Assessing the distribution of *Piper porphyrophyllum (Sireh rimau*) using species distribution model (SDM) in Kelantan, Peninsular Malaysia

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Assessing the distribution of *Piper porphyrophyllum* (*Sireh rimau*) using species distribution model (SDM) in Kelantan, Peninsular Malaysia

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Abstract. *Piper porphyrophyllum* (Lindl.) N.E.Br. is one of the genera from the family Piperaceae. The local names for *Piper porphyrophyllum* are Sireh Rimau, Kerakap Rimau or Akar Bugu. *P. porphyrophyllum* was recorded in Machang and Jeli, Kelantan. and very common in the forests of Peninsular Malaya, but flowers are scarcely ever found. However, limited information on its distribution occurred in Kelantan. The objective of this study is to map the potential distribution of *P. porphyrophyllum* that occurs in Kelantan using the Species Distribution Model (SDM). During the survey, a total of five individuals and twelve individuals of *P. porphyrophyllum* were recorded respectively at Pulai Chondong, Machang and Lata Cuit, Jeli, Kelantan. The potential distribution of *P. porphyrophyllum* that occurred in Kelantan was mapped using the species distribution model (SDM) to predict their occurrence in Kelantan and mostly distributed in Jeli and Gua Musang. According to the Malaysia Plant Red List *P. porphyrophyllum* is listed as Not Evaluated (NE).

1. Introduction

Piper is a genus in the Piperaceae family with five genera [1]. This pantropical genus is thought to have around 2000 species spread across the Asian and American tropics, including Indonesian, Indian, and Malaysian tropical rainforests. Most Piper species appeared to be confined to altitudes ranging from 0 to 2500 m with only a few occurring above 3000 m and growing in moist and shady areas [2]. Piper species range from locally endemic to widespread in their geographical patterns. Piper is a common understory species in tropical forests and has been identified as one of the five most speciose genera in certain tropical forests.

Piper species are ecologically significant and have been categorised as "key" species due to their affiliation with frugivorous bats [3]. Piperaceae includes slender, often spindly trees and shrubs, as well as robust climbers and terrestrial and epiphytic herbs. The climbing species in this family use adventitious roots at nodes to attach themselves to supporting vegetation. The Piperaceae leaves are exceedingly polymorphic, ranging in size from 2 mm to 70 cm in length, and can be elliptic, round, oblong, ovate, sagittate, or cordate [4].

Many plant families have a worldwide distribution, but few have the ethnobotanical and ethnopharmaceutical heritage that Piperaceae does. Although the latter has been used for decades both medicinally and as a food additive, the associated health risk to humans is typically regarded as moderate [5] (Scott et al., 2007). However, *Piper porphyrophyllum* (Lindl.) N.E. Br. is a Malaysian indigenous plant also known locally as kerakap rimau, sireh rimau, or akar bugu. This purple and the speckled wild plant is said to be useful against leprosy, stomachaches in children, and a variety of skin disorders [6]. To estimate species distributions, species distribution models (SDMs) were used to predict future distributions of a species based on information on environmental circumstances. SDMs employ several

algorithms to evaluate correlations between species locations and environmental circumstances, as well as to predict and map habitat suitability [7].

2. Methodology

2.1. Study area

The study was conducted in two districts, Pulai Chondong in Machang and Lata Cuit in Jeli, Kelantan (Figure 1). Pulai Chondong is located at the coordinates 5.87134°N, 102.23573°E and covers a total area of 5,498 hectares. It is in the state's centre, bordered by the Kelantan territories of Kota Bharu to the north, Terengganu State to the southeast, Pasir Puteh to the east, and Kuala Krai to the south, and Tanah Merah to the west [8]. While, Lata Cuit is located at 5°37'28.5°N, 101°44'19.7°E. Lata Cuit is one of the Gunung Basor coverage areas, with an elevation of 1,840 m and is located about 6 kilometres from Lata Janggut.

