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Research Article

Predicting Potential Habitat Distribution of *Rauwolfia serpentina* an Important Medicinal Plant using Maxent Modeling in Doon Valley, Uttarakhand State, India

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Abstract The growing demand and dependencies of people for herbal care is time need. Among the list of various used herbal plants, *Rauwolfia serpentina* (Apocynaceae) is an important and due to relief of various central nervous system disorders. The root of this plant has been used in the treatment of hypertension or as a sedative and tranquillizing agent. This plant is variously used in Ayurveda, Unani system of medicine and Homeopathy for various disease ailments. Predicting potential geographic distribution of the species is important from species occurrence and habitat restoration point of view. This paper hearsay the results of a study carried out in the Dehradun valley in India (Dehradun surrounding forest area) on potential distribution modeling for *Rauwolfia serpentina* using Maxent model. The Worldclim bioclimatic variables, slope, aspect, elevation, and the FSI forest type data and 100 spatially well-dispersed species occurrence points were used to predict the potential distribution of *Rauwolfia serpentina* in ca. nearly 1277 km^2 of Doon valley study area. Jackknife test was used to evaluate the importance of the environmental variables for predictive modeling. Maxent model was highly accurate with a statistically significant AUC value of 88.5. The approach could be promising in knowing the eventing the potential distribution of medicinal plant species and thus, can be an effective tool in species restoration and conservation planning.
Keywords: *Dehradun; Jackknife; Maxent; Medicinal and aromatic plant; Potential distribution; Rauwolfia serpentina*

1. Introduction

The habitat restoration of species is one of the successful ecological engineering measures for the species rehabilitation and habitat conservation (Polak and Saltz, 2011). Knowledge on the distribution of species is often a pre-requisite to rehabilitate the species in any ecosystem (Barik and Adhikari, 2011; Franklin et al., 2009). The species-environment analysis relationship has always been a central issue in ecology and biogeography (Guisan and Zimmerman, 2000; Haines, 1925). The application of remote sensing and Geographic Information System (GIS) provides several useful input variables such as vegetation type and density, biome landscape or eco-region maps and for geospatial database creation, data integration and modeling (Turner et al., 2003; Kushwaha, 2011, Irfan-Ullah et al., 2006).

Models predicting the potential geographic distribution of species are important for a variety of applications in conservation biology with a number of statistical models to simulate the spatial distribution of plant species invasive species, species diversity and impact of climate change (Ferrier et al., 2002; Graham et al., 2004, Kumar and Stohlgren, 2009; Adhikari et al., 2012, Peterson et al., 2003; Thuiller et al., 2005, Graham et al., 2006, Thomas et al., 2004; Saran et al., 2010).

Maximum entropy (Maxent) model is a species distribution model (SDM) originating from the statistical mechanics (Phillips et al., 2004; Jaynes, 1957). This environmental model for predicting the potential distribution of species has several advantages; it requires only species presence (or occurrence) data and environmental information (Elith et al., 2011). The presence modeling methods simply require a set of known occurrences together with predictor variables such as topography, climate, soil, biogeography etc. that make use of both continuous and categorical data and incorporate the interactions between the variables (Phillips and Dudik, 2008, Phillips et al., 2006).

Rauwolfia serpentina (L.) Benth. ex Kurz.(Family:*Apocynaceae*), is widely distributed in the foothills of Himalayan range, up to the elevation of 1300-1400 m and in the sub-Himalayan tract from Punjab eastwards to Nepal, Sikkim and Bhutan, in Assam, in the lower hills of Gangetic plains, Eastern and Western Ghats, in some parts of central India and in the Andamans. The natural reserves of this plants are declining as a result of over harvesting, IUCN has kept this plant under endangered status, and it is listed in CITES Appendix II. The National Medicinal Plants Board (NMBP), Govt. of India has also placed this plant among 32 plants identified and prioritized for cultivation, development, formulating schemes and guidelines for financial assistance because of their high demand. *Rauwolfia serpentina* is an erect evergreen perennial under shrub with a cluster of branches (2- 6) arising from the root, attains a height up to 75 cm. to 1 m under cultivation, rootstock is long, irregularly, nodular and yellowish.It prefers clay-loam to silt-loam soils with plenty of humus and rich in nitrogenous and organic matter with good drainage. The plant requires slightly acidic to neutral soils for good growth with medium to deep well drained fertile soils. Alkaline soils are not suitable for commercial cultivation. Generally, organic cultivation is practiced. It grows well in frost-free tropical to sub-tropical situations under irrigation. It grows luxuriantly well where the rainfall is 2500 mm or more. The major alkaloid present in root, stem and leaves of the plant is reserpine varies from 1.7 to 3.0%. The root barks has more than 90% of the total alkaloids in roots. The minor alkaloids present in the plant are Ajmalicine, ajmaline, isoajmaline, ajmalinine, chandrine, rauwolfinine, renoxidine, rescin-namine, reserpiline, reserpin, reserpinine, sarpagine, serpentine, serpentinine, tetraphyllicine, yohimbine, 3-epi-ayohimbine. The root contains ophioxylin, resin, starch and wax (Sastri, 1990).

