Buchanania cochinchinensis (Lour.) M.R. Almedia habitat exhibited robust adaptability to diverse socioeconomic scenarios in eastern India

Sanjoy Garai
ICFRE - Institute of Forest Productivity
Yogeshwar Mishra
ICFRE - Institute of Forest Productivity
Ayushman Malakar
ICFRE - Institute of Forest Productivity
Rikesh Kumar
ICFRE - Institute of Forest Productivity
Ronak Singh
ICFRE - Institute of Forest Productivity
Jassi Sharma
ICFRE - Institute of Forest Productivity
Sharad Tiwari (sharadtiwari8@gmail.com)
ICFRE - Institute of Forest Productivity

Research Article

Keywords: B. cochinchinensis, Climate change, MaxEnt, Phytosociological Study, Shared Socioeconomic Pathways (SSPs)

Posted Date: May 4th, 2023

DOI: https://doi.org/10.21203/rs.3.rs-2863372/v1

Additional Declarations: No competing interests reported.

Version of Record: A version of this preprint was published at Environmental Monitoring and Assessment on July 28th, 2023. See the published version at https://doi.org/10.1007/s10661-023-11611-0.

Abstract

One of the greatest challenges to ecosystems is the rapidity of climate change, and their ability to adjust swiftly will be constrained. Climate change will disrupt the ecological balances, causing species to track suitable habitats for survival. Consequently, understanding the species' response to climate change is crucial for its conservation and management, and for enhancing biodiversity through effective management. This research intends to examine the response of the vulnerable *Buchanania cochinchinensis* species to climate change. We modeled the potential suitable habitats of *B. cochinchinensis* for the present and future climatic scenario proxies based on the Shared Socioeconomic Pathways (SSP) i.e. SSP126, 245, 370 and 585. Maxent was used to simulate the potential habitats of *B. cochinchinensis*. The study found ~ 28313 sq km (~ 10.7% of the study area) was a potentially suitable habitat of *B. cochinchinensis* for the current scenario. The majority of the suitable habitat area ~ 25169 sq km occurred in the central and southern part of the study area. The future projection shows that the suitable habitat to largely increase in the range of 10.5–20% across all the SSPs, with maximum gain ~ 20% for SSP 126. The mean temperature of the wettest quarter (Bio_08) was the most influential contributing variable in limiting the distribution of *B. cochinchinensis*. The majority of the suitable habitat area occurred in the vegetation landscape. The study shows southward shifting of *B. cochinchinensis* habitat by 2050. The phytosociological research determined *B. cochinchinensis* as *Shorea robusta's* primary associate. Our research provides significant insight into the prospective distribution scenario of *B. cochinchinensis* habitat and its response to diverse socioeconomic scenarios, and offers a solid foundation for management of this extremely important species.

Highlights

- The study emphasizes the robustness of *B. cochinchinensis* habitat to diverse Socioeconomic scenarios.
- *B. cochinchinensis* habitat shows a southward shift in the future (2050).
- *B. cochinchinensis* is found as an associate of *D. sissoo.*
- *B. cochinchinensis* is a promising species in wasteland and dry land management.

1 Introduction

Climate change coupled with anthropogenic stresses pose a great threat to the ecosystem (León et al. 2020). Its combined influence altered environmental niches, forcing species' habitat range to migrate (Zhongming et al. 2020). The habitat range may expand or contract, influencing the tolerant limits of a species (Kraemer et al. 2021). Climate change has also caused extinction and several studies have predicted shifting of species habitat (Hickling et al. 2005; Melles et al. 2011). The increased anthropogenic pressure has led to exploitation of various important tree species (Acácio et al. 2017). Thus, understanding a species' potential adaptability to climate change is crucial for ensuring its survival (Pearson and Dawson 2003; Raxworthy et al. 2003). Especially, species with high socio-economic significance are more likely to be affected by such stresses. *B. cochinchinensis* (Lour.) M.R. Almedia, is one such tree species that has been overexploited due to its great medicinal and socioeconomic value. The International Union for the Conservation of Nature (IUCN) has listed the species as vulnerable due to indiscriminate and illegal logging by local inhabitants (Prasad 2020).

B. cochinchinensis is endemic to the tropical dry deciduous forests of India (Siddiqui et al. 2014) and is found as an associate of *S. robusta*, *Anogeissus pendula*, *Tectona grandis*, *Boswellia serrata* and *Madhuca longifolia* in natural forests (Sharma 2012). It is a reliable source of income for indigenous people owing to its delicious wild fruits with pleasant sub-acidic flavour (Malakar et al. 2022) or its seeds and kernels which are delicious, nutritious, and used in confectioneries as an alternative for almonds (Singh et al. 2018). The sweet, non-toxic, edible oil produced from the kernels may be employed as a low-cost alternative of cooking oil (Avani et al. 2019). The species also yields moderate-quality timber with natural termite resistance, which is used to make light furniture, boxes and crates, tables, match boxes, and packing cases. With some minor modifications and treatments, its wood holds a great prospect in the timber industries as they are highly economical (Malakar et al. 2023). The bark contains around 14% tannin and can be useful in tanning industries. The roots of *B. cochinchinensis* are astringent, depurative, acrid, constipating (Kala 2009). The leaf juice can be used as an aphrodisiac, purgative, expectorant, blood purifier, thirst quencher, and diuretic. (Rajput et al. 2018). Its fruits are used to relieve high body temperature, fever, cough, asthma etc. (Dai et al. 2002). The paste of its bark and leaves are reported to treat poisonous snake bites (Shukla et al. 2001).

B. cochinchinensis shows a high tolerance to adverse climatic conditions (Rajput et al. 2018). Its deep tap roots allow it to maintain high water potentials in scarcity of moisture during severe drought conditions (Zhang et al. 2007). The species prefers a dry, sub-humid climate. It can withstand a wide range of temperatures as high as 45°C and low to moderate annual rainfall of 750–1200 mm (Chauhan et al. 2012). Understanding *B. cochinchinensis'* response to climate change is the focus of the present work. To accomplish this, we have utilized Maxent to simulate the potential distribution of *B. cochinchinensis* under present and future temperature scenarios. Maxent uses presence data to estimate the optimal scenario for species distribution (Wisz et al. 2008; Chitale and Behera 2012; Deb et al. 2017; Kumar et al. 2020). Numerous studies have demonstrated the use of machine learning tools to determine species response to climate change (Tiwari et al. 2021; Ghosh et al. 2021; Souza et al. 2022; Siddig 2016). Concerning *B. cochinchinensis*, however, we could find only one such study (Mishra et al. 2021), that modeled the future prospective distribution scenario, for different Representative Concentration Pathways (RCPs). Considering the socio-economic relevance of *B. cochinchinensis*, we assume that modeling the prospective distribution of *B. cochinchinensis* under the influence of SSP, can project a more realistic scenario (Song et al. 2022). Further, phytosociological evaluation is also important for realizing the relative distribution abundance of this species in the region. We used historical climatic data (1970–2000) and four different types of future climatic scenarios that are SSPs 126, 245, 370 and 585 from the MIROC6 climate model for the year of 2041–2060 to evaluate the habitats suitable for *B. cochinchinensis*. Analyzing probable distribution scenarios with respect to its current phytosociological status, can provide better insights in determining prospective distribution scenarios for a species (Wani et al. 2021). The previous study lacks these aspects and we intend to fill these gaps. The present study aims to (i) study and assess the distribution abundance of *B. cochinchinensis*(ii) model the potential distribution range of *B. cochinchinensis* for the current and future scenario for different SSPs; (iii) Correlation of the habitat suitability with the phytosociological for *B. cochinchinensis*. It is expected that the outcome of the study will provide better insights to the current vegetation scenario of the region, especially of *B. cochinchinensis* and its response to diverse socioeconomic scenarios.

2 Materials and Methodology

2.1 Study Area:

The study area lies between 83° E to 90° E latitude and 21° N to 28° N longitude (Fig. 1) and is surrounded by Bhutan, Nepal and Bangladesh. The study area features diverse landforms, including hills, plateaus, plains, and the Bay of Bengal coastline (Garai et al. 2022). The Great Himalayan Range located in the northern portion and the Sundarbans in the southern portion of the study area are the regions of global importance. Tropical dry and moist deciduous forests, subtropical woods, and subtropical broad-leaved montane forests are the predominant forest types in the region (Sharma et al. 2022). The central part is primarily a plateau, and has a prominent tribal population, and is a mineral hotspot of the country. Consequently, it is the most land-degraded part of the country. Being tribal dominated, Non Timber Forest Products (NTFP) are a major source of livelihood support to the majority of the marginal population settled in the forest fringe.

2.2 Field Survey

We used multistage stratified sampling to collect *B. cochinchinensis* geographical locations from forest and agricultural landscapes in the study area during the pre and post-monsoon months of 2020–2022. Trees with DBH > 30 cm at 1.37 m above ground were GPS-tagged (Swayze and Tinkham 2022). We preferred strong canopy cover, no stagheads, injuries, or root-exposed trees for recording coordinates using the GPS (Garmin etrex 30x) with an accuracy of ± 8. We used 10m x 10m grids to survey forest ranges using the Nested Quadrat Method (Misra 1968). Spatial thinning of occurrence data has been done to significantly reduce the sampling bias (Aiello-Lammens et al. 2015). Overall 249 ground points were used for the *B. cochinchinensis* occurrence. To physically validate the modeled area of *B. cochinchinensis*, we randomly visited 47 locations. These locations were not part of prior field surveys.

2.3 Bioclimatic variables and habitat modeling

We used WorldClim version 2.1 bioclimatic data from Bio_1 to Bio_19 (Table S1) with a spatial resolution of 30 arc seconds (~ 1 km) (Fick and Hijmans 2017) for current and future scenarios, acquired from the WorldClim site (http://www.worldclim.org). Current statistics represent an average of 1970–2000, whereas future data span 2041–2060. As a proxy to future socioeconomic scenarios, we used Shared Socio-economic Pathways (SSPs) i.e. 126, 245, 370 and 585 from the Coupled Model Intercomparison Project phase 6 (CMIP6). The Global Climate Model (GCM), Model for Interdisciplinary Research on

Climate 6 (MIROC6) was employed (Sharma et al 2022) to model the potential habitat distribution of *B. cochinchinensis*.

