

Habitat Distribution Modeling for Reintroduction of *Cordia macleodii* in India

Reena Panwar, Pragya Sourabh*

Faculty of Science, Mansarovar, Global University, Sehore, Madhya Pradesh (INDIA)

*Corresponding author: pragya_sourabh@rediffmail.com

Received September 12, 2024; Revised October 14, 2024; Accepted October 20, 2024

Abstract *Cordia macleodii* (Boraginaceae), small-sized tree, is distributed in moist and dry deciduous forests of India. *C. macleodii* is a reputed folk medicinal plant used by locals and tribal communities in several disease treatments. Due to its high medicinal value, *C. macleodii* is susceptible to a high degree of anthropogenic pressure. Despite the enormous threats, there have been very limited concentrated 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 *C. macleodii* in India using Maxent species distribution model. Output of maxent model reveal that the suitable habitat for distribution is Western Ghat. When compared to the currently predicted suitable habitat area, future prediction model for 2050 showed decrease of habitat area by 4.84%. The strongest predictors for the distribution of *C. macleodii* were Annual Precipitation (bio 12), Minimum Temperature of Coldest Month (bio 6) and Precipitation of Warmest Quarter (bio 18).

Keywords: *Cordia macleodii*, Maxent, Western Ghat, Annual Precipitation

Cite This Article: Reena Panwar, and Pragya Sourabh, “Habitat Distribution Modeling for Reintroduction of *Cordia macleodii* in India.” *Applied Ecology and Environmental Sciences*, vol. 12, no. 2 (2024): 18-22. doi: 10.12691/aees-12-2-2.

1. Introduction

Cordia macleodii (Boraginaceae), native to India, is a small-sized tree. It is distributed in moist and dry deciduous forests of India such as Chattisgarh, Madhya Pradesh, Odisha, Maharashtra. It is a reputed folk medicinal plant which is used ethnomedicinally for various purposes like healing wounds (leaf, bark), mouth sores (leaf), treating jaundice (bark) and also as an aphrodisiac (seed) by the tribal people of Odisha, Chhattisgarh and Madhya Pradesh [1]. It is an endangered species with a very low population [2,3]. While IUCN assessment of the *C. macleodii* is not available, but the survey records indicate its status to be Critically Endangered [3].

The application of suitable ecological methods, such as phytosociological analysis and environmental niche modeling, plays a crucial role in preserving and conserving the natural populations of endangered species. Despite being an important species, there is a lack of information on suitable habitat distribution range of *C. macleodii*. Predicting its potential habitat distribution is primordial for its sustainable management, especially in the light of climatic variability. Without a clear understanding of habitat distribution and climatic preferences of *C. macleodii*, it is challenging to formulate effective measures and management strategies for its conservation, cultivation or reintroduction. Therefore, this

study was done to construct a habitat suitability map and predict suitable habitats for reintroduction and conservation under current climatic conditions as well as to conduct an area change analysis under future climatic conditions projected for 2050.

2. Methodology

Occurrence data collection

Primary occurrence data for model building and evaluation were collected through field surveys in different parts of India. We also obtained occurrence records from the web resource of Global Biodiversity Information Facility (<http://www.gbif.org>) [4] and published literature [5,6,7]. The coordinates of all the occurrence points obtained through field surveys were recorded to an accuracy of ≤ 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 km $\times$ 1 km) was used in modeling. Finally, a total of 80 occurrence points of *Cordia macleodii* were compiled and included in this study to model current and future potential distribution of the species.

Climatic data

Bioclimatic variables [8,9] with 30 seconds spatial resolution, downloaded from World Clim dataset (www.worldclim.org) were used in the present study. The

WorldClim 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 [10,11,12,13]. The 19 bioclimatic variables from the WorldClim dataset were used to assess current climatic conditions. These variables are frequently used in modeling species distributions [11,14,15] and capture annual ranges, seasonality, and limiting factors such as monthly and quarterly temperature and precipitation extremes [8]. 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 (<http://www.cs.princeton.edu/wschapire>) [16]. This software generates a 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, seventy-five percent were used for model training and twenty five percent for testing. To validate the model robustness, 10 replicated models 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 [17]. 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) 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 [18]. Higher AUC values correspond to better model quality and accuracy. The Area under the ROC curve was used to evaluate model performance.

