

Predicting Potential Habitat Distribution of *Acacia catechu* in India

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Abstract *Acacia catechu*, commonly known as Khair, is a multipurpose tree with high social, economic and ecological value. It has been exploited commercially in tannin and Katha industry for decades. Besides its commercial importance, it is equally significant for the people particularly rural communities living in the vicinity of catechu forests, since these people are dependent on this plant to fulfill their day to day need of fuel, fodder, building material and others. Due to their high commercial and social value, Khair forests are susceptible to a high degree of anthropogenic pressure, especially illicit logging. Despite its vast ecological and socio-economic significance, there is a lack of information on its suitable habitat distribution range. Therefore, the present study was carried out to predict the current and future suitable distribution of *A. catechu* in India using Maxent species distribution model. Output of maxent model reveal that the suitable habitat for distribution is Middle, South west and Northern part of India. Future prediction model for 2050 showed decrease of habitat area. The strongest predictors for the distribution of *A. catechu* were precipitation of wettest month, precipitation seasonality and max temperature of warmest month. The probability of presence of *A. catechu* increased with an increase in precipitation of wettest month.

Keywords: *Acacia catechu*, Maxent, habitat distribution

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1. Introduction

Acacia catechu, commonly known as Khair, is a multipurpose medium sized deciduous tree with crooked and forked trunk. *A. catechu* is very popular in the Southern part of Asia and holds a high social, economic and ecological value over the areas where it grows. The heartwood of tree is mainly used for extracting Katha (Catechin) and Cutch (Catechu tannic acid) which are sold in the market [1]. Katha is commonly used in ayurvedic preparations. Besides this, it serves as one of the major components in masticatory i.e. chewing of betel leaf (pan) in India.

A. catechu is a valuable bioresource and has been exploited commercially in tannin and Katha industry for decades. Besides its commercial importance, it is equally significant for the people particularly rural communities living in the vicinity of catechu forests as it is a subsidiary source of income to them. To a certain extent, these people are dependent on this plant to fulfill their day to day need of fuel, fodder, building material and others. On account of its multi variate usefulness and value of wood, *A. catechu* is an ideal species for the conversion of miscellaneous forests, containing inferior species and is being used to a considerable extent for afforestation. Owing to their high commercial and social value, Khair

forests are susceptible to a high degree of anthropogenic pressure, especially illicit logging [2].

Despite its vast ecological and socio-economic significance, there is a lack of information on suitable habitat distribution range. Thus, there is an urgent need to study and provide a country wide picture of the present status of potentially suitable habitats of *A. catechu* and generate scientific data on its response to future climate change scenario. 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.

To achieve these objectives, we employ the maximum entropy model (Maxent version 3.3.3; Phillips *et al.*, 2006). This selection is based on the model's superior performance with small sample sizes compared to other modeling methods [3-5]. Maxent, which is based on the principle of maximum entropy, utilizes presence-only data to predict species distribution, while aiming to estimate a probability distribution of species occurrence that aligns as closely as possible with uniformity but is still subject to environmental constraints [6]. The Maxent model inherently includes variable interactions and can manage both continuous and categorical predictor variables. It employs a set of features, such as linear, quadratic, product, threshold, and hinge, which are functions of environmental variables that limit the geographic

distribution of a species. Additionally, it utilizes an empirically determined regularization parameter to prevent model overfitting.

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>) and published literature [7,8]. 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 96 occurrence points of *A. catechu* were compiled and included in this study to model current and future potential distribution of the species.

Climatic data

Bioclimatic variables [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 [5, 10-12]. The 19 bioclimatic variables from the WorldClim dataset were used to assess current climatic conditions. These variables are frequently used in modeling species distributions [5,10,13] and capture annual ranges, seasonality, and limiting factors such as monthly and quarterly temperature and precipitation extremes [9]. 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://ccaafclimate.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>) [14]. 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 96 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 [15]. 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 [16]. 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 [17]. The maxent model for *A. catechu* performed well with an average AUC value of 0.92 (Figure 1). To minimize the possible errors in species occurrence data, duplicate records were eliminated. Most suitable habitat is predicted in Middle, South west and Northern part of India (Figure 2a, b). The relative contributions of the predictor variables in Maxent for distribution of *A. catechu* is given in Table 1. Precipitation of Wettest Month (Bio 13), Precipitation Seasonality (Bio 15) and Max Temperature of Warmest Month (Bio 5) were the strongest predictors for the distribution of *A. catechu* with 47.2%, 15.6% and 7.2% respectively. The probability of presence of *A. catechu* increased with an increase in precipitation of wettest month (Figure 3). Relative importance of different environmental variables based on results of jackknife tests in Maxent are shown in Figure 4. Compared with the area of most suitable habitat under current climate prediction, the future prediction model for 2050 (A2a emission scenario) showed decrease of habitat (Figure 2b),

