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Species The Passion 7

St. Thomas College (Autonomous), Thrissur

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"Species The Passion 7"

Editor–in–Chief

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Convenor – "Species the Passion 7"

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Addressing the Limitations of Niche Modelling for Species Distribution Prediction with Reference to the Western Ghats

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Abstract

Ecological Niche modelling has a prime importance in prediction of niche suitability of a species. The study addresses the limitations of Species Distribution Modelling (SDM) using a modified methodology (MSDM) and experimented here with four threatened species of the Western Ghats. The authentic distribution records and bioclimatic variable gives an accurate Maxent-based prediction to the potential habitat of the species. SDM is facing a greater challenge hence it not considering the factors of the Eltonian niche. The incorporation of species associates, altitude and terrain features helps to consider the factors of the Eltonian niche which probably lack in the Species Distribution Modelling (SDM). The study with the support of detailed works affirms here the MSDM is more efficient and suitable for prediction of potential locations for species in the Western Ghats compared to the normal SDM. The coalescence of habitat degradation factors based on vegetation and land use spatial information imparts more precision into the suitability of projected areas. Here, we tested this with the habitat prediction of four threatened species *Cryptocarya anamalayana* Gamble, *Diospyros crumenata* Thwaites, *Prioria pinnata* (Roxb. ex DC.) Breteler, *Orophea erythrocarpa* Bedd. which occupies a unique and narrow niche in the forest of the Western Ghats. This approach can be used for the prediction of potential habitat of threatened species for conservation and ecorestoration.

Keywords: Eltonian niche, Bioclimate, Maxent, Niche profile, Conservation, Ecorestoration.

Introduction

Species Distribution Modelling (SDM) has been considered as an effective tool for prediction of potential areas of species in conservation planning and recently in ecorestoration. The conservation assessments reveal nearly 361 tree species which are globally threatened with a threat level of 13.8 % in India (BGCI, 2022). A total of 332 species are threatened in the Western Ghats, in which 55 of them are Critically Endangered (CR) (Bawa *et al.*, 2007). Most of the insitu conservation programs lack proper species selection, propagation techniques and occasionally result as mono species planting without considering the habitat suitability. This intensify decrease in species diversity, invasion of a species into the niches of other species and degradation of ecosystems (Bachan and Devika, 2022). Therefore, a well-defined species conservation planning is required for conservation and restoration of the natural habitat of a species. Pearson and Dawson (2003) emphasized the concept of bioclimate envelope and pointed out this factor can be only considered as a key characteristic for species distribution.

The advancement of ecological concepts such as niche and its applications using statistical and computational techniques highly supports ecological studies, understanding the species heterogeneity and often to predict the spatial distribution of species. Even though we have only limited data for a particular species, the model-based predictions help to overcome those database limitations by predicting heterogeneity in species distribution. The prescence or absence records and now a days prescence only records of species occurrence are commonly used in different species distribution models (Naimi, 2015). The different kinds of models which are using prescence only records include Bioclim (Busby, 1991), Domain (Carpenter *et al.*, 1993), Mahalanobis (Farber and Kadmon, 2003), Maxent (Phillips *et al.*, 2006) and Maxlike (Royle *et al.*, 2012). Maxent based Niche modelling technique have been used most commonly. It is a simple and effective tool for habitat prediction based on the distribution records which have been used before (Peterson *et al.*, 2011). This method significantly contributes to protected area prediction, climate change, species invasion, animal and plant distribution (Miller, 2010). Hence, this approach generates an overpass between the conservation biology and ecological restoration.

The concept of habitat is closely related to the niche of a species which were popularized by Hutchinson in 1957. The term ‘niche’ can be defined as the physical and functional space occupied by an organism. According to the Grinnellian niche only the environmental factors, especially climatic, constitute the niche of a species (Grinnell, 1971). But later the Eltonian niche concept disclosed the species composition and its interactions have a fundamental role in constituting the niche of a particular species (Elton, 1927). The Eltonian niche was considered as the baseline knowledge for understanding species intricacy and interactions. Therefore, the species occurrence is highly influenced by the bioclimatic factors, associated species composition and other intrageneric and intragroup interactions (Devika and Bachan, 2021). The WorldClim database provides 19 different combinations of variables for predicting the bioclimate that are used in SDM and other ecological modelling techniques. Here the bioclimatic suitability is well addressed in this Maxent-based Niche Modelling.

