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# Habitat Distribution Modelling for Reintroduction of Endangered Medicinal Plants - *Ephedra gerardiana*, *Lilium polyphyllum*, *Crepidium acuminatum*, *Pittosporum eriocarpum* and *Skimmia anquetilia* in India

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## ABSTRACT

The populations of *Crepidium acuminatum*, *Ephedra gerardiana*, *Lilium polyphyllum*, *Pittosporum eriocarpum* and *Skimmia anquetilia* have been shrinking in their natural habitats due to habitat destruction, over harvesting for medicinal purposes and increased human interference such as conversion of forest areas in agricultural land, and urbanization. In order to improve the conservation status of species, potential areas and habitats for reintroduction, were predicted using Maximum Entropy (Maxent) distribution modelling algorithm. The model was developed using 112 species occurrence data and Worldclim bioclimatic variables. Jackknife test was used to evaluate the importance of the environmental variables for predictive modelling. Based on our studies, the most suitable habitat for these endangered species is predicted in Western Himalayas. Precipitation of the driest quarter has played an important role in the potential habitat distribution of *L. polyphyllum*, *P. eriocarpum* and *S. anquetilia* which are largely affected by precipitation variables whereas mean diurnal range was the strongest predictor for the distribution of *C. acuminatum*. Output of the maxent model and field surveys has revealed that most suitable natural habitats for introduction of *C. acuminatum, L. polyphyllum*, *P. eriocarpum* and *S. anquetilia* are Uttarakhand and Himachal Pradesh, whereas it is Kashmir Himalaya, Himachal Pradesh and Uttarakhand for *E. gerardiana*.

Key Words: Conservation; Ecological Niche Modelling; Endangered Taxa; Maxent; Restoration.

## INTRODUCTION

Locating populations of rare, endangered and threatened species is an important consideration in biodiversity conservation and for developing effective strategies for in-situ and ex-situ conservation (Menon et al. 2010). With the advances in remote sensing and GIS technologies, use of ecological niche modelling (ENM)/ species distribution modelling (SDM) to generate potential geographic distributions of species has rapidly increased in ecology, conservation and evolutionary biology (Terribile et al. 2009). Species distribution modelling tools are very helpful in the study of niche specificity and are being widely used in many ecological applications (Elith et al. 2006, Peterson and Nakazawa 2008). ENM establishes relationships between occurrence of species with biophysical and environmental conditions (Soberon and Peterson 2005, Kumar and Stohlgren 2009). Most species distribution modelling methods are sensitive to sample size (Wisz et al. 2008) and may not accurately predict habitat distribution patterns for threatened and endangered species but maximum entropy distribution (Maxent) has been found to perform best among many different modelling methods (Elith et al. 2006, Ortega-Huerta and Peterson 2008) and is effective despite of small sample sizes (Hernandez et al. 2006, Phillips et al. 2006, Papes and Gaubert 2007, Pearson et al. 2007, Wisz et al. 2008). Maxent is a bioclimatic model, which deals with the climatic data and makes it well-suited for ENM/SDM

(Chitale and Behera 2012). Availability of high to low resolution satellite imageries, environmental variables and interpolated datasets on climate and vegetation have enhanced the accuracy of prediction of these models (Adhikari et al. 2012).

The populations of *Ephedra gerardiana* Wall., *Lilium polyphyllum* D. Don ex Royle, *Crepidium acumintum* (D. Don) Szlach., *Pittosporum eriocarpum* Royle and *Skimmia anquetilia* N.P. Taylor & Airy Shaw have been decreasing during the past decade (Haq 2012, IUCN 2017). They are overexploited continuously for medicinal trade.

*Ephedra gerardiana* is used as a stimulant, and its tea is used as medicine for colds, coughs, bronchitis, asthma and arthritis. It is endemic to the mountains of Afghanistan, Bhutan, few pockets of Northern India and Sikkim, Tajikistan and Tibet. It is a perennial small shrub composed primarily of fibrous stalks, generally about 20 cm, though sometimes growing to 60 cm in height, with small, red or yellow female cones. *E. gerardiana* has been found growing on open exposed shiny slopes among rocks and dry soil. Only mature plants are observed in the population. Plants are over-harvested for traditional Amchi system of medicine and for the extraction of ephedrine. Low seed viability is another reason for shrinking of population size.

The belowground bulb of *L. polyphyllum* is used for the preparation of drugs in traditional and modern system of medicines (Sourabh et al. 2015). The bulbs are also used in revitalizing night cream and in Chyawan-prash (an ancient ayurvedic herbal preparation).The whole plant is uprooted resulting in the prevention of flowering and fruiting which hampers the regeneration of species. *L. polyphyllum* has been red listed (Nayar and Sastry 1987) and presently it is categorized as Critically Endangered (Ved et al. 2003, Saha et al. 2015). Our observations reveal that, *L. polyphyllum* has only a few populations in the Uttarakhand, Himachal Pradesh and Jammu and Kashmir, which are at the risk of extermination in view of the present trend of climate change and developmental activities (Sourabh et al. 2015).

*Crepidium acuminatum* grows under shady *Quercus* and pine forest at the altitudinal range of 1700-2400 m. It is generally found in the sites with high rainfall (8 mm), humidity 97% and low soil pH (5.0-5.1) which indicate that *C. auminatum* grows under acidic soil. Overexploitation for the preparation of herbal medicines and grazing are the main causes of species depletion. *C. acuminatum* is a small to medium sized, hot to warm growing terrestrial or lithophytic orchid. It occurs on highly eroded, stratified limestone cliffs and bluffs with horizontal rhizomes giving rise to rather thin, short stems, each bearing 3-5, broadly lance-like, acuminate and acute, leaves. The plant blooms in monsoon and possesses an erect, c. 4-22 cm long inflorescence with lanceolate acute floral bracts and many flowers. Flowers are minute, pale-yellowish green, tinged with purple, in terminal racemes. The pseudobulbs are sweet, refrigerant aphrodisiac, febrifuge and tonic. It is useful in the treatment of fever, seminal weakness, haematemis, dipsia, emaciation and general debility (Sharma et al. 2007).