Table 1. Selected environmental variables and their percent contribution in maxent model for *Acacia catechu*

Environment Variables	Percent Contribution
Precipitation of Wettest Month (Bio 13)	47.2
Precipitation Seasonality (Bio 15)	15.6
Max Temperature of Warmest Month (Bio 5)	7.2
Precipitation of Coldest Quarter (Bio 19)	5.6
Mean Temperature of Wettest Quarter (Bio 8)	4.4
Mean Diurnal Range (Bio 2)	3.7
Annual Precipitation (Bio 12)	3.7
Precipitation of Warmest Quarter (Bio 18)	3.3
Mean Temperature of Coldest Quarter (Bio 11)	2.7
Precipitation of Driest Quarter (Bio 17)	2.5
Annual Mean Temperature (Bio 1)	1.8
Precipitation of Driest Month (Bio 14)	1.2
Isothermality (Bio 3)	0.8
Temperature Seasonality (Bio 4)	0.2

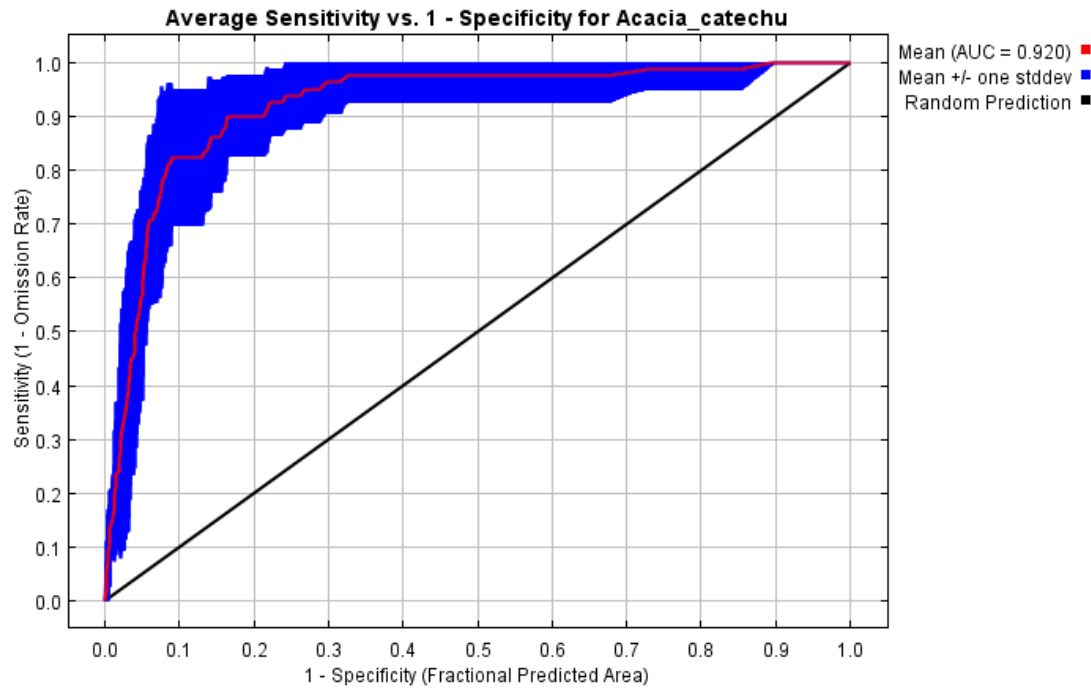


Figure 1. Result of AUC in developing habitat suitability model for *Acacia catechu*