To avoid model over-fitting (Profirio et al. 2014), highly correlated variables were removed using multicollinearity tests. Pearson's R value 0.8 was considered as a threshold (Yadav et al. 2021). We evaluated the probable distribution zone of *B. cochinchinensis* using Maximum Entropy (MaxEnt) version 3.4.4 (Phillips et al. 2022). Numerous studies (Padalia et al. 2014; Elith et al. 2006; Panda et al. 2018) have shown that Maxent is the most resilient and accurate tool to model species habitat We clipped the bioclimatic data using the study area shape file and converted it into the American Standard Code for Information Interchange (ASCII) format. We arranged all data in the same projection system and uniform geographical extent to successfully run the model. We considered all the model parameters stated by Phillips (2017). The mean test AUC for the 15 times replicate runs was 0.853 (Fig. S1) with a standard deviation of 0.014. Maxent algorithm defines the model accuracy performance through the AUC (Area Under Curve) value under the ROC (Receiver Operating Characteristic) curve. It determines the continuity of the model using the trial data (Peterson 2006; Lobo et al. 2008). The most contributing variable was determined using the Jackknife test (Fig. S2). The test evaluates which bioclimatic variable contributes most in limiting the distribution of species under the consideration (Young et al. 2011). Figure 2 demonstrates the ROC curve for the most contributing variable Bio_8.

2.4 Calculation of Importance Value Index (IVI):

The number of species and the ratio in which each species is geospatially dispersed in any community are the most prevalent expressions of any ecosystem which can be measured by calculating the Importance Value Index (IVI) of the occurring species (Vidhyarthy 2011). Sample quadrates of 10m X 10m were laid down in Tropical moist deciduous forests and Tropical dry deciduous forests, respectively, to assess tree species diversity. We further analyzed the recorded data quantitatively for calculating frequency, density, dominance and the relative values of these parameters (Curtis 1959; Misra 1968). Importance Value Index (IVI) of the available tree species (Mueller-Dombois and Ellenberg 1974) was calculated based on species dominance because it has been demonstrated to be more appropriate when calculating IVI for tree communities with greater girth (Bhadra and Pattanayak 2017). Shannon-Wiener index (Shannon and Weiner 1963), Simpson’s index of diversity (Simpson 1949) and Pielou’s Evenness index (Pielou 1966) for both forest types were calculated.

2.5 TSS Analysis

We further evaluated the model efficacy using, the overall accuracy, True Skill Statistics (TSS) and kappa statistics. TSS normalizes the overall accuracy by the accuracy that would have happened by chance solitary. TSS values > 0.6 represent good to excellent performance (Komac et al. 2016), and imply a greater agreement between the observed and anticipated species distribution (Allouche et al. 2006). Kappa statistics vary from − 1 to + 1, where + 1 indicates perfect agreement (Cohen 1960). The calculated TSS value of 0.58 (Table S2), along with overall statistics of 89% and kappa value of 1, indicates good model performance.

3 Results

3.1 Projected distribution range of *B. cochinchinensis* for the current scenario

The study exhibited a prominent distribution of suitable habitat of *B. cochinchinensis* in the central and southern part of the study area. The study showed that 28313 sq km (~ 10.7% of the total geographical area of the study region) is currently suitable for *B. cochinchinensis* habitat. The majority of the ~ 25611 sq km distribution area is located in the central and southern regions. Study also showed a sporadic distribution in the northern part (Fig. 3a). The modeled potential sites ranged between ~ 33 to 1,225 meters elevation (Fig. S4). The LULC wise distribution analysis revealed that the majority of suitable habitat ~ 61% occurred under the vegetation class, followed by ~ 25% on cropland (Fig. 3b and Fig. 4).

3.2 Projected distribution range of *B. cochinchinensis* for the future scenario (2050)

The study shows that the potentially suitable habitat of *B. cochinchinensis* is increasing from SSP126 to SSP370, but for the extreme scenario SSP 585(Fig. 5). The model predicted an increase in suitable habitat for *B. cochinchinensis* of ~ 67%, 35.43% and 31.39% for SSP 126, 245 and 370 respectively, but a slight ~ 3% decrease for SSP 585 than the current suitable habitat area (Fig. 6). The distribution pattern depicts southward shifting of habitat, and intensifying in the central and southern part.

3.3 Calculation of Importance Value Index (IVI)

The analysis of the Importance Value Index (IVI) from the collected data revealed that *S. Robusta* showed the highest IVI for the two studied forests (Fig. 7, Fig. 8 and Fig. S3). This result is very much pertinent as both Tropical dry and moist deciduous forests are dominated by the species *S. Robusta* (Sahu et al. 2012). S. robusta demonstrated the greatest Important Value Index (IVI) for the two forests under study, according to the analysis of the data that was gathered (Table S3 and Table S4). This finding is extremely relevant because S. robusta dominates both tropical moist and dry deciduous forests. *B. cochinchinensis*, the species of interest in this study, comes in second place in tropical moist deciduous forests and third place in tropical dry deciduous forests. The importance of *B. cochinchinensis* as a significant companion in the forests of S. robusta is well established. The study area is the natural distribution zone of *S. robusta*, *B. cochinchinensis* and other major species such as *M. longifolia, Lagerstroemia parviflora, Diospyros melanoxylon, Terminalia alata*, and *Casearia tomentos a*re corded through phytosociological study. All of these species are native to the study area and thrive there naturally. But, due to the anthropological and varying climatic conditions most of these species are on decline.

4 Discussion

The study showed a prevalence of potentially suitable sites of *B. cochinchinensis* distribution for the current climatic scenario, in the central and southern part of the study area. The prominent distribution of *B. cochinchinensis* on the modeled locations was consistent with field surveys. The mean temperature of the wettest quarter (Bio_8) contributed the most towards limiting the distribution of *B. cochinchinensis*. The results for the future scenario indicate that the potentially suitable habitats will increase or remain intact across all the SSPs in the central and south-west parts, but will decrease in the south-east portions. Potentially suitable *B. cochinchinensis* modelled sites were primarily located in the relatively drier portion of the study area (Deshmukh and Ganeshani 2013). Thus, it demonstrates its utmost significance in horticulture practices for dry land and the improvement of the wastelands.(Hiwale and Hiwale 2015). The larger picture of the modeled habitat scenario depicts an increase in potentially suitable habitat of *B. cochinchinensis* across all the SSPs. In particular, the study predicts the optimal scenario for potentially suitable habitat under SSP 126. This looks logically agreeable, as SSP 126 portrays a sustainable socioeconomic scenario. Numerous studies have demonstrated the importance of sustaining the use of natural resources (Qi et al. 2022; Cao et al. 2021). For middle SSP pathways SSP245 and SSP370 also, the study showed an increase in the potentially suitable habitat of *B. cochinchinensis.* However, for SSP 585, the overall area may decline slightly. The increase in potentially suitable habitat for middle pathways i.e. SSP 245 and SSP 370 indicate resilience of *B. cochinchnensis* to possible climate change conditions due to increasing socio economic pressure. Yet, resource constraints may cause restricted migration (Benveniste et al. 2022), as increasing anthropogenic pressure is one of the major causes for diminishing natural resources (Vanbergen and IPI 2013). Further, the study demonstrating increase in potentially suitable habitat, only indicates the optimal environmental conditions for growth of *B. cochinchinensis*. Yet, considering its social and medicinal significance (Sharma et al. 2012; Rodríguez et al. 2017) and rising population growth (Pelletier et al. 2019; Sher et al. 2010), the actual scenario of *B. cochinchinensis* distribution may be restricted than its current distribution status. Moreover, other factors such as forest fire (Chowdhury and Hassan 2015) and projected increase in invasive species (Tiwari et al. 2021; Sharma et al. 2022) are also major concerns for native resources.

The analysis revealed southward shifting of potentially suitable habitat of *B. cochinchinensis*, with prominence of distribution may occur in the central part of the study area (Mishra and Tiwari 2018). A similar study on another drought-tolerant species *M. longifolia*, also showed southward shifting of suitable habitat in the eastern Indian region(Garai et al. 2021). Numerous studies focused on the responses of species to climate change have shown evidence of habitat shifts (McHenry et al. 2019; Hazen et al. 2013; Liu and Mai 2022; Hu and Dong 2022, Mohammad et al. 2022).

The *B. cochinchinensis* IVI value shows that it grows well in both tropical dry deciduous forests and tropical moist forests. The higher IVI rank of *B. Cochinchinensis* in tropical dry deciduous forests corroborates its arid tolerance (Biswas and Khan 2011). The phytosociological analysis showed, *B. cochinchinensis* is one of the major associates of *S. robusta*, which is the most dominating species in the study area (Kumar and Saikia 2020). The overlapping of prospective suitable habitat areas with IVI value points to better growth conditions for *B. cochinchinensis*.

Previous research indicates that climate change (Ellwood et al. 2013) and socioeconomic factors (Ray et al. 2015) have caused *B. cochinchinensis* to migrate. Due to diminishing vegetation, forests are also experiencing land degradation stress (Chalise et al. 2019; Solomun et al. 2018). Considering the resilience of *B. cochinchinensis* to degraded lands (Rajput et al. 2018), conserving and promoting *B. cochinchinensis* in such areas can help address the land degradation. These initiatives should adopt a mixed plantation strategy in addition to soil moisture conservation measures. The high distribution *B. cochinchinensis* was primarily found in mixed natural landscapes. Especially, the Palamau Tiger Reserve (PTR) being a protected site, consists of a notable distribution of *B. cochinchinensis*. We did not find the presence of *B. cochinchinensis* in the isolation along the agriculture fields or homestead. This points out that isolated patches are more vulnerable to human and climatic stress (Benchimol and Peres, 2015).

