Predicting the geographical distribution of *Calamus lakshmanae* Renuka (Arecaceae), an endemic rattan in the Western Ghats, India

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Abstract: We used maximum entropy distribution modeling (MaxEnt) for predicting the potential habitat suitability for *Calamus lakshmanae*, an endemic rattan found in Western Ghats, India. Of the twelve environmental variables tested, Bio 2 (Mean Diurnal Range), Bio 5 (Maximum Temperature of Warmest Month) and Bio 12 (Annual Precipitation) are the main variables contributing the prediction. The result of jackknife test indicated that the prediction is significantly better than at random ($P < 0.05$). The test and training Area under Curve (AUC) values (Training: 0.958; Test: 0.974; Number of Occurrences: 7) were also higher (above 0.97) which implies that the model is accurate and justifies the construction of final niche model with all the available points. The species predicted high suitability in forests of New Amarambalam Reserve, Kakkayam, Aralam, Kottiyur, Wayanad WLS, Tirunelli, Virajpet and Talakkaveri. The approach presented here appears to be quite promising in predicting suitable habitat for endemic and threatened species with small sample records and can be an effective tool for biodiversity conservation planning, monitoring and management.

Keywords: Area Under the Curve (AUC), Maximum entropy (MaxEnt), Environmental variables, Geographical distribution, Habitat Suitability, *Calamus*

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Introduction

The genus *Calamus* L. is the largest of all palm genera, including over 400 species distributed in the Asia-Pacific region, with one species in Africa (Baker, 2015; Henderson, 2020). The flexible stem '*cane*' of this rattan is a source of livelihood income for the forest dwelling communities and is mainly exploited for the furniture and handicraft industry. Due to overexploitation, the habitats and resources of the genus have been drastically reduced and most of the species are in a narrow distribution range. As per the IUCN status (2020), 4 species are red listed as critically endangered, 1 vulnerable, 1 near threatened, 11 Least concern and 2 as data deficient. Despite their commercial and ecological importance, not much is known about the resource inventory and basic knowledge on current distribution patterns in order to develop suitable *in-situ* and *ex-situ* conservation plans especially as in the case of endemic and threatened species.

Recent developments on ecological niche modelling (ENM) have explored applications to diverse conservation issues, which produces potential distribution maps by establishing a relation between the known presence localities and background information. ENM can provide diverse insights into the species range estimates (Gaubert *et al*., 2006; Guisan *et al*., 2006), protected area prioritization and network design (Rondinini *et al*., 2005), effects of habitat disturbance on species distributions (Sánchez-Cordero *et al*., 2005; Rhodes *et al.*, 2006) and also in ecology and evolutionary biology (Kozak and Wiens, 2006). The information on spatial distribution of species is one of the most crucial part of the systematic conservation planning and management of biodiversity. The information on the conservation aspects such as distribution, abundance and habitat quality, is important to identify threats, which enables one to derive a management strategy. Conventional methods to estimate the status and distribution are costly and time consuming. Alternatives are the ecological niche models (ENM) which reconstruct the potential distribution by combining the known occurrence records (accumulated through field surveys and other means) with the GIS coverages that summarize the background environmental information of a particular region. The ENM generates accurate maps and is very much useful and cost effective in understanding the geographical spread of rare, threatened and lesser known species. ENM are the best way to explore the availability of potential habitat, which will help in determining the possible range of distribution, planning further exploration and applying management decisions in regions.

Calamus lakshmanae is a medium sized endemic rattan restricted to few localities in Kerala and

Fig 1. *Calamus lakshmanae* Renuka - a view from Talakkaveri Wildlife Sanctuary

Karnataka part of the Western Ghats. This is a cluster forming rattan, with stems to grow up to 20 m long or more and the diameter is to 2.5 cm with leaf sheaths and to 1 cm in diameter without sheaths (Fig. 1). Leaves are ecirrate to 1.5 m long. The leaf sheath is yellowish green to green, densely armed with spines up to one cm in length. This rattan can easily identify with its yellowish, bulbous-based spines, pointing horizontally or upwards with distal younger sheaths less spiny and with brown markings. The length of petiole is 22 cm, armed with small, sometimes curved spines. Rachis is biconvex towards the basal portion, and triangular in the upper portion, with presence of many small recurved spines. Leaflets are 45cm in length, regular, linear - lanceolate, and 3 veined. The lateral veins ciliate on the dorsal surface, midvein ciliate below and spinulose at its margin. Inflorescence is long, pendulous; the partial inflorescence is to 60 cm long, and is attached well above the mouth of sheath. Fruit is ovate, 1 × 0.7 cm in length with scales in 26 rows, bright green when young, channeled along the middle. The type locality of this species is Makkuta forest in Karnataka (Renuka, 1990) and later, Rangan *et al*., (2003) reported this species from Kidakkamala forest in New Amarambalam Forest Division and also from Rosemala forests in Shendurney Wildlife Sanctuary. Renuka and Sreekumar (2012) conducted an exhaustive field survey to map distribution of this species in connection with the publication of field guide to Indian palms and potential distribution of this species was mapped. The details of specimens examined for *C. lakshmanae* is provided in Table 1 which shows that the species represent a typical example for narrow endemic species with limited distribution range and broken into disjunct patches.

