Asian Journal of Conservation Biology, December 2014. Vol. 3 No. 2, pp. 127–134 AJCB: FP0043
ISSN 2278-7666 ©*TCRP* 2014

Species distribution modeling of *Taxus wallichiana* (Himalayan Yew) in Nepal Himalaya

Jyoti Prasad Gajurel[1,2*] Silke Werth[2,3,4], Krishna Kumar Shrestha[1] and Christoph Scheidegger[2]
[1]*Central Department of Botany, Tribhuvan University, Kirtipur, Kathmandu, Nepal.*
[2]*WSL Swiss Federal Research Institute, Zürcherstrasse 111, CH-8903 Birmensdorf, Switzerland.*
[3]*Institute for Plant Sciences, University of Graz, Holteigasse 6, 8010 Graz, Austria.*
[4]*Faculty of Life and Environmental Sciences, University of Iceland , Reykjavík, Iceland.*

(Accepted December 15, 2014)

ABSTRACT

Predictions on potential sites of endangered species like *Taxus wallichiana* (Himalayan Yew) could help the conservation of this species. Based on collection information of 124 study sites and 18 herbarium records from the Southern slopes of Nepal Himalaya, we used species distribution modeling as implemented in Maxent. The information from collection sites of the herbarium specimens and some of our own collections were used to validate model predictions. Our study revealed two species distribution models with slightly higher AUC. The model with eco-physiologically important bioclimatic variables seems to perform best, covering most potential sites of *Taxus wallichiana*. Our results also showed that predicted potential distribution based on current conditions and future projections showed effects of climate change on distribution of *T. wallichiana*. We found that there will be more areas of less impact while fewer areas will have severe effects. This study also revealed that the most suitable altitudinal range was from 2600-3000 m a.s.l. while temperature and precipitation played important role in the species. The altitudinal boundaries observed in each research site suggest the precise distribution in Nepal Himalaya. Results from our models can be utilized for developing conservation strategies for the species in the Nepal Himalaya.

Key words: Bioclimatic variables, climate change, maxent, mountain, conservation.

INTRODUCTION

Many techniques have been developed for predicting species' distributions (Guisan and Thuiller, 2005). Such models relate occurrence records of species to environmental variables and help in specifying the environmental conditions required for the conservation of populations (Pearson, 2007). *Taxus wallichiana* Zucc. is an important and threatened species at the national and Himalayan level. It is distributed in the mid hills of the Nepal Himalaya between 2300 to 3400 m a.s.l. (Press, Shrestha, and Sutton, 2000). *Taxus wallichiana* was listed in Appendix II CITES (Thomas and Farjon, 2011) in 1995. It was assessed as data deficient (DD) by IUCN in 2006 (Paul *et al*., 2013).

The species is very rare but of a high economic importance and despite its protected status the species is currently used in multiple ways as food, timber and medicines (Joshi, 2009). In Nepal forest management, harvesting and sale of the forest products are regulated by Forest Act (1993, Government of Nepal) and National Park and Wildlife Conservation Act (1973, Government of Nepal). Nevertheless, populations of *Taxus wallichiana* are regionally over exploited by local people for medicinal uses and the preparation of anticancer drug by multinational companies (Mulliken and Crofton, 2008). Here, we use species distribution models based on fine-resolution bioclimatic datasets (current and future conditions) and species presence data that we collected during extensive fieldwork in the Himalayas (Scheidegger *et al*., 2010).

The aim of the present study was (i) to investigate population size and altitudinal distribution of *T. wallichiana* in six intensively studied valleys in the Nepal Himalaya, (ii) to test which bioclimatic parameters influence the species presence and (iii) to test species distribution models and compare the species' extent of occurrence under current climatic situation and under climate change scenarios.

MATERIALS AND METHODS

Data collection

The study area included six valleys belonging to three regions with different precipitation gradients in the Southern slopes of the Nepal Himalaya. The six valleys include Sagarmatha valley (SNP1) in Sagarmatha National Park and surrounding and Dudkunda valley (SNP2) in Solukhumbu District; Nubri valley (MCA1) and Tsum valley (MCA2) of Manaslu Conservation Area of Gorkha District; and Olangchungola valley (KCA1) and Ghunsa valley (KCA2) in Kanchenjunga Conservation Area and surrounding of Taplejung District (Figure 1).

