Synthetic Biobots

Biogeography

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Introduction

Piper nigrum is naturally distributed in India in the Western Ghats biodiversity hotspot and other parts of Asia, this distribution is a result of the realized ecological niche of the plant, this means that these are the places were the plant is actually found and thrive, but there are many other places where this crop could grow, this would be its fundamental ecological niche.[7;6] The ecological niche modelling approach has been used to predict fundamental and potential geographic distribution of black pepper before. HAO et al. 2012 predicted the potential geographic distribution of *Piper nigrum* using the maximum entropy algorithm, the analysis predicted these areas successfully and was found useful in applications such as crop introduction and conservation. Sen et al. 2016 used this same methodology and algorithm to study the impact of climate change on black pepper in Western Ghats, India.

We could be able to determine the fundamental ecological niche of *P. nigrum* in Mexico in order to determine whether or not it's possible to grow this crop in the area of interest, which are the states of Michoacán, Jalisco and Sinaloa, mainly.

Methodology

In order to model the ecological niche of *P. nigrum*, the 19 bioclimatic variables of WorldClim version 2 and the elevation data used for WorldClim version 2.1 derived from the SRTM elevation data were used at a resolution of 2.5 minutes, this variables are shown in Table 1.

Table 1: Bioclimatica variables useed and their codes.

Code	Variable
Bio_1	Annual Mean Temperature
Bio_2	Mean Diurnal Range (Mean of monthly (max temp - min temp))
Bio_3	Isothermality (BIO2/BIO7) ($\times$100)
Bio_4	Temperature Seasonality (standard deviation $\times$100)
Bio_5	Max Temperature of Warmest Month
Bio_6	Min Temperature of Coldest Month
Bio_7	Temperature Annual Range (BIO5-BIO6)
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 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
Elev	Elevation

The occurrences data of *P. nigrum* were obtained from the Global Biodiversity Information Facility (GBIF) database.[3] The ecological niche modeling was made using the Maximun Entropy (Maxent) algorithm described by Phillips et al. 2006; it is a machine learning method well suited for prediction of the distribution of species with presence-only data. The model used a 30% presence data points as test dataset and the resting data points as the training dataset, bootstrap was performed with 1000 iterations.

Results

In figure 1 the omission and prediction area for the presence data when variation with the choice of cumulative threshold is shown, here we can see that the omission on test samples is matches the predicted omission rate. The plot shown in Figure 2 shows the receiver operating curve (ROC) for training and test data, along with the area under the curve (AUC). In this case the AUC is bigger than 0.9 for both training and test datasets, indicating a very high performance.[1]

In order to know wich variables are the most important when predicting the ecological niche of *P. nigrum* a jackknife analysis was performed, for this analysis a model excluding every variable at once and also a model using only that variable was created and evaluated using training gain, test gain and AUC. In figure 3 the training gain for the jackknife analysis is shown, here we can see that the most important bioclimatic variables to predict the distribution of black pepper are bioclimatic variables 6, 7, 12, 13 and 16. In Figure 4 the same results are shown for test gain, in this case the most important variables were the same than in training gain. In the cas eof AUC (Fig. 5) the results were not different and these same five variable were the most informative to predict the ecological niche; these results are consistent with HAO et al. 2012, who found the same five variable as the most informative ones when predicting the potential niche in Asia for black pepper.

In Figure 6 the response of *Piper nigrum* to the different bioclimatic variables is shown, this response is when only that variable is taken into account and not its response to the variable reported by our model. In Figure 7 the response of *P. nigrum* to the different variables according to our predicted ecological niche. All this plots are shown in cloglog scale.

Whit all this values and the response of *P. nigrum* to the diffrent variables in the value the ecological niche was projected on the map of Mexico (Figure 8). In this figure we can see that the main region were the ecological niche is projected is in the sudeast of the country, mainly the states of Chiapas, Tabasco, Veracruz and Oaxaca. The states of interest (Michoacán, Jalisco and Sinaloa) do not provide an appropriate environment for the grow of this crop, so the production of the piperine and related piperamides directly from the cultivation of *P. nigrum* in this region is not suitable.