The bark of *Pittosporum eriocarpum* is used in preparation of a drug for bronchitis and as expectorant. Removal of bark and roots of the plant hampers its growth and also causes the death of plant. There is a scarce population of *P. eriocarpum* in the Lesser Himalayan range including Mussoorie hills and Doon valley (Singh and Goel1999). The species has been cited as vulnerable (Nayar and Shastri 1987), and recently as endangered (IUCN2017).Habitat degradation, increased human activities for agriculture and urbanization have resulted in the change in microclimatic conditions. It has caused considerable depletion of natural populations. The fast rate of depletion of populations is a matter of great concern and there is a need to initiate effective conservation strategies to maintain their populations in natural habitats (Ray et al. 2011). The geographical distribution, habitat and ecological characteristics of the endangered and threatened species must be thoroughly studied for restoration and maintenance of the threatened species.

*Skimmia anquetilia* is considered a sacred plant. The stem is used to make handles of axe and hoe. In a popular ritual in Uttarakhand, leaves are offered to Lord Shiva. Paste of leaves mixed with turmeric is used for alleviating rheumatism and swellings. Bark powder is used for healing of wounds (Negi et al. 2011, Singh and Rawat 2011), and also used for clearing the nasal tract. Leaves are commercially harvested and are used in food as flavouring agent, in traditional healing and cultural practices, being made into garlands and considered sacred (Bhattarai and Karki 2006, Jangwan et al. 2010). In Bhadarwah (Jammu and Kashmir), the leaves are chewed for cooling effects and are used for stomach problems like stomach ache, dysentery, nausea and worm complaints (Dutt 2012). The leaves are mixed with other ingredients to manufacture incense sticks and used as insecticides and pesticides (Qureshi et al. 2009). *Skimmia anquetilia* is an under shrub found in rocky places in oak and fir forests growing in patches. It grows under *Cedrus deodara, Rhododendron campanulatum* and *Abies pindrow* in semi-shaded (light woodland) or exposed sites in Uttarakhand. The plant grows in well - drained loamy, alkaline soil and cool temperature with seasonal snow fall. In India, *S. anquetilia* is distributed in temperate Western Himalayan region from Kashmir, Garhwal and Kumaun hills between 1800 to 3000 m altitude in moist places (Gaur 1999, Jangwan et al. 2010).).

Our objective is to predict suitable habitat distribution for *E. gerardiana*, *L. polyphyllum*, *C. acuminatum*, *P. eriocarpum* and *S. anquetilia*. In the present study, we used species occurrence records, environmental layers (bioclimatic) and the maximum entropy distribution modelling to predict suitable habitat for these threatened species. It would help in developing a strategic planning for their conservation.

## STUDIED SPECIES

### *Ephedra gerardiana* (Ephedraceae)

It is a perennial shrub with densely clustered slender erect joined branches arising from a woody base. The plants are dioecious. Male cones are arranged in catkins and covered by a membranous perianth. Female cones are solitary, sessile or shortly pedunculate. Pistillate flowers occur on terminal axillary stalks, within a two-leaved involucre. Flowering occurs during August - September. Pollination occurs in August and seeds mature during September (Figure1a). Mostly it is wind pollinated, however, ants are found visiting frequently to the cones. Fruit has two carpels with a single seed in each and is a succulent cone.

### *Lilium polyphyllum* (Liliaceae)

*L. polyphyllum* is a perennial bulbous herb, grows up to 1m in height and possesses hollow stem. Leaves are 6-12cm long, 0.5-1 cm wide, narrow, alternate, sessile, fleshy, lanceolate, ovate with acuminate tip, and show parallel venation (Dhaliwal and Sharma 1999, Dhyani et al. 2009). The lower leaves are sometimes whorled and margins are papilose (Balkrishna et al. 2012). Flowers are 4-10 in numbers, 6-8 cm long in terminal racemes, large, fragrant, solitary, pendulous. Flowers are dull yellowish or greenish outside, white within speckled with long purple streaks, having six tepals, with nectar gland at their bases. Tepals are recurved when fully expanded, pedicel 7-9 cm long, bracts are leaf like, whorled, crenulate. Fruit is a three angled, oblong, 3-6 cm long capsule. A capsule contains nearly 100 vertically compressed brown seeds. Baskin and Baskin (1998) reported linear seeds in *Lilium* species. The testa of the seed is pale and membranous (Balkrishna et al. 2012). Flowering occurs in July-August (Figure1b).

### *Crepidium acuminatum* (Orchidaceae)

The plant is a perennial terrestrial herb. Leaves are sessile, ovate-lanceolate, acute to acuminate, narrowed to sheathing base and petiolate. Inflorescence is racemose with many flowers;peduncleis12-27 cm long, ribbed; rachis is glabrous; floral bracts are lanceolate, subacute, reflexed. Flowers are yellow tinged with red-purple or pink-purple streaks on the petals. Sepals are subsimilar; dorsal sepal is linear-oblong, subacute; lateral sepals are broadly oblong and obtuse. Petals are linear, obtuse with recurved margins. Lip is slightly convex, base with auricles, narrowly ovate-sagittate; apex flat. Column is 1-1.1 mm long, fleshy. Flowering occurs during June-July and fruiting from July to September (Figure 1d).

### *Pittosporum eriocarpum* (Pittosporaceae)

It is a small evergreen tree up to 5 m height with alternate or whorled leaves. Inflorescence is terminal or pseudo-terminal, paniculately corymbose; peduncles are small (2-4 cm) and conspicuously hairy. Flowers are pale yellow, which remain in many umbellate corymbs. Sepals are short, triangular, acute, free or slightly connate at the base and densely tomentose. Petals are oblong, glabrous and golden yellow. Fruit is a globose capsule with 8–10 blackish red seeds. It flowers from March to April and fruits appear in May-June (Gowda 1951, Gaur 1999, Singh and Goel 1999, Thakur et al. 2016) (Figure 1c).

### *Skimmia anquetilia* (Rutaceae)

*S. anquetilia* is an aromatic, evergreen, shrub. Leaves are arranged nearly opposite manner or whorled, oblong-lanceolate and clustered near apex of branches. They are adaxially dark green and shiny. When crushed, the leaves give a musky odour due to presence of a poisonous compound skimnianine (Ahmed et al. 2015). The inflorescence is 5-8 cm long with stout and angulate rachis.

