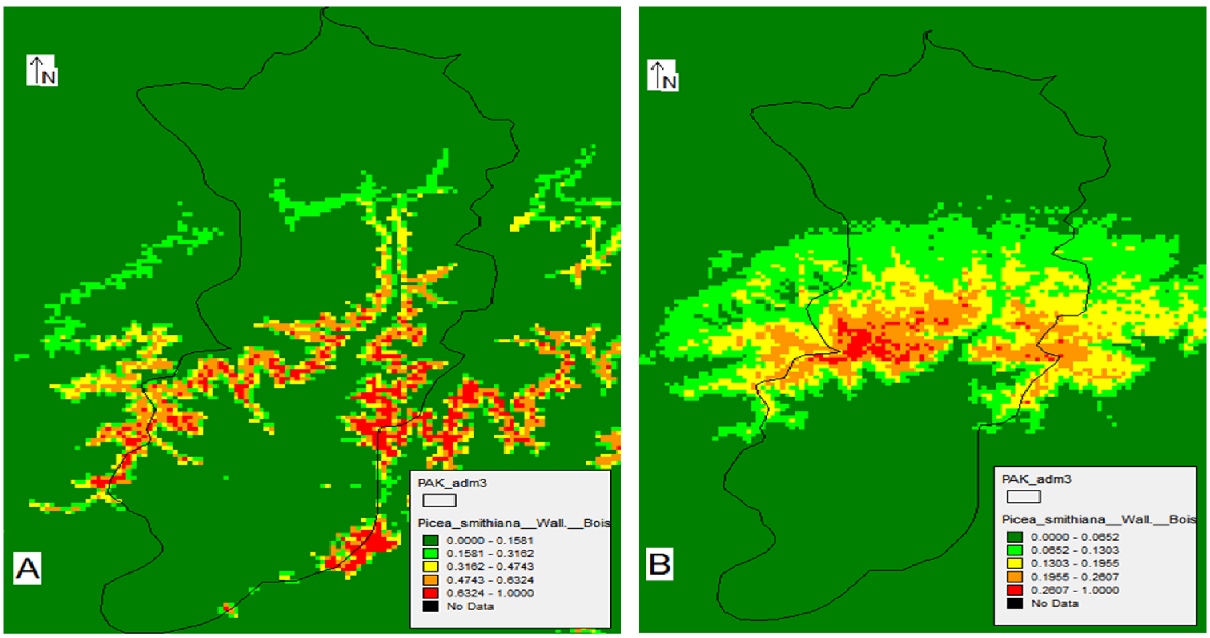

Fig.1 A. Present distribution of *Picea smithiana*; B. Future projected distribution of *P. smithiana*

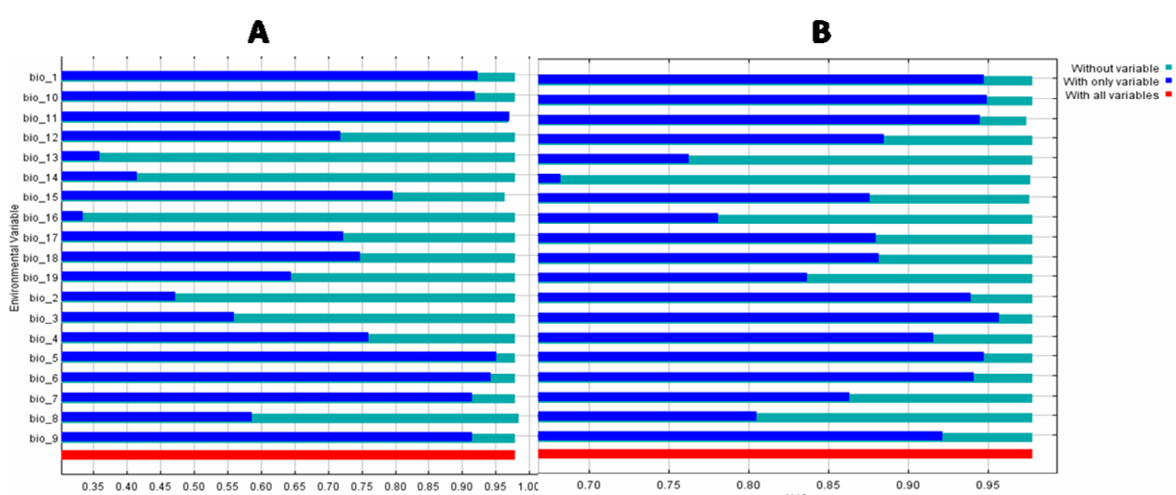

Fig.2 A. Jackknife of AUC for *Picea smithiana*, present prediction model. B. Jackknife of AUC for *Picea smithiana*, future prediction model; results of a Jackknife AUC of variable importance for *Picea smithiana* in the A2a scenario using all point localities and 19 bioclimatic variables (Phillips 2006).