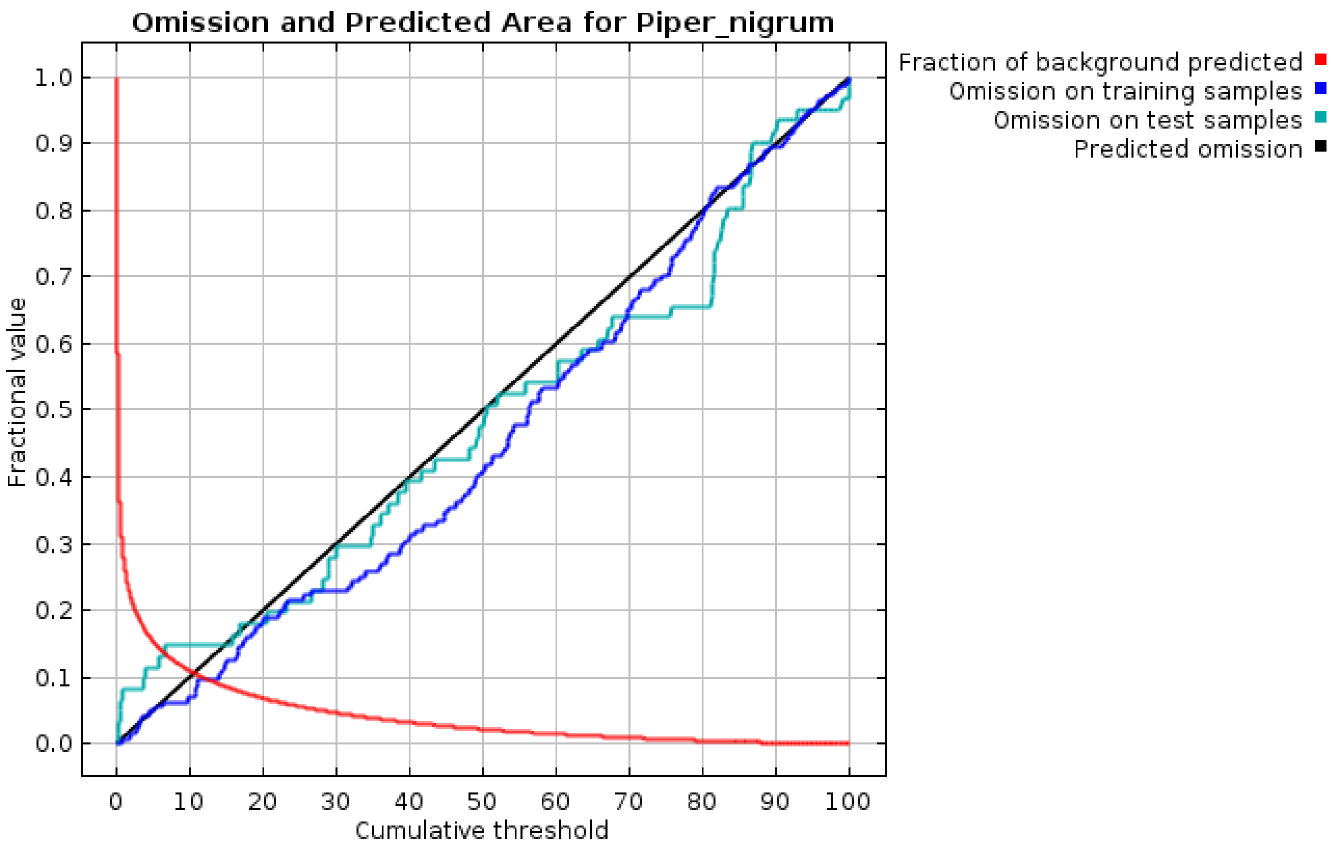

Figure 1: Testing and training omission vs cumulative threshold.