3. Results

An AUC value of 0.50 indicates that model did not perform better than random whereas a value of 1.0 indicates perfect discrimination [19]. The maxent model for *Cordia macleodii* performed well with an average AUC value of 0.943 (Figure 1). In an effort to reduce potential inaccuracies in species occurrence data, any duplicated records were removed. The model suggests Western Ghats to be the most suitable habitat, with a significant area of 1,71,667 km² (Figure 2a). The relative contributions of each predictor variable in the Maxent model for the distribution of *C. macleodii* shows that Annual Precipitation (bio 12), Minimum Temperature of Coldest Month (bio 6) and Precipitation of Warmest Quarter (bio 18) were the strongest predictors for the distribution of *C. macleodii* with 22.6%, 19.5% and 18.6% respectively (Figure 3). Relative importance of different environmental variables based on results of jackknife tests in Maxent are shown in Figure 4.

When compared to the currently predicted most suitable habitat area of 1,71,667 km², the future prediction model for 2050 (under the A2a emission scenario) indicates a reduction in habitat, as illustrated in Figure 2b, with an optimal geographic distribution measuring 1,63,353 km². While the prospective distribution of *C. macleodii* closely mirrors the existing potential distribution, the model's findings suggest a decrease in highly suitable habitat by 4.84% in terms of area.

Table 1. Selected environmental variables and their percent contribution in maxent model for *C. macleodii*

Environment Variables	Percent Contribution
Annual Precipitation (bio 12)	22.6
Minimum Temperature of Coldest Month (bio 6)	19.5
Precipitation of Warmest Quarter (bio 18)	18.6
Temperature Seasonality (bio 4)	8.6
Annual Mean Temperature (bio 1)	7.8
Precipitation of Wettest Month (bio 13)	4.4
Precipitation of Coldest Quarter (bio 19)	2.7
Precipitation Seasonality (bio 15)	2.3
Mean Temperature of Coldest Quarter (bio 11)	2.3
Precipitation of Driest Month (bio 14)	2.3
Isothermality (bio 3)	2
Mean Diurnal Range (bio 2)	1.8
Temperature Annual range (bio 7)	1.8
Mean Temperature of Warmest Quarter (bio 10)	1.1
Mean Temperature of Wettest Quarter (bio 8)	0.9
Precipitation of Driest Quarter (bio 17)	0.7
Precipitation of Wettest Quarter (bio 16)	0.6
Mean Temperature of Driest Quarter (bio 9)	0.2

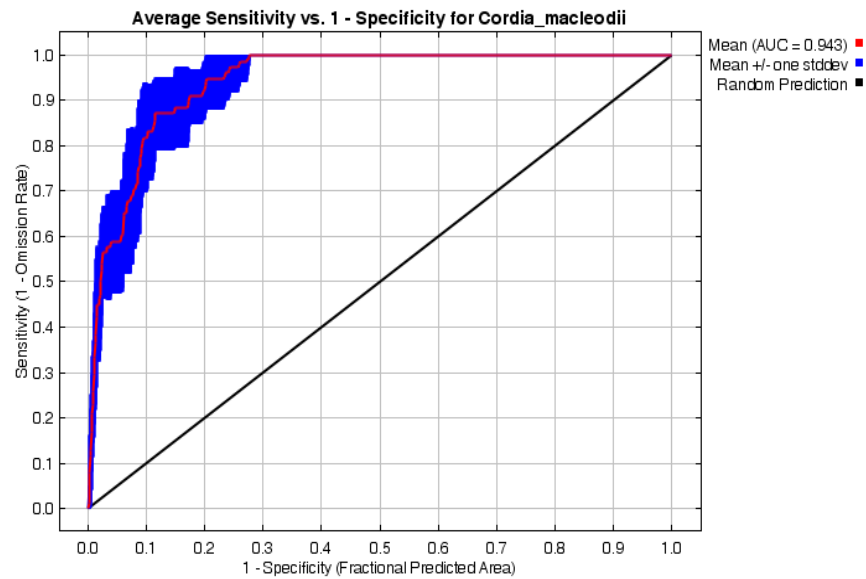


Figure 1. Result of AUC in developing habitat suitability model for *C. macleodii*