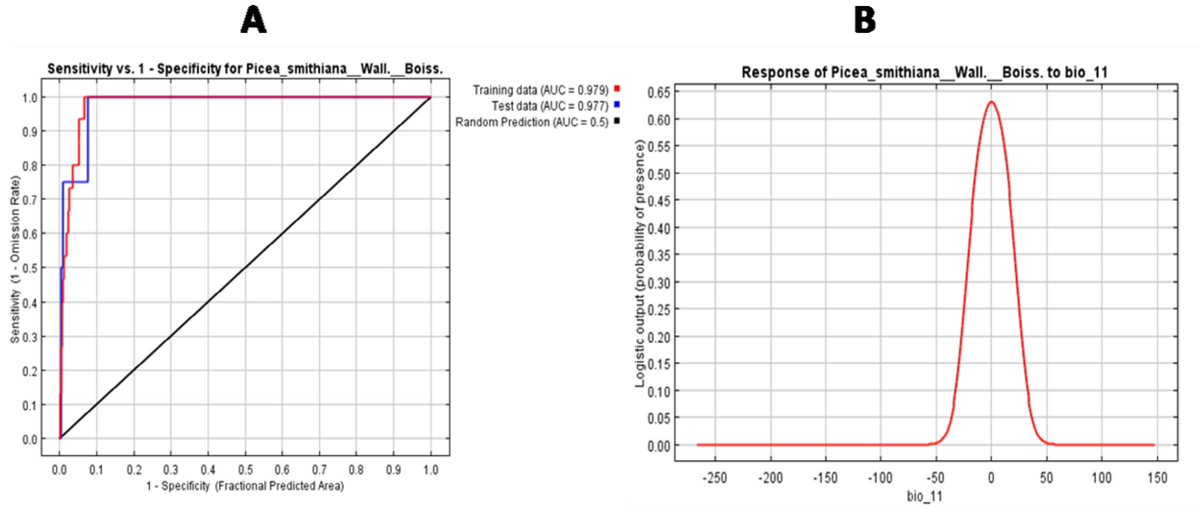

Figure.3 A. Sensitivity vs. 1- specificity for *Picea smithiana*; Future predicted distribution. **B**. Response of the most important variable (bio-11) in predicting the fu

It was predicted in the MaxEnt present prediction model that the species currently have still some suitable locations available for expansion in density and distribution. These locations are mostly on the western borders of the district. The highest species density was therefore, recorded for the eastern border of the Valley in the areas of Sulatanr (Fig. 1 A).

The Jackknife analysis for the present distribution probability (Fig. 2 A and B) of the area shows that the Area Under Curve (AUC) values were highly contributed by bio_11 and bio_5 climatic variables (Fig. 3 A and B), which are the Mean temperature of coldest quarter and temperature of the warmest month, respectively, while the least contributing variables for AUC gain was bio_16; precipitation of wettest quarter. Accuracy was measured by the area under the receiver operating characteristic (ROC) curve. An area of 1 represents a perfect test; an area of 0.5 represents a worthless test.

For future projection, the model showed a different trend: bio_6 was the main contributing variable along with bio_3 and bio_10, while bio_14 was found to be the least contributing variable (see Table 2 and Fig. 2 A and B). The bio_14 is the precipitation of the driest month, and is not a significant factor in the distribution of *Picea smithiana* of the future climatic conditions (see Fig. 2 A and B).

The results indicate that the *Picea smithiana's* population density in the area will be negatively affected by the climate change effect. The Swat valley will have less *Picea smithiana* stands in 2080 and the southern parts of the Valley will not support the tree species anymore.

Species colonization on the new habitat

Species never live on their own (Hizrel and Le Lay, 2008) and always interact with their environment, both physical and biological. Some species are very prone to minute changes in the climate as Beigh et al. (2005) pointed out for *Aconitum heterophyllum* in the complex Himalayan region. The current study concludes similar results: the current species will not completely vanish, but their current habitat and population density will be significantly affected. As a result, the sub-flora dependant on these trees will either have to move or "walk" with them or go extinct.

A general trend of altitudinal movement of species is observed in the Hindu Kush-Himalayan region as a consequence of global warming or climate change. Song et al. (2004) reported the effect of climate change on the northward movements of the some of the tree species, including *Abies* spp. and *Picea* spp. In the current study, the same climate change response was found for *Picea smithiana*; results are in total agreement with Song et al., (2004).

As the northern parts provide high altitudes and are significantly colder than the southern parts of the study area, *Picea smithiana* shows similar trend of walking north in the future predictive model (Fig. 1 B). Variation in the bioclimatic variables, like bio_16 which is the "precipitation of the wettest quarter" means that *Picea smithiana* is currently getting the optimum rainfall at a particular temporal variation. However, that trend will change with the changing climate, especially in the Hindu Kush Himalayas, see Ahmad et al. (2010).

The results suggest that global climate change will have a very significant effect on the distribution of some of the important tree flora of the Swat Valley and will eventually cause scarcity of the non-timber forest products (NTFPs), especially MAPs, as most of the MAPs in the study area grow under shady or semi-shady niches of the forests (Adnan and Hölscher, 2011). It is therefore anticipated that the change in the climate will only force the tree species like *Picea smithiana* and *Abies pindrow* to either shift their habitat or simply vanish, but could possibly create serious socio-economical issues related to the health and economy of the local and regional communities.

People are unaware of this significant anthropogenic hanging over their heads. Neither, the Federal Governments of Pakistan nor the Provincial Government of Khyber Pukhtun Khwa (KPK) has any strategy in place to deal with the consequences. There is a clear need for alternative crops to support the already exploding population of the Valley, with the less land for cultivation and less water resources. Selection of suitable future species will be critical as all species will not be able to survive the future climatic conditions. Serious changes to conservation policy will be needed at the governmental level, and strict measures will be needed to implement conservation policy.

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