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MODELLING POTENTIAL DISTRIBUTION OF *VANDA TESSELLATA* (ROXB.) HOOK. EX G.DON IN INDIA

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Abstract

Vanda tessellata (Roxb.) Hook. ex G.Don (Orchidaceae) is an epiphytic plant mostly found in moist to dry deciduous forests and is distributed in different parts of India, Sri Lanka, Nepal, Bangladesh, Myanmar, Vietnam, and China. It possesses antioxidant, cytotoxicity, and anti-microbial activities. Due to its medicinal properties, it is used by traditional healers to treat many ailments. Apart from medicinal uses, it also has a vital role in ecological aspects. Its populations are declining due to over-exploitation for its traditional medicinal uses which has caused pressure on its populations. There have been very limited efforts to address conservation concerns, such as mapping of the distribution pattern. Therefore, the present study was carried out to predict the current and future suitable distribution of *V. tessellata* in India using MaxEnt species distribution model. Output of MaxEnt model revealed that the suitable habitat for distribution is Central and Southern part of India, with a significant area of 1,57,285 km^2. When compared to the currently predicted suitable habitat area, future prediction model for 2050 showed decrease of habitat area by 3.54%. annual precipitation (bio 12) and minimum temperature of coldest month (bio 6) were the strongest predictors for the distribution of *V. tessellata* with 42.8% and 13.6%, respectively.

Introduction

VANDA TESSELLATA (Roxb.) Hook. ex G.Don (Orchidaceae), commonly known as *grey orchid*, is a sun loving epiphytic plant mostly found in moist to dry deciduous forests and is distributed in different parts of India, Sri Lanka, Nepal, Bangladesh, Myanmar, Vietnam, and China (Kowsalya *et al*., 2017; Mundugaru *et al*., 2020). It grows mostly on specific host plants such as *Diospyros melanoxylon, Madhuca longifolia*, *Mangifera indica*, *Shorea robusta etc*. It possesses several pharmacological properties such as anti-inflammatory, anti-convulsant, anti-diarrhoea, anti-oxidant, anti-microbial, wound healing, neuroprotective, and hepatoprotective activity (Nayak *et al*., 2021; Padhee *et al*., 2024). Due to its medicinal properties, it is used by traditional healers to treat many ailments (Swain *et al*., 2019). Different parts of the plant are used to treat pain, inflammation, arthritis, sciatica, liver disease, bronchitis, hiccough, and fever. In Unani system, the plant juice is used for treating toothaches, bronchitis, boils and as a tonic for brain and liver (Uddin *et al*., 2015). Konda Reddis of Khammam district in India use the roots and leaves of *V. tessellata* against rheumatic pains by applying these externally daily once for 5-6 days (Friesen and Friesen, 2012). In Rajasthan, *V. tessellata* is used by local tribals for treating ailments in cattle (Sharma, 2003). Apart from medicinal uses, it also has a vital role in ecological aspects. Many insects, bees, and spiders depend on this particular orchid for shelter and food purposes.

While IUCN assessment of the *Vanda tessellata* is not available, reports indicate that its populations have declined (Khan and Salunkhe, 2019; Prakash and Bais, 2016). Exploitation for its traditional medicinal use has caused pressure on its natural populations. Significant population declines have been attributed to changing environmental conditions and habitat loss and degradation through industrialization in India. It is particularly vulnerable to the loss of mature host trees. The application of suitable ecological methods, such as phytosociological analysis and environmental niche modelling, plays a crucial role in preserving and conserving the natural populations of endangered species. However, without a clear understanding of the habitat distribution and climatic preferences of *Vanda tessellata*, it proves challenging to formulate effective measures and management strategies for its conservation, cultivation, or reintroduction. Therefore, the study was undertaken to construct a habitat suitability map and predict suitable habitats for reintroduction and conservation under current climatic conditions and to conduct an area change analysis under future climatic conditions projected for 2050.