In each of the six study areas, we searched *T. wallichiana* along altitudinal gradients from the valley bottom and along vertical gradients. The sites for altitudinal gradients along the valley bottom were located

*Corresponding Author's E-mail: gajurelomjyoti@yahoo.com

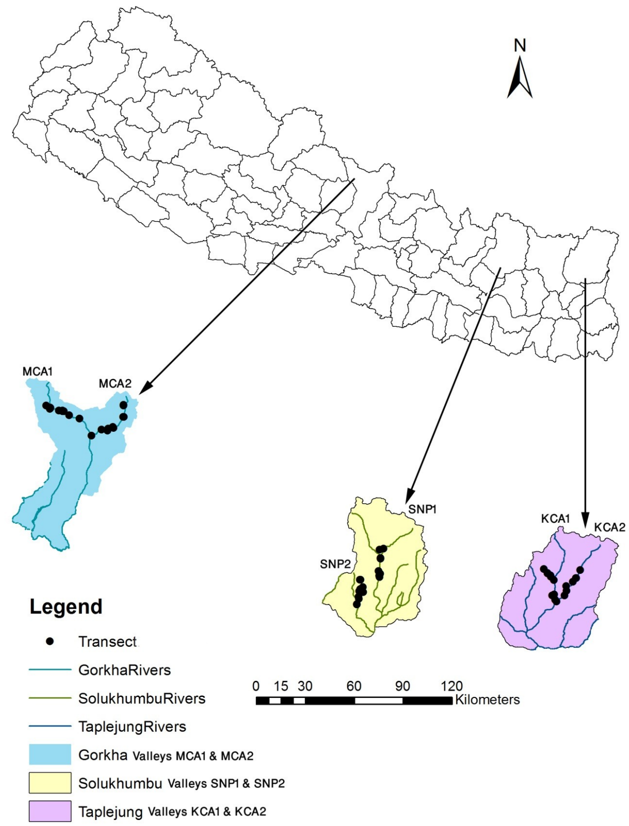

Figure 1. Map of studied valleys in Nepal Himalaya (Source: Department of Survey, Nepal).

at about 2200, 2600, 3000, 3400 and 3800 m a.s.l., and considered both slopes of the valleys (Scheidegger *et al*., 2010) which was standard design where transects of other vascular plants were located. Vertical altitudinal gradients were studied with altitudinal interval of 200 m a.s.l. from each of the five sites and following the dip line on either side of the valley up to an altitude of 3800 m a.s.l. Land-use types at each locality where we found *T. wallichiana* was classified as crop field (c), meadow (m), exploited forest (e) and natural forest (f), respectively (Scheidegger *et al*., 2010).

Due to a high degree of population fragmentation and low population density, each individual of this species found in the study area was considered and coordinates recorded with a GPS (Garmin, series 60, Kansas, USA). Voucher specimens (JPG-IZ70Z0_131338/1-NTW1 to NTW813) were collected from the six valleys by JPG and his team between 2011 and 2013, and were deposited in National Herbarium and Plant Laboratories, Godawari, Nepal (KATH). Herbarium specimens were identified based on morphology according to the literature (Möller *et al*., 2007; Farjon, 2010; Poudel *et al*., 2012) in KATH and Tribhuvan University Central Herbarium, Kirtipur, Kathmandu, Nepal (TUCH).

Data analysis

The altitudinal distribution of the species was analyzed with R 3.0.1 (R Development Core Team, 2012). Species distribution modeling was based on Maxent v3.3.3.k (Phillips *et al*., 2006) using default parameters, after removing duplicate records from the same locality. The input data for modeling consisted of 62 presence records from the research sites as well as nine different locations obtained from additional herbarium specimens found in KATH and TUCH. Maxent is based on the maximum entropy method, and has proved to provide robust estimations of species distributions (Phillips *et al*., 2006). The 19 Bioclim data (current and future HadGEM2-ES) including Bioclim Altitude at a spatial resolution of 30 arc were obtained from WorldClim (www.worldclim.org). First and second models were based on current climate conditions while third and fourth models were based on future climate condition (HadGEM2-ES). All bioclim variables were tested for correlation (Pearson's correlation) in R 3.0.1.

In the first model, six eco-physiologically important bioclim variables (BIO4 = temperature seasonality, BIO5 = maximum temperature of warmest month, BIO6 = minimum temperature of coldest month, BIO12 = annual precipitation, BIO15 = precipitation seasonality, BIO17 = precipitation of driest quarter) were used. In the second model, those variable with $|r| > 0.80$ ($|x|$) were excluded (final variables were BIO3 = isothermality, BIO5, BIO14 = precipitation of driest month, BIO15, BIO17 and BIO19 = precipitation of coldest quarter).

In the third model, six eco-physiologically important future bioclim (HadGEM2-ES) variables (BIO4, BIO5, BIO6, BIO12, BIO15 and BIO17) were used. Those future bioclim (HadGEM2-ES) variable with $|r| > 0.80$ ($|x|$) were excluded from the model (final variables were BIO3, BIO5, BIO14, BIO15, BIO17 and BIO19).

Model evaluations and tests were done by selecting the model that is best at predicting those points that were kept aside (50% of points from herbarium records and from the research sites) and not used as training data. Similarly, the value of AUC (the area under the receiver operating characteristics curve), maximum entropy and LPT (lowest presence threshold value) were compared to predict the potential distribution of the species in Nepal Himalaya and to find the most important bioclimatic variables contributing to the model.

