Predicting The Potential Global Range of Two Invasive Alien Plant Species - Lantana Camara and Hyptis Suaveolens Using Principal Component Analysis of Bioclimatic Variables and Species Distribution Modelling

Neethu Visakh V R[1], Dr. R. Jaishanker[2], Dr. C. Sudhakar Reddy[3]
[1]*M. Phil Scholar, Ecological Informatics, IIITM-K, Thiruvananthapuram*
[2]*Professor & Coordinator, Ecological Informatics, IIITM-K*
[3]*Scientist-SG & Head, NRSC, ISRO, Hyderabad*
doi.org/10.64643/IJIRTV12I10-204379-459

***Abstract*—Biological invasions represent the expansion of species beyond their native geographical limits, posing significant threats to biodiversity and ecosystem stability. Invasive alien plant species (IAPS) are particularly impactful due to their rapid spread and adaptability. This study focuses on predicting the potential global distribution of two invasive species, *Lantana camara* and *Hyptis suaveolens*, using Species Distribution Modelling (SDM) integrated with Principal Component Analysis (PCA) of 19 bioclimatic variables. The Koppen climate classification was applied to analyse the relationship between climate zones and species distribution. The study identifies key environmental predictors influencing invasion and evaluates habitat suitability using the MaxEnt model. The findings highlight the wide ecological tolerance of selected species and their strong invasive potential across tropical and subtropical regions.**

***Index Terms*—Bioclimatic variables, Invasive alien plant species (IAPS), *Hyptis suaveolens*, *Lantana camara*, MaxEnt, Principal Component Analysis (PCA), Species Distribution Modelling (SDM).**

I. INTRODUCTION

Biological invasion can be described as the spread of species into regions outside their natural habitats, often resulting in ecological imbalance [1], [8]. These invasions can adversely affect native biodiversity, ecosystem processes, and even economic systems [2], [21]. Among invasive organisms, plant species are particularly significant due to their high reproductive capacity and environmental adaptability [4], [9].

Species Distribution Modelling (SDM) has emerged as an effective approach for predicting the geographical spread of species based on environmental conditions [28], [34]. Climatic variables, especially temperature and precipitation, play a dominant role in determining habitat suitability [17], [30]. In this study, the global distribution patterns of *Lantana camara* and *Hyptis suaveolens* are analysed using PCA and MaxEnt modelling to identify key environmental drivers and potential invasion zones [23], [27], [40].

II. MATERIALS AND METHODS

A. Data Collection

Data on invasive alien plant species (IAPS) were collected from global databases including the Global Invasive Species Database (GISD), Global Biodiversity Information Facility (GBIF), Centre for Agriculture and Bioscience International (CABI), and National Remote Sensing Centre (NRSC) [3], [4]. A total of 300 invasive plant species were compiled, out of which 50 species with wide geographical distribution were selected for detailed analysis [8], [9]. Occurrence data for *Lantana camara* and *Hyptis suaveolens* were obtained from GBIF and NRSC databases [23], [27].

B. Bioclimatic Variables

Nineteen bioclimatic variables representing temperature and precipitation were used as environmental predictors [30], [34]. These variables were obtained from global climate datasets and

processed using ArcGIS software [37], [38]. The variables include annual mean temperature, precipitation patterns, and seasonal variations, which significantly influence species distribution [17], [33].

Table I: Bioclimatic Variables Used in the Study

Variable	Description
BIO1	Annual Mean Temperature
BIO2	Mean Diurnal Range
BIO3	Isothermality
BIO4	Temperature Seasonality
BIO5	Max Temperature of Warmest Month
BIO6	Min Temperature of Coldest Month
BIO7	Temperature Annual Range
BIO8	Mean Temperature of Wettest Quarter
BIO9	Mean Temperature of Driest Quarter
BIO10	Mean Temperature of Warmest Quarter
BIO11	Mean Temperature of Coldest Quarter
BIO12	Annual Precipitation
BIO13	Precipitation of Wettest Month
BIO14	Precipitation of Driest Month
BIO15	Precipitation Seasonality
BIO16	Precipitation of Wettest Quarter
BIO17	Precipitation of Driest Quarter
BIO18	Precipitation of Warmest Quarter
BIO19	Precipitation of Coldest Quarter

C. Principal Component Analysis (PCA)

Principal Component Analysis (PCA) was performed to reduce the dimensionality of the dataset and identify the most influential climatic variables [34], [35]. The analysis was conducted using R statistical software. PCA transforms correlated variables into a set of uncorrelated principal components, helping to determine the key environmental factors governing species distribution [28], [30].