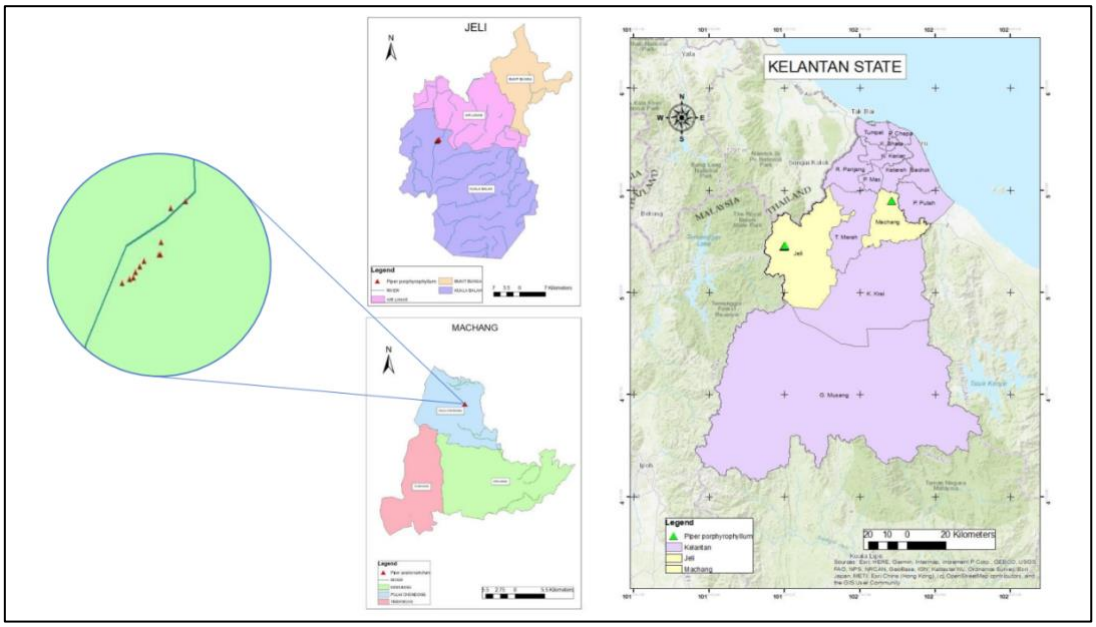

Figure 1. The map shows the study area at Pulai Chondong and Lata Cuit, Kelantan.

2.2. Sampling data

In this study, the species occurrence of *Piper porphyrophyllum* was recorded using a hand-held Global Navigation Satellite System (GNSS) receiver that occurred along 6 km of trail [9]. The random sampling method was applied during sampling because is based on likelihood and randomised picking, the smaller sample that results is quite certain to be indicative of the whole population and is free of researcher bias. All locality data encountered during these surveys were identified and their position recorded with a GPS (Garmin GPSmap CSX60, Olathe, Kansas, USA). In developing models where multiple locality records that positioned within the same grid cell (6 arcs per second), only one record was included in the analysis to minimise sampling bias [10].

2.3. Generate Species Distribution Model (SDM)

2.3.1 Preparing data layers

The species distribution model (SDM) was generated using MAXENT v3.3.4 software and freely can be downloaded from (www.cs.princeton.edu/~schapire/maxent/) [11]. MAXENT is shown to perform better than other modelling techniques [12] because it can reduce the least errors in locality data

collected and performs more strong outcomes when there are limited numbers of collection localities [13][14]. The most outstanding highlighted in this method uses maximum entropy density estimations to represent the distribution of a species as a probability distribution over the study site [15]. The models are obtained from locality data (presence-only data) and the layer of environmental variables that are considered the most important for defining the suitability of the environment for the species. These data are used to develop a model that predicts environmental suitability as a function of the environmental variables. The model is then projected into geographic space to predict the distribution of the species [11]. In Maxent, locality data of *Piper porphyrophyllum* (Lindl.) N.E. Br. was saved as a comma-separated value (.csv) file.

2.3.2 Modifying Environmental Layers

The ENMs were developed using bioclimatic and altitudinal variables. Bioclimatic data (1-19) for Kelantan at 30 arc-second (~1 km^2) resolution were obtained from WorldClim (http://www.worldclim.org) (Table 1) and altitudinal layers were also obtained from the same online source at 30 arcs second resolution. Maxent v3.3.4 only allowed ESRI ASCII grid format to be added to the software. All environmental data were projected to the WGS84 projection. All bioclimatic and altitude are continuous data types that were resampled to the smallest common size of 6 arc seconds (~0.04 km^2). The steps of modifying the environmental layers were summarised in Figure 2. All the steps of preparing, modifying and generating the species distribution models of *Piper porphyrophyllum* (Lindl.) N.E. Br. were referred in from [16].