The impact of climate change on the distribution of the species was determined by overlaying the binary raster of current and future climate condition. The binary raster resulted in four possible situations (*high impact areas*: areas with present climate occurrence; *areas outside of the realized niche*: not suitable for present as well in future climate; *low impact areas*: areas of potential occurrence in present as well as future; *new suitable areas*: areas where species can occur in future but species do not occur in present climate condition) for each cell after raster cell values were re-classed in DIVA GIS (Hijmans *et al*., 2012; Scheldeman and Zonneveld, 2010).

RESULTS

Distribution of Taxus wallichiana in the study areas

In the six valleys (Figure 1) altogether 812 individuals of *Taxus wallichiana* were found (Table 1), out of which only five individuals were recorded in transects together with other vascular plants. All individuals belonged to *T. wallichiana* and no other species of *Taxus* were found in our study area. *T. wallichiana* is distributed in the study area within an altitudinal range of 2200 to 3450 m a.s.l.

Table 1. Distribution of *Taxus wallichiana* in Nepal Himalaya along altitudinal gradient.

	Altitudinal Gradients																
	2200			2400		2600			2800			3000			3200		To-
Valleys	H	V	Total	H	Total	H	V	Total	H	V	Total	H	V	Total	H	V	tal
MCA1						4	2	6	11		11	46		46	28	1	29
MCA2						80		80	10		10	104	31	135	100		100
SNP1	3		3			30		30	30		30					5	5
SNP2				20	20	48		48	49	3	52	17	1	18	2		2
KCA1		1	1			52	3	55	8	12	20						
KCA2		1	1			7	12	19	85	5	90	1		1			
Total in Each Gradient			5		20			238			213			200			136

Note: H means Horizontal ; V means vertical

distribution of the population ranged from 2700 to 3000 m a.s.l. In SNP, most of the populations were distributed from 2600 to 2800 m a.s.l.(Figure 2).

The number of individuals sharply increased in the altitudinal range between 2800 and 3100 m a.s.l. and then sharply decreased to a patch or sometimes one or two individuals (Table 1).

Five observations of *Taxus wallichiana* individuals were made on transects together with other vascular plants. Among them, two individuals were in natural forests and three were in exploited forests.

Performance of species distribution models of Taxus wallichiana in the Nepal Himalaya

The value of AUC (Area under the receiver operating characteristics curve) and LPT (Lowest presence threshold value) were slightly higher for the first model as compared to the second model (Table 2).

However, for the future models, the value of AUC was slightly higher in the third model with eco-physiologically important bioclimatic variables while LPT was higher in fourth model (Table 2).

A comparison of model predictions with records of the herbarium specimens and sampling sites which were not included as training data suggested that the first and third models with eco-physiologically important bioclimatic variables generated the best predictions (Figure 3, 5) of the distribution of *Taxus wallichiana* as compared to second model and fourth with less correlated variables (Figure 4, 6).

The first model also predicted a distribution of *Taxus wallichiana* ranging from the Mid-West to the East of the Nepal Himalaya. According to the model predictions based on current climate condition, the most suitable sites for *T. wallichiana* ranged from Central Nepal through Eastern Nepal (Figure 3). Presence data from herbarium specimens suggested a range of the species

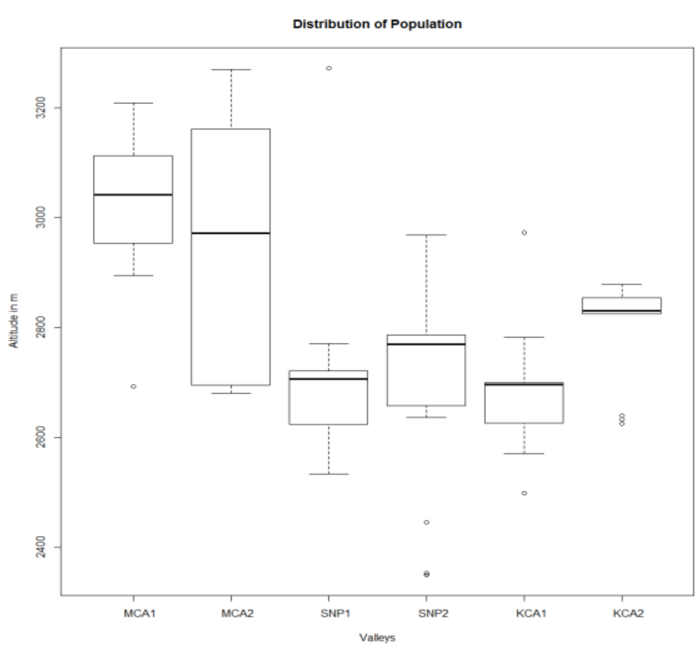

Figure 2. Altitudinal distribution of *Taxus wallichiana* in the studied valleys. Dot represents outlayer.

Table 2. Bioclimatic variables used for predicting the spatial distribution of *Taxus wallichiana* in Nepal Himalaya and their contribution to the models (%) including Entropy, LPT and AUC.