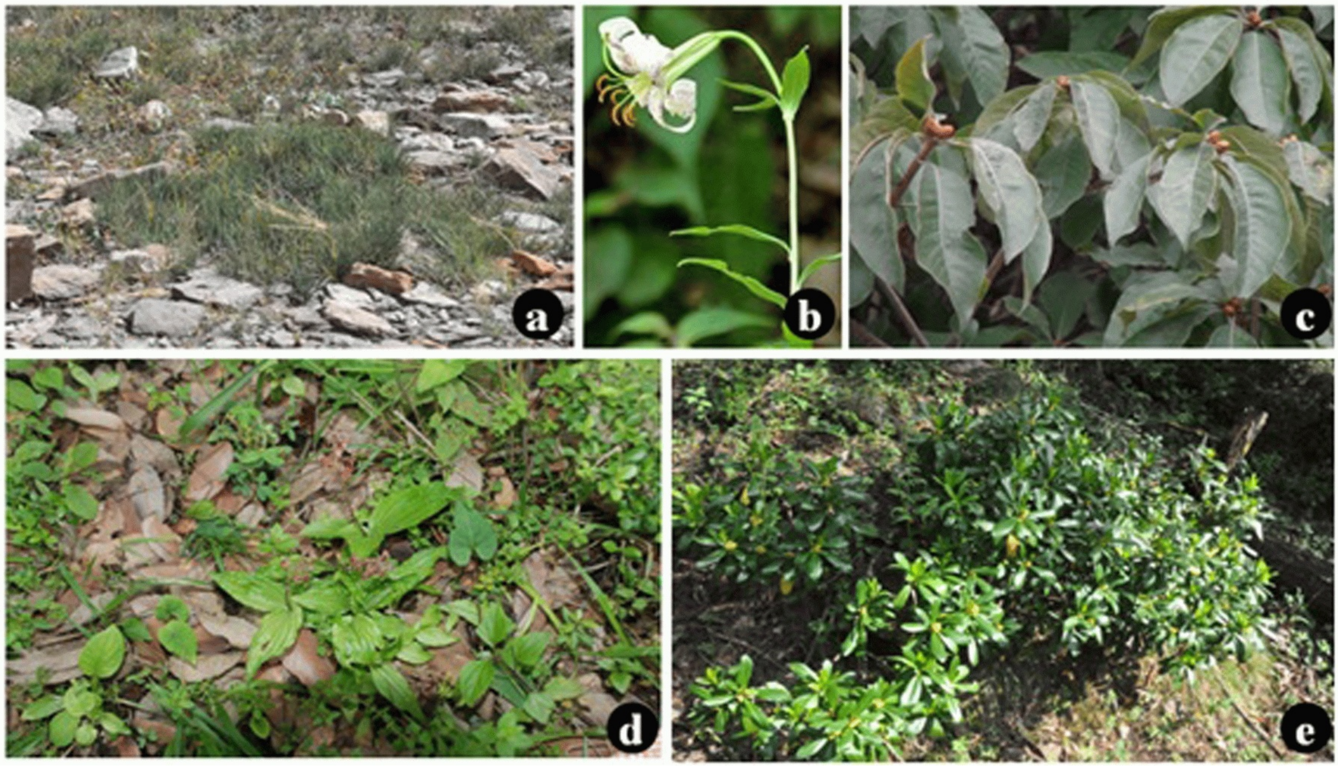

Figure 1. Habitat : a. *E. gerardiana;* b. *L. polyphyllu*m; c. *P. eriocarpum;* d. *C. acuminatum;* e. *S. anqetilia*

Sepals are ovate with pubescent base. There are 5 erect stamens. Ovary is ovoid, 2- or 3-loculed, glabrous, with oil glands; style short; stigma small. Fruit isovoid. Flowering occurs during April to September and fruiting from October to November (Figure 1e).

## METHODS

### Habitat Distribution Modelling

Total 112 coordinates obtained through field surveys of the sites of occurrence were used. The coordinates of the occurrence points were recorded to an accuracy of 3-10m using GPS (Garmin). These coordinates were then converted to decimal degrees for use in the Maxent. In the present study, bioclimatic variables (Hijmans et al. with 30 seconds spatial resolution, downloaded from World Clim dataset (www.worldclim.org) were used. These World Clim data (period 1950-2000) are derived from measurements of altitude, temperature and rainfall from weather stations across the globe (Khanum et al. 2013) and are frequently used in modelling species distribution (Kumar and Stoghlgren 2009, Sanchez et al. 2011, Khanum et al. 2013, Adhikari et al. 2015).

### Validation of Model Robustness

For habitat modelling, the model was developed using Maximum entropy distribution software (Maxent version 3.3.3; Phillips et al. 2006; http://www.cs.princeton.edu/wschapire/), which generates an estimate of probability of the presence of species that varies from 0 to 1, where 0 is the lowest and 1 is the highest probability. Maxent is a maximum entropy based machine learning program that estimates the probability distribution for a species' occurrence based on environmental constraints (Phillips et al. 2006). It requires only presence data to predict the distribution of a species based on the theory of maximum entropy.

Of the 112 records, seventy five percent were used for model training and twenty five percent for testing. To validate the model robustness, 10 replicated model runs for the species with a threshold rule of 10 percentile training presence was executed. In the replicated runs, cross validation technique was employed, where samples were divided into replicate folds and each fold was used for test data. Other parameters were set to default as the program is already calibrated on a wide range of species datasets (Phillips and Dudík 2008). From the replicated runs average, maximum, minimum, median and standard deviation were generated. Jackknife procedure and percent variable contributions were used to estimate the relative influence of different predictor variables. Receiver operating characteristics (ROC) Analysis is used for analyzing the performance of a model at all possible threshold by a single number called, the area under the curve (AUC). Higher AUC values correspond to better model quality and accuracy. The Area under the ROC curve (AUC) was used to evaluate model performance. AUC is a measure of model performance and varies from 0 to 1 (Fielding and Bell 1997). An AUC value of 0.50 indicates that model did not perform better than random whereas a value of 1.0 indicates perfect discrimination (Swets 1988).

RESULTS

Output of the maxent model shows that most suitable habitats for presently studied species are in Western Himalayas. The current distribution of *Ephedra gerardiana*, *Lilium polyphyllum*, *Pittosporum eriocarpum* and *Skimmia anquetilia* is largely affected by precipitation variables whereas mean diurnal range was the strongest predictor for the distribution of *C. acuminatum*. The current distributions of these species as modelled are as follows.