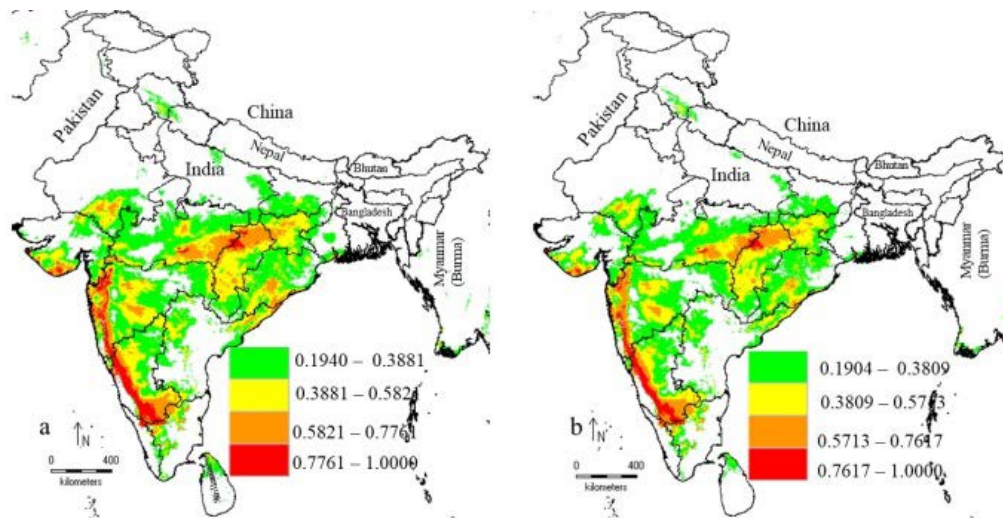


Figure 2. Predicted current (a) and future (b) potential suitable habitat of *Cordia macleodii* (Shapefile republished from DIVA-GIS database (<https://www.diva-gis.org/>) under a CC BY license, with permission from Global Administrative Areas (GADM), original copyright 2018.)

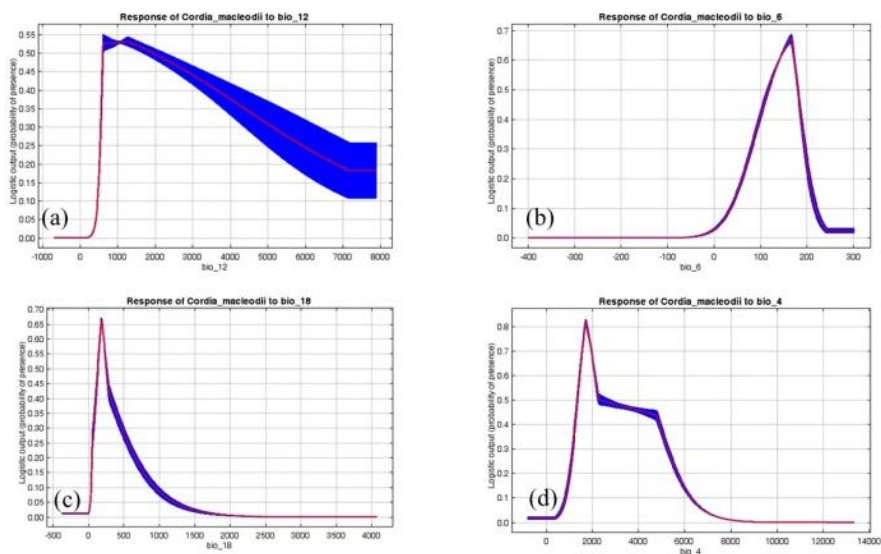


Figure 3. Response curves showing relationships between probability of presence of a species and top bioclimatic predictor of *Cordia macleodii* (a) Annual Precipitation (bio 12); (b) Minimum Temperature of Coldest Month (bio 6); (c) Precipitation of Warmest Quarter (bio 18); (d) Temperature Seasonality (bio 4)