	Percent contribution			
Variables	**First Model**	**Second Model**	**Third Model**	**Fourth Model**
Bio3_Isothermality		2.3746		**24.6621**
Bio4_Temperature Seasonality (standard deviation)	0.8375		**23.3897**	
Bio5_Max Temperature of Warmest Month	**64.9495**	**73.6786**	18.9591	**31.8194**
Bio6_Min Temperature of Coldest Month	14.2949		11.8404	
Bio12_Annual Precipitation	1.4009		0.2094	
Bio14_Precipitation of Driest Month		0.0711		6.3316
Bio15_Precipitation Seasonality (Coefficient of Variation)	2.3607	2.5557	**32.6707**	22.2749
Bio17_Precipitation of Driest Quarter	**16.1565**	**19.1798**	12.9305	8.6985
Bio19_Precipitation of Coldest Quarter		2.1403		6.2135
Entropy	5.56	5.7	4.52	4.59
LPT	0.24	0.22	0.31	0.43
AUC	0.992	0.989	0.997	0.996

Note: LPT, lowest presence threshold value; AUC, the area under the receiver operating characteristics curve.

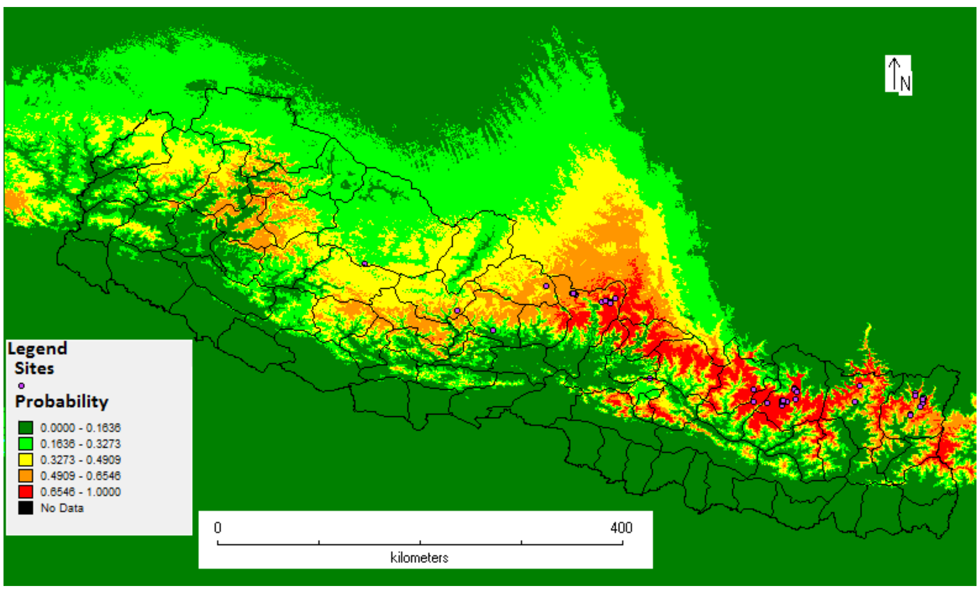

Figure 3. Species distribution model of *Taxus wallichiana* in Nepal Himalaya. Observations are indicated with purple dots and habitat suitability is based on "First Model".

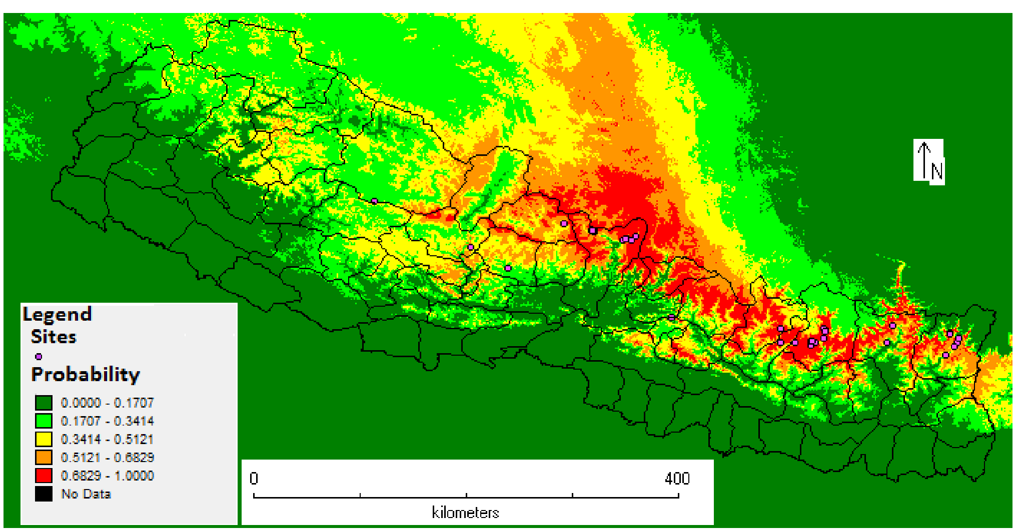

Figure 4. Species distribution model of *Taxus wallichiana* in Nepal Himalaya. Observations are indicated with purple dots and habitat suitability is based on "Second Model".