Table 1. Code of bioclimatic variables that represent each code

Code	Bioclimatic
Bio_1	Annual Mean Temperature
Bio_2	Mean Diurnal Range (Mean of monthly (max temp – min temp))
Bio_3	Isothermality (P2/P7)*(100)
Bio_4	Temperature Seasonality (standard deviation*100)
Bio_5	Max Temperature of Warmest Month
Bio_6	Min Temperature of Coldest Month
Bio_7	Temperature Annual Range (P5-P6)
Bio_8	Mean Temperature of Wettest Quarter
Bio_9	Mean Temperature of Driest Quarter
Bio_10	Mean Temperature of Warmest Quarter
Bio_11	Mean Temperature of Coldest Quarter
Bio_12	Annual Precipitation
Bio_13	Precipitation of Wettest Month
Bio_14	Precipitation of Driest Month
Bio_15	Precipitation of Seasonality (Coefficient of Variation)
Bio_16	Precipitation of Wettest Quarter
Bio_17	Precipitation of Driest Quarter
Bio_18	Precipitation of Warmest Quarter
Bio_19	Precipitation of Coldest Quarter

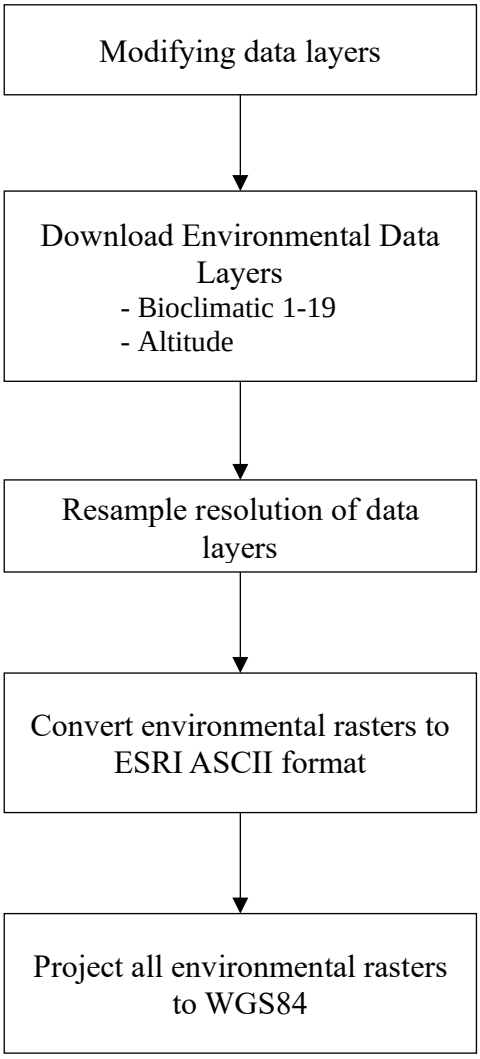

Figure 2. Steps in modifying all environmental data layers before adding into Maxent software

2.3.3. Running the MaxEnt Model

After all environmental data layers were set up accordingly to steps as shown in Figure 2, the species distribution model of *Piper porphyrophyllum* were all set to be ran. The model was replicated to 100 replications. The steps in setting up the Maxent setup to run the model of *Piper porphyrophyllum* (Lindl.) N.E. Br. was refered from [16].

3. Results and Discussion

As a result, four maps of the model were generated as shown in Figures 3(a), (b), (c), and (d) in predicting the distribution of *Piper porphyrophyllum* in Kelantan. The gradient colour shown in the output map indicated blue to red which ranges from 0 to 1. As shown in Figure (3d) blue indicates the area that is not suitable precited area of *Piper porphyrophyllum* to occur and gradually changed to the suitable habitat to occur from green to red colour. As a result Figure (3d), there is a certain area indicating green colour as suitable habitat for species to occur however the location is mostly along the coastal area in Pengkalan Chepa. Other predicted areas show that the suitable habitat of *Piper porphyrophyllum* such as in Jeli, Kuala Krai and Gua Musang most suitable habitat because those three districts are still covered with forest areas.

The result shows the species, the number of individual of *P. porphyrophyllum* found at Lata Cuit is

more than compared to Pulai Chondong. Both study sites are still covered with forest and undisturb area. *Piper porphyrophyllum* in both Lata Cuit, Jeli and Pulai Chondong, Machang were ecologically found at 320 m above sea level.The point-wise standard deviation is decreased because of insufficient data. Insufficient data may cause the poor prediction of species distribution model for *P. porphyrophyllum* in Kelantan. Another implication on model prediction were predited to be appeared in the area that are fully developed and covered with agricultural such as in Kota Bharu as shown in Figures 3 (a), (b), (c) and (d). Figure 3(c) shows the point-wise max located at Kota Bharu, Jeli, and Gua Musang. It also shows the suitable environment for *P. porphyrophyllum* to occur in certain preferable habitat. Figure 3(d) shows the point-wise 95% confidence level lowerci prediction located at Kota Bharu, Jeli, Kuala Krai and Gua Musang. Prediction data is unavailable for Bachok, Pasir Mas, Pasir Puteh, Tumpat, Machang, and Tanah Merah. Hence, more locality data need to be sampled in other district to double confirm the occurrence of *P. porphyrophyllum*.