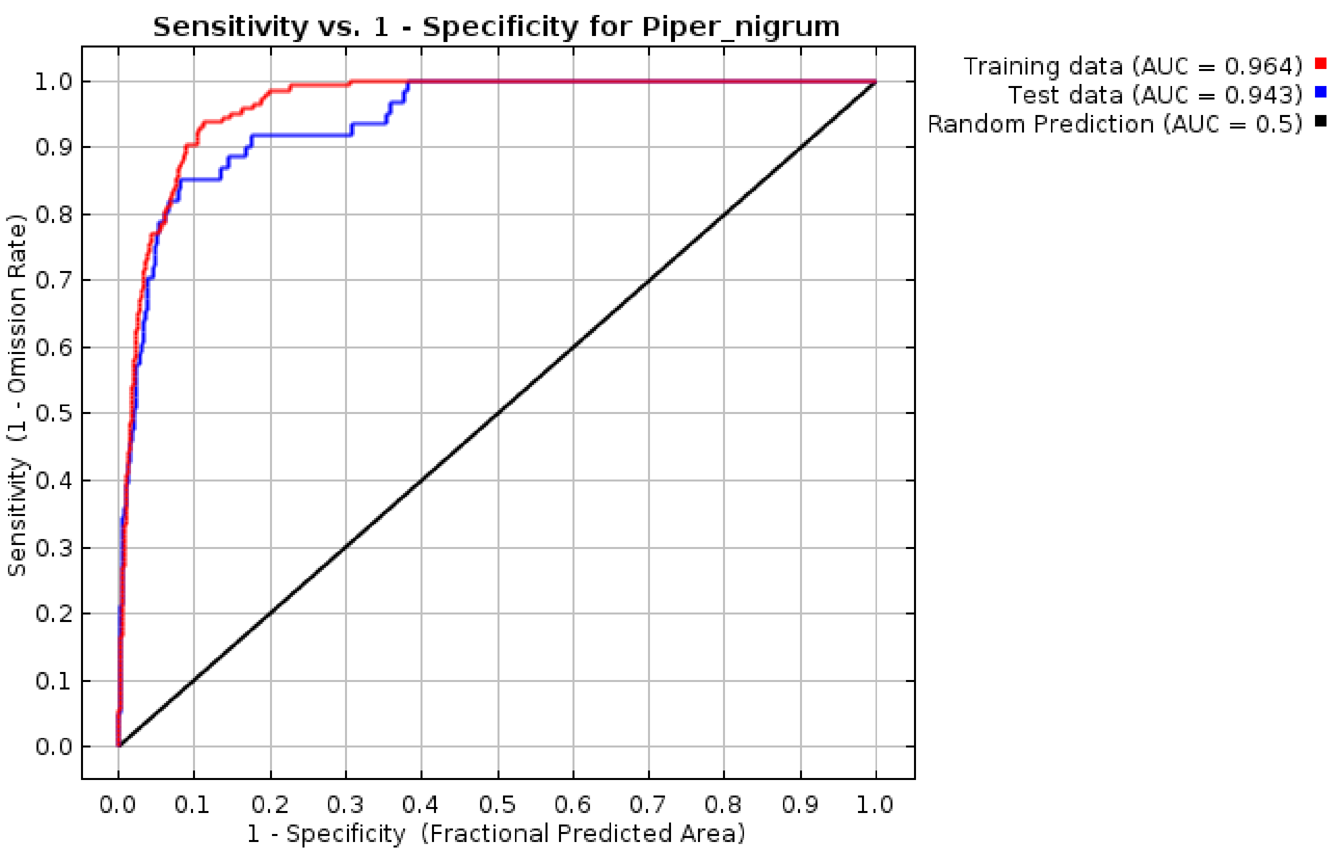

Figure 2: Receiver operating curve (ROC) and area under the curve (AUC).