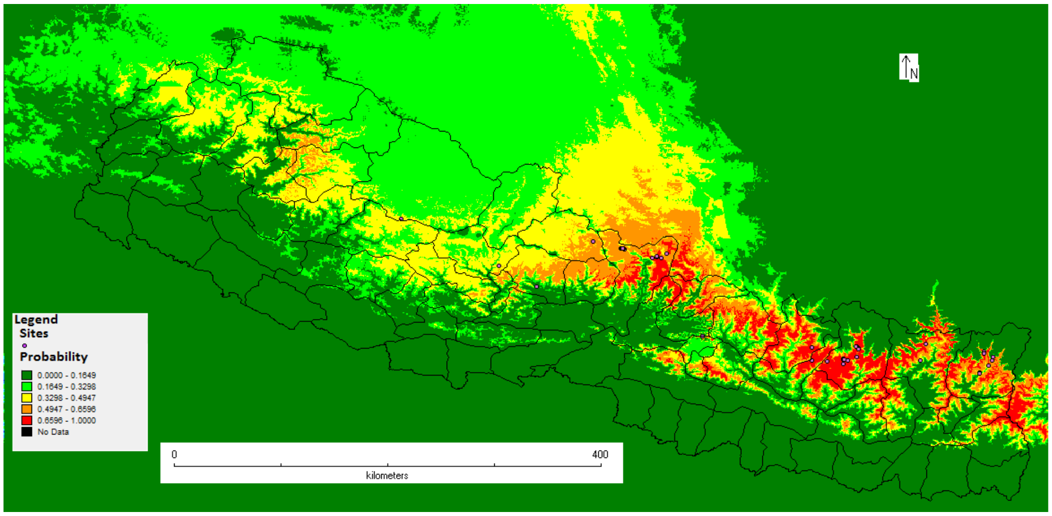

Figure 5. Species distribution model of *Taxus wallichiana* in Nepal Himalaya. Observations are indicated with purple dots and habitat suitability is based on "Third Model".

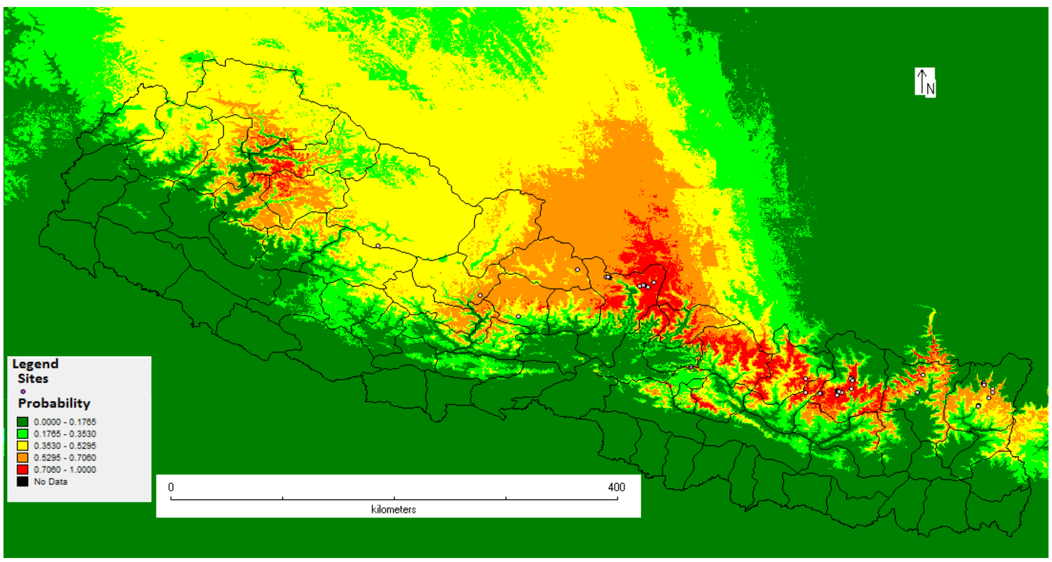

Figure 6. Species distribution model of *Taxus wallichiana* in Nepal Himalaya. Observations are indicated with purple dots and habitat suitability is based on "Fourth Model".

from Eastern Nepal through Central Nepal, with very few sites located in Mid-Western Nepal.

For the first, second (current climatic condition) and fourth models (future climatic condition), percentage contribution of bioclimatic variable maximum temperature of the warmest month (Bio5) was highest while for third (future climatic condition) model, precipitation seasonality (Bio15) was highest. When future climate condition was used for the model prediction, the potential distribution areas decreased in valleys of Manaslu Conservation Area and Kanchenjunga Conservation Area (Figures 5, 6).