Therefore, extend and availability of this important medicinal plants becomes necessary and the present study is designed for predicting the potential habitat distribution of *Rauwolfia serpentina* in Dehradun valley of Uttarakhand using Maxent modeling.

1.1. Study Area

Dehradun valley is situated in lesser Himalaya of Uttarakhand State, India. The Dun Valley occupies an area of 1277 km^2, and is bounded by Shivalik hills in the south and Lesser Himalayas in the north. It receives a mean annual rainfall of 2051 mm. The temperature ranges from 2°C in winter to 42°C in summer. Dun valley is a forested landscape with forests, agriculture, settlements, orchards and tea gardens. The principal forest types are: (i) Moist Bhabar-Dun Sal Forest (3C/C2bi), (ii) Lower Himalayan Moist Temperate Forest (12C1), (iii) Himalayan Subtropical Pine Forest (9/C1), and (iv) Northern Dry Mixed Deciduous Forest (5B/C2) (Champion and Seth, 1968). *Shroea robusta, Terminalia tomentosa, Anogeissus latifolia, Mallotus philippensis, Dalbergia sissoo, and Acacia catechu* are some of the important tree species in the Valley.

2. Materials and Methods

The dataset used for the present study are the Forest Survey of India (FSI) forest type map based on Champion and Seth classification. The Environmental variables and species occurrence data Nineteen bioclimatic variables (Hijmans et al., 2005; Corvellec and Hultman, 2012) with 30 seconds (ca. 1 km) spatial resolution, downloaded from WorldClim dataset (www.worldclim.org), were used to find out the most influential variables associated with *Rauwolfia serpentina* distribution. The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Digital Terrain Model (DTM) with 30 m resolution, was used to generate the slope, aspect and elevation data layers. A total of 100 species occurrences were recorded randomly in the study area. A hand-held Global Positioning System (GPS) receiver with ±5 m positional accuracy was used to acquire the species occurrence geocoordinates. Spatial modeling: Erdas 11 and ArcGIS 10.2 were used to create the spatial data layers. The categorical data were re-sampled to 1 km spatial resolution using nearest neighbor re-sampling technique. The 70% of selected data used for training and the rest 30% for testing. A total of 100 runs were set for model building (Flory et al., 2012). Other values were kept as default. The area under the Receiving Operator Curve (AUC) was used to evaluate model's goodness-of-fit and model with highest AUC value was considered as the best performer. The Jackknife procedure was used to assess the importance of the variables. The final potential species distribution map had a range of values from 0 to 1 which were regrouped in to three classes of potential habitats viz., 'High potential' (>0.55), 'Moderate potential' (0.38-0.55), 'Less potential' (0.2-0.38).