***Ephedra gerardiana***

The maxent model for *E. gerardiana* performed well with an average AUC value of 0.977. Suitable habitats for *E. gerardiana* are predicted in Uttarakhand, Himachal Pradesh and Kashmir (Figure 2). Table 1 shows the relative contributions of the predictor variables in Maxent for distribution of *E. gerardiana*. Precipitation Seasonality (bio 15), Precipitation of driest month (Bio 14), Isothermality (Bio 3) and Annual Mean Temperature(Bio 1) were the trongest predictors forthe distribution of *E. gerardiana* with 29.3, 22.6, 10 and 9.1%contributions, respectively. Relative importance of different environmental variables based on results of jackknife tests in Maxent are shown in Figure 3. Jackknife results also showed that Precipitation Seasonality, Precipitation of driest month, Isothermality and Annual Mean Temperature are the most important predictors for the distribution of *E. gerardiana*.

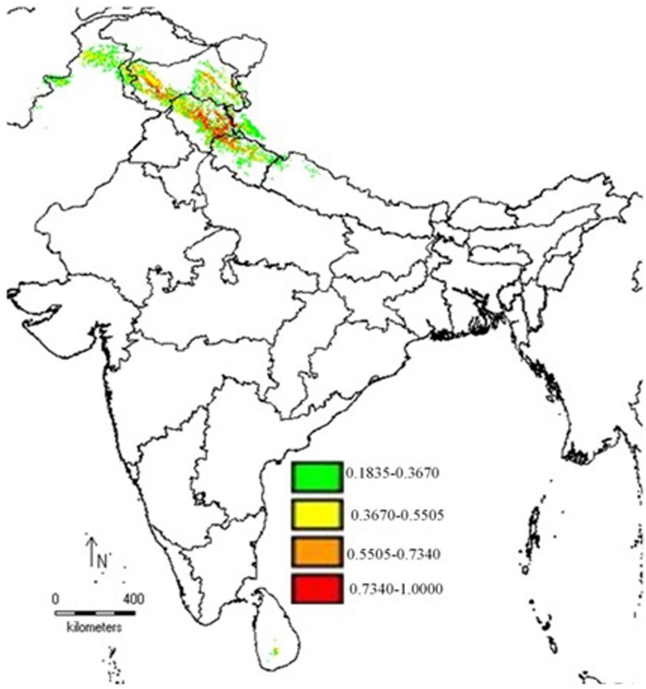


Figure 2. Predicted distribution of *E. gerardiana* in Western Himalaya.

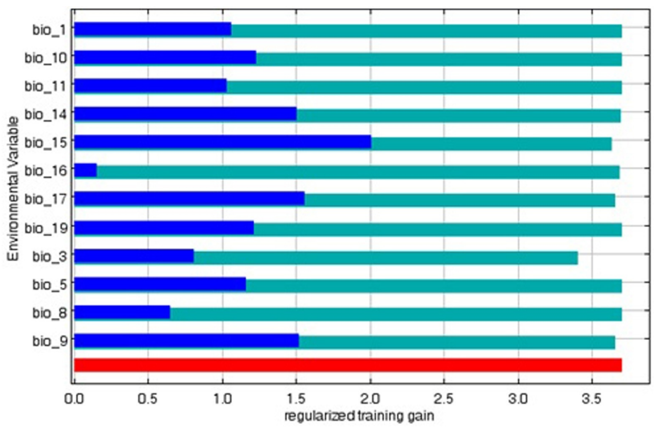


Figure 3. Relative predictive power of different bioclimatic variables based on jackknife of regularized training gain in Maxent model for *E. gerardiana.*

***Lilium polyphyllum***

The maxent model for *L. polyphyllum* performed well with an average AUC value of 0.997. Suitable habitat for *L. polyphyllum* is predicted in Uttarakhand and Himachal Pradesh (Figure 4). Table 1 shows the relative contributions of the predictor variables in Maxent for distribution of *L. polyphyllum*. Precipitation of driest quarter

Table 1. Selected environmental variables and their percent contribution in Maxent model for *E. gerardiana, L. polyphyllum, C. acuminatum, P. eriocarpum* and *S. anquetilia.*

| Environmental Variables | *Ephedra gerardiana* | *Lillium polyphyllum* | *Crepidium acuminatum* | *Pittosporum eriocarpum* | *Skimmia anquetilia* |
|---|---|---|---|---|---|
| Annual Mean Temperature(Bio 1) | 9.1 | ----- | ----- | ----- | ---- |
| Mean Diurnal Range (Bio 2) | ----- | 9.4 | 45.1 | ----- | ---- |
| Isothermality (Bio 3) | 10 | 0.2 | ----- | ----- | 1.6 |
| Temperature Seasonality (Bio 4) | | 2.4 | | | 6.7 |
| Maximum Temperature of Warmest Quarter (Bio 5) | `0.3 | ----- | ----- | ----- | 0.6 |
| Minimum Temperature of Coldest Month (Bio 6) | ----- | 8.1 | 4.3 | 12.5 | ---- |
| Temperature Annual Range (Bio 7) | ----- | ----- | 11.5 | ----- | ---- |
| Mean Temperature of Wettest Quarter (Bio 8) | 0.6 | ----- | ----- | ----- | 0.2 |
| Mean Temperature of Driest Quarter (Bio 9) | 3.6 | 1.2 | 0.3 | 0.7 | 0.5 |
| Mean Temperature of Warmest Quarter (Bio 10) | 2.1 | ------ | ----- | ----- | 13.8 |
| Mean Temperature of Coldest Quarter (Bio 11) | 8.5 | 27.3 | 33.3 | 11.3 | ---- |
| Annual Precipitation (Bio 12) | ----- | ----- | 0.5 | ----- | ---- |
| Precipitation of Wettest Month (bio 13) | ----- | ----- | 0.5 | 14 | 0.1 |
| Precipitation of driest month (Bio 14) | 22.6 | 1.2 | ----- | ----- | 5.2 |
| Precipitation seasonality (Bio 15) | 29.3 | ------ | 0.1 | 15.4 | 0.2 |
| Precipitation of Wettest Quarter (Bio 16) | 1.4 | ------ | 0.1 | 0.8 | ---- |
| Precipitation of Driest Quarter (Bio 17) | 8.4 | 52.5 | 40 | 44.1 | ---- |
| Precipitation of Warmest Quarter (Bio 18) | ----- | ----- | 1.9 | 4.6 | 9.5 |
| Precipitation of Coldest Quarter (Bio 19) | 4.2 | ----- | ----- | 0.8 | 17.5 |