Overall, the study demonstrated the robust resilience of *B. cochinchinensis* to diverse socioeconomic scenarios. Correlating, the modeled suitable habitat to phytosociological study and physical validation (Boral and Moktan 2021; Wani et al. 2021) of the potentially projected sites was the major strength of the current study. Physical validation of modeled suitable habitats was another strength of this study. The study showed *B. cochinchinensis* as the main associate of*S. Robusta* and grows well in mixed populations.Present study projected the potential suitable habitats of *B. cochinchinensis* using the SSP pathways. Considering the wide use of *B. cochinchinensis* in the food industry and for medical purposes, the future distribution scenario with respect to the expected SSP scenarios portrays a more realistic picture and adds to technical strength of the study (Zhang et al. 2022; Song et al. 2022). Given the predicted vigorous resilience of *B. cochinchinensis* to climate change, an ex-situ strategy can be adapted to further introduce *B. cochinchinensis* to sites deemed suitable by the present study. The projection of suitable sites enables better decision making for introducing species into a new area. Another implication is identification of distribution patches established through the extensive field surveys. The information on healthy patches enables collection of superior germplasm for propagation activities (Degrande et al. 2013). The prospective shifting of habitats projected by the current and other comparable research contributes in terms of comprehending the anticipated future alteration of the region's biological composition and ecosystem services (Inague et al. 2021). The information generated from the study also contributes to the environmental security framework (Zurlini and Müller 2008). Taking into account the drought resistance of *B. cochinchinensis*, the extension of its habitat, especially in the middle portion of the study region, points to prospective future prevalence of drought conditions in this part.This region of the country has the most degraded land conditions (Chamberlain 2013).

Although predictive modeling offers a practical approach for identifying the future potential migration hot-spots, yet considering the local physical factors would provide a more realistic and locally adaptable strategy (Horton et al. 2021). Considering the coarser resolution of the bioclimatic variables, the modeled area may be exaggerated. Moreover, land use change, anthropogenic influences, and invasion does not seem to decrease, thus including these elements can provide a more realistic assessment. The current study examined the potential habitat response of *B. cochinchinensis* using a single climatic scenario, MIROC6; however, adopting an ensemble approach could provide more precise estimates. Nevertheless, addressing such symptoms caused due to anthropogenic influences and climate related concerns and adopting a sustained approach is crucial for biodiversity conservation and livelihood support to indigenous people and communities living in forest fringe. In light of the rapidly changing socioeconomic scenarios, the study offers further scope for deploying SSPs to address diverse ecological and social studies.

5 Conclusion

The study found *B. cochinchinensis* resilient to climate change and highlighted its latent prospects in terms of its drought and degraded land tolerance potential. The study indicated that by 2050, the suitable habitat of *B. cochinchinensis*, will largely expand with prominence in the central part and shift southward.The species naturally occurs in forest landscape primarily as the major associate of *S. robusta.* However, the species' tendency to coexist with naturally occurring forest species offers a barrier to its cultivation or introduction in suitable forest regions, as a significant part of its highly suited habitat has been degraded. It is crucial to address these concerns to achieve healthier ecosystems and preserve ecosystem services indispensable to the indigenous peoples and communities. In order to prevent the continued depletion of natural resources, land management and conservation strategies focusing on natural landscapes are recommended.

Declarations

Acknowledgement

The authors gratefully acknowledge the financial assistance provided by CAMPA fund (Ministry of Environment, Forest and Climate change) under FGR (Forest Genetic Resources) [Sanction Order No.75/2019/ICFRE (R)/RP/SFRESPE (CAMPA)/FGR/Main File/ 55 dated:10/01/2020]. Authors sincerely acknowledge the Director, the Institute of Forest Productivity, Ranchi for providing institutional support. Authors also acknowledge the administrational assistance provided by the officials of the Jharkhand, Bihar, West Bengal State Forest Department during the field surveys. We acknowledge the resources and services provided by the WorldClim (https://www.worldclim.org/data/cmip6/cmip6climate.html), Diva GIS (https://www.diva-gis.org/) data site and the open-source MAXENT software.

Statements and Declarations

Funding

Authors gratefully acknowledge the receipt of research grant from National Authority Compensatory Afforestation Fund Management, (CAMPA) through Ministry of Environment, Forest and Climate Change, New Delhi, Government of India, [Sanction Order No.75/2019/ICFRE (R)/RP/SFRESPE (CAMPA)/FGR/Main File/ 55 dated:10/01/2020] for the work reported herein.

Conflict of Interest

Authors declare no conflict of interest.

Authors Contribution

All the authors of this manuscript have contributed towards its conceptualization, designing and implementation. Material preparation, field data collection and analysis were performed by Sanjoy Garai, Yogeshwar Mishra, Ayushman Malakar, Rikesh Kumar. The first draft of the manuscript was written by Sanjoy Garai, Ayushman Malakar, Ronak Singh and Jassi Sharma. Sharad Tiwari supervised the entire manuscript writing and edited the document. All manuscripts are finally approved by all the authors.

Data Availability Statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

References

1. Acácio V, Dias FS, Catry FX, Rocha M, Moreira F (2017) Landscape dynamics in Mediterranean oak forests under global change: understanding the role of anthropogenic and environmental drivers across forest types. Global change biology, *23*(3), 1199–1217. https://doi.org/10.1111/gcb.13487
2. Aiello-Lammens ME, Boria RA, Radosavljevic A, Vilela B, Anderson RP (2015) spThin: an R package for spatial thinning of species occurrence records for use in ecological niche models. Ecography, *38*(5), 541–545. https://doi.org/10.1111/ecog.01132
3. Allouche O, Tsoar A, Kadmon R (2006) Assessing the accuracy of species distribution models: prevalence, kappa and the true skill statistic (TSS). J. Appl. Ecol. 43 (6), 1223–1232. https://doi.org/10.1111/j.1365-2664.2006.01214.x
4. Avani P, Bauri FK, Sarkar SK (2019) Chironji: a golden nut fruit of Indian tribes. ActaHotic., *1241*, 37–42. https://doi.org/10.17660/ActaHortic.2019.1241.6
5. Beltrán-Rodríguez L, Manzo-Ramos F, Maldonado-Almanza B, Martínez-BallestéA, Blancas J (2017) Wild medicinal species traded in the Balsas Basin, Mexico: risk analysis and recommendations for their conservation. Journal of Ethnobiology, *37*(4), 743–764. https://doi.org/10.2993/0278-0771-37.4.743
6. Benchimol M, Peres CA (2015) Edge-mediated compositional and functional decay of tree assemblages in Amazonian forest islands after 26 years of isolation. Journal of Ecology, *103*(2), 408–420. https://doi.org/10.1111/1365-2745.12371
7. Benveniste H, Oppenheimer M, Fleurbaey M (2022) Climate change increases resource-constrained international immobility. Nature Climate Change, *12*(7), 634–641. https://doi.org/10.1038/s41558-022-01401-w
8. Bhadra AK, Pattanayak SK (2017) Dominance is more justified than Abundance to calculate Importance Value Index (IVI) of plant species. Asian Journal of Science and Technology, *8*(2), 4304–

4326.

9. Biswas S, Khan DK (2011) Habitat fragmentation and nutrient dynamics in tropical dry deciduous forests of West Bengal, India. ARPN Journal of Science and Technology, *2*(Special Issue), 109–119.
10. Boral D, Moktan S (2021) Predictive distribution modeling of Swertia bimaculata in Darjeeling-Sikkim Eastern Himalaya using MaxEnt: current and future scenarios. Ecological Processes, *10*(1), 26. https://doi.org/10.1186/s13717-021-00294-5
11. Cao Z, Zhang L, Zhang X, Guo Z (2021) Predicting the potential distribution of Hylomecon japonica in China under current and future climate change based on Maxent model. Sustainability, *13*(20), 11253. https://doi.org/10.3390/su132011253
12. Chalise D, Kumar L, Kristiansen P (2019) Land degradation by soil erosion in Nepal: A review. Soil systems, *3*(1), 12. https://doi.org/10.3390/soilsystems3010012
13. Chamberlain S (2013) Socio-Economic Development in India's Jharkhand: An Analysis of the Influence of Coal Mining. *Available at SSRN 2386181*. http://dx.doi.org/10.2139/ssrn.2386181
14. Chauhan PS, Jitendra S, Kavita A (2012) Chironjee: a promising tree fruits of dry subtropics. HortFlora Research Spectrum, *1*(4), 375–379.
15. Chitale VS, Behera MD (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. http://www.jstor.org/stable/24107755.
16. Chowdhury EH, Hassan QK (2015) Operational perspective of remote sensing-based forest fire danger forecasting systems. ISPRS Journal of Photogrammetry and Remote Sensing, *104*, 224–236. https://doi.org/10.1016/j.isprsjprs.2014.03.011
17. Cohen J (1960) A coefficient of agreement of nominal scales. Educational and Psychological Measurement, 20, 37–46. https://doi.org/10.1177/001316446002000104
18. Curtis JT (1959) *The vegetation of Wisconsin: an ordination of plant communities*. University of Wisconsin Pres.
19. Dai Y, Ye WC, Wang ZT, Matsuda H, Kubo M, But PPH (2002) Antipruritic and antinociceptive effects of Chenopodium album L. in mice. Journal of ethnopharmacology, *81*(2), 245–250. https://doi.org/10.1016/S0378-8741(02)00096-X
20. Deb JC, Phinn S, Butt N, McAlpine CA (2017) The impact of climate change on the distribution of two threatened Dipterocarp trees. EcolEvol 7(7):2238–2248. https://doi.org/10.1002/ece3.2846
21. Degrande A, Tadjo P, Takoutsing B, Asaah E, Tsobeng A, Tchoundjeu Z (2013) Getting trees into farmers' fields: success of rural nurseries in distributing high quality planting material in Cameroon. Small-scale forestry, *12*(3), 403–420. https://doi.org/10.1007/s11842-012-9220-4
22. Deshmukh AS, Ganeshani G (2013) Kalmkari—an eco-friendly approach for sustainable fashion development. Int J TheorApplSci, *5*(1), 84–87.
23. Elith J, Graham CH, Anderson RP, Dudik M, Ferrier S, Guisan A, Hijmans RJ, Huettmann F, Leathwick JR, Lehmann A, Li J, Lohmann LG, Loiselle BA, Manion G, Moritz C, Nakamura M, Nakazawa Y,