Limitations of Niche modelling

Earliest efforts in species distribution prediction brought out simple envelope method describing species in relation with environment (Box, 1981), later with a non linear species environmental relationship (Elith and Graham, 2009). These wide range use of species distribution prediction is facing a great challenge in this complex nature. The recent studies (Woodward and Beerling, 1997; Lawton, 2000) debated the validity of bioclimatic concept and they indicated the factors determining species distribution. According to Pearson and Dawson (2003), the great complexity of nature cannot be confined into a single bioclimatic factor hence need to focus the range of spatial scale in habitat prediction. Some of the other studies such as (Naimi, 2015; Lissovsky and Dudov, 2021; Bachan and Devika, 2022) brought up the limitations of species distribution modelling.

The SDM has been widely used as a tool for predicting the suitable habitat of a species but it is not enough for proper niche modelling since it only considers the factors of the Grinnellian niche. A combination of GIS Software and environmental layers can be considered as an improved technique of Niche modelling for larger geographic area (Rotenberry *et al.*, 2006). It is essential to consider the factors of Eltonian niche for defining the habitat of a species, therefore factors like species associates, altitude, terrain features, and landuse need to be considered which are not being covered in the present SDM techniques (Devika and Bachan, 2021). Therefore, to overcome the limitations of SDM we integrated these factors using the QGIS platform for better predictions. The incorporation of vegetation types along with the environmental layers such as elevation, precipitation, slope aspect, temperature, soil type, landuse were suggested to regional niche models (Rotenberry *et al.*, 2006). This standardized methodology can have a greater importance in the conservation of threatened plants. A combined methodology using Niche modelling and Niche profiling has been developed for conservation planning and ecorestoration (Bachan and Devika, 2021). In this study we tried to use the potential of Niche modelling in conservation planning and ecorestoration but at the same time we tried to address the limitations of Niche modelling.

Methodology

Taxonomic publications and herbariums were reviewed for authentic distribution records. Field works were conducted for more populations, specimens were collected from newly recorded subpopulations and herbariums were prepared based on the standardized method (Fosberg and Sachet, 1965; Bridson and Forman, 1991). Some of the distribution records were recorded from floras and virtual herbarium specimens. The ecological niche modelling uses distribution records of the species in correlation with the bioclimatic parameters to predict the suitable geolocations. Here we used Maxent-based Niche modelling, Version. 3.4.1 (Philips *et al.*, 2006). The QGIS mapping platform was used to extract bioclimatic data for the targeted species. Generated outputs were run in the Maxent program for the bioclimatic prediction of potential habitat of the species. This has been considered an experiment to standardize method for endemic and threatened tree species in the Western Ghats region. The prediction outputs were further analyzed with standardized vegetation, terrain and land use factors for the Western Ghats in the QGIS environment as suggested by Bachan and Devika, (2021) to cover the limitations of Niche modelling. The species compositions were also profiled for some species for more precise niche prediction and suitability.

Results and Discussion

i. Scrutiny of taxonomic collection and distribution records

Taxonomic identity of the species and its critical review is an essential part of the species prediction modelling since the taxonomic collection records provide basic and essential information on distribution patterns. Various kinds of species occurrence data were analyzed for the four selected species (*Cryptocarya anamalayana* Gamble, *Diospyros crumenata* Thwaites, *Prioria pinnata* (Roxb. ex DC.) Breteler, *Orophea erythrocarpa* Bedd.) including herbarium specimens, human observations, checklists and so on. The study recommend use of preserved specimen records at least 80% of the data keeping human observations, checklist, revision works or population study with proper taxonomic scrutiny for the remaining 20%. A critical review to understand the taxonomic identity, range and habitat ecology of the species is necessary since many of the herbarium specimens lack exact location details (Fig. 1 & 2).