Materials and methods

For predicting the geographic distribution of *C. lakshmanae*, seven occurrence points (four from Karnataka and three from Kerala) were recorded during the field surveys (Renuka and Sreekumar, 2012) and from herbarium records. These points were further geo-referenced in GIS tool and Google map to make presence locality points. The background environmental data is summarized by

Table 1. Details of specimens used for the present study.

Sl. No	Specimen details
1	**Karnataka**
	Makutta, 14 March 1989, Renuka 4086 (KFRI) Makutta, 16 April 1992, Renuka 10231, 10232 (KFRI) Makutta 9 June 2002, Rangan & Sreekumar 10488, 10489, 10490 (KFRI) Madikkeri, 8 April 2003, Sreekumar V B, 8425 (KFRI) Agumbae, 10 April 2003, Sreekumar V B, 8436 (KFRI) Chettukaya, 15 April 2003, 10741, 10742 (KFRI)
2	**Kerala**
	Malappuram, Nilambur, Kidakkamala, 22 January 2002, Rangan V V & Sreekumar V B 10222, 10223, 10224, 10225, 10226 (KFRI) Kollam, Rosemala, Shendurney WLS, 9 June 2002, Sreekumar V B & Rangan V V 10227, 10229 (KFRI).

12 environmental variables describing the peninsular India (Table 2). Of the 12 variables, seven were bioclimatic variables based on the global climate data sets developed by Hijmans *et al*., (2005). The Worldclim dataset version 1.4 is publicly available for download (http://www.worldclim.org). The GIS data sets characterize the global climates from 1950-2000 making use of different monthly weather station data. The elevation data was extracted from the Shuttle Radar Topography Mission (SRTM) 30 Plus data version 8.0 dated October 2012 (http://topex.ucsd.edu/WWW_html/srtm30_plus.html). Aspect, slope, CTI and TRI were computed in the GIS software ArcGIS. The slope and aspect were calculated in degrees. The CTI or compound topographic index is a steady state wetness index which is a function of both the slope and the upstream contribution per unit width orthogonal to the flow direction (Gessler *et al.,* 1995). The higher values of CTI represent higher water retention capacity for a particular pixel. The TRI or terrain ruggedness index is defined as the mean difference between a central pixel and its surrounding cells (Wilson, *et al*., 2007) computed from the elevation data. The resolution of all GIS raster coverages was standardized to the unit of 30 arc seconds, which roughly correspond to one square kilometre area per pixel. All the layers are masked to the peninsular Indian land mass south of Tropic of Cancer, approximately 23.5° North of the equator. The Maximum Entropy Modelling (MaxEnt) was used to predict the potential distribution which is shown to produce good results when compared to other general purpose modelling algorithms (Elith *et al*., 2006) and works extremely well with small number of occurrence records. The recent MaxEnt version 3.3.3k (http://www.cs.princeton.edu/~schapire/maxent/) was used to develop the models. In the program, 500 iterations were run with a convergence threshold of 0.00001 and a maximum of 10,000 background points and algorithm parameters were set to auto features (Phillips and Dudik, 2008). All other parameters were set at default settings. Maxent produces outputs in the form of cumulative raster with real numbers ranging between 0 and 100 representing the probability of occurrence. The model quality was tested with the receiver operating characteristic (ROC) analysis which is available in the form of area under curve values (AUC). Maxent computes response curves of each variable though jackknife procedure that computes the percentage of variable importance that influences the probability of occurrence of a species in its environmental space. The random test percentage in the settings was turned to 50% which randomly splits the dataset in to two and one is trained to produce the model and second is used to validate it (Fielding and Bell, 1997). Thus, two AUC scores were produced to check the predictability of the model.