D. Species Distribution Modelling

Species Distribution Modelling was carried out using the MaxEnt (Maximum Entropy) algorithm [28], [40]. The model uses presence-only species occurrence data along with environmental variables to predict suitable habitats [34], [39]. Occurrence data for *Lantana camara* and *Hyptis suaveolens* were integrated with the 19 bioclimatic variables to generate predictive distribution maps [23], [27]. Model performance was evaluated using Receiver Operating Characteristic (ROC) curves and Area Under Curve (AUC) values [35], [40].

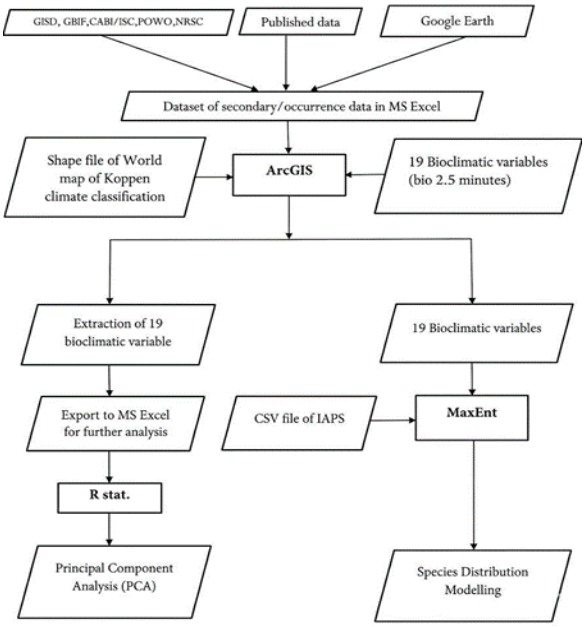

Fig. 1: Flow diagram of methodology

III. RESULTS AND DISCUSSION

A. Principal Component Analysis (PCA) Results

The Principal Component Analysis (PCA) was performed to identify the most significant bioclimatic variables influencing the distribution of the selected invasive species [34], [35]. The scree plot indicates that the first few principal components account for the majority of variance in the dataset, demonstrating effective dimensionality reduction [28], [30].

The PCA component plot reveals strong correlations among temperature- and precipitation-related variables, highlighting their combined influence on species distribution [17], [33]. Variables such as temperature seasonality and annual precipitation showed higher loadings, indicating their importance in determining habitat suitability [30], [34].

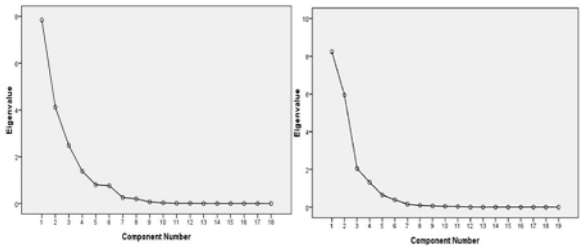

Fig. 2: Scree Plot (PCA)

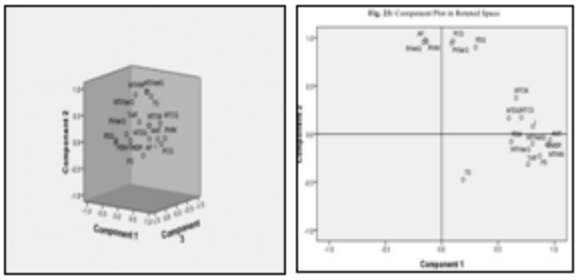

Fig. 3: PCA Component Plot

B. Influence of Climatic Variables

The analysis indicates that climatic conditions strongly influence the distribution patterns of invasive plant species [17], [30]. Both *Lantana camara* and *Hyptis suaveolens* demonstrate the ability to survive across a wide range of climatic zones, particularly in tropical and subtropical regions [23], [27].