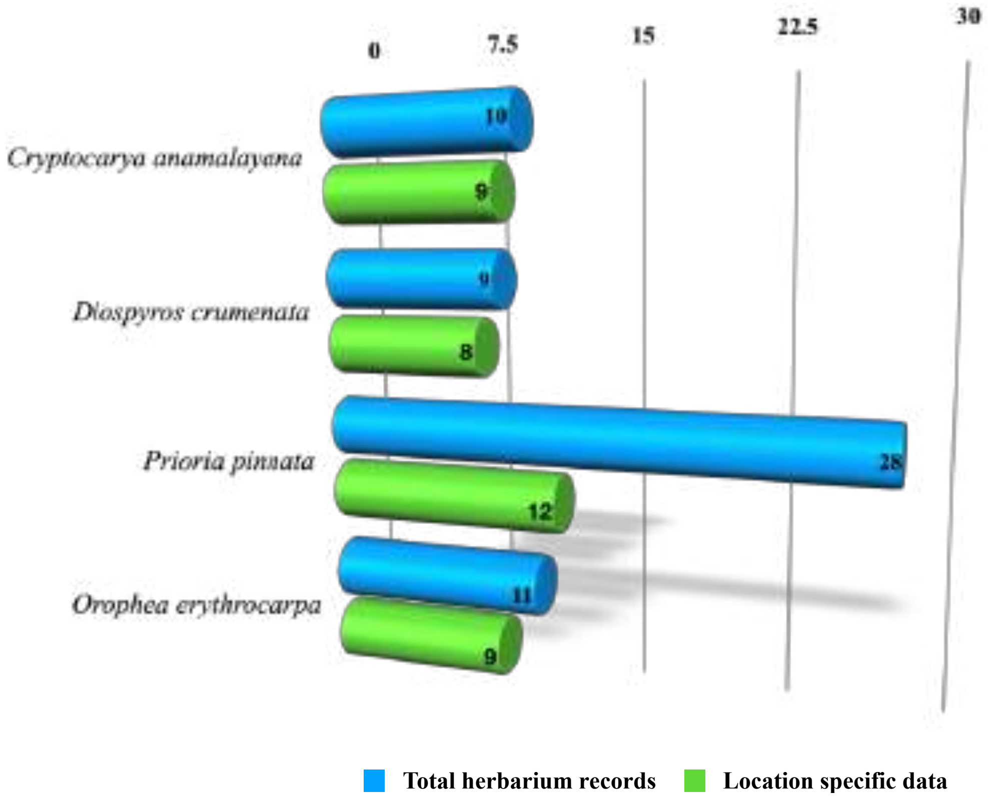


Fig. 1. Location specific herbariums data of four species

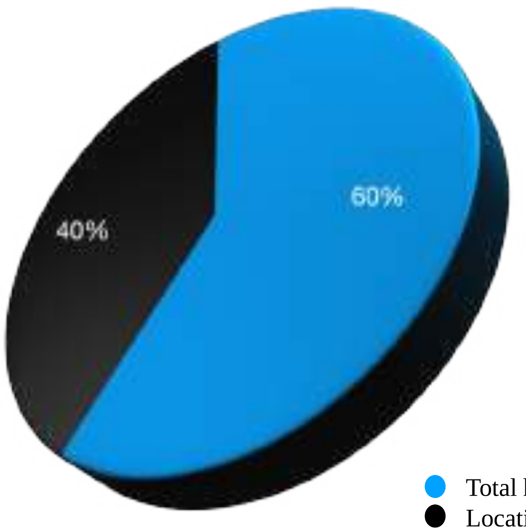
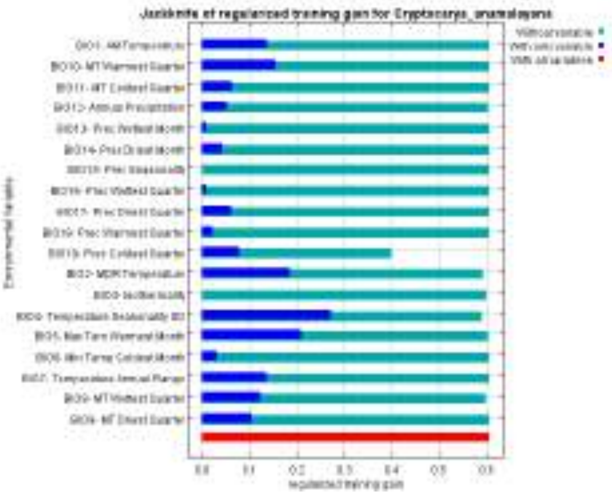