Overton JM, Peterson AT, Phillips SJ, Richardson K, Scachetti-Pereira R, Schapire RE, Soberon J, Williams S, Wisz MS, Zimmermann NE (2006) Novel methods improve prediction of species distributions from occurrence data. Ecography 29:129–151. https://doi.org/10.1111/j.2006.0906-7590.04596.x

24. Ellwood ER, Temple SA, Primack RB, Bradley NL, Davis CC (2013) Record-breaking early flowering in the Eastern United States (edHérault B). PLoS ONE, 8, e53788. https://doi.org/10.1371/journal.pone.0053788
25. Fick SE, Hijmans RJ (2017) WorldClim 2: new 1-km spatial resolution climate surfaces for global land areas. Int J Climatol 37(12):4302–4315. https://doi.org/10.1002/joc.5086
26. Garai S, Khatun M, Singh R, Sharma J, Pradhan M, Ranjan A, Rahaman SM, Khan ML, Tiwari S (2022) Assessing correlation between Rainfall, normalized difference Vegetation Index (NDVI) and land surface temperature (LST) in Eastern India. Safety in Extreme Environments, 1–9. https://doi.org/10.1007/s42797-022-00056-2
27. Garai S, Ranjan A, Rahaman SK, Khatun M, Kumar R, Kumar B, Mishra SN, Tiwari S (2021) Climate change and habitat adaptability of Madhuca longifolia (j. koenig ex L.) jfmacbr.: An endangered tree species of high socio-economic significance to tribal community of eastern India. Indian Journal of Ecology, *48*(4), 1062–1067.
28. Ghosh BG, Garai S, Rahaman SM, Khatun M, Mohammad N, Mishra Y, Ranjan A, Tiwari S (2021) Assessing potential habitat distribution range of the endangered tree species Pterocarpus marsupium Roxb. Under the climate change scenario in India. Trees, Forests and People, *6*, 100124. https://doi.org/10.1016/j.tfp.2021.100124
29. Hazen EL, Jorgensen S, Rykaczewski RR, Bograd SJ, Foley DG, Jonsen ID, Shaffer SA, Dunne JP, Costa DP, Crowder LB, Block BA (2013) Predicted habitat shifts of Pacific top predators in a changing climate. Nature Climate Change, 3(3), 234–238. https://doi.org/10.1038/nclimate1686
30. Hickling R, Roy DB, Hill JK, Thomas CD (2005) A northward shift of range margins in British Odonata. Global change biology, 11(3), 502–506. https://doi.org/10.1111/j.1365-2486.2005.00904.x
31. Hiwale S, Hiwale S (2015) Chironji (Buchanania lanzan Spreng.). *Sustainable horticulture in semiarid dry lands*, 247–253. https://doi.org/10.1007/978-81-322-2244-6_17
32. Horton RM, de Sherbinin A, Wrathall D, Oppenheimer M (2021). Assessing human habitability and migration. Science, *372*(6548), 1279–1283.
33. Hu LS, Dong YW (2022) Northward shift of a biogeographical barrier on China's coast. Diversity and Distributions, 28(2), 318–330. https://doi.org/10.1111/ddi.13463
34. Inague GM, Zwiener VP, Marques MC (2021) Climate change threatens the woody plant taxonomic and functional diversities of the Restinga vegetation in Brazil. Perspectives in Ecology and Conservation, *19*(1), 53–60. https://doi.org/10.1016/j.pecon.2020.12.006
35. Kala CP (2009) Aboriginal uses and management of ethnobotanical species in deciduous forests of Chhattisgarh state in India. Journal of Ethnobiology and Ethnomedicine, *5*(1), 1–9. https://doi.org/10.1186/1746-4269-5-20

36. Komac B, Esteban P, Trapero L, Caritg R (2016) Modelization of the current and future habitat suitability of Rhododendron ferrugineum using potential snow accumulation. PLoS One, *11*(1), e0147324. https://doi.org/10.1371/journal.pone.0147324
37. Kraemer BM, Pilla RM, Woolway RI, Anneville O, Ban S, Colom-Montero W, Devlin SP, Dokulil MT, Gaiser EE, Hambright KD, Hessen DO, Higgins SN, Johnk KD, Keller W, Knoll LB, Leavitt PR, Lepori F, Luger MS, Maberly SC, Muller-Navarra DC, Paterson AM, Pierson DC, Richardson DC, Rogora M, Rusak JA, Sadro S, Salmaso N, Schmid M, Silow EA, Sommaruga R, Stelzer JAA, Straile D, Thiery W, Timofeyev MA, Verburg P, Weyhenmeyer GA, Adrian R (2021) Climate change drives widespread shifts in lake thermal habitat. Nature Climate Change, 11(6), 521–529. https://doi.org/10.1038/s41558-021-01060-3
38. Kumar A, Kumar A, Saikia P, Adhikari D, Ravikant G, Khan ML (2020) Ecological Niche modeling for assessing potential distribution of Pterocarpus marsupium Roxb. in Ranchi, East India. Ecol Res 35:1095–1105. https://doi.org/10.1111/1440-1703.12176
39. Kumar R, Saikia P (2020) Forest Resources of Jharkhand, Eastern India: Socio-economic and Bio-ecological Perspectives. In: Roy, N., Roychoudhury, S., Nautiyal, S., Agarwal, S., Baksi, S. (eds) Socio-economic and Eco-biological Dimensions in Resource use and Conservation. Environmental Science and Engineering(). Springer, Cham. https://doi.org/10.1007/978-3-030-32463-6_4
40. Liu G, Mai J (2022) Habitat shifts of Jatropha curcas L. in the Asia-Pacific region under climate change scenarios. Energy, 251, 123885. https://doi.org/10.1016/j.energy.2022.123885
41. Lobo JM, Jimenez-Valverde A, Real R (2008) AUC: a misleading measure of the performance of predictive distribution models. Glob Ecol Biogeogr 17:145–151. https://doi.org/10.1111/j.1466-8238.2007.00358.x
42. Malakar A, Sahoo H, Kumar A (2022) Commercial cultivation procedure of Chironji (*Buchanania cochinchinensis* (Lour.) M.R. Almedia): A money spinning native tree species of India. *IJHESM, 3*(1), 1–14. http://dx.doi.org/10.13140/RG.2.2.25073.76646/1
43. Malakar A, Sahoo H, Sinha A, Kumar A (2023) Necessity of genetic diversity study and conservation practices in chironji (Buchanania cochinchinensis (Lour.) MR Almedia). Environment Conservation Journal, *24*(1), 253–260. https://doi.org/10.36953/ECJ.12802358
44. McHenry J, Welch H, Lester SE, Saba V (2019) Projecting marine species range shifts from only temperature can mask climate vulnerability. Global Change Biology, 25(12), 4208–4221. https://doi.org/10.1111/gcb.14828
45. Melles SJ, Fortin MJ, Lindsay K, Badzinski D (2011) Expanding northward: influence of climate change, forest connectivity, and population processes on a threatened species' range shift. Global Change Biology, 17(1), 17–31. https://doi.org/10.1111/j.1365-2486.2010.02214.x
46. Mishra SN, Kumar D, Kumar B, Tiwari S (2021) Assessing impact of varying climatic conditions on distribution of *Buchanania cochinchinensis* in Jharkhand using species distribution modeling approach. Current Research in Environmental Sustainability, *3*, 100025. https://doi.org/10.1016/j.crsust.2021.100025

47. Mishra S, Tiwari S (2018) Spatial distribution of Buchanania cochinchinensis in Jharkhand. Biobrio, *5*, 344–353.
48. Misra R (1968) *Ecology Work Book*. Oxford & IBH Publishers. New Delhi, India.
49. Mohammad N, Rahaman SM, Khatun M, Rajkumar M, Garai S, Ranjan A, Tiwari, S (2022) Teak (Tectona grandis Lf) demonstrates robust adaptability to climate change scenarios in central India. *Vegetos*, 1–10. https://doi.org/10.1007/s42535-022-00444-w
50. Mueller-Dombois D, Ellenberg H (1974) *Aims and methods of vegetation ecology*. Wiley, New York.
51. Padalia H, Srivastava V, Kushwaha SPS (2014) Modeling potential invasion range of alien invasive species, Hyptissuaveolens (L.) Poit. in India: comparison of MaxEnt and GARP. Eco Inform 22:36–43. https://doi.org/10.1016/j.ecoinf.2014.04.002
52. Panda RM, Behera MD, Roy PS (2018) Assessing distributions of two invasive species of contrasting habits in future climate. J Environ Manage 213:478–488. https://doi.org/10.1016/j.jenvman.2017.12.053
53. Pearson RG, Dawson TE (2003) Predicting the impacts of climate change on the distribution of species: Are bioclimate envelope models useful. Global Ecology and Biogeography, 12,361–371. https://doi.org/10.1046/j.1466-822X.2003.00042.x
54. Pelletier J, Chidumayo E, Trainor A, Siampale A, Mbindo K (2019) Distribution of tree species with high economic and livelihood value for Zambia. Forest Ecology and Management, *441*, 280–292. https://doi.org/10.1016/j.foreco.2019.03.051
55. Peterson AT (2006) Uses and requirements of ecological niche models and related distributional models. Biodivers Inform. https://doi.org/10.17161/bi.v3i0.29
56. Phillips SJ, Dudik M, Schepire RE (2022) Maxent software for modeling species niches and distributions (version 3.4.4). https://biodiversityinformatics.amnh.org/open_source/maxent/. Accessed on 10 October 2022
57. Phillips SJ (2017) A Brief Tutorial on Maxent. Available from url: http://biodiversityinformatics.amnh.org/open_source/maxent/. Accessed on 2022-12-05
58. Pielou EC (1966) The measurement of diversity in different types of biological collections. Journal of theoretical biology, *13*, 131–144. https://doi.org/10.1016/0022-5193(66)90013-0
59. Prasad S (2020) Chironji (*Buchanania lanzan*): A Retreating Valuable Resource of Central India. International Journal of Bioresource Science, *7*(1), 01–04. https://doi.org/10.30954/2347-9655.01.2020.1
60. Profirio LL, Harris RMB, Lefroy EC, Hugh S, Gould SF, Lee G, Bindoff NL, Mackey B (2014) Improving the use of species distribution models in conservation planning and management under climate change. PLoS ONE 9(11):e113749. https://doi.org/10.1371/journal.pone.0113749
61. Qi S, Luo W, Chen KL, Li X, Luo HL, Yang ZQ, Yin DM (2022) The Prediction of the Potentially Suitable Distribution Area of Cinnamomum mairei H. Lév in China Based on the MaxEnt Model. Sustainability, *14*(13), 7682.https://doi.org/10.3390/su14137682

62. Rajput BS, Gupta D, Kumar S, Singh K, Tiwari C (2018) Buchanania lanzan Spreng (Chironji): A vulnerable multipurpose tree species in Vindhyan region. J Pharmacogn Phytochem, *7*(5), 833–836.