Variables associated with temperature variability and precipitation patterns showed significant contributions to habitat suitability [33], [34]. This adaptability reflects a broad ecological niche, which enhances the invasive capacity of these species [8], [9].

C. Species Distribution Modelling Outputs

The MaxEnt model generated spatial distribution maps indicating potential suitable habitats for both species [28], [40]. The predicted distribution of *Lantana camara* shows extensive suitability across tropical and subtropical regions, including parts of Asia, Africa, and South America, indicating its high invasive potential [23], [24], [25].

In contrast, *Hyptis suaveolens* shows comparatively moderate distribution but still demonstrates strong adaptability across multiple climatic zones [27], [29]. The model outputs confirm that both species possess a wide ecological tolerance, enabling their spread across diverse environments [8], [9].

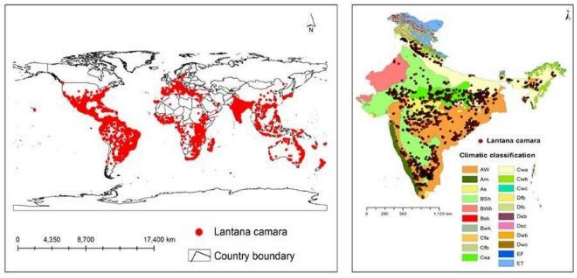

Fig. 4: Predicted distribution map (Lantana camara)

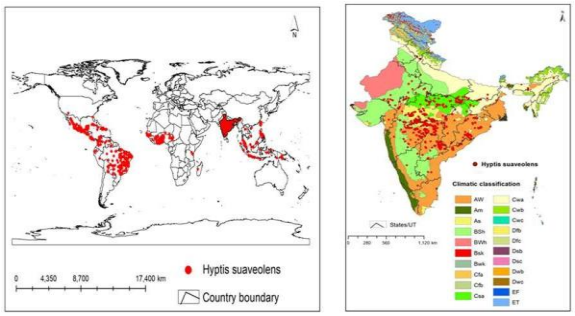

Fig. 5: Predicted distribution map (Hyptis suaveolens)

D. Model Evaluation and Variable Contribution

The performance of the MaxEnt model was evaluated using the Receiver Operating Characteristic (ROC) curve [35], [40]. The Area Under Curve (AUC) values indicate high model accuracy, confirming the reliability of the predictions [28], [39].

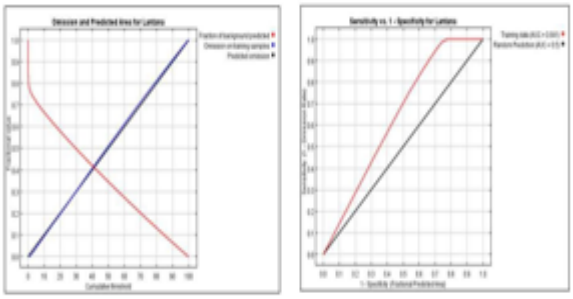

Fig. 6: ROC curves (Lantana camara)

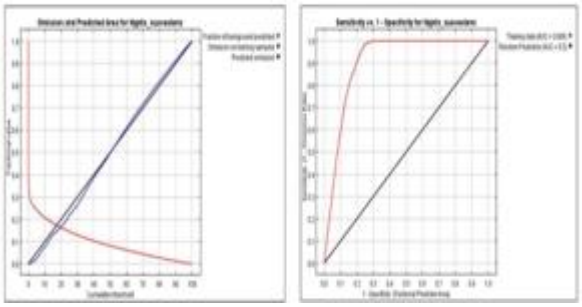

Fig. 7: ROC curves ((Hyptis suaveolens)

Further, the Jackknife test was used to determine the relative importance of individual bioclimatic variables [28], [40]. The results show that certain variables, particularly temperature seasonality and precipitation-related factors, contribute significantly to the model performance [30], [33].