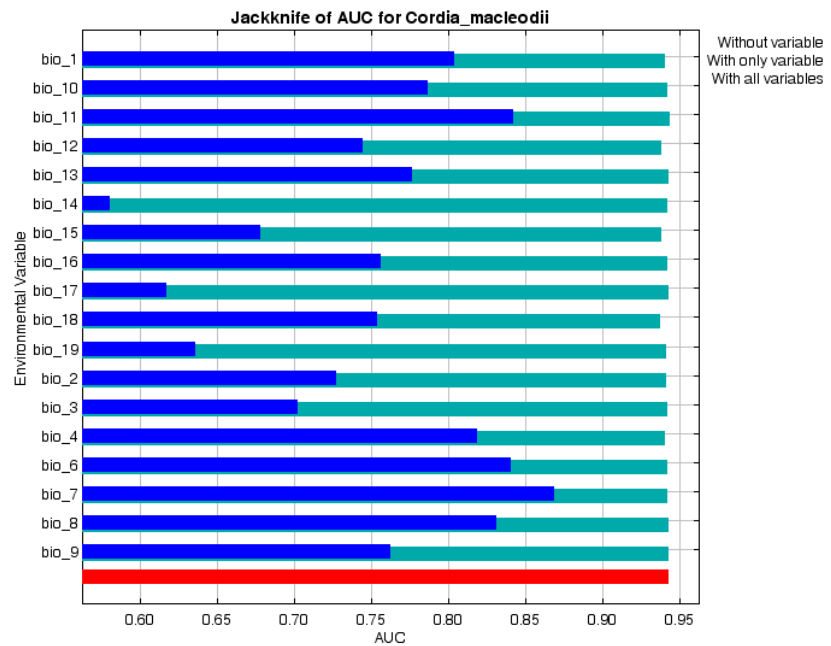


Figure 4. Relative predictive power of different bioclimatic variables based on the jackknife of regularized training gain in maxent model for *Cordia macleodii*

4. Discussion

Species like *Cordia macleodii*, 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 [12]. 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 [20,21]. Both macro- and micropropagation techniques should be employed to cultivate plantlets, which can then be introduced to appropriate protected sites identified via ecological niche modeling.

The model outputs show that Annual Precipitation (bio 12) significantly influences the potential habitat distribution of *C. macleodii*. The model identifies the Western Ghats 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 indicates a loss of habitat in Western Ghat 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.

5. Conclusion

The current study describes the application of ecological niche modeling to identify the areas that support *C. macleodii* populations using occurrence points and environmental variables. The areas located through current distribution modeling can be very helpful in

identifying suitable habitats for reintroducing *C. macleodii*. Under future climatic scenarios (A2a emission scenario), this species shows a decrease in the habitat suitability 1,63,353 km² as compared to the current prediction where the suitable habitats range across 1,71,667 km². 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 could help in the species' rehabilitation and 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, could boost species recovery rate and promote germplasm conservation. The Maxent model, which is used to estimate a species' ideal habitat, may be used to predict the potential suitable habitats of other economically important endangered species, which can further assist in conservation planning of these species.

ACKNOWLEDGEMENT

Author is thankful to Prof. Arun K. Pandey, Pro-Chancellor, Mansarovar Global University, Sehore for encouragement and facilities.

References

- [1] Chandrakar, J., & Dixit, A. K. *Cordia macleodii* Hook f. Thomson-A potential Medicinal Plant. *International Journal of Phytomedicine*, 9(3), 394-398. 2017.
- [2] Rawat, G. S. Special habitats and threatened plants of India. *ENVIS Bulletin: Wildlife and Protected Areas*, 11(1), 239. 2008.
- [3] Deb, D., Li, B., Chattopadhyay, S. K., & Ray, A. Identification of an endangered tree as a new record of *Cordia macleodii*, with an update of *Cordia* in West Bengal, India. *Webbia*, 73(1), 81-88. 2018.
- [4] GBIF.org (30 August 2024) GBIF Occurrence Download.
- [5] Jyoti S. & Kanhaiya, L. M. An Extended Distribution and