63. Raxworthy C, Martinez-Meyer E, Horning N, Nussbaum R, Schneider G, Ortega-Huerta M, Peterson AT (2003) Predicting distributions of known and unknown reptile species in Madagascar. Nature, 426, 837–841. https://doi.org/10.1038/nature02205

64. Ray D, Behera MD, Jacob J (2015) *Predicting the distribution of rubber trees (Hevea brasiliensis) through ecological niche modeling with climate, soil, topography and socioeconomic factors. Ecological Research, 31(1), 75–91.* doi:10.1007/s11284-015-1318-7

65. Sahu SC, Dhal NK, Mohanty RC (2012) Tree species diversity, distribution and population structure in a tropical dry deciduous forest of Malyagiri hill ranges, Eastern Ghats, India. Tropical Ecology, *53*(2), 163–168.

66. Salinas-de-León P, Andrade S, Arnés-Urgellés C, Bermudez JR, Bucaram S, Buglass S, Cerutti F, Cheung W, Hoz CDL, Hickey V, Jíménez-Uzcátegui G, Keith I, MarínJarrín JR, Martí-Puig P, Medina M, Moya A, Pauly D, Orellana D, Ostergaard-Klem R, Stock C, Witman J, Worm B (2020) Evolution of the Galapagos in the Anthropocene. Nature Climate Change, *10*(5), 380–382. https://doi.org/10.1038/s41558-020-0761-9

67. Shannon CE, Weiner W (1963) *The Mathematical Theory of Communities*. University of Illinois Press, Urbana.

68. Sharma A (2012) Scientific harvesting for quality seed collection of Buchanania lanzan Spreng for its conservation and sustainable management–Case study of Chhindwara, Madhya Pradesh, India. International Journal of Bio-Science and Bio-Technology, *4*(1), 65–74.

69. Sharma J, Singh R, Garai S, Rahaman SM, Khatun M, Ranjan A, Mishra SN, Tiwari S (2022) Climate change and dispersion dynamics of the invasive plant species Chromolaena odorata and Lantana camara in parts of the central and eastern India. Ecological Informatics, *72*, 101824. https://doi.org/10.1016/j.ecoinf.2022.101824

70. Sharma V, Bhardwaj U, Sharma S, Sharma S (2012) Medicinal plants: need for sustainable exploitation (with special reference to Himachal Pradesh). J. Pharm. Res, *5*, 4313–4317.

71. Sher H, Al-Yemeni MN, Masrahi YS, Shah AH (2010) Ethnomedicinal and ethnoecological evaluation of Salvadorapersica L.: a threatened medicinal plant in Arabian Peninsula. J Med Plants Res, *4*(12), 1209–1215.

72. Shukla KML, Khan AA, Khan S, Verma AK (2001) Traditional phototherapy of Maikal range and plateau of Pendra district Bilaspur MP. India Adv Plant Sci. *14*, 11.

73. Siddig AA, Ellison AM, Ochs A, Villar-Leeman C, Lau MK (2016) How do ecologists select and use indicator species to monitor ecological change? Insights from 14 years of publication in Ecological Indicators. Ecological Indicators, *60*, 223–230. https://doi.org/10.1016/j.ecolind.2015.06.036

74. Siddiqui MZ, Chowdhury AR, Prasad N, Thomas M (2014) Buchanania lanzan: a species of enormous potential. World journal of pharmaceutical sciences, 374–379.

75. Simpson EH (1949) Measurement of diversity. Nature, *163*(4148), 688–688. https://doi.org/10.1038/163688a0
76. Singh S, Singh AK, Mishra DS, Saroj PL, AppaRao VV (2018) Chironji is promising fruit for the tribal. Journal of Indian Horticulture, *63*(5), 37–41.
77. Solomun MK, Barger N, Cerda A, Keesstra S, Marković M (2018) Assessing land condition as a first step to achieving land degradation neutrality: A case study of the Republic of Srpska. Environmental Science & Policy, *90*, 19–27. https://doi.org/10.1016/j.envsci.2018.09.014
78. Song YH, Shahid S, Chung ES (2022) Differences in multi-model ensembles of CMIP5 and CMIP6 projections for future droughts in South Korea. International Journal of Climatology, *42*(5), 2688–2716. https://doi.org/10.1002/joc.7386
79. Souza AT, Ilarri M, Campos J, Ribas FO, Marques JC, Martins I (2022) Boom and bust: Simulating the effects of climate change on the population dynamics of a global invader near the edge of its native range. Science of The Total Environment, *851*, 158294. https://doi.org/10.1016/j.scitotenv.2022.158294
80. Swayze NC, Tinkham WT (2022) Application of unmanned aerial system structure from motion point cloud detected tree heights and stem diameters to model missing stem diameters. MethodsX, 101729. https://doi.org/10.1016/j.mex.2022.101729
81. Tiwari S, Ghosh BG, Vaidya SN, Rahaman SM, Khatun M, Garai S, Saikia P, Kumar A (2021) Modeling potentially suitable lac cultivation zones of Butea monosperma to promote livelihood security in rural India. Vegetos, *34*(3), 630–637..https://doi.org/10.1007/s42535-021-00222-0
82. Tiwari S, Mishra SN, Kumar D, Kumar B, Vaidya SN, Ghosh BG, Rahaman SM, Khatun M, Garai S, Kumar A (2022) Modeling the potential risk zone of Lantana camara invasion and response to climate change in eastern India. Ecological Processes, *11*(1), 1–13.https://doi.org/10.1186/s13717-021-00354-w
83. Vanbergen AJ, Initiative TIP (2013) Threats to an ecosystem service: pressures on pollinators. Frontiers in Ecology and the Environment, *11*(5), 251–259. https://doi.org/10.1890/120126
84. Vidhyarthy AK (2011) Studies on important value index (IVI) of important tree species in sal forest of Jharkhand. Journal of Tropical Forestry, *27*(2), 54–60.
85. Wani IA, Verma S, Kumari P, Charles B, Hashim MJ, El-Serehy HA (2021) Ecological assessment and environmental niche modeling of Himalayan rhubarb (Rheum webbianum Royle) in northwest Himalaya. PLoS One, *16*(11), e0259345. https://doi.org/10.1371/journal.pone.0259345
86. Wisz MS, Hijmans RJ, Li J, Peterson AT, Graham CH, Guisan A, NCEAS Predicting Species Distributions Working Group (2008) Effects of sample size on the performance of species distribution models. Diversity and distributions, *14*(5), 763–773. https://doi.org/10.1111/j.1472-4642.2008.00482.x
87. Yadav S, Bhattacharya P, Areendran G, Sahana M, Raj K, Sajjad H (2021) Predicting impact of climate change on geographical distribution of major NTFP species in the Central India Region. Modeling Earth Systems and Environment, *8*(1), 449–468. https://doi.org/10.1007/s40808-020-01074-4

88. Young N, Carter L, Evangelista P (2011) A MaxEnt model v3. 3.3 e tutorial (ArcGIS v10). *Natural Resource Ecology Laboratory, Colorado State University and the National Institute of Invasive Species Science*.
89. Zhang JL, Zhu JJ, Cao KF (2007) Seasonal variation in photosynthesis in six woody species with different leaf phenology in a valley savanna in southwestern China. Trees, *21*(6), 631–643. https://doi.org/10.1007/s00468-007-0156-9
90. Zhang X, Zhao J, Wang M, Li Z, Lin S, Chen H (2022) Potential distribution prediction of Amaranthus palmeri S. Watson in China under current and future climate scenarios. Ecology and Evolution, *12*(12), e9505. https://doi.org/10.1002/ece3.9505
91. Zhongming Z, Linong L, Xiaona Y, Wangqiang Z, Wei L (2020) Shifting habitats. https://doi.org/10.1038/s41558-020-0789-x
92. Zurlini G, Müller F (2008) Environmental security. Encyclopedia of ecology, *2*, 1350–1356.