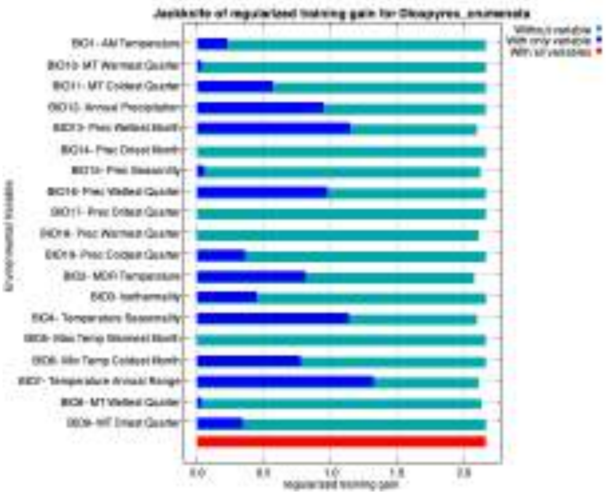
Fig. 2. Percentage contributed to the location specific data in herbarium records

The virtual herbarium facilities of different herbaria especially of the Kew and International Plant Name Index (IPNI) were useful in fine tuning the taxonomic identity. A critical review of taxonomic revision works and similar published papers of the taxon were critical especially when the species has several synonyms.

ii. Bioclimatic variables defining the niche

The bioclimatic prediction includes 19 different variables among which each taxon shows differences in bioclimatic correlation in relation with vegetation type and brought out a narrow range of bioclimatic variables that determine the niches of the species within the given vegetation type (Fig. 3). All the four species *Cryptocarya anamalayana* Gamble, *Diospyros crumenata* Thwaites, *Prioria pinnata* (Roxb. ex DC.) Breteler, *Orophea erythrocarpa* Bedd. discussed here comes within the tropical moist evergreen forest in the Western Ghats. The bioclimatic prediction further delineates suitability of these species within the vegetation types. For example, the *Cryptocarya anamalayana* showed a narrow niche between the medium elevation evergreen and wet evergreen forest formations (Bachan and Devika, 2022). Hence the predicted suitable bioclimatic niches for the species were highly restricted. The *Diospyros crumenata* is basically a low elevation evergreen species with very restricted distribution. Niche modelling reveals a niche of the *Diospyros crumenata* within a very rare niche of low elevation evergreen having more wet evergreen bioclimatic parameters (Devika and Bachan, 2021). This kind of niche is scares within a low elevation area inferring the rarity of species. *Prioria pinnata* is a low to medium elevation species, the Niche modelling indicated a narrow range in between low elevation and medium elevation seen continuously across the Southern and Central Western Ghats. A shift of the suitable bioclimate to a little higher elevation indicate the transition from the Southern Western Ghats to central part. Whereas, *Orophea erythrocarpa* shows affinity towards moist deciduous and evergreen bioclimatic niches.