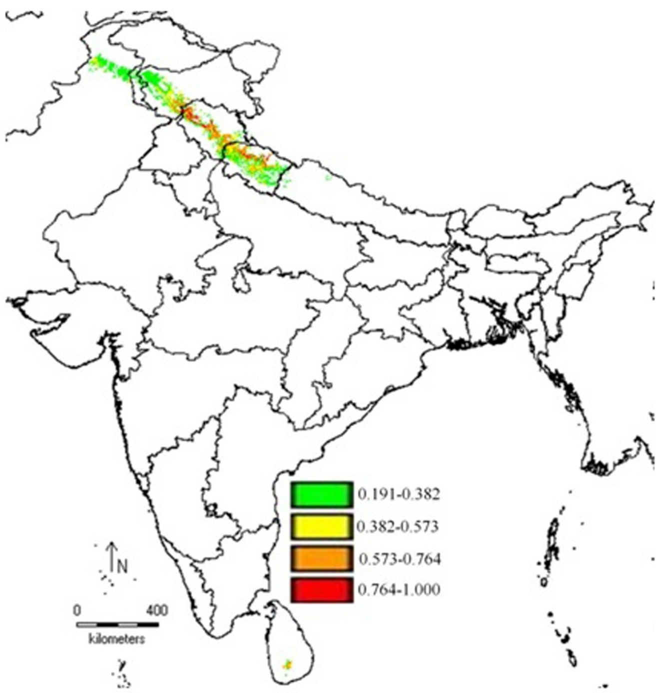


Figure 4. Predicted distribution of *L. polyphyllum* in Western Himalaya.

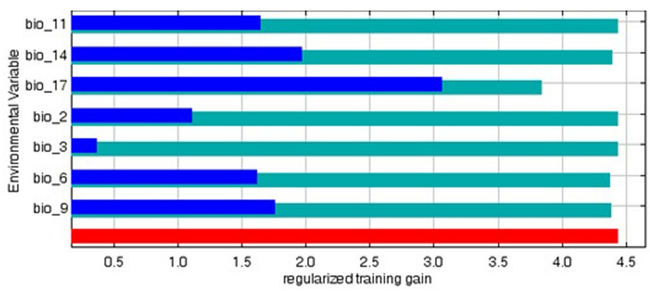


Figure 5. Relative predictive power of different bioclimatic variables based on jackknife of regularized training gain in Maxent model for *L. polyphyllum.*

(bio 17), Mean Temperature of coldest quarter (Bio 11), Mean diurnal Range and Minimum Temperature of Coldest Month (Bio 6) were the strongest predictors for the distribution of *L. polyphyllum* with 52.5, 27.3, 9.4 and 8.1% contributions, respectively.

Relative importance of different environmental variables based on results of jackknife tests in Maxent are shown in Figure 5. The results also show that Precipitation of driest quarter, Mean Temperature of coldest quarter, Mean diurnal Range and Minimum Temperature of Coldest Month are the most important predictors for the distribution of *L. polyphyllum*.

***Crepidium acuminatum***

The Maxent model for *C. acuminatum* performed well with an average AUC value of 0.981. Most suitable habitats for this species are predicted in Uttarakhand and Himachal Pradesh (Figure 6). Table 1shows the relative contributions of the predictor variables in Maxent for distribution of *C. acuminatum*. Mean diurnal range (Bio 2) and Mean temperature of coldest quarter (Bio 11) were the strongest predictors for the distribution of this species with 45.1and33.3% contributions, respectively. Relative importance of different environmental variables based on results of jackknife tests in Maxent are shown in Figure 7. Jackknife results also showed that Mean diurnal range and Mean temperature of coldest quarter are the most important predictors for the distribution of *C. acuminatum*.

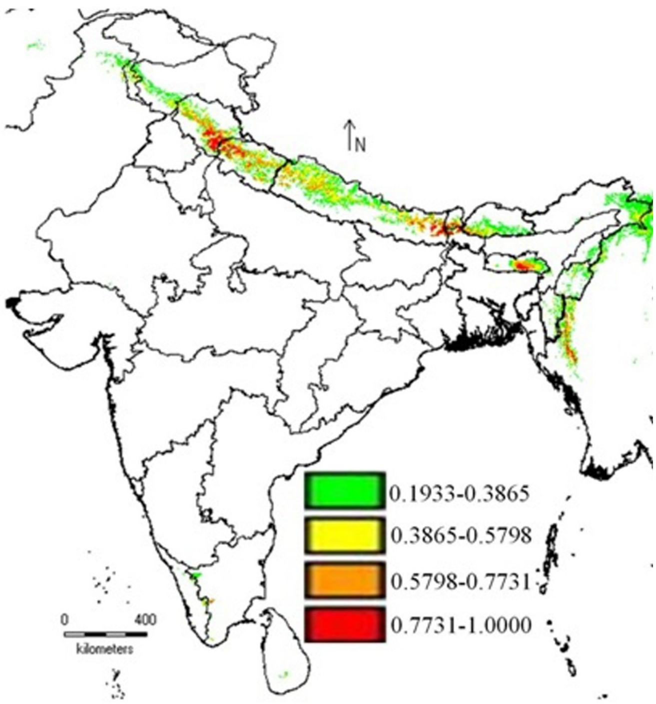


Figure 6. Predicted distribution of *C. acuminatum.*

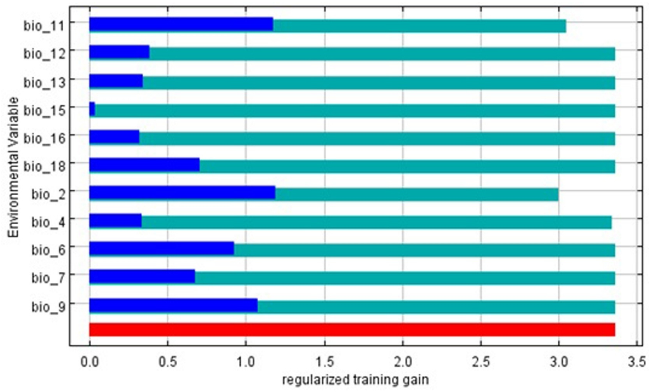


Figure 7. Relative predictive power of different bioclimatic variables based on jackknife of regularized training gain in maxent model for *C. acuminatum.*

***Pittosporum eriocarpum***

The maxent model for *P. eriocarpum* performed well with an average AUC value of 0.998 and most suitable habitat is predicted in Uttarakhand (Figure 8). Table 1 shows the relative contributions of the predictor variables in Maxent for distribution of *P. eriocarpum*. Precipitation of Driest Quarter (Bio 17), Precipitation Seasonality (Bio 15), Precipitation of Wettest Month (bio 13) and Min Temperature of Coldest Month (Bio 6) were the strongest predictors for the distribution of *P. eriocarpum* with 40, 15.4, 14 and 12.5% contributions, respectively.