Table 2. Environmental data used in modelling

Sl. No	Environmental Variables	Type	Source
1	Bio 01 Annual Mean Temperature	Bioclimatic- Temperature	Worldclim
2	Bio 02 Mean Diurnal Range	Bioclimatic- Temperature	Worldclim
3	Bio 05 Maximum Temperature of Warmest Month	Bioclimatic- Temperature	Worldclim
4	Bio 06 Minimum Temperature of Coldest Month	Bioclimatic- Temperature	Worldclim
5	Bio 12 Annual Precipitation	Bioclimatic- Rainfall	Worldclim
6	Bio 13 Precipitation of Wettest Month	Bioclimatic- Rainfall	Worldclim
7	Bio 14 Precipitation of Driest Month	Bioclimatic- Rainfall	Worldclim
8	Elevation	Topographic	SRTM
9	Slope	Topographic	SRTM
10	Aspect	Topographic	SRTM
11	CTI Compound Topographic Index	Topographic	SRTM
12	TRI Terrain Ruggedness Index	Topographic	SRTM

Results and discussion

The predicted distribution shows that the maximum potential of this rattan along the crest line of the Western Ghats and west coastal region of peninsular India (Fig. 2). Mean Diurnal Range, Maximum Temperature of Warmest Month and Annual Precipitation are the main variables contributing the prediction (Table 3; Fig. 3). The result of jackknife test indicated that the prediction is significantly better than at random ($P < 0.05$). The test and training Area under Curve (AUC) values (Training: 0.958; Test: 0.974; Number of Occurrences: 7) were also higher (above 0.97) which implies that the model is accurate and justifies the construction of final niche model with all the available points.The importance of climate for individual palm species distributions within tropical regions has been assessed (Blach-Overgaard *et al.,* 2009, 2010) and found climate to be more important than habitat and human impact in determining the continent-wide distributions. Most climbing palms show an overall preference for humid climates and precipitation is one of the important factors which affect the landscape-scale distributions of some abundant canopy palm species (Svenning, 2001; Sesnie *et al*., 2009). According to Tovaranonte *et al*., (2015) the four strongest single predictors of palm species distributions were, in decreasing order of importance, 1) latitude, 2) precipitation of driest quarter, 3) annual precipitation, and 4) minimum temperature of the coldest month, suggesting rainfall patterns and latitudinal spatial constraints as the main range determinants. Couvreur *et al*., (2015) has also pointed that climbing palm species richness in tropical forests is associ-

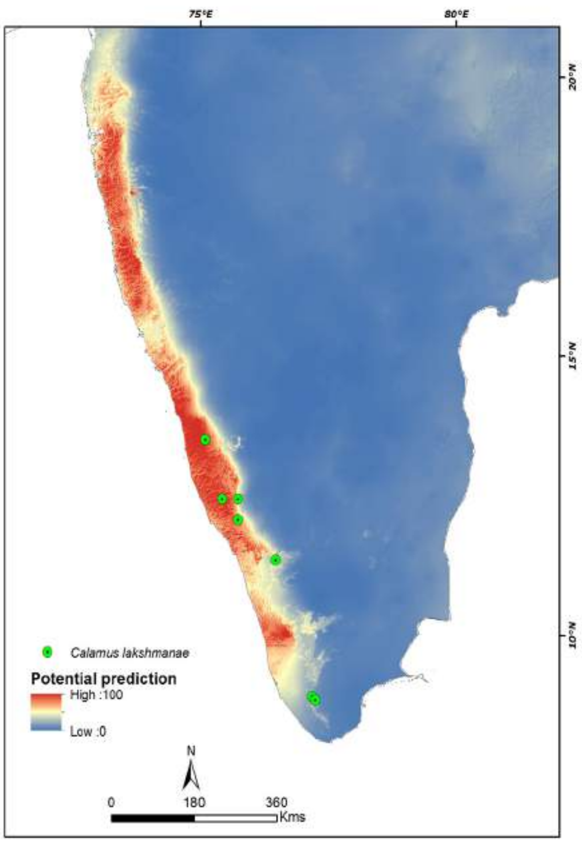

Fig 2. Maxtent predictive modelling showing potential distribution of C. *lakshmanae*