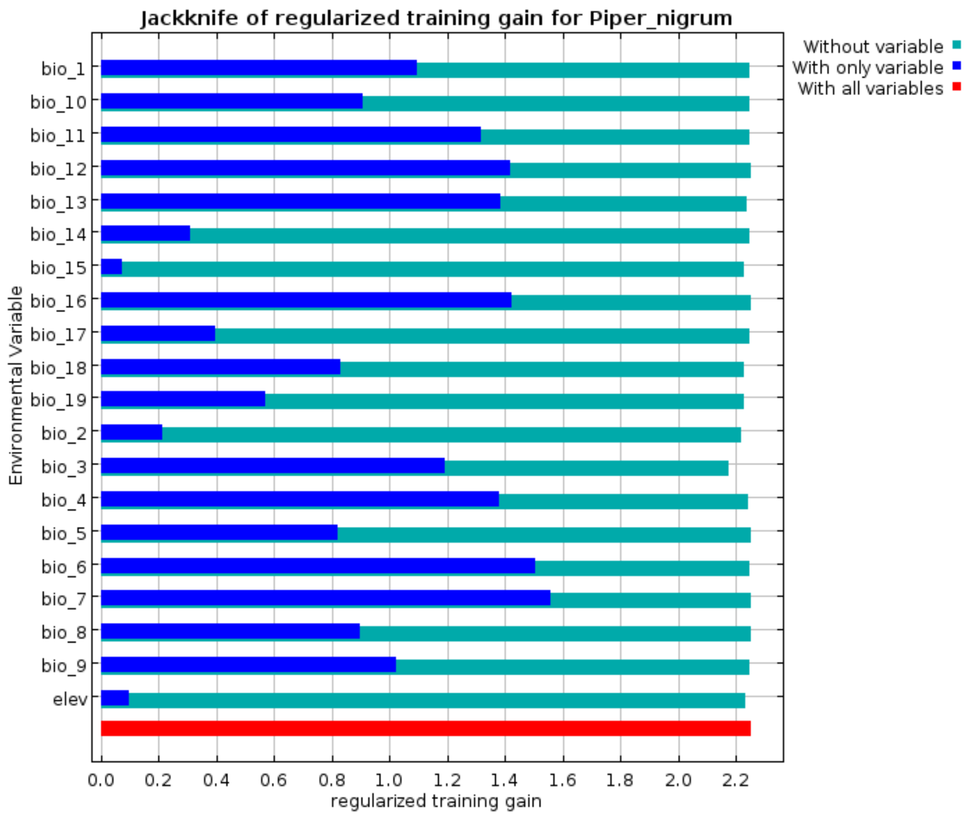

Figure 3: Jackknife of training gain.