To achieve these objectives, the Maximum Entropy model was employed (MaxEnt version 3.3.3; Phillips *et al*., 2006). This selection is based on the model's superior performance with small sample sizes compared to other modeling methods (Elith *et al*., 2006; Kumar and Stohlgren, 2009; Pearson *et al*., 2007). MaxEnt, which is based on the principle of Maximum Entropy, utilizes presence-only data to predict species distribution, while aiming to estimate a probability distribution of species occurrence that aligns as closely as possible with uniformity but is still subject to

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environmental constraints (Elith *et al*., 2011). The MaxEnt model inherently includes variable interactions and can manage both continuous and categorical predictor variables. It employs a set of features, such as linear, quadratic, product, threshold, and hinge, which are functions of environmental variables that limit the geographic distribution of a species. Additionally, it utilizes an empirically determined regularization parameter to prevent model over fitting.

Material and Methods

Occurrence Data Collection

Primary occurrence data for model building and evaluation were collected through field surveys in different parts of India. Occurrence records from the web resource of Global Biodiversity Information Facility (http://www.gbif.org) and published literature (Gupta and Katewa, 2014; Padhee *et al*., 2024; Teja *et al*., 2012) were collected. The coordinates of all the occurrence points obtained through field surveys were recorded to an accuracy of d” 10 m using a GPS (Garmin). These coordinates were then converted to decimal degrees for use in modeling the distribution of habitats of the species. To avoid spatial autocorrelations, only one location per grid (1×1 km) was used in modeling. Finally, a total of 120 occurrence points of *Vanda tessellata* were compiled and included in this study to model current and future potential distribution of the species.

Climatic Data

Bioclimatic variables (Booth *et al*., 2014) with 30 sec spatial resolution, downloaded from World Clim dataset (www.worldclim.org), were used in the present study. The World Clim data (for the period from 1950 to 2000) are compiled from measurements of temperature and precipitation collected from weather stations worldwide. These data are often used in species distribution modeling (Adhikari *et al*., 2015; Khanum *et al*., 2013; Kumar and Stoghlgren 2009; Sanchez *et al*., 2011). The 19 bioclimatic variables from the World Clim dataset were used to assess current climatic conditions. These variables are frequently used in modeling species distributions (*e.g*., Evangelista *et al*., 2008; Kumar *et al*., 2009; Sanchez *et al*., 2011) and capture annual ranges, seasonality, and limiting factors such as monthly and quarterly temperature and precipitation extremes (Hijmans *et al*., 2005). Future climate scenario data for 2050 (A2a emission scenario) were obtained from Consultative Group on International Agricultural Research (CGIAR)'s Research Program on Climate Change, Agriculture and Food Security (CCAFS) climate data archive (http://ccafsclimate.org). These future climate projections are based on IPCC 4th assessment data and were calibrated and statistically downscaled using the data for 'current' conditions.

Predictive Modeling

The habitat model was constructed using the Maximum Entropy Distribution Software, MaxEnt version 3.3.3 (Phillips *et al*., 2006; http://www.cs.princeton.edu/wschapire). This software generates likelihood estimation for the presence of species, providing a range from 0 to 1, where 0 signifies the lowest probability and 1 indicates the highest probability. Of the 80 records, 75% were used for model training and 25% for testing. To validate the model robustness, 10 replicated models were run 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 per cent variable contributions were used to estimate the relative influence of different predictor variables. Receiver operating characteristics (ROC) analyses the performance of a model at all possible threshold by a single number called, the area under the curve (AUC). AUC is a measure of model performance and varies from 0 to 1 (Fielding and Bell, 1997). Higher AUC values correspond to better model quality and accuracy. The area under the ROC curve was used to evaluate model performance.

Results

An AUC value of 0.50 indicates that model did not perform better than random whereas a value of 1.0

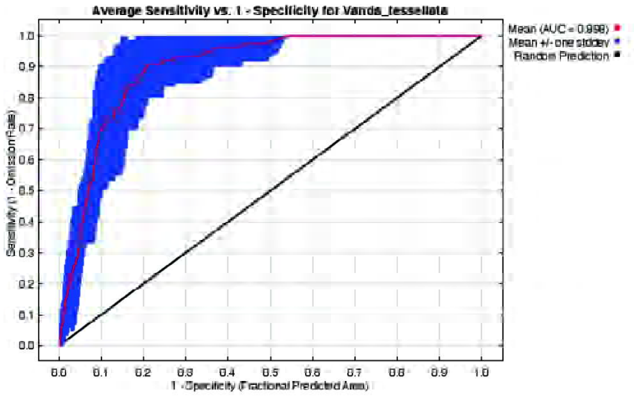

Fig. 1. Result of AUC in developing habitat suitability model for *Vanda tessellata*.