Overlaying binary raster resulted in four possible situations (Figure 7). The Mid-Western Nepal as well as Far-Western Nepal will have high impact on the distribution from climate change. New suitable areas were also observed in Mid-Western Nepal, Central Nepal as well as Eastern Nepal. Some sites of collection of *Taxus wallichiana* population will have negative impact due to climate change (Figure 7).

DISCUSSION

Altitudinal distribution boundaries of the species in the study area

In the KCA valleys of Kanchenjunga Conservation Areas, the lower altitudinal limit of *Taxus wallichiana* is 2400 m a.l.s. and the upper limit is at 3000 m a.l.s. In the SNP valleys of Sagarmatha National Park and surroundings, the lower limit of altitude is 2200 m a.l.s. while upper limit is 3450 m a.l.s. The lower limit of altitude is 2600 m a.l.s. and upper limit is 3300 m a.l.s. for the MCA valleys of Manaslu Conservation Area. The number of individuals in present condition either decrease or remain absent above or below the limits of altitude suggesting the precise boundaries of distribution in the study sites. The altitudinal ranges reported here are similar to those reported in earlier studies (Hara, Stearn, and Williams, 1978; Press *et al.*, 2000). This study also revealed that the most suitable altitudinal range was between 2600 – 3000 m a.l.s. where most of the populations recorded.

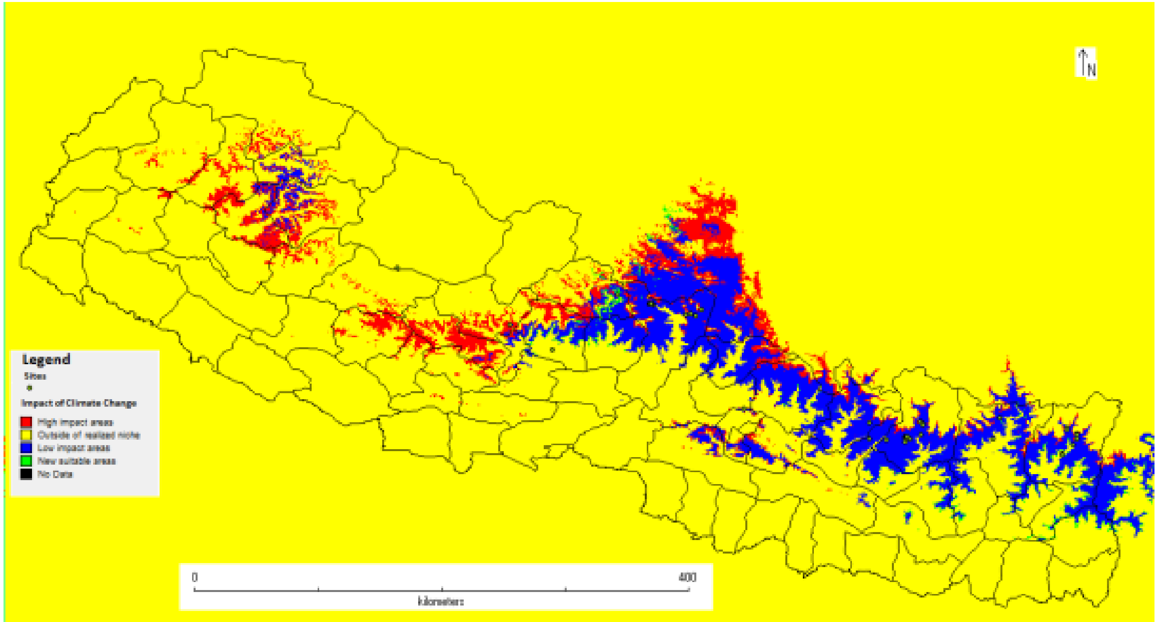

Figure 7. Species distribution model of *Taxus wallichiana* in Nepal Himalaya under climate change scenario. Observations are indicated with green dots.

Species distribution models of Taxus wallichiana in the Nepal Himalaya

The species distribution models generated with Maxent based on our data revealed a number of potential sites for *T. wallichiana* in Nepal Himalaya. From those sites, no direct observations or collections has been deposited in the major scientific collections in Nepal. The collection information of this species from different sites as observed in herbarium specimens supported the first model with eco-physiologically important bioclimatic variables. There are several studies, which show that distribution modeling can be used as a tool for finding additional localities of a known species (Bourg, McShea, and Gill, 2005; Phillips *et al*., 2006; Rinnhofer *et al*., 2012). The first model can be used in future to locate new populations of *T. wallichiana*. Finding new population will help in conservation planning in remote areas (Pearson, 2007) such as the Nepal Himalaya.

The two species distribution models that we generated revealed higher AUC values compared to species distribution models described earlier (Poudel *et al*., 2012). The first model with eco physiologically important bioclimatic variables seems to be the best model that will likely cover a vast majority of the sites of *T. wallichiana* in Nepal Himalaya. However, based on herbarium records, there is a discrepancy between model prediction and known distribution. Species distribution models predict suitable areas in Far-Western Nepal despite intensive studies of *T. wallichiana* which has not yet been reported from this area. For all the models, temperature plays an important role in the species distribution as seen from the contribution of bioclimatic variables. The contribution of precipitation to the predicted models is also substantial. Some model predictions may provide useful information even if the species is not expected to colonize all the suitable sites (Pearson, 2007).