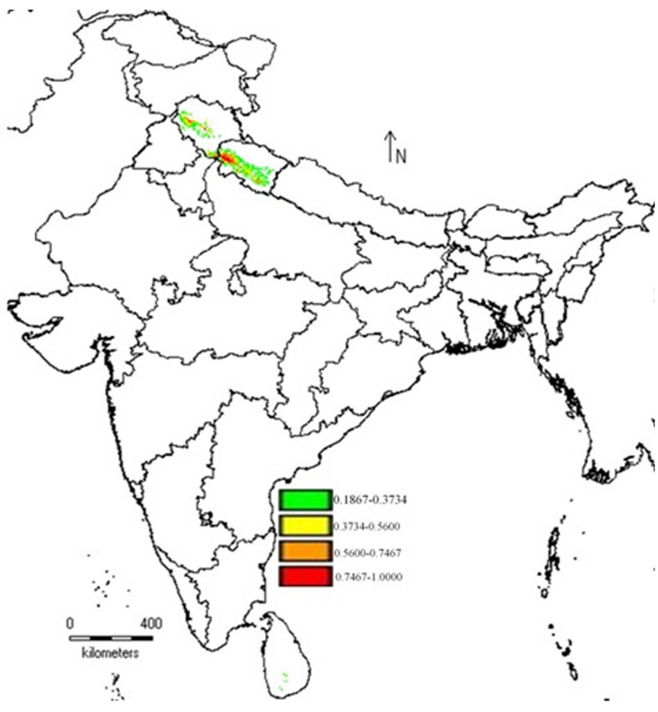


Figure 8. Predicted distribution of *P. eriocarpum.*

Relative importance of different environmental variables based on results of jackknife tests in Maxent are shown in Figure 9. Jackknife results also showed that Mean diurnal range and Mean temperature of coldest quarter are the most important predictors for the distribution of *P. eriocarpum*.

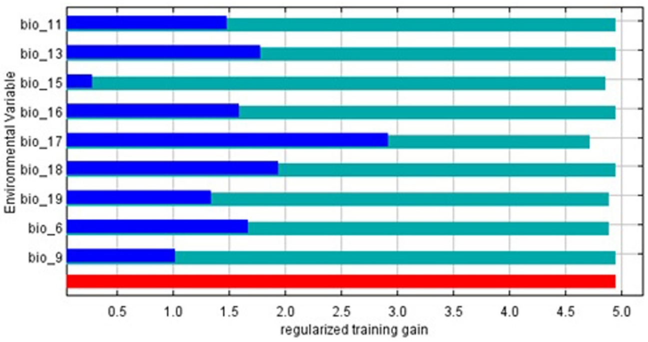


Figure 9. Relative predictive power of different bioclimatic variables based on jackknife of regularized training gain in Maxent model for *P. eriocarpum*.

***Skimmia anquetilia***

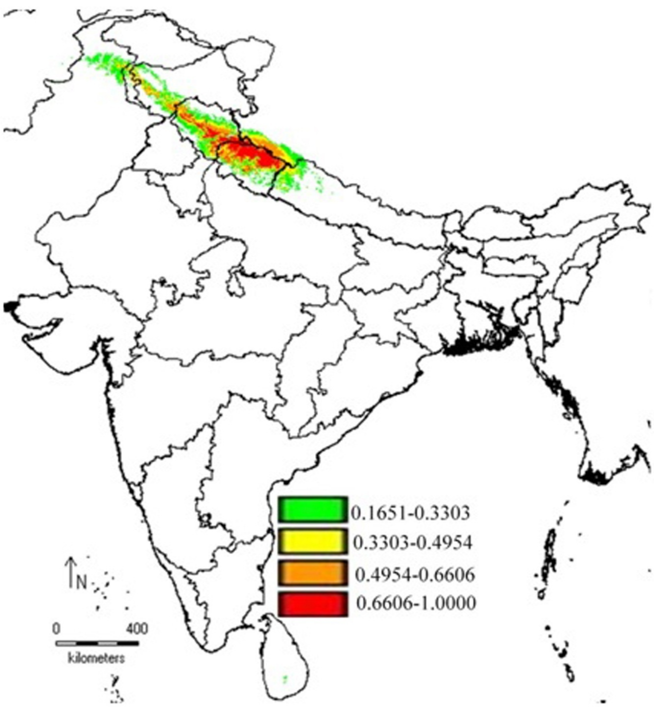


Figure 10. Predicted distribution of *S. anquetilia*.

The maxent model for *S. anquetilia* performed well with an average AUC value of 0.993. Most suitable habitat for this species is predicted in Uttarakhand and Himachal Pradesh (Figure 10). Table 1 shows the relative contributions of the predictor variables in Maxent for distribution of *S. anquetilia*. Precipitation of Driest Quarter (Bio 17), Precipitation of Coldest Quarter (Bio 19) and Mean Temperature of Warmest Quarter (Bio 10) were the strongest predictors for the distribution of *S. anquetilia* with 44.1, 17.5 and 13.8% contributions, respectively.

Relative importance of different environmental variables based on results of jackknife tests in Maxent are shown in Figure 11. Jackknife results also showed that Precipitation of Driest Quarter, Precipitation of Coldest Quarter and Mean Temperature of Warmest Quarter are the most important predictors for the distribution of *S. anquetilia*.

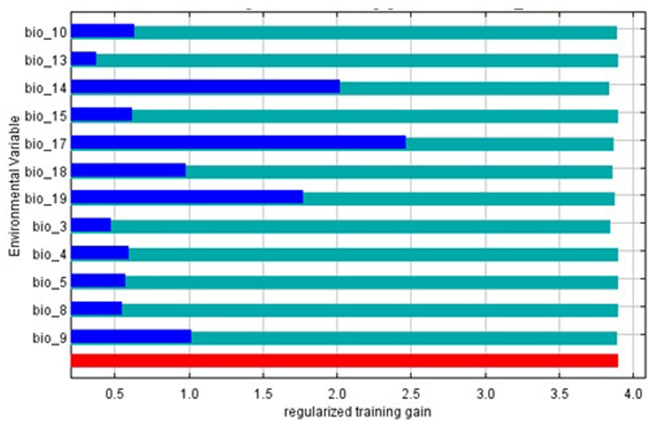


Figure 11. Relative predictive power of different bioclimatic variables based on jackknife of regularized training gain in maxent model for *S. anquetilia*.