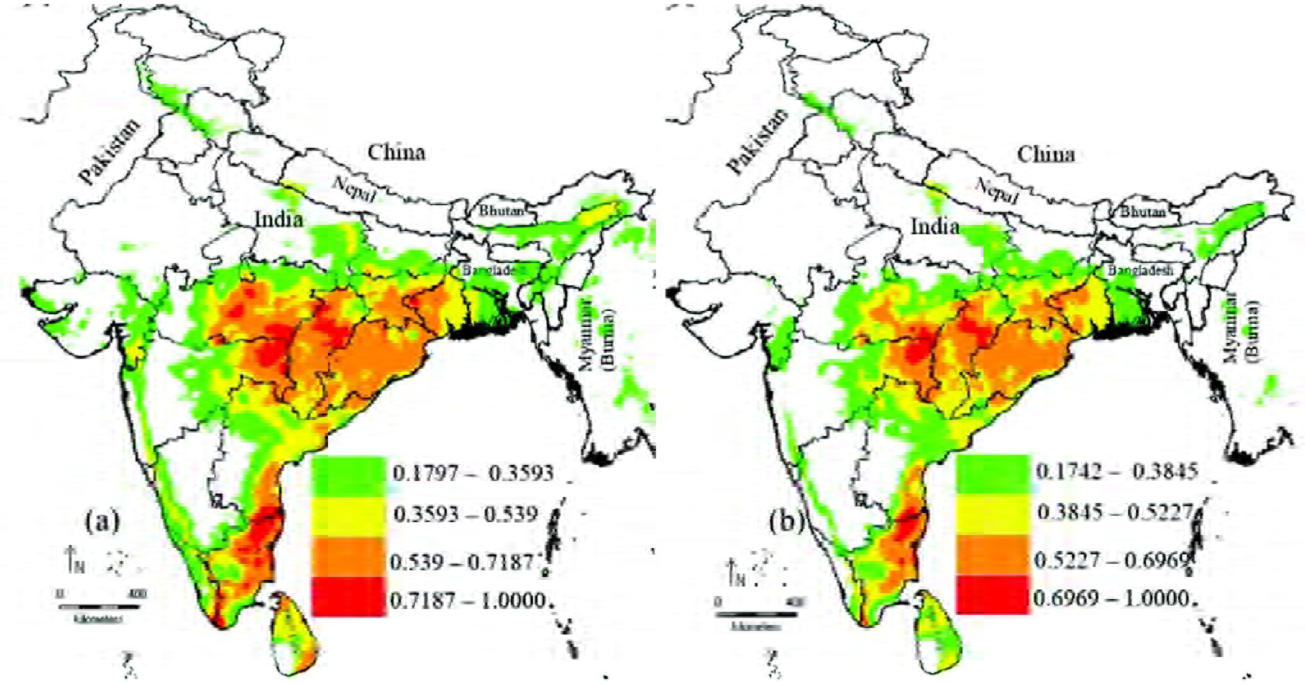

Fig. 2. MaxEnt model for *Vanda tessellata*: a, Predicted current; b, future potential suitable habitat of *Vanda tessellata* (Shapefile republished from DIVA-GIS database (https:// www.diva-gis.org/) under a CC BY license, with permission from Global Administrative Areas (GADM), original copyright 2018).

indicates perfect discrimination (Swets, 1988). The MaxEnt model for *Vanda tessellata* performed well with an average AUC value of 0.898 (Fig. 1). The model suggests Central and Southern part of India to be the most suitable habitat, with a significant area of 1,57,285 km^2 (Fig. 2a). The relative contributions of each predictor variable in the MaxEnt model for the distribution of *V. tessellata* is given in Table 1. Annual precipitation (bio 12) and minimum temperature of coldest month (bio 6) were the strongest predictors for the distribution of *V. tessellata* with 42.8% and 13.6%, respectively (Fig. 3). Relative importance of different environmental variables based on results of jackknife tests in MaxEnt are shown in Fig. 4. When compared to the currently predicted most suitable habitat area of 1,57,285 km^2, the future prediction model for 2050 (under the A2a emission scenario) indicates a reduction in habitat (Fig. 2b), with an optimal geographic distribution measuring 1,51,715 km^2. While the prospective distribution of *V. tessellata* closely mirrors the existing potential distribution, the model's findings suggest a decrease in highly suitable habitat by 3.54% in terms of area.