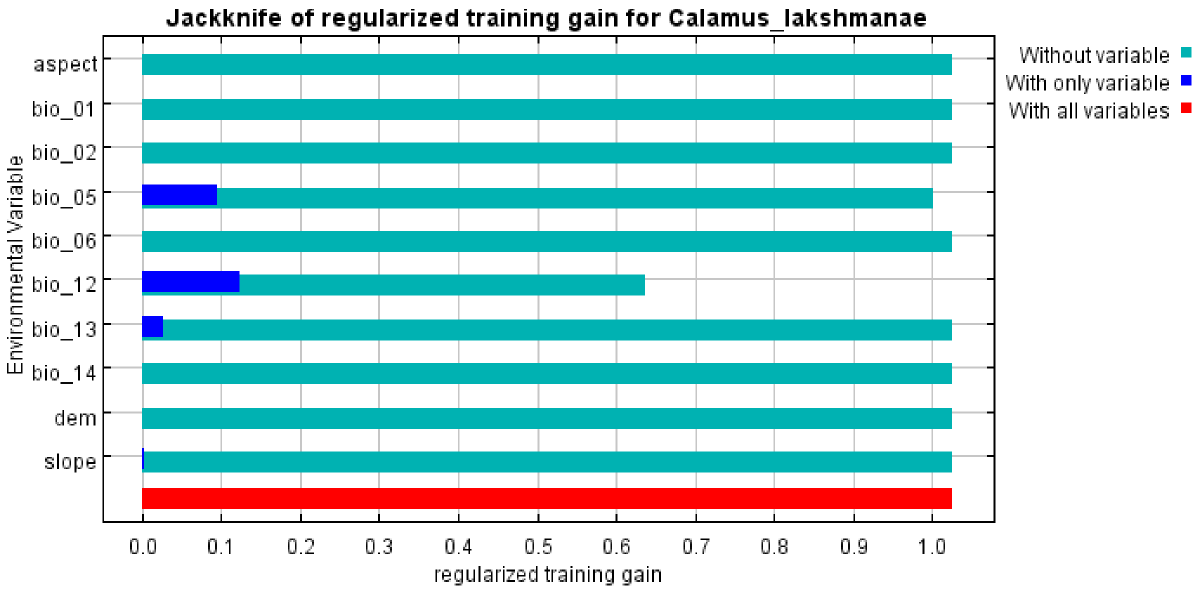

Fig 3. The Jackknife test for evaluating the relative importance of environmental variables for *C. lakshmanae* ("Bio05"is Maximum Temperature of Warmest Month; "Bio12" is Annual Precipitation; "Bio13" is Precipitation of Wettest Month.)

ated with present day climate (temperature, precipitation seasonality) and paleoclimatic changes since the late Neogene (Miocene and Pliocene). With regard to prediction of *C. lakshmanae*, the Central Western Ghats, forest areas like New Amarambalam Reserve, Kakkayam, Aralam, Kottiyur, Wayanad WLS, Tirunelli in Kerala and Virajpet and Talakkaveri shows high suitability. Though the species are not reported from northern Western Ghats, areas like Lonavala, Amby valley, Raigad nature Reserve, Koyna and Mahabaleswar predicted the high suitability for *C. lakshmanae.* However, in Southern Western Ghats, the highly predicted areas are limited to the Cardomom Hill Reserve and coastal plains of Alapuzha. The natural distribution areas like Rosemala and Umayar in Shenduruney WLS were predicted as medium suitability sites. The main associated trees here are *Vateria indica*, *Hopea rachophloea*, *Dysoxylum malabaricum* etc. characterised by low tree plant diversity and are facing severe issues in natural regeneration also. The main distribution zone of *C. lakshmanae* is the forest areas of Karnataka like Makkuta, Agumbae, Virajpet, Karike and Sampaje as represented by herbarium specimens. Here, the vegetation is tropical evergreen type and dominant tree species are *Dysoxylum malabaricum*, *Knema attenuata*. The other common plant species are *Archidendron monadelphum*, *Aglaia lawii*, *Diospyros candolleana*, *Euonymus crenulatus, Humboldtia brunonis, Kingiodendron pinnatum* and *Sterculia urens*. The other associated rattans are *Calamus* thwaitesii and *C. prasinus*. These areas represent elevation ranging between 150 and 400 m above MSL and receive an annual rainfall ranging from 4250 - 5500 mm. In Shenduruney WLS, the dominant associated trees are *Hopea rachophloea, Vateria indica* and other rattans like *Calamus* hookerianus, *C. travancoricus*, *C. thwaitesii* are also represented.

Table 3. Relative contribution of bioclimatic variables of *C. lakshmanae*

Variable Contribution	Bio 2 Mean Diurnal Range	Bio 5 Max Temperature of Warmest Month	Bio 12 Annual Precipitation
Percent contribution	33.1	1.4	65.4
Permutation importance	0	1.3	98.6

Conclusion

ENM is quite promising in predicting suitable habitat for threatened and endangered species with small sample records and can be an effective tool for biodiversity conservation planning, monitoring and management (Khafag *et al.*, 2012). The results of distribution mapping of *C. lakshmanae* can be utilised for planning land use management around its existing populations, discover new populations, identify top-priority survey sites, or set priorities to restore its natural habitat for more effective conservation. Populations representing different geographical areas of this species are conserved in the rattan germplasm of Kerala Forest Research Institute.

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