- Conservation of *Cordia macleodii* (Griff.) Hook. f. & Thomson in Rajasthan, India. *Asian Resonance*, 7(4), 9-12. 2018.
- [6] Anish, K. S., Chandra, K. K. & Arun, K. S. A detail review on *Cordia macleodii* Hook F. Thomson an ethno-medicinal Plant. *Chhattisgarh Journal of Science and Technology*, 17(2), 26-33. 2020.
- [7] Ahirwar, K., Kumar, A., Nag, M. & Khan, J. Phytopharmacology and applications of *Cordia macleodii*: A miraculous plant. *International Journal of Biology, Pharmacy and Allied Sciences*, 12(4): 1519-1535. 2023.
- [8] Hijmans, R. J., Cameron, S. E., Parra, J. L., Jones, P. G., & Jarvis, A. Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology: A Journal of the Royal Meteorological Society*, 25(15), 1965-1978. 2005.
- [9] Booth, T. H., Nix, H. A., Busby, J. R., & Hutchinson, M. F. BIOCLIM: the first species distribution modelling package, its early applications and relevance to most current MAXENT studies. *Diversity and Distributions*, 20(1), 1-9. 2014.
- [10] Kumar, S., & Stohlgren, T. J. Maxent modeling for predicting suitable habitat for threatened and endangered tree *Canacomyrica monticola* in New Caledonia. *Journal of Ecology and natural Environment*, 1(4), 94-98. 2009.
- [11] Sanchez, A. C., Osborne, P. E., & Haq, N. Climate change and the African baobab (*Adansonia digitata* L.): the need for better conservation strategies. *African Journal of Ecology*, 49(2), 234-245. 2011.
- [12] Khanum, R., Mumtaz, A. S., & Kumar, S. Predicting impacts of climate change on medicinal asclepiads of Pakistan using Maxent modeling. *Acta Oecologica*, 49, 23-31. 2013.
- [13] Adhikari, U., Nejadhashemi, A. P., & Herman, M. R. A review of climate change impacts on water resources in East Africa. *Transactions of the ASABE*, 58(6), 1493-1507. 2015.
- [14] Evangelista, P. H., Kumar, S., Stohlgren, T. J., Jarnevich, C. S., Crall, A. W., Norman III, J. B., & Barnett, D. T. Modelling invasion for a habitat generalist and a specialist plant species. *Diversity and distributions*, 14(5), 808-817. 2008.
- [15] Kumar, S., Spaulding, S. A., Stohlgren, T. J., Hermann, K. A., Schmidt, T. S., & Bahls, L. L. Potential habitat distribution for the freshwater diatom *Didymosphenia geminata* in the continental US. *Frontiers in Ecology and the Environment* 7(8): 415-420. 2009.
- [16] Phillips, S. J., Anderson, R. P., & Schapire, R. E. Maximum entropy modeling of species geographic distributions. *Ecological modelling*, 190(3-4), 231-259. 2006.
- [17] Phillips, S. J., & Dudík, M. Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. *Ecography*, 31(2), 161-175. 2008.
- [18] Fielding, A. H., & Bell, J. F. A review of methods for the assessment of prediction errors in conservation presence/absence models. *Environmental conservation*, 24(1), 38-49. 1997.
- [19] Swets, J. A. Measuring the accuracy of diagnostic systems. *Science*, 240(4857), 1285-1293. 1988.
- [20] URBINA-CARDONA, J. N., & Flores-Villela, O. S. C. A. R. Ecological-niche modeling and prioritization of conservation-area networks for Mexican herpetofauna. *Conservation biology*, 24(4), 1031-1041. 2010.
- [21] Adhikari, D., Barik, S. K., & Upadhaya, K. Habitat distribution modelling for reintroduction of *Ilex khasiana* Purk., a critically endangered tree species of northeastern India. *Ecological Engineering*, 40, 37-43. 2012.



© The Author(s) 2024. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>).