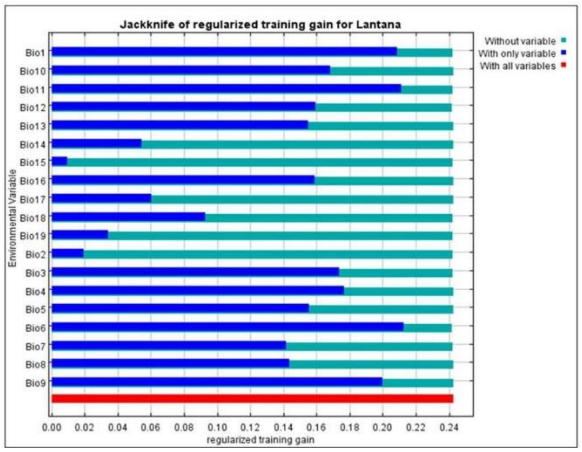

Fig. 9: Jackknife test (Lantana camara)

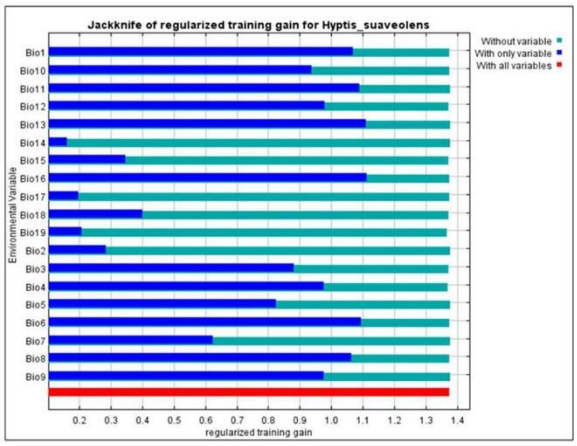

Fig. 10: Jackknife test (Hyptis suaveolens)

E. MaxEnt Model Prediction

The MaxEnt model was used to predict the potential distribution of *Lantana camara* and *Hyptis suaveolens* based on presence-only occurrence data and bioclimatic variables [28], [40]. The model outputs indicate high habitat suitability across tropical and subtropical regions, confirming the strong invasive potential of both species [23], [27].

The model performance, evaluated using AUC values, demonstrated high predictive accuracy [35], [39]. The response curves generated by the model illustrate the relationship between environmental variables and species occurrence, indicating that temperature and precipitation play a dominant role in determining distribution patterns [30], [33]. These curves indicate how environmental factors influence habitat suitability.

For both *Lantana camara* and *Hyptis suaveolens*, temperature and precipitation variables showed strong influence on predicted distribution [17], [30]. The response curves suggest that moderate temperature ranges and seasonal precipitation patterns favour species establishment and spread [33], [34].

The results further reveal that *Lantana camara* exhibits a broader ecological niche compared to *Hyptis suaveolens*, making it more aggressive in terms of invasion potential [24], [25].