Figures

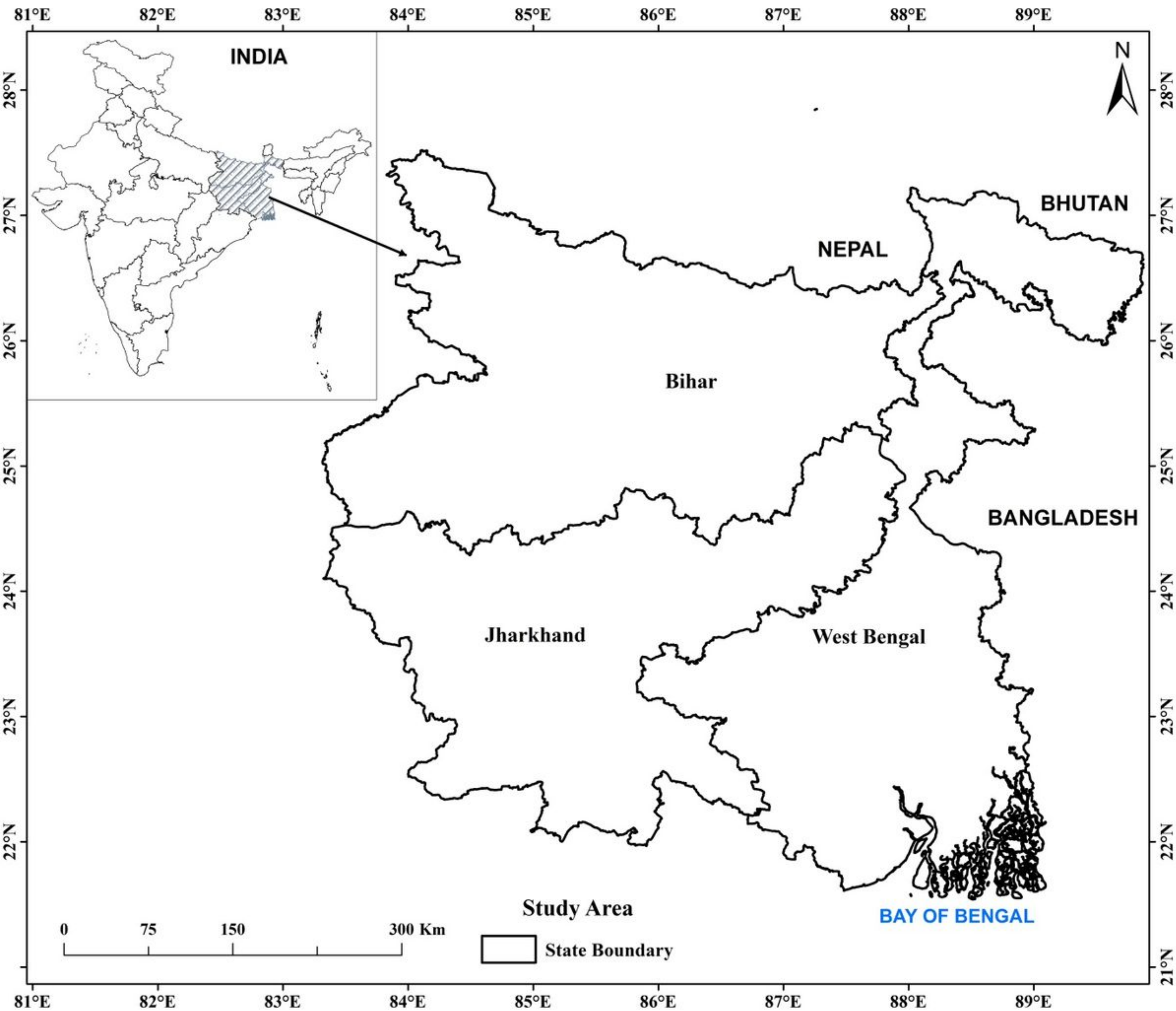

Figure 1

Location map of the study area including state boundary of Jharkhand, Bihar and West Bengal

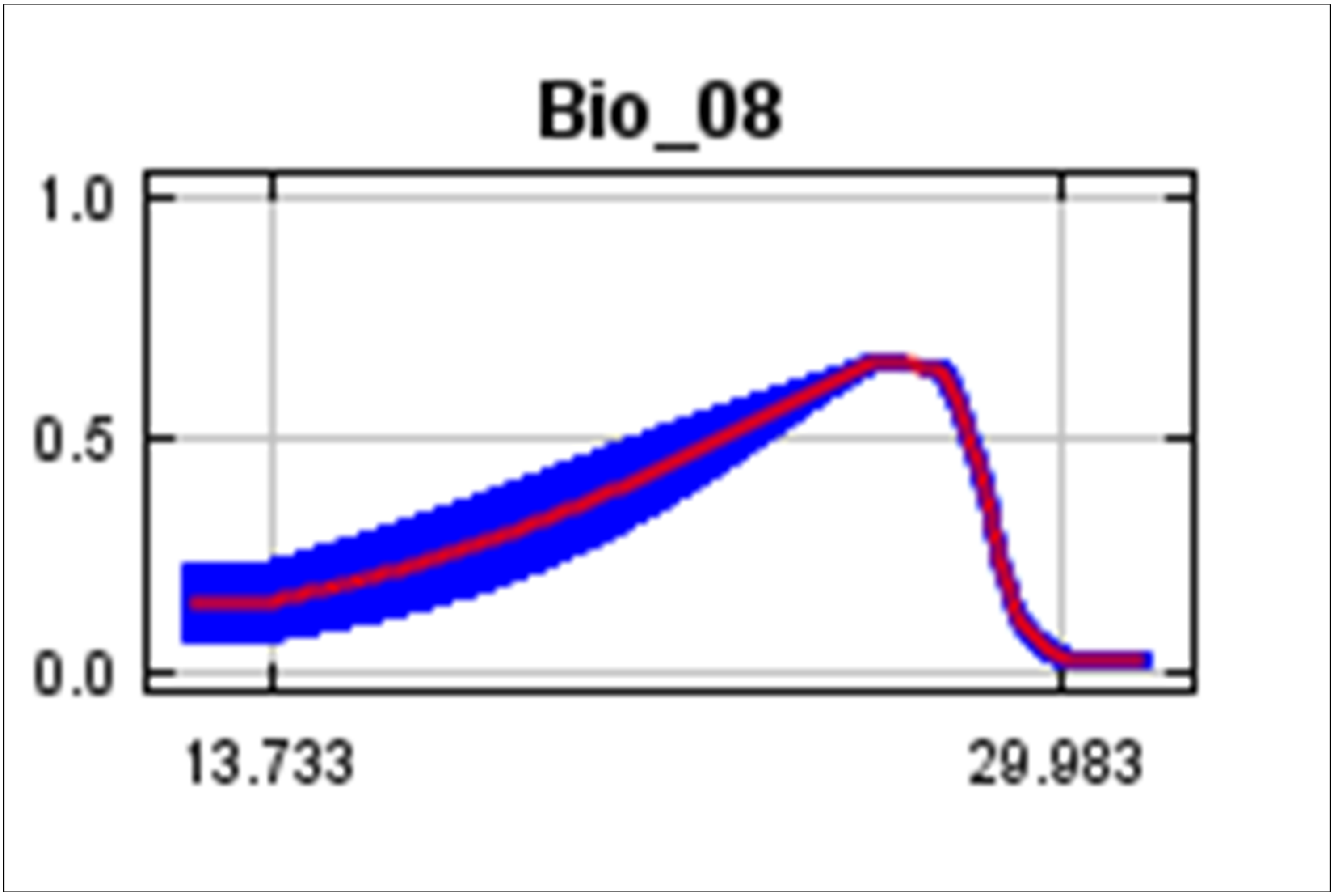

Figure 2

The ROC curve for Bio_08, the most influential variable in restricting the distribution of *B. cochinchinensis*. The graph demonstrates that, value ranging ~ 20 to 27 is most suitable for the distribution of *B. cochinchinensis*. The value initially rises from 13.733 and gains the optimal range between ~20 to 25 before beginning to decline. Bio_08 values greater than 27 fall precipitously to 29.983 before reaching a saturated state.

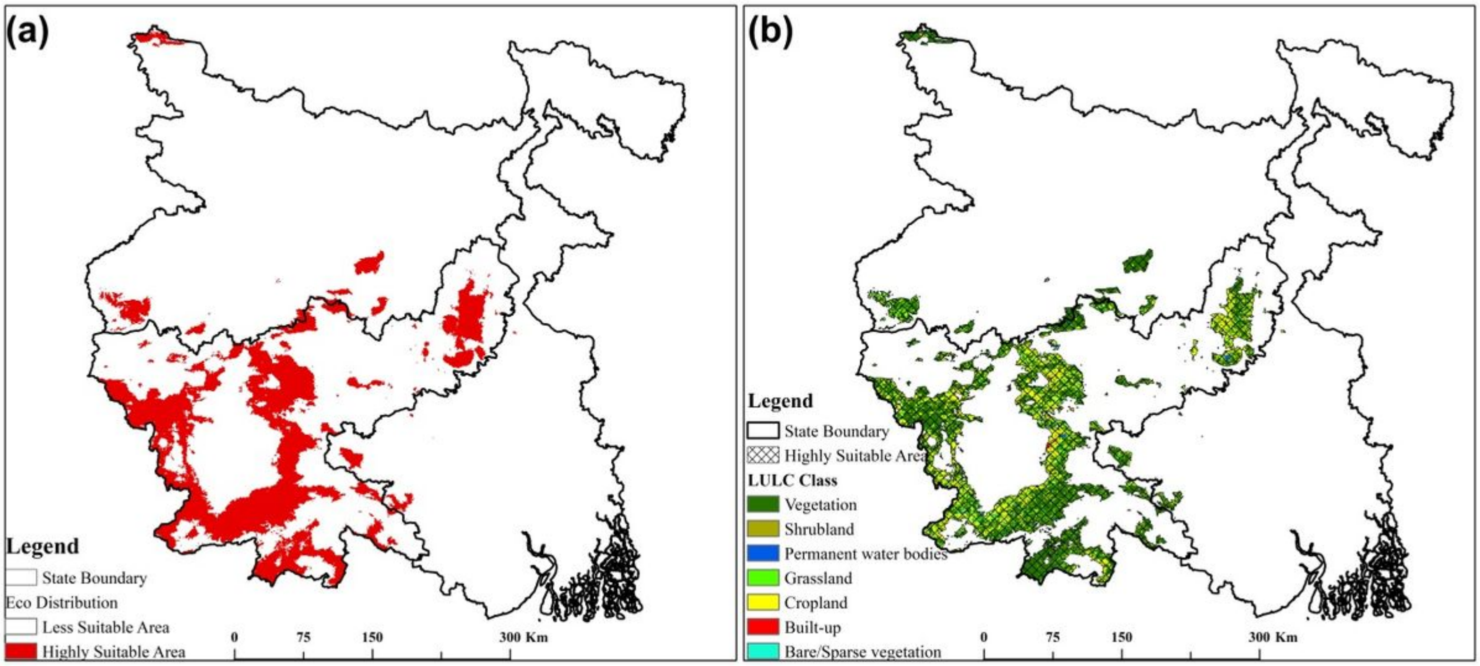

Figure 3

(a) Potential distribution range of *B. cochinchinensis* for current scenario. The map shows the prominence of the potential distribution range of *B. cochinchinensis* in the central and southern part. Few sporadic distributions can also be seen on the northern part. **(b)**The LULC wise map shows suitable habitat range mostly occurring over vegetation and cropland classes.