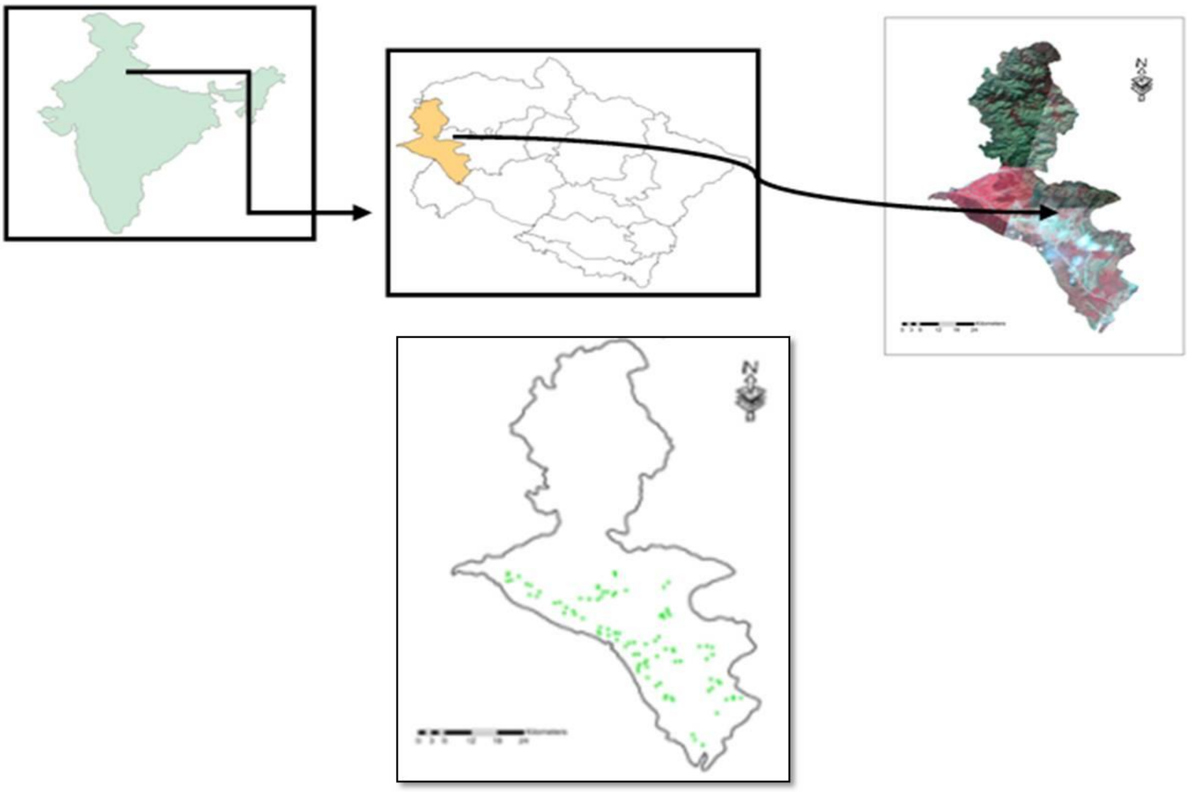

Figure 1: *Study area location map of present study*

3. Results and Discussion

The Jackknife evaluation results indicated forest type, slope, isothermality and meantemperature of driest quarteras main factors influencing *Rauwolfia serpentina* distribution. The percent contribution values given in are only heuristically defined; they depend on the particular path that the Maxent code uses to get to optimal solution. These results were consistent with the Jackknife evaluation. The model output provided satisfactory results with the given set of training and test data, the final model had high accuracy with an AUC value of 88.5. It is important to note that AUC values tend to be lower for species that have broad distribution scope (Mcpherson and Jetz, 2007; Evangelista et al., 2008).

Table 1: *Environmental variables used in the study and their percentage contribution*

Code	Environmental variables	Percent contribution	Permutation importance
Bio1	Annual mean temperature		
Bio2	Mean diurnal range (mean of monthly max. and min. temp.)		
Bio3	Isothermality ((Bio2/Bio7) ×100)	10.9	2.9
Bio4	Temperature seasonality (standard deviation ×100)		
Bio5	Maximum temperature of warmest month		
Bio6	Minimum temperature of coldest month		
Bio7	Temperature annual range (Bio5–Bio6) ◦		
Bio8	Mean temperature of wettest quarter ◦C		
Bio9	Mean temperature of driest quarter	0.9	0.7
Bio10	Mean temperature of warmest quarter		
Bio11	Mean temperature of coldest quarter		
Bio12	Annual precipitation	1.6	1.2
Bio13	Precipitation of wettest period		
Bio14	Precipitation of driest period	0.2	0.9
Bio15	Precipitation seasonality (CV)	0.6	8
Bio16	Precipitation of wettest quarter		
Bio17	Precipitation of driest quarter		
Bio18	Precipitation of warmest quarter		
Bio19	Precipitation of coldest quarter	5	41.9
SLO	Slope	19.9	10.1
Ftype	Forest type	61	34.2