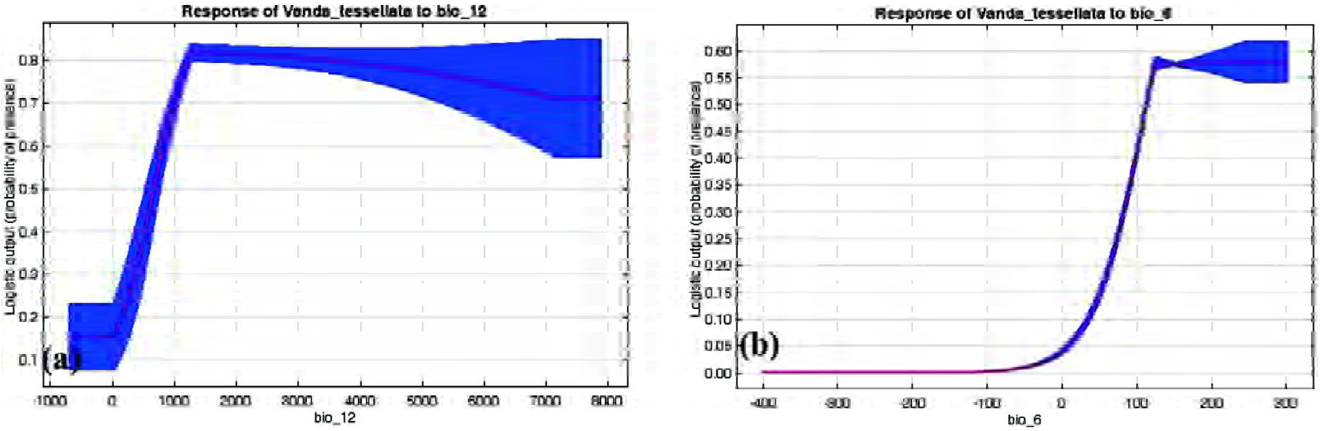

Fig. 3. Response curves showing relationships between probability of presence of a species and top bioclimatic predictor of *Vanda tessellata*: a, Annual precipitation (bio 12); b, Minimum temperature of coldest month (bio 6).

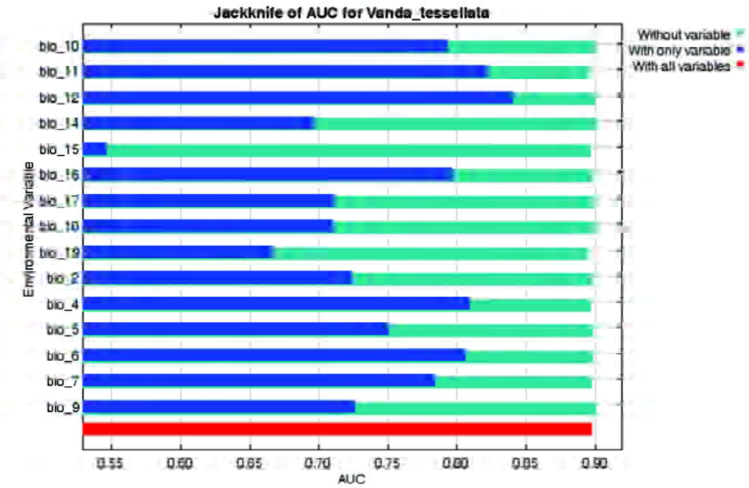

Fig. 4. Relative predictive power of different bioclimatic variables based on the jackknife of regularized training gain in MaxEnt model for *Vanda tessellata.*

Table 1. Selected environmental variables and their per cent contribution in MaxEnt model for *V. tessellata.*