## DISCUSSION

Most suitable habitat for these endangered species is predicted inWestern Himalayas. Better population status of these species in areas of higher model thresholds indicates that these areas have ideal habitat conditions for reintroduction of the species. Precipitation of the driest quarter played an important role in the potential habitat distribution of *Lilium polyphyllum*, *Pittosporum eriocarpum* and *Skimmia anquetilia* whereas mean diurnal range was the strongest predictor for the distribution of *C. acuminatum*. Output of the maxent model and field surveys revealed that most suitable natural habitats for *L.* polyphyllum are in Uttarakhand and Himachal Pradesh whereas for *P. eriocarpum*, it is in Uttarakhand. The restricted distribution of highly suitable habitats of *P. eriocarpum* in Uttarakhand indicate that the plant is endemic. Previous field surveys, herbarium records and literature have also suggested that *P. eriocarpum* is endemic to Uttarakhand (Padalia et al. 2010).

*E. gerardiana*, *L. polyphyllum*, *C. acuminatum*, *P. eriocarpum* and *S. anquetilia* are valuable resources that face pressure like loss of habitat due to climate change, change in land use and land cover and over exploitation. Flood in Uttarakhand in 2013 is one of most recent examples of natural calamity which has caused habitat destruction in Uttarakhand. These are serious threats and should be managed properly.

Many areas predicted to have suitable habitat for these species might already be devoid of populations due to over collection for medicinal purposes and increased anthropogenic activities in the areas of their occurrence which has led to considerable depletion of their natural population. Therefore, conservation planning is immediately needed for *E. gerardiana*, *L. polyphyllum*, *acuminatum*, *P. eriocarpum* and *S. anquetilia*. Multiple strategies to preserve these plants including In-situ conservation in protected areas with suitable habitats to ex-situ conservation should be implemented. Macro- and micro-propagation of these plants can be done in controlled conditions and these plantlets can be introduced to the suitable protected sites identified through the ecological niche modelling.

Our study suggests that the habitat distribution modelling can be of great help in predicting the suitable habitats for reintroduction of these endangered species. The method is certainly promising in predicting the potential distribution of other endangered species and can be a valuable tool in species distribution studies, species conservation planning and climate change. The areas predicted in the present study can help in rehabilitation of these species and improving their conservation status. The Maxent model for predicting the suitable habitat of a species can be useful in predicting the potential suitable habitat of other medicinal plants which further can help in species conservation planning.

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**Contributions of authors**: Pragya Sourabh mainly worked on the Habitat Distribution Modelling and made prediction of habitat distribution patterns for the selected species using maximum entropy distribution (Maxent) software. Julie Thakur collected the actual population data on *Crepidium acuminatum* and *Skimmia anquetilia* and helped in the authentication of the habitat by Maxent, by visiting the sites. Priti collected the actual population data on *Lilium polyphyllum* and *Pittosporum eriocarpum* and helped in the authentication of the habitat by Maxent by visiting the sites. Prabha Sharma collected the actual field data on the populations of *Ephedra gerardiana* and helped in the authentication of the habitat by Maxent by visiting the sites and prepared the distribution maps.

## REFERENCES

Adhikari, D.; Barik, S.K. and Upadhaya, K. 2012. Habitat distribution modelling for reintroduction of *Ilex khasiana* Purk., a critically endangered tree species of northeastern India. Ecological Engineering 40: 37-43.

Adhikari, D.; Tiwary, R. and Barik, S.K. 2015. Modelling Hotspots for InvasiveAlien Plants in India. PLoS ONE 10(7): e0134665.

Ahmed, M.J.; Murtaza, G.; Mehmood, A. and Bhatti, T.M. 2015. Green synthesis of silver nanoparticles using leaves extract of *Skimmia anquetilia*: characterization and antibacterial activity. Materials Letters 153: 10-13.

Balkrishna, A.; Srivastava, A.; Mishra, R.K.; Patel, S.P.; Vashistha, R.K.; Singh, A.; Jadon, V. and Saxena, P. 2012. Astavarga plants-threatened medicinal herbs of the North-West Himalaya. International Journal of Medicinal and Aromatic Plants 2(4): 661-676.

Baskin, C.C. and Baskin, J.M. 1998. Seeds Ecology, Biogeography and Evolutionof Dormancyand Germination. Academic Press, San Diego, California, USA. 666 pages.

Bhattarai, N. and Karki, M. 2006. Community management of medicinal plants in Nepal: Practices and trends towards sustainability. Paper presented at: Workshop on Assessing the Sustainable Yield in Medicinal and Aromatic Plant Collection; 14–17 September, 2006, ICIMOD, Kathmandu, Nepal. http://www.floraweb.de/map-pro/lectures/ Bhattarai.pdf

Chitale, V.S. and Behera, M.D., 2012. Can the distribution of sal (*Shorea robusta* Gaertn. f.) shift in the northeastern direction in India due to changing climate. Current Science 102(8): 1126-1135.

Dhaliwal, D.S. and Sharma, M. 1999. Flora of Kullu District (Himachal Pradesh). Bishen Singh Mahendra Pal Singh, Dehra Dun, India. 744 pages.

Dhyani, A.; Bahuguna, Y.M.; Semwal, D.P.; Nautiyal, B.P. and Nautiyal, M.C. 2009. Anatomical features of *Lilium polyphyllum* D. Don ex Royle (Liliaceae). American Journal of Science 5(5): 85-90.

Dutt, B.; Sharma, S.S.; Sharma, K.R.; Gupta, A and Singh, H. 2011. Ethnobotanical survey of plants used by Gaddi tribe of Bharmour area in Himachal Pradesh. ENVIS Bulletin 19: 22-27.

Elith, J., Graham, C.H., Anderson, R.P., Dudik, M., Ferrier, S. and Guisan, A., 2006. Novel methods improve prediction of species distributions from occurrence data. Ecography 29: 129–151.

Fielding, A.H. and Bell, J.F. 1997. A review of methods for the assessment of prediction errors in conservation presence/ absence models. Environmental Conservation 24: 38-49.