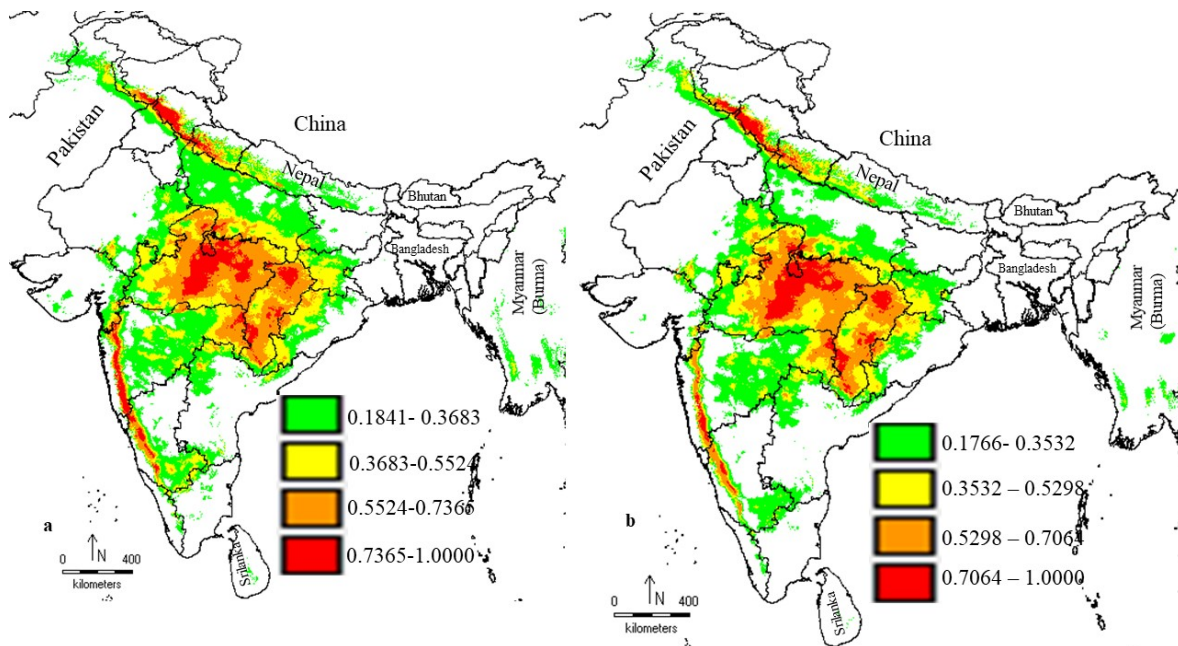


Figure 2. Predicted current (a) and future (2050) (b) potential suitable habitat of *Acacia catechu* (Shapefile republished from DIVA-GIS database (<https://www.diva-gis.org/>) under a CC BY license, with permission from Global Administrative Areas (GADM), original copyright 2018.)