Environment variables	Per cent contribution
Annual precipitation (bio 12)	42.8
Minimum temperature of coldest month (bio 6)	13.6
Precipitation of warmest quarter (bio_18)	10.7
Mean temperature of coldest quarter (bio 11)	7.8
Mean temperature of warmest quarter (bio_10)	6.4
Temperature seasonality (bio_4)	5
Precipitation of driest month (bio 14)	4.2
Precipitation of coldest quarter (bio 19)	3.7
Precipitation seasonality (bio 15)	1.3
Maximum temperature of warmest month (bio 5)	1.2
Mean temperature of driest quarter (bio 9)	1.1
Precipitation of driest quarter (bio 17)	0.8
Mean diurnal range (bio 2)	0.7
Precipitation of wettest quarter (bio 16	0.6
Temperature annual range (bio 7)	0.2

Discussion

Species like *Vanda tessellata*, which possess recognized medicinal and economic value, face pressures like habitat loss resulting from rapid climate change, land use and land cover alterations, and overexploitation due to their known usefulness (Khanum *et al*., 2013). Land transformations for agricultural and urban purposes, along with climate changes, will lead to an expansion of unsuitable habitats in the species' range. Therefore, proper planning is essential to preserve the species through successful execution of *in situ* conservation within protected areas offering suitable habitats, as well as *ex situ* conservation (Adhikari *et al*., 2012; Urbina and Flores, 2010). Both macro- and micropropagation techniques should be employed to mass propagate and cultivate plantlets, which can then be introduced to appropriate protected sites identified via ecological niche modeling. Some attempts have been made earlier to propagate and conserve a few medicinally and rare, endangered, and threatened (RET) orchid species using *in vitro* propagation techniques (Anuprabha and Pathak, 2012; Arora *et al.,* 2014; Bhowmik and Rahman, 2022, 2023; Dhillon and Pathak, 2023; Kaur *et al.,* 2006; Kirti *et al.,* 2023; Lalduhsanga *et al.,* 2021; Mutum *et al.,* 2022; Pathak *et al.,* 2022, 2023; Sunita *et al.,* 2021; Thakur and Pathak, 2021; Tripura *et al.,* 2022; Vasundhra *et al.,* 2019, 2021).

The model outputs showed that annual precipitation (bio 12) and minimum temperature of coldest month (bio 6) significantly influences the potential habitat distribution of *V. tessellata*. Annual precipitation is the sum of all total monthly precipitation values. It approximates the total water inputs and is therefore, useful when ascertaining the importance of water availability to a species distribution. Minimum temperature of coldest month is the minimum monthly temperature occurrence over a given year or averaged span of years. This information is useful while examining whether species distributions are affected by cold temperature anomalies throughout the year. Higher per cent contribution of annual precipitation and minimum temperature of coldest month for *Vanda tessellata* indicated that the species distributions is highly affected by precipitation and cold temperature anomalies throughout the year. The model identified the Central and Southern part of India as the most suitable natural habitat for the species. The areas pinpointed through current distribution modeling can be utilized for the re-introduction of the species. Regarding future species predictions, MaxEnt modeling indicated a loss of habitat by 2050 within the presently predicted areas. Given the forecast of habitat contraction in the future, it is essential to prioritize and diligently preserve potential suitable areas.

Conclusion

The present study described the application of ecological niche modelling to identify the areas that support *Vanda tessellata* populations using occurrence points and environmental variables. The areas identified by current distribution modeling can be very useful in determining appropriate habitats for reintroduction of *V. tessellata*. Under future climatic scenarios (A2a emission scenario), this species shows a decrease in the habitat suitability (1,51,715km^2) as compared to the current prediction where the suitable habitats range across 1,71,667 km^2. Based on habitat contraction prediction in the near future, potential suitable areas must be prioritized and maintained at an utmost importance. The predicted areas in this research may help in the species' rehabilitation and further improve its conservation status. Employing various integrative *in situ* conservation approaches, along with captive propagation in controlled settings like natural habitats, botanical gardens, and other conservation facilities, may boost species recovery rate and promote germplasm conservation. The MaxEnt model, which is used to estimate a species' ideal habitat, may be used to forecast the potential suitable habitats of other related orchid species.

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