Effect of climate on distribution of T. wallichiana in the potential sites

We investigated potential impacts of climate change on the future distribution of *T. wallichiana*. Similarly to the current distribution, the future climate model with eco-physiologically important bioclimatic variables seems to be the best model explaining the potential impact of climate change on the distribution of *T. wallichiana* in Nepal Himalaya. A major finding of this study is that there will be some high impact places due to climate change similar to other studies on other plant species (Salick, Zhendong, and Byg, 2009). Similarly, for most of the population of *T. wallichiana* in Central and Eastern Nepal, the effects of climate change will be less severe. Some new sites of the potential distribution of the species in future. The results also showed that some existing sites will a strong negative impact and there will be loss of the ecological niche creating a serious problem for the species.

Conservation measures and applicability of the study

The collections of *T. wallichiana* included in herbarium records show that most of the collections were done along trails. However, there have been relatively few expeditions targeting the collection of gymnosperms in Nepal including *T. wallichiana*. The collections made and the populations identified from our research sites suggest that there is a need to look for the species in the potential sites. In some cases, the potential distribution of the species from a species distribution model can be valuable to find sites for the reintroduction of a species (Pearce and Lindenmayer, 1998).

*T*axus *wallichiana* is a tree species with a high importance for the local population. The wood is used as door frames, cabinet works, knife handles and burnt as incense while leaves are used as fodder, poisons and tinctures (Mulliken and Crofton, 2008; Thomas and Farjon, 2011). Our observation showed that overexploitation was strongest in Nubri valley of Manaslu, Central Nepal where people have damaged the whole tree during leave and bark collection while wood was sold to Tibet. In the Ghunsa Valley, the seeds were half eaten by rodent while in Manaslu, the arils of seed eaten by *Semnopithecus* sp. (Langur). In all study sites local people collect ground litter for cattle bed which reduce the possibility of seeds to germinate. This results in a slow regeneration rate in respective study areas besides overexploitation. Our finding is similar with a study carried out in Arunachal Himalaya (Paul *et al*., 2013) where author reported that sale of timber and frugivory of seeds by rodents caused the decline of population of *T. wallichiana* in that region. Therefore, there is urgent need to help in conserving the wild population.

The habitat of *T. wallichiana* in Manaslu Conservation Area has come under pressure because of increased demand for space due to more flow of tourists where the natural forest has been cleared for making new guest houses. Similar is the condition of Dudhkunda Valley (Sagarmatha region). There was also over exploitation in Olangchungola valley (Kanchenjunga Conservation Area) in East Nepal. A strong sex-bias could lead to the extinction of the species (Iszkuło, Jasińska, Giertych, and Boratyński, 2008). In Nubri Valley (Manaslu Conservation Area) and Olangchungola Valley (Kanchenjunga Conservation Area), trees were cut and regenerate but are not yet reproducing. In Ghunsa Valley (Kanchenjunga Conservation Area), seeds were eaten by rodents. These indicated reduce fertility in the population due to human activity, management and natural causes in these studied sites. Different anthropogenic disturbances causing threat to the forest of *T. wallichiana* was also reported in Arunachal Himalaya (Paul *et al*., 2013). The Sagarmatha National park and buffer zones had relatively more females as compared to rest of the valleys which may be due to less dependency of people in the region where each year many tourists visit. Also, conservation efforts need to inform local people about the importance of the species. Lack of knowledge and poverty has played an important role in the overexploitation of this species in the research sites.

CONCLUSION

Taxus wallichiana has been collected only rarely, but species distribution model predicts a relatively large area of occupancy. It is known that the species is economically important, has been red listed and is nationally protected. Expected species distribution under climate change shows that the area of occupancy changes in Central and Eastern Nepal where some portion of the future area of occupancy is outside of the current distribution area. The species will face a strong range shift (current habitat will be lost, new habitat be gained) in those places. With the current management in protected areas it is unlikely that the species will manage to spread naturally. Only with strong habitat protection or assisted migration can the species be maintained under climate change. We consider the Red list status of *T. wallichiana* vulnerable or endangered based on the criterion A3 (projected decline during the next 3 generations) and vulnerable under A4.

ACKNOWLEDGEMENTS

This study was supported by The Swiss National Science Foundation, Switzerland (grant JRP IZ70Z0_131338 / 1 to C. Scheidegger). We would like to thank the faculty members of the Central Department of Botany, Tribhuvan University, Nepal. We thank the Department of National Parks and Wildlife Conservation, Ministry of Forest and Soil Conservation, Government of Nepal and the National Trust for Nature Conservation, Nepal for providing permits. Silke Werth was supported by a Marie Curie Fellowship (Lichenomics) within the program FP7 of the European Commission. We also thank Dr. Michael Nobis (WSL Switzerland), Mr. Sanjeev Kumar Rai, Mr. Shiva Devkota, Mr. Bhim Rai and staff of KATH herbarium of Nepal for their support during the study period.