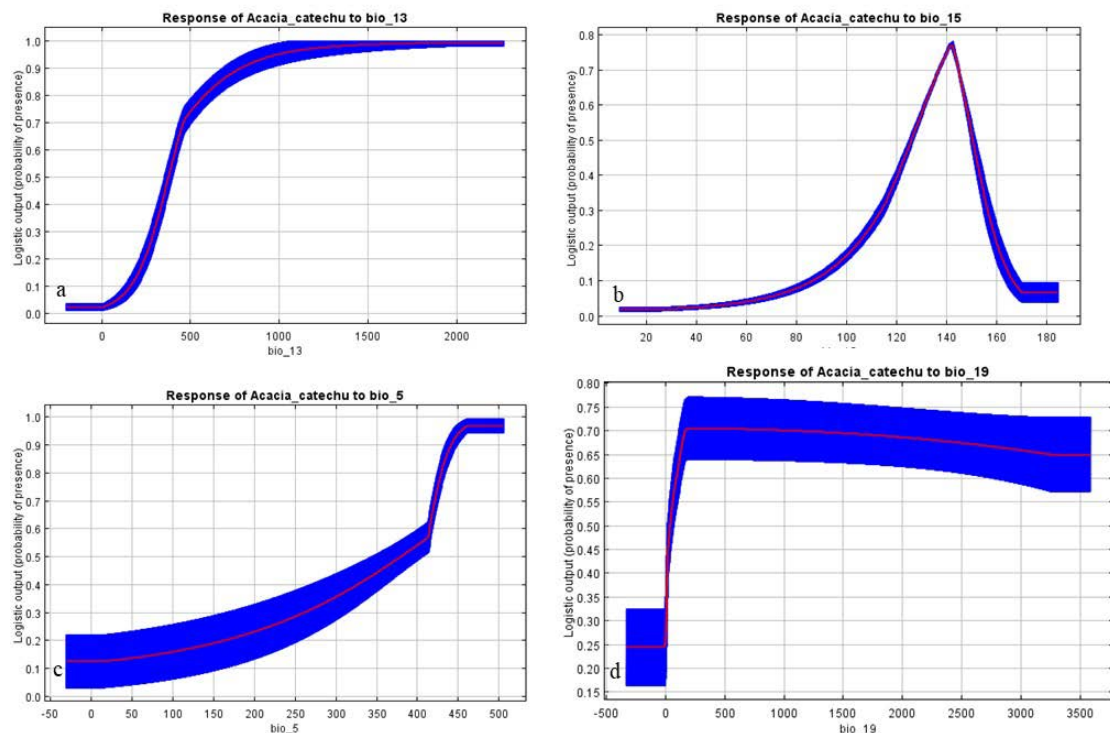


Figure 3. Response curves showing relationships between probability of presence of a species and top bioclimatic predictor of *Acacia catechu* (a) Precipitation of Wettest Month (Bio 13); (b) Precipitation Seasonality (Bio 15); (c) Max Temperature of Warmest Month (Bio 5); (d) Precipitation of Coldest Quarter (Bio 19)

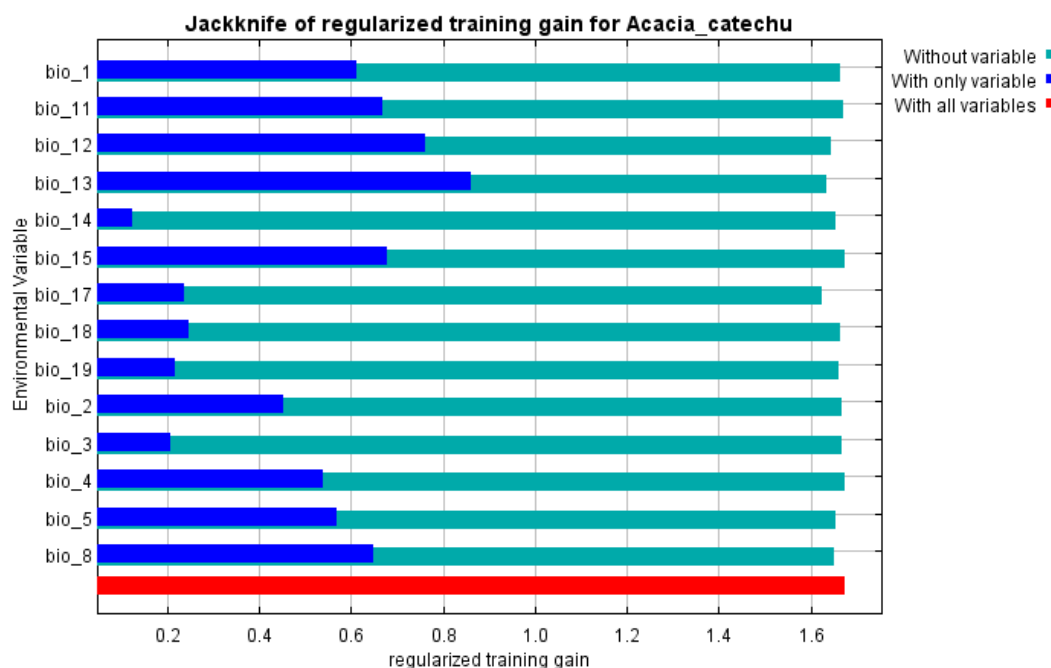


Figure 4. Relative predictive power of different bioclimatic variables based on the jackknife of regularized training gain in maxent model for *Acacia catechu*

4. Discussion

Precipitation of Wettest Month (Bio 13) plays an important role in the potential habitat distribution of *A. catechu*. Output of the maxent model shows that most suitable natural habitat for *A. catechu* is Middle, South west and Northern part of India. With regard to future prediction of the species, maxent modeling shows loss of habitat in 2050 in the current predicted areas.

Due to high commercial and social value of *A. catechu*, increased anthropogenic activities, and change in the climatic conditions in the areas of their occurrence, there is considerable depletion of their natural populations. Species such as *A. catechu* which possess recognized 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 [18]. The effects of land transformations for agriculture and urbanization and climatic changes will

increase unsuitable habitats in their region of occurrence. Therefore, proper planning is needed to preserve *A. catechu*. Present study suggests that the habitat distribution modeling can be of great help in predicting the suitable habitats for introduction of *A. catechu*. The maxent model for predicting the suitable habitat of a species can be used in predicting the potential suitable habitat of other economically important plants which further can help in species conservation planning.

Authors Contributions

PS made contributions in conception & design of the paper and Species Distribution Modelling programme.

RP was involved in collection of the coordinates of *Acacia catechu*.

VS was involved in drafting the manuscript.

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