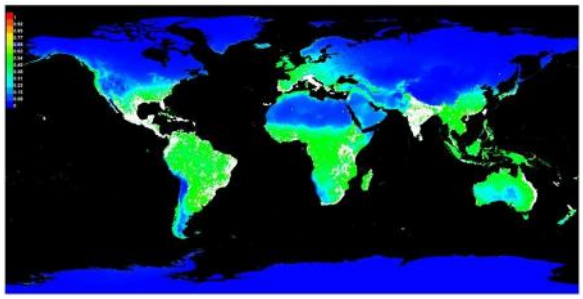

Fig. 11: Maxent model for Lantana camara

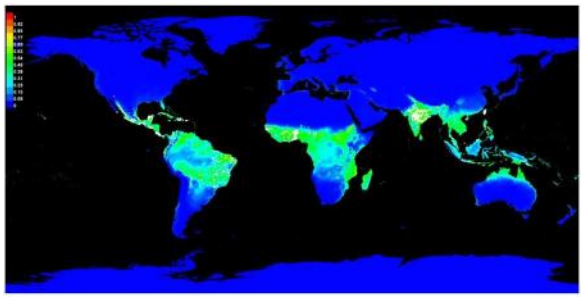

Fig. 12: Maxent model for Hyptis suaveolens

Warmer colors show areas with better predicted conditions. White dots show the presence locations used for training, while violet dots show test locations.

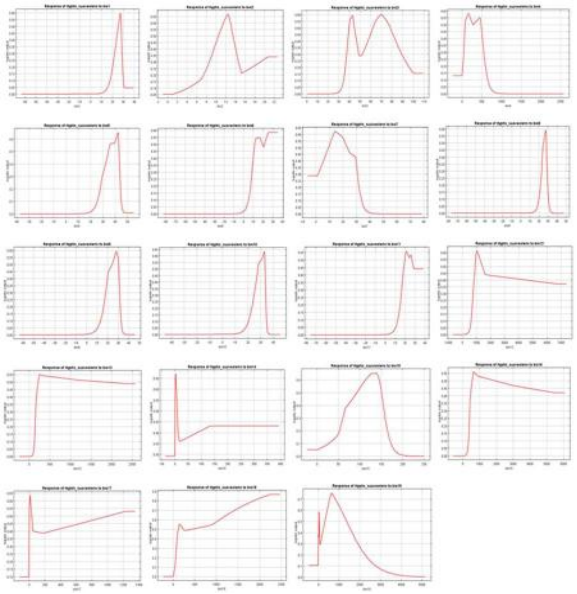

Fig. 13: Response curve (Lantana camara)

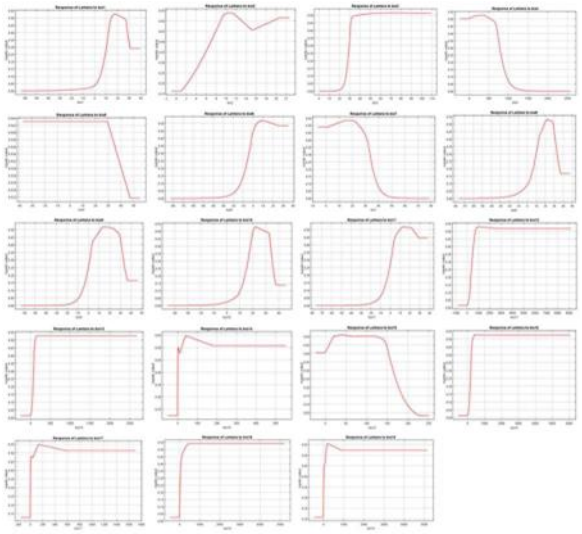

Fig. 14: Response curves (Hyptis suaveolens)

IV. CONCLUSION

This study demonstrates the effectiveness of integrating PCA and MaxEnt modelling techniques for predicting the distribution of invasive plant species. The results confirm that *Lantana camara* and *Hyptis suaveolens* possess high ecological adaptability, enabling them to spread across diverse climatic regions. Identifying the environmental factors that drive species distribution is essential for developing management strategies to control biological invasions. Future research can incorporate climate change projections to further improve prediction accuracy and support conservation planning.

ACKNOWLEDGMENT

The authors express sincere gratitude to IIITM-K and NRSC, ISRO, for providing support, data, and guidance throughout the study.