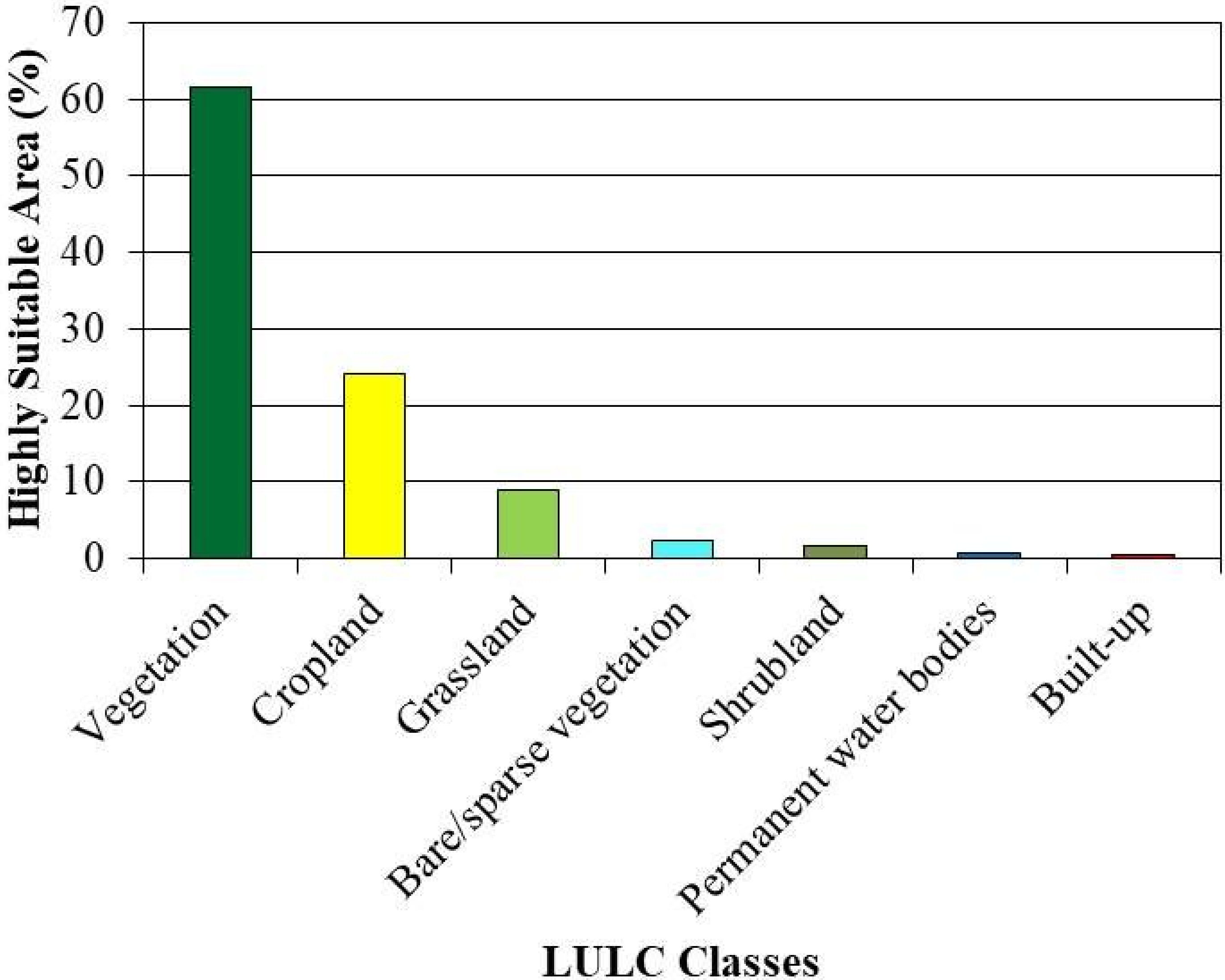

Figure 4

The graph illustrates LULC class wise distribution of potentially suitable habitats of *B. cochinchinensis*

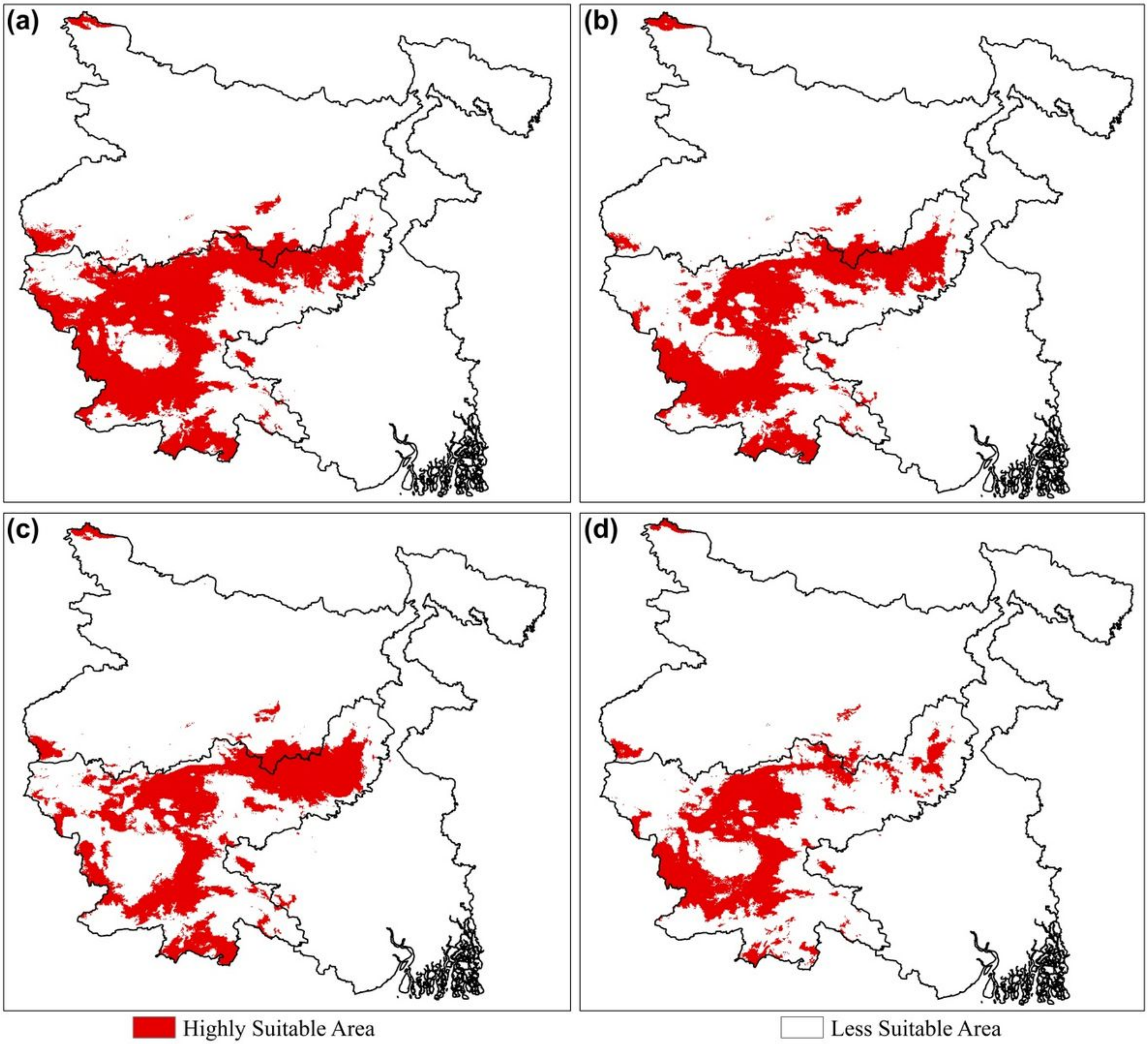

Figure 5

Map showing potential distribution range of *B. cochinchinensis* for 2050 under different SSP pathways (a) SSP 126 (b) SSP 245 (c) SSP 370 (d) SSP 585. The graph demonstrates southward shifting of suitable habitat. The suitable habitat area of *B. cochinchinensis* to increase across scenarios SSP 126, 245, and 345, but decline for SSP 585.