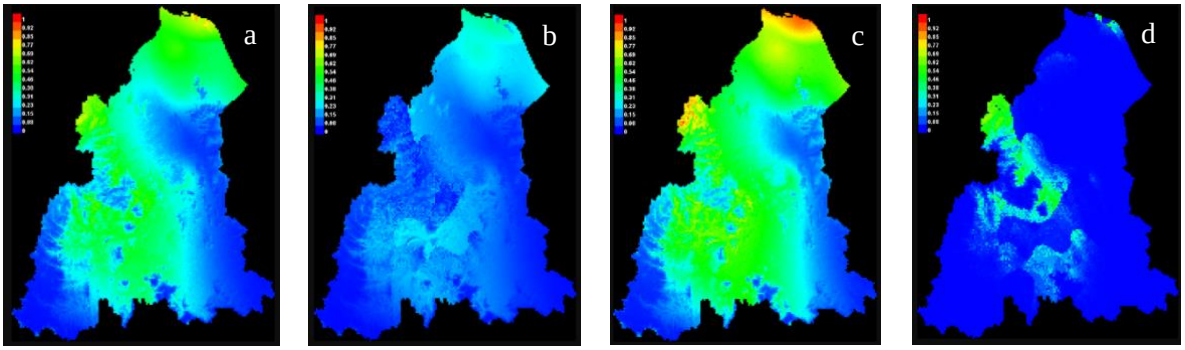

Figure 3. This map shows the point-wise which are a (mean) and b (standard deviation) of the 100 output grids. Other available summary grids are c (max) and d. (95% confidence level or called lowerci).

3.1. The variable contributions

Table 2 shows the environmental variables used in the model and the percent predictive contribution of each variable included during model running. The highest the contribution, the more impact that particular variable has on predicting the occurrence of that species. In this exercise, Precipitation of Driest Month (i.e. *kelbio14res*) had the highest predictive contribution of 80.4%.

Table 2. The analysis of variable contributions has shown the estimates of relative contributions of the environmental variables to the Maxent model. Values shown are averages over replicate runs.

Variable	Percent contribution	Permutation importance
kelbio14res	80.4	52.1
kelbio3res	5.5	4
soil_kelres	3.4	1.1
alt_kelres	3.3	21.3
kelbio13res	2.9	1.5
kelbio19res	2.8	6.6
kelbio12res	1.1	0
kelbio16res	0.5	9.4
kelbio9res	0	3.8

3.2. Jackknife test of variable importance.

Figure 4(a) shows the Jackknife of Regularized Training Gain that the training gain of each variable if the model was run in isolation, and compares it to the training gain with all the variables. This is useful to identify which variables contribute the most individually. The *Piper porphyrophyllum* model also provides a jackknife for test gain of the species as shown in Figure 4(b) and Figure 4(c) and AUC.

The estimations of relative contributions of the environmental factors to the Maxent model are shown in Table 2. The first estimate is required to decide whether the increase in systemized gain is included in the involvement of the related parameter for every repetition of the training procedure, or deducted from that if the changes in the absolute amount of lambda are negative. The values of each environmental variable on training involvement and background data are casually permuted in the second estimate for every environmental parameter. On the permuted data, the models are reevaluated, and the subsequent decline in training AUC is given in the table, normalised to percentages. When the predictor parameters are associated, parameter contributions should be taken carefully, just like the variable jackknife. The table displays the environmental factors utilised in the model as well as the % predictive contribution for each parameter, along with the parameter contribution analysis.

Figure 4(b) shows the same jackknife test, using test gain instead of training gain for *P. porphyrophyllum*. The positive value of test gain are kelbio14res, kelbio17res, kelbio18res, kelbio3res, kelbio5res, and kelbio9res. The data for kelbio14res is the highest value of *P. porphyrophyllum*. The testing gain with all variables is negative because there are more negative data compared to those that are positive. Figure 4(c) shows the jackknife of AUC for *Piper porphyrophyllum*. Since the value of the AUC with all variables is 0.68 it is a moderate model. The precipitation Driest months in the north are October, November, and December; in the south, December, January, February, and March and summer are the rainy season, and May, June, and July are the driest months of the year. The best performing model for species distribution should be obtained that ranges from AUC values of 0.7-1.0.