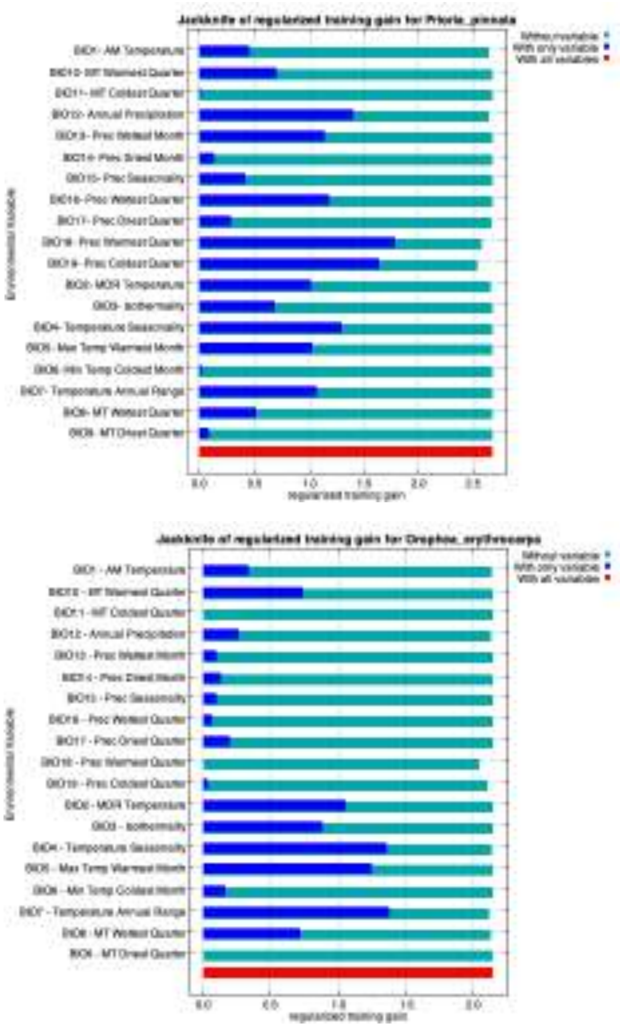


Fig. 3. The Jackknife test using different bioclimatic variables for the species

iii. Addressing the Limitations of Niche Modelling

The SDM was criticized for only considering environmental factors. Bachan and Devika (2022) demonstrated that the Maxent-based model considers 19 bioclimatic parameters which are more than a mere environmental variable such as temperature, light and precipitation. These factors vary across the globe along with latitude and altitude also with topographic and orographic features. Whereas the bioclimatic parameters show heterogeneity within given topographic regime or landscape and could not be completely explained with differential permutation combination of environmental factors. The species exist as populations with the surrounding community within a given environmental condition or factors decided by the Grinnellian niche habitat. Here we hypothesized that the overall species interaction with a given environmental and topographic regime influence and modify the environment and hence influence the bioclimate. Hence, the bioclimatic prediction which is also a reflection of species interaction within a given environmental realm. Here we affirms that the bioclimatic prediction model accommodates very well the factors of the Eltonian niche and to some extent the factors of Grinnellian niche or the factors of species interaction with our detailed studies on *Cryptocarya anamalayana* (Bachan and Devika, 2022), *Diospyros crumenata* and *Prioria pinnata* (Devika and Bachan, 2021). A comparative account of the four species *Cryptocarya anamalayana, Diospyros crumenata, Prioria pinnata, Orophea erythrocarpa* here provided with further evidence of delineation of niches specific to the species according to the bioclimate (Fig. 5). A modified methodology was suggested (Bachan and Devika, 2021) to accommodate the factors of the Grinnellian niche using bioclimatic prediction in combination with elucidation of species association and its three-dimensional modelling as Niche profiling. This was successfully experimented in detail for *Cryptocarya anamalayana* (Bachan and Devika, 2022) and succeeded in fine tuning species prediction areas while incorporating terrain and landuse factors. A detailed study on the other three species (Devika and Bachan, 2021) provided similar conclusions. A comparison of prediction location based on the Maxent based Niche modelling and the modified methodology further fine-tuned to yield better result for the four species (Fig. 4.).