REFERENCES

Bourg, N., McShea, W., and Gill, D. 2005. Putting a cart before the search: successful habitat prediction for a rare forest herb. *Ecology* 86: 2793–2804.

Farjon, A. 2010. A handbook of the world's conifers. Leiden, the Netherlands: Brill Academic Publishers.

Guisan, A., and Thuiller, W. 2005. Predicting species distribution: offering more than simple habitat models. *Ecology Letters* 8(9): 993–1009.

Hara, H., Stearn, W.T., and Williams, L.H.J. 1978. An enumeration of the flowering plants of Nepal, vol. 1 (eds.). London: British Museum (Natural History).

Hijmans, R., Guarino, L., and Mathur, P. 2012. DIVA-GIS. Retrieved on April 20, 2014 from http://www.diva-gis.org.

Iszkuło, G., Jasińska, A. K., Giertych, M. J., and Boratyński, A. (2008). Do secondary sexual dimorphism and female intolerance to drought influence the sex ratio and extinction risk of *Taxus baccata*? *Plant Ecology* 200(2): 229–240.

Joshi, K. 2009. *Taxus wallichiana* (Himalayan Yew; Loth salla) in Nepal: Indigenous uses, conservation and agenda for sustainable management. *Ethnobotanical Leaflets* 13: 1504–1508.

Möller, M., Gao, L., Mill, R. R., Li, D., Hollingsworth, M. L., and Gibby, M. 2007. Morphometric analysis of the *Taxus wallichiana* complex (Taxaceae) based on herbarium material. *Botanical Journal of Linnean Society* 155: 307–335.

Mulliken, T., and Crofton, P. 2008. Review of the status, harvest, trade and management of seven Asian CITES-listed medicinal and aromatic plant species. BfN-Skripten, Federal Agency for Natural Conservation, Bonn, Germany.

Paul, A., Bharali, S., Khan, M. L., and Tripathi, O. P. 2013. Anthropogenic disturbances led to risk of extinction of *Taxus wallichiana* Zuccarini, an endangered medicinal tree in Arunachal Himalaya. *Natural Area Journal* 33(4): 447–454.

Pearce, J., and Lindenmayer, D. 1998. Bioclimatic analysis to enhance reintroduction biology of the endangered helmeted honeyeater (*Lichenostomus melanops cassidix*) in southeastern Australia. *Natural Area Journal* 6(3): 238–243.

Pearson, R. G. 2007. Species' distribution modeling for conservation educators and practitioners. American Museum of Natural History. Retrieved on April 20, 2014 from http://ncep.amnh.org.

Phillips, S. J., Avenue, P., and Park, F. 2006. A maximum entropy approach to species distribution modeling. *Ecological Modelling* 190: 231–251.

Poudel, R. C., Möller, M., Gao, L., Ahrends, A., Baral, S. R., Liu, J., et. al. 2012. Using morphological, molecular and climatic data to delimitate yews along the Hindu Kush-Himalaya and adjacent regions. *PloS One* 7(10): e46873.

Press, J., Shrestha, K., and Sutton, D. 2000. Annotated checklist of the flowering plants of Nepal. London: The Natural History Museum.

R Development Core Team, R. 2012. R: A Language and environment for statistical computing. (R. D. C. Team, Ed.). R Foundation for Statistical Computing.

Rinnhofer, L. J., Roura-Pascual, N., Arthofer, W., Dejaco, T., Thaler-Knoflach, B., Wachter, G., et al. 2012. Iterative species distribution modelling and ground validation in endemism research: an Alpine jumping bristletail as example. *Biodiversity and Conservation* 21(11): 2845–2863. doi:10.1007/s10531-012-0341-z

Salick, J., Zhendong, F., and Byg, A. 2009. Eastern Himalayan alpine plant ecology, Tibetan ethnobotany, and climate change. *Global Environmental Change* 19: 147–155.

Scheidegger, C., Nobis, M. P., and Shrestha, K. K. 2010. Biodiversity and livelihood in land-use gradients in an era of climate change - outline of a Nepal-Swiss research project. *Botanica Orientalis* 7: 7–17.

Scheldeman, X., and Zonneveld, M. Van. 2010. Training manual on spatial analysis of plant diversity and distribution. Biodiversity International, Rome, Italy.

Spjut R.J. 2007. Taxonomy and nomenclature of *Taxus* (Taxaceae). *Journal of the Botanical Research Institute of Texas* 1: 203–289.

Thomas, P., and Farjon, A. 2011. *Taxus wallichiana*. IUCN red list of threatened species. version 2013.2. Retrieved on April 20, 2014 from www.iucnredlist.org