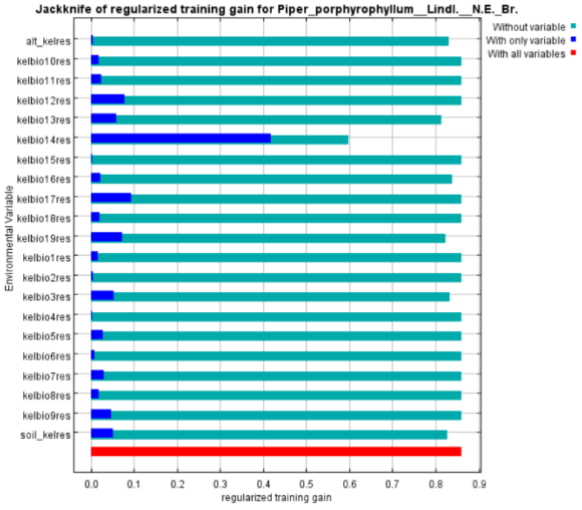

Figure 4(a). Jackknife of regularised training gain for *Piper porphyrophyllum* (Lindl.) N.E.Br.

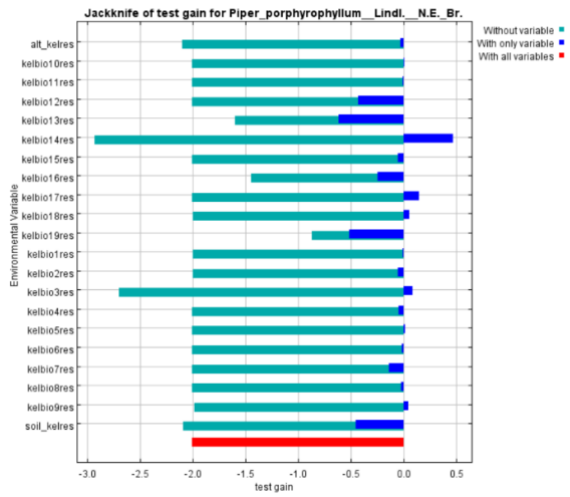

Figure 4(b). Jackknife of test gain for *Piper porphyrophyllum* (Lindl.) N.E.Br.

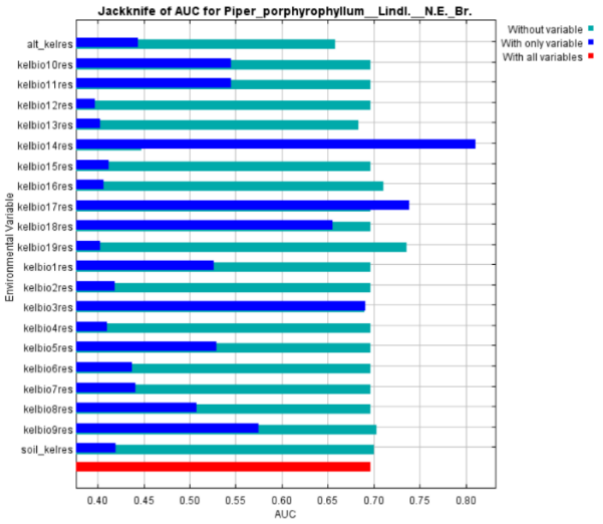

Figure 4(c). Jackknife of test gain for *Piper porphyrophyllum* (Lindl.) N.E.Br.

The advantage of using Maxent uses only presence-only data, recognising that absence data are rarely available or reliable [11], [17], [18]. This is appropriate for species distribution modelling concerned with predicting areas of potential species occurrence – for which MaxEnt has been largely used. For example, during the modelling task background values in the environment were not suitable and were not encountered as absences [19] [20]. Secondly, the model output is continuously allowing for fine distinctions to be made between the levels of wildfire risk in different areas. Thirdly, Maxent is a productive approach that uses the environmental data from across the study area rather than a discriminative approach, which is an advantage when the presence of data is limited [18].

4. Conclusion

As conclusion, twelve and five individuals with *Piper porphyrophyllum* were recorded in Lata Cuit and Pulai Chondong, Kelantan, respectively. This study determined that species distribution models (SDM s) could be applied to forecast the species distributions. of *Piper* sp. in Kelantan, Malaysia. Despite the data, we obtained consisting of only two locations, Pulai Chondong and Lata Cuit. Species distribution models (SDMs) can be used to predict another potential habitat for *Piper porphyrophyllum* in Kelantan. As a result, the locations with the highest predicted distribution are Jeli and Gua Musang. It is recommended for future studies to conduct more sampling on locality data in obtaining better model performance.

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