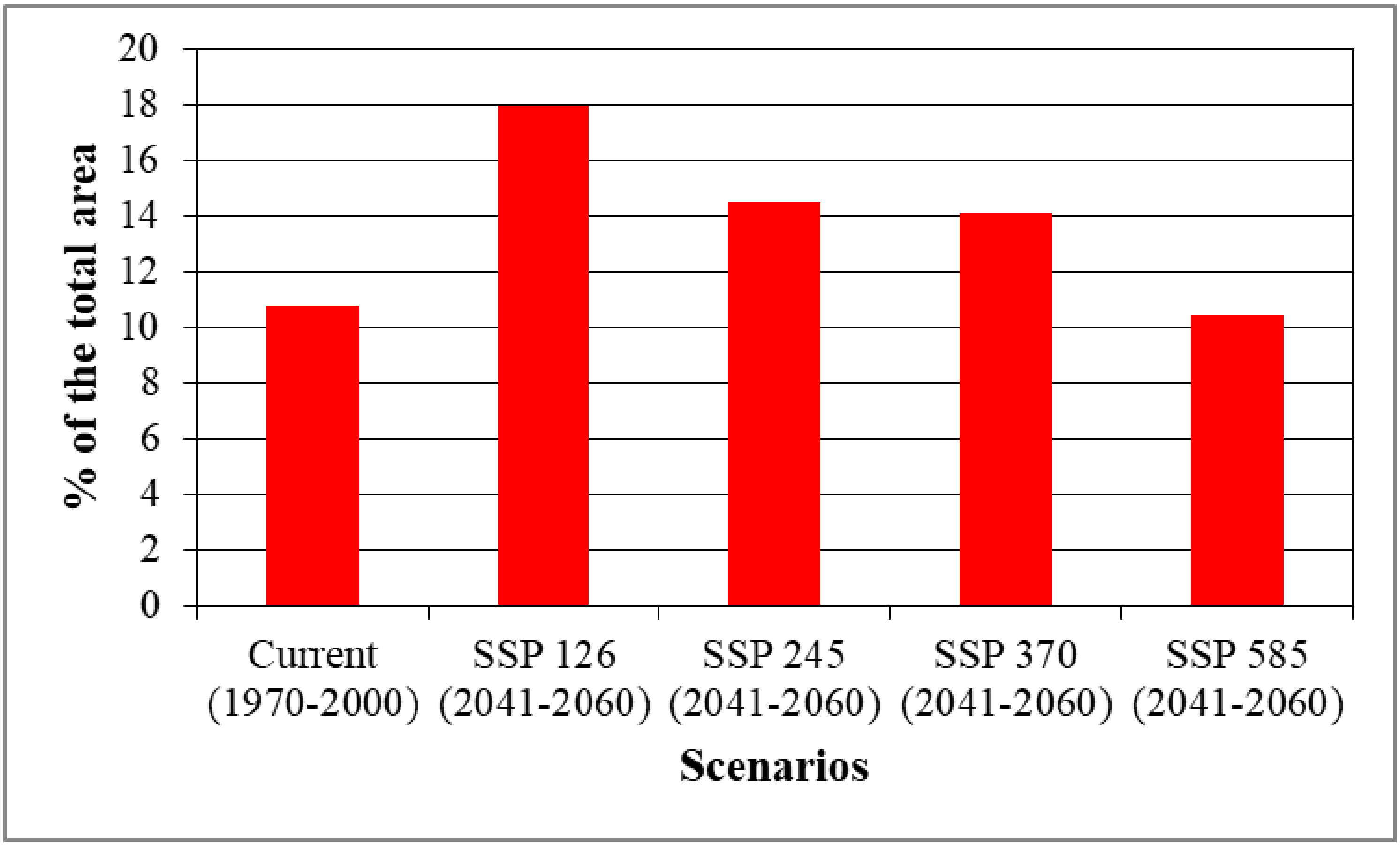

Figure 6

Potentially suitable habitat area of (in percentage) of *B. cochinchinensis* for different shared socioeconomic pathways. By 2050, the suitable habitat area for *B. cochinchinensis* is expected to rise for SSPs 126, 245, and 370, but may slightly decrease for SSP 585, as shown in the graph. The graph depicts the potential for SSP126 to reach its maximal habitat gain.

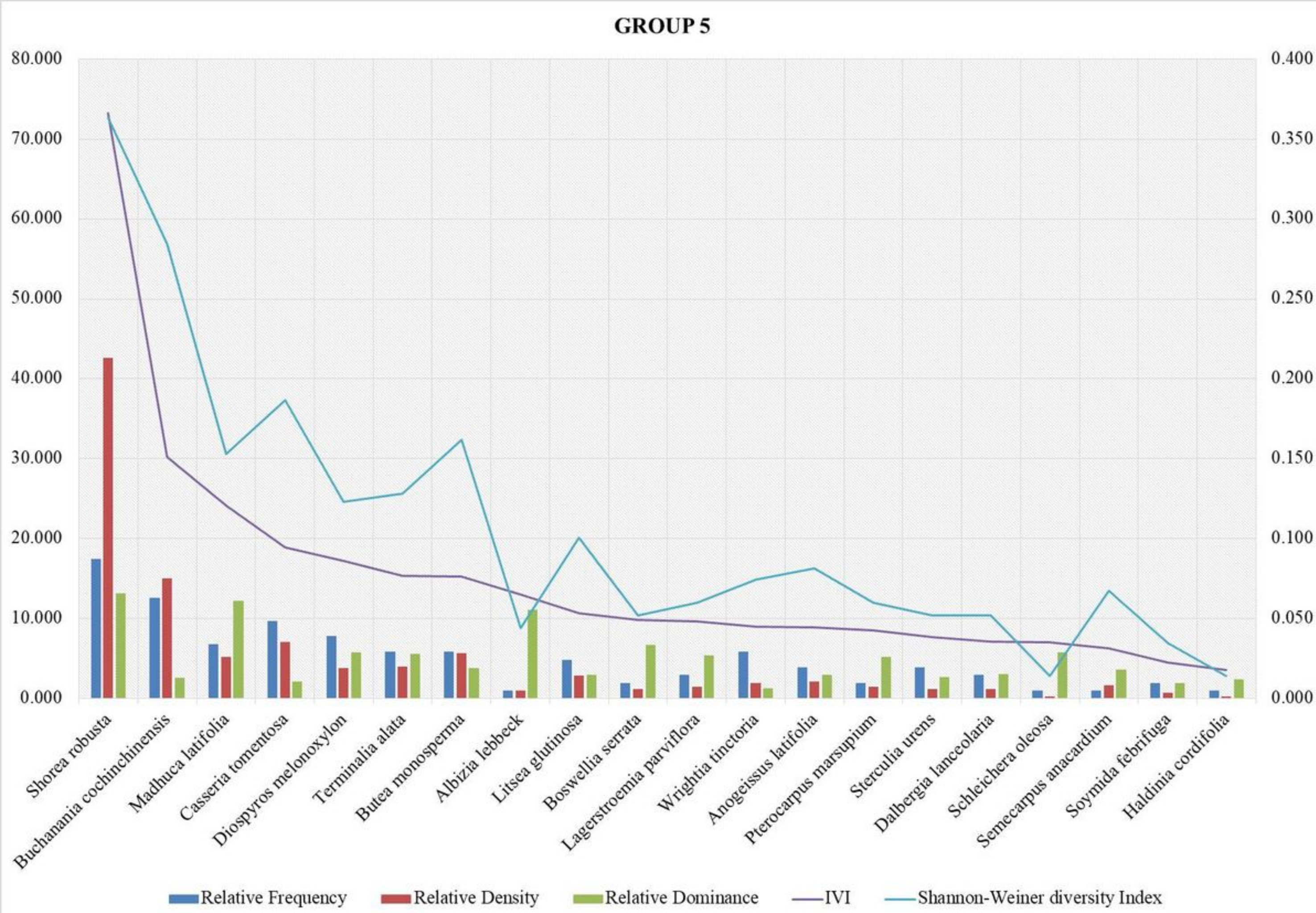

Figure 7

Importance Value Index and Shannon-Weiner diversity Index for tree species available in the study area falling under Tropical dry deciduous forests (Group 5).

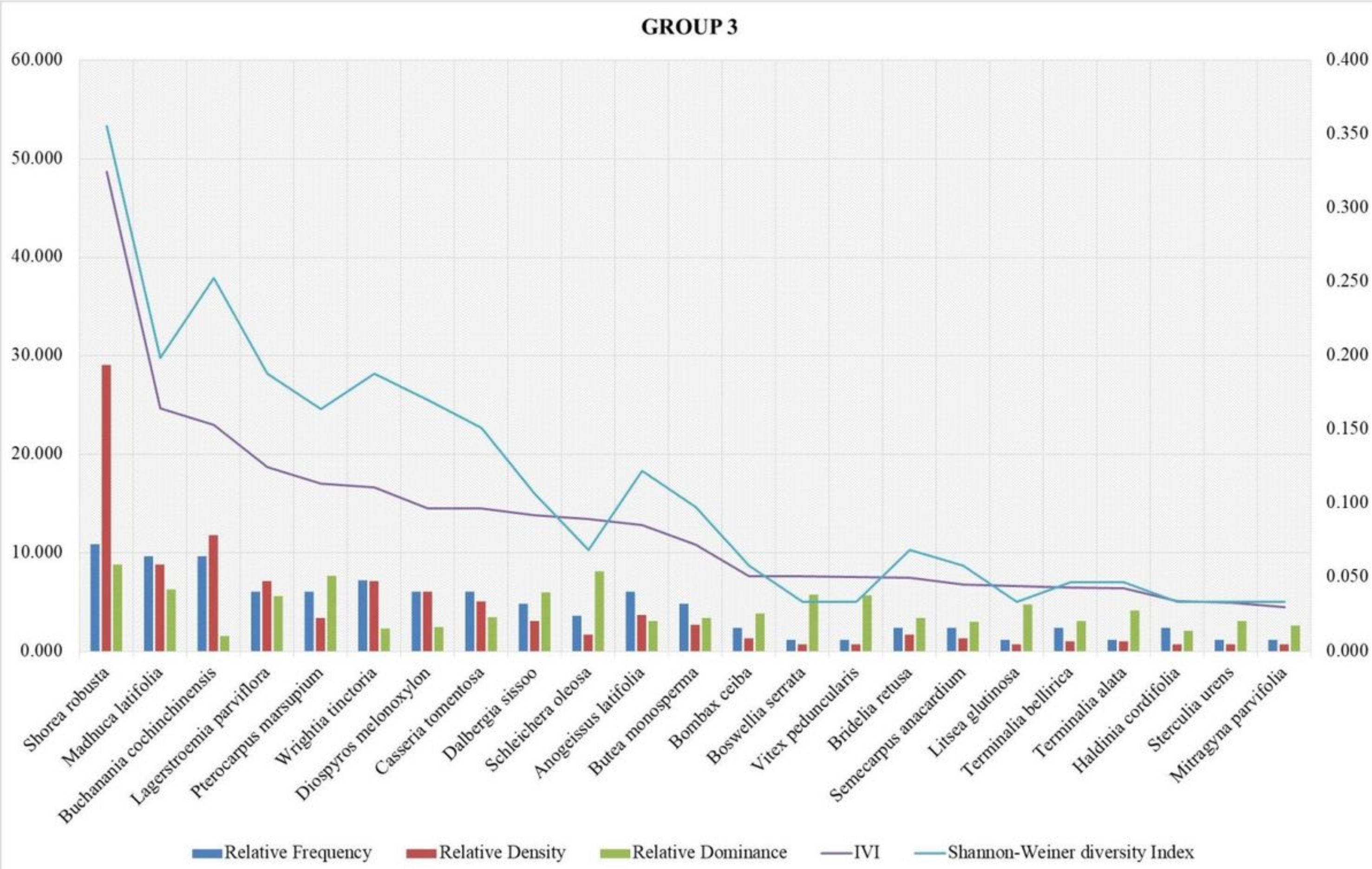

Figure 8

Importance Value Index and Shannon-Weiner diversity Index for tree species available in the study area falling under Tropical moist deciduous forests (Group 3)

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Supplementarymaterial.docx