REFERENCES

[1] C. S. Elton, *The Ecology of Invasions by Animals and Plants*. London, U.K.: Methuen, 1958.
[2] E. O. Wilson, "Biodiversity and ecological threats," Environmental Studies Journal, 2002.
[3] Global Invasive Species Programme (GISP), "100 of the world's worst invasive alien species," 2001.
[4] C. S. Reddy et al., "Invasive alien flora of India," Journal of Forestry Research, 2008.
[5] K. C. Sekar, "Invasive alien plants of Indian Himalayan region," Biodiversity Journal, 2014.
[6] V. V. Wagh and A. K. Jain, "Status of ethnobotanical invasive plants," Indian Journal of Ecology, 2013.
[7] P. D. Charan and M. Singh, "Distribution of invasive species in Thar Desert," Ecological Studies, 2010.
[8] K. S. Dogra et al., "Alien plant invasion: A global review," Environmental Reviews, 2010.
[9] F. Essl et al., "Plant invasion richness across the globe," Nature Ecology & Evolution, 2019.
[10] S. Henderson et al., "Progress in invasive plant research," Ecology Letters, 2009.
[11] M. Langmaier and K. Lapin, "Impact of invasive plants on forest ecosystems," Forest Ecology and Management, 2020.
[12] P. Raizada et al., "Impact of invasive species on soil processes," Soil Biology and Biochemistry, 2008.
[13] K. P. Kumar, "Invasive species in Kerala wetlands," Wetlands Ecology and Management, 2012.
[14] N. P. Sooraj et al., "Forest canopy gaps and invasive plants," Tropical Ecology, 2015.
[15] A. Singh and I. Mohammed, "Diversity of invasive species in Haryana," Botanical Studies, 2013.
[16] S. Vijayan and C. M. Joy, "Growth and spread of Mikania micrantha," Plant Science Today, 2014.
[17] P. Tripathi et al., "Plant invasion and climate anomaly," Global Change Biology, 2012.
[18] S. H. Reichard et al., "Predicting woody plant invasions," Ecological Applications, 2007.
[19] A. Weidlich et al., "Controlling invasive plant species," Restoration Ecology, 2020.
[20] G. Durigan et al., "Control of invasive plants," Environmental Management, 2013.
[21] A. Kumar and S. Prasad, "Threats of invasive alien species," Environmental Reviews, 2011.
[22] I. A. M. S. Wake et al., "Invasive plants in conservation areas," Biodiversity and Conservation, 2009.
[23] F. P. J. Pagny, "Prediction of Lantana camara invasion," Ecological Modelling, 2012.
[24] B. Sundaram et al., "Ecology of Lantana camara in India," Environmental Research Letters, 2012.
[25] W. Vardien et al., "Invasion dynamics of Lantana camara," South African Journal of Botany, 2012.

[26] S. Taylor et al., “Climate change impact on Lantana camara,” Climate Research, 2012.
[27] O. A. David et al., “Distribution of Hyptis suaveolens,” Ecological Informatics, 2013.
[28] H. Padalia et al., “MaxEnt vs GARP modelling,” Ecological Modelling, 2014.
[29] T. Afreen et al., “Impact of Hyptis suaveolens,” Grassland Science, 2011.
[30] J. M. Jeschke and D. L. Strayer, “Bioclimatic models and invasive species,” Global Ecology and Biogeography, 2008.
[31] U. Thinley et al., “Invasive weeds under climate change,” Mountain Research and Development, 2015.
[32] S. Thapa et al., “Distribution dynamics of invasive plants,” Himalayan Journal of Sciences, 2013.
[33] P. Adhikari et al., “Climate change and plant invasion,” Asian Journal of Ecology, 2015.
[34] C. S. Jarnevich et al., “Invasive species distribution modelling,” Ecological Applications, 2015.
[35] A. Datta et al., “Transferability of SDM models,” Biodiversity Informatics, 2010.
[36] B. Wiatrowska et al., “Future niche distribution modelling,” Plant Ecology, 2017.
[37] N. Ahmed et al., “Remote sensing for invasive species,” Remote Sensing Applications, 2015.
[38] D. Kopec et al., “Mapping invasive species,” International Journal of Geographical Information Science, 2013.
[39] R. D. B. Runquist et al., “Predicting invasion risk,” Ecology Letters, 2016.
[40] Q. A. et al., “MaxEnt modelling and climate change,” Ecological Modelling, 2012.