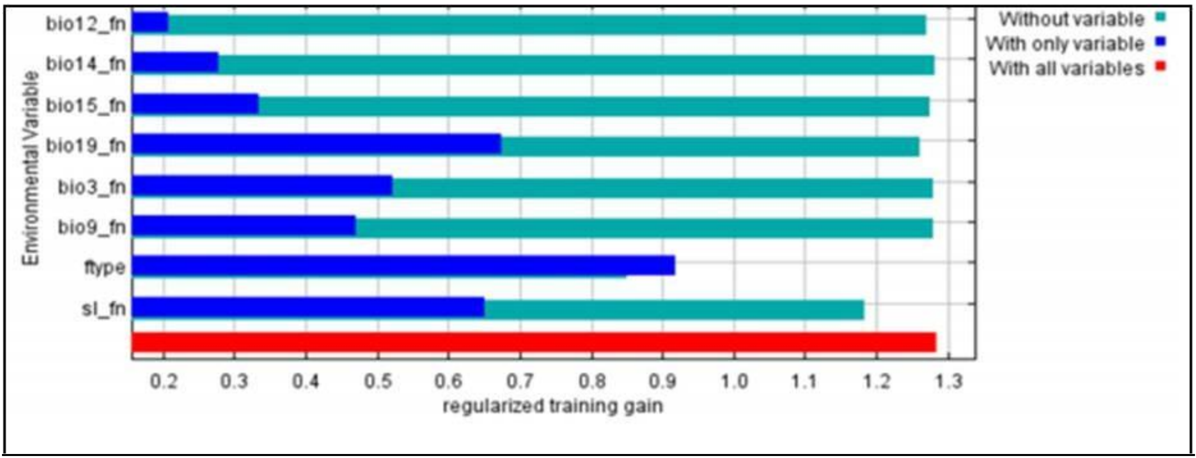

Figure 2: *The Jackknife test for evaluating the relative importance of environmental variables*

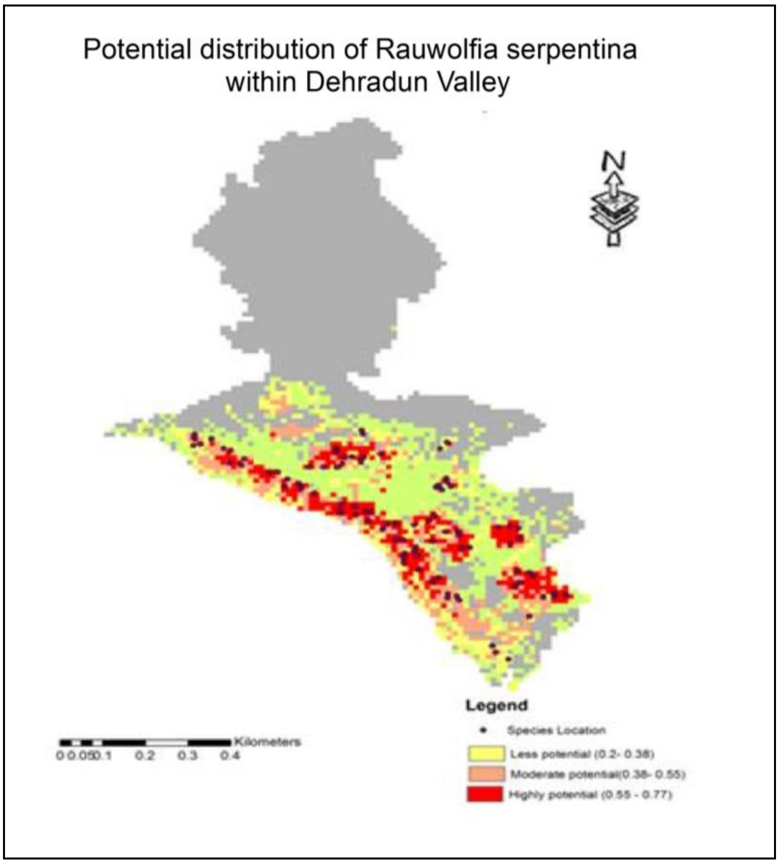

Figure 3: *Predicted potential distribution of Rauwolfia serpentina within dun valley*

As evident from the Figure 2, the eastern part of Dun valley, in general, has higher potential than the western part for *Rauwolfia serpentina*, which could primarily be attributed to the Forest types in this part of the Valley, especially Sal dominated areas. The model results showed that an area of 231.46 km^2 has high potential area. Approximately 254.50 km^2 area showed moderate potential while 234.39 km^2 area showed less potential. Our results support the statement that the predicted potential distribution areas through Maxent modeling almost always appear as over-estimated compared to realized niche of the species, i.e. the habitat. Since Maxent model considers only niche-based presence data, it predicts the species fundamental niche rather than realized niche (Pearson, 2007; Kumar and Stohlgren, 2009). In reality, a species might have failed to disperse due to geographic barriers, human disturbance or associated competitive species. The method is certainly promising in predicting the potential distribution of other medicinal plant species and can be a valuable tool in species conservation planning and climate change-species distribution studies.

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