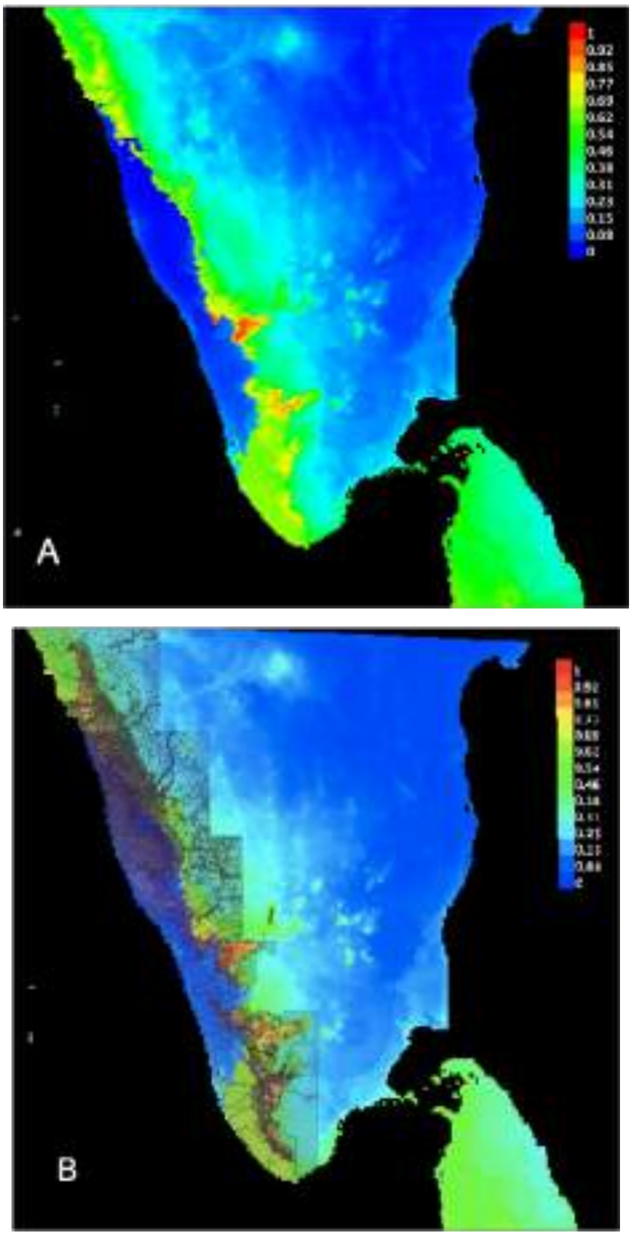


Fig. 4. (A). Map showing the predicted habitat suitability of *Cryptocarya anamalyana* Gamble (Maxent based SDM) (B). Predicted map of *Cryptocarya anamalyana* Gamble incorporated with the vegetation factors and terrain features (Maxent based Modified SDM).

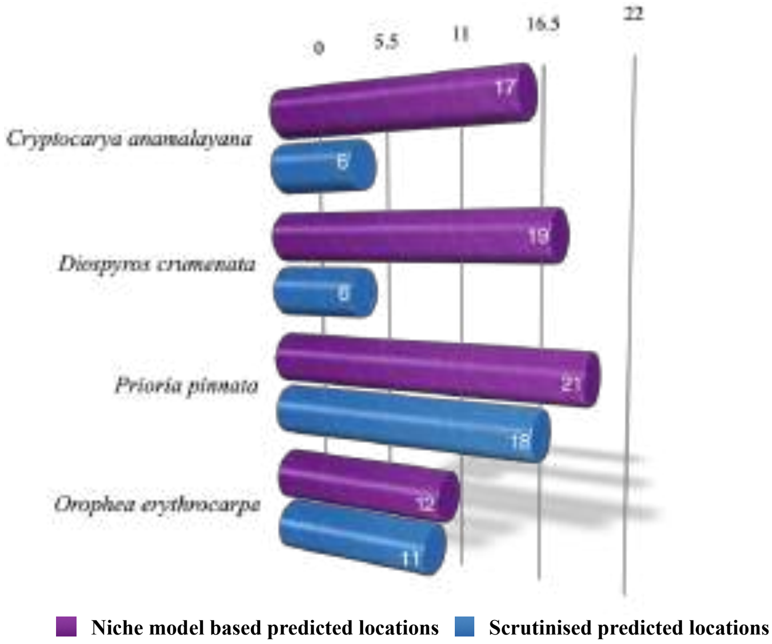


Fig. 5. Comparison of predicted SDM with Modified SDM (MSDM)