Gaur, R.D. 1999. Flora of the District Garhwal, North West Himalaya. Transmedia, Srinagar, U.P. 811 pages.

Gowda, M. 1951. The genus *Pittosporum* in the Sino-Indian region. Journal of the Arnold Arboretum 32(3): 263-301.

Haq, F. 2012. The critically endangered flora and fauna of district Battagram Pakistan. Advances in Life sciences 2(4): 118-123.

Hernandez, P.A.; Graham, C.H.; Master, L.L. and Albert, D.L. 2006. The effect of sample size and species characteristics on performance of different species distribution modeling methods. Ecography 29(5): 773-785.

Hijmans, R.J.; Cameron, S.E.; Parra, J.L.; Jones, P.G. and Jarvis, A. 2005. Very high res-olution interpolated climate surface for global land areas. International Journal of Climatology 25: 1965-2198.

IUCN, 2017. The IUCN Red List of Threatened Species. Version 2017-1. <www.iucnredlist.org>

Jangwan, J.S.;Kumar, N. and Singh, R. 2010. Analysis of Composition and Antibacterial activity of essential oil of *Skimmia anquetilia* from Garhwal Himalaya.International Journal of Chemical Sciences 8(3): 1433-1439.

Khanum, R.; Mumtaz, A.S. and Kumar, S. 2013. Predicting impacts of climate change on medicinal asclepiads of Pakistan using Maxent modelling. Acta Oecologica 49: 23-31.

Kumar, S. and Stohlgren, T.J. 2009. Maxent modelling for predicting suitable habitat for threatened and endangered tree *Canacomyrica monticola* in New Caledonia. Journal of Ecology and Natural Environment 1(4): 94-98.

Menon, S.; Choudhury, B.I.; Khan, M.L. and Peterson, A.T. 2010. Ecological niche modelling and local knowledge predict new populations of Gymnocladus assamicus a critically endangered tree species. Endangered Species Research11(2): 175-181.

Nayar, M.P. and Sastry, A.R.K. 1990. Red Data Book of Indian Plants. Volume 3. Botanical Survey of India, Calcutta. 271 pages.

Negi,V.; Ikram, S.; Maikhuri, R.K. and Vashishtha, D.P. 2011. Traditional health care practices among the villages of the Rawain valley, Uttarkashi, Uttarakhand, India. Indian Journal of Traditional Knowledge 10 (3): 533-537.

Ortega-Huerta, M.A. and Peterson, A.T., 2008. Modeling ecological niches and predicting geographic distributions: a test of six presence-only methods. Revista Mexicana de Biodiversidad 79(1): 205-216.

Padalia, H.; Bharti, R.R.; Pundir, Y.P.S. and Sharma, K.P. 2010. Geospatial multiple logistic regression approach for habitat characterization of scarce plant population: A case study of *Pittosporum eriocarpum* Royle (an endemic species of Uttarakhand, India). Journal of the Indian Society of Remote Sensing 38(3): 513-521.

Phillips, S.J.; Anderson, R.P. and Schapire, R.E. 2006. Maximum entropy modelling of species geographic distributions. Ecological Modelling 190: 231-259.

Qureshi, R.A. and Udani, S.K. 2009. Indigenous medicinal plants used by local women in southern Himalayan regions of Pakistan. Pakistan Journal of Botany 41(1): 19-25.

Ray, R.; Gururaja, K.V. and Ramchandra, T.V. 2011. Predictive distribution modeling for rare Himalayan medicinal plant *Berberis aristata* DC. Journal of Environmental Biology 32(6): 725-730.

Saha, D., Ved, D., Ravikumar, K., Haridasan, K. and Dhyani, A. 2015. *Lilium polyphyllum*. The IUCN Red List of Threatened Species 2015: e .T50126623A79918170

Sanchez, A.C.; Osborne, P.E. and Haq, N. 2011. Climate change and the African baobab (*Adansonia digitata* L.): the need for better conservation strategies. African Journal of Ecology 49: 234-245.

Sharma, A.; Kaushik, A.; Tiwari, R.K. and Rao, C.V. 2007. Analgesic and anti-inflammatory activity of *Carissa carandas* Linn fruits and *Microstylis wallichii* Lindl tubers. Natural Product Sciences 13(1): 6-10.

Singh, D. and Goel, R. 1999. *Pittosporum eriocarpum* (Pittosporaceae)-an endangered species with its new distribution record from Tehri district. Annals of Forestry *7*(2): 185-191.

Singh, G. and Rawat, G.S. 2011. Ethnomedicinal survey of Kedarnath Wildlife Sanctuary in Western Himalaya, India. Journal of Fundamental and Applied Life Sciences 1: 35-46.

Soberon, J. and Peterson, A.T. 2005. Interpretation of models of fundamental ecological niches and species' distributional areas. Biodiversity Informatics 2: 1-10.

Sourabh, P.; Thakur, J.; Uniyal, P.L. and Pandey, A.K. 2015. Biology of *Lilium polyphyllum* - A threatened medicinal plant. Medicinal Plants 7(2): 158-166.

Swets, J.A. 1988. Measuring the accuracy of diagnostic systems. Science 240 (4857): 1285-1293.

Terribile, L.C.; Olalla Tárraga, M.Á.; Diniz Filho, J.A.F. and Rodríguez, M.Á. 2009. Ecological and evolutionary components of body size: geographic variation of venomous snakes at the global scale. Biological Journal of the Linnean Society 98(1): 94-109.

Thakur, J.; Dwivedi, M.D.; Sourabh, P.; Uniyal, P.L. and Pandey, A.K. 2016. Genetic homogeneity revealed using SCoT, ISSR and RAPD markers in micropropagated *Pittosporum eriocarpum* Royle-An endemic and endangered medicinal plant. PloS one11(7): p.e0159050.

Ved, D.K.; Kinhal, G.A.; Ravikumar, K; Prabhakaran, V; Ghate, U; Vijayshankar, R. and Indresha, J.H. 2003. Conservation Assessment and Management Prioritisation for the Medicinal Plants of Himanchal Pradesh, Jammu and Kashmir and Uttaranchal. Foundation for Revitalisation of Local Health Traditions, Bangalore, India.

Wisz, M.S.; Hijmans, R.J.; Li, J.; Peterson, A.T.; Graham, C.H. and Guisan, A., 2008. Effects of sample size on the performance of species distribution models. Diversity and Distributions 14(5): 763-773.

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