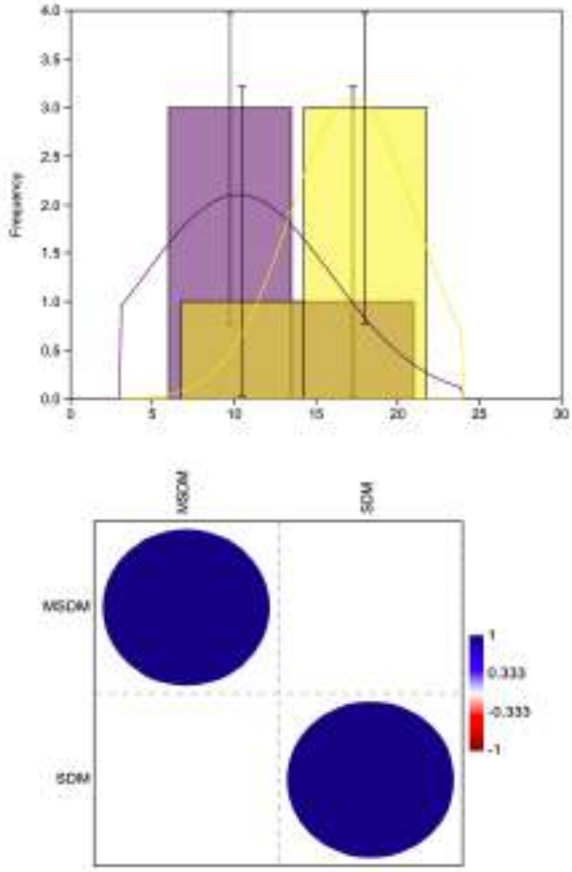


Fig. 6. (A). Histogram showing correlation within. (B). Correlation and P value between SDM and MSDM.

The correlation coefficient value of 7.8 indicated high correlation within both SDM and MSDM (Fig. 6. A), the correlation and high P value indicated significant variation between the SDM and MSDM (Fig. 6. B) proving the hypothesis that the modified SDM has more efficiency.

Conclusion

The Maxent based species distribution modelling (SDM) is commonly used in prediction of potential habitat of a species and has been criticized for its limitation restricting to the environmental factors of Grinnellian niche. The study addresses the limitations of the SDM using a modified methodology (MSDM) and experimented here with four threatened species of the Western Ghats. The study recommends use of scrutinized taxonomic specimen records for data validation for species distribution limiting other record to 20%. The study with the support of detailed works (Devika and Bachan, 2021; Bachan and Devika, 2022) affirms here the MSDM is more efficient and suitable for prediction of potential locations for species in the Western Ghats compared to the normal SDM. Using the SDM, predicted suitable habitat locations (Fig. 5) for *Cryptocarya anamalayana* (17), *Diospyros crumenata* (19), *Prioria pinnata* (21), *Orophea erythrocarpa* (12). While applying the modified methodology of SDM, the predicted location is further sharpened (Fig. 5) to forest areas such as in the case of *Cryptocarya anamalayana* (6), *Diospyros crumenata* (6), *Prioria pinnata* (18), *Orophea erythrocarpa* (11). This difference has been statistically proved (Fig. 6) to be significant during the study. This approach provides a better understanding of the percentage contribution of bioclimatic factors and also the topographic and vegetation factors, the factors of species assemblage. This again can be used for prediction of potential habitat of threatened species for conservation and ecorestoration.

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