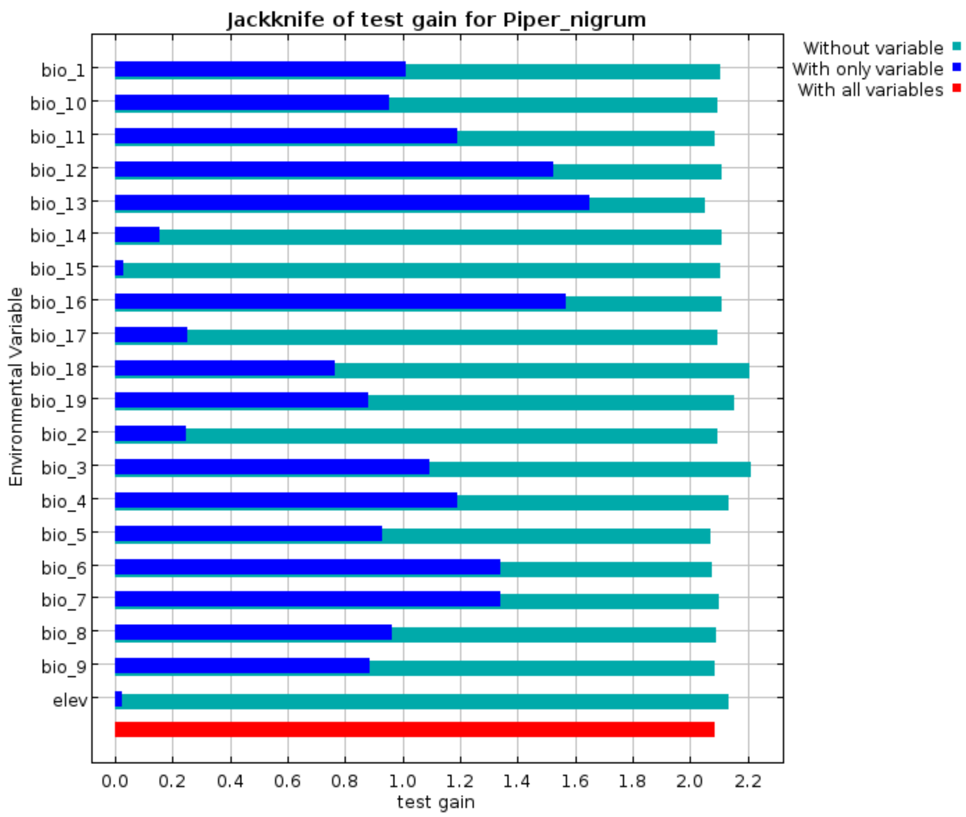

Figure 4: Jackknife of test gain.

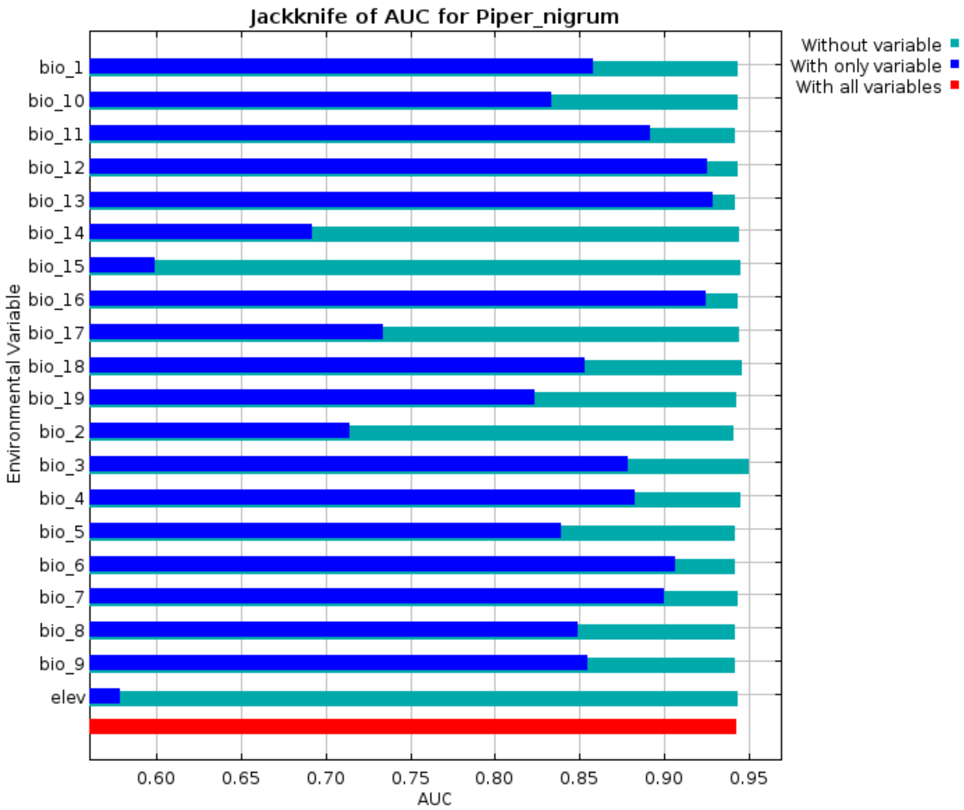

Figure 5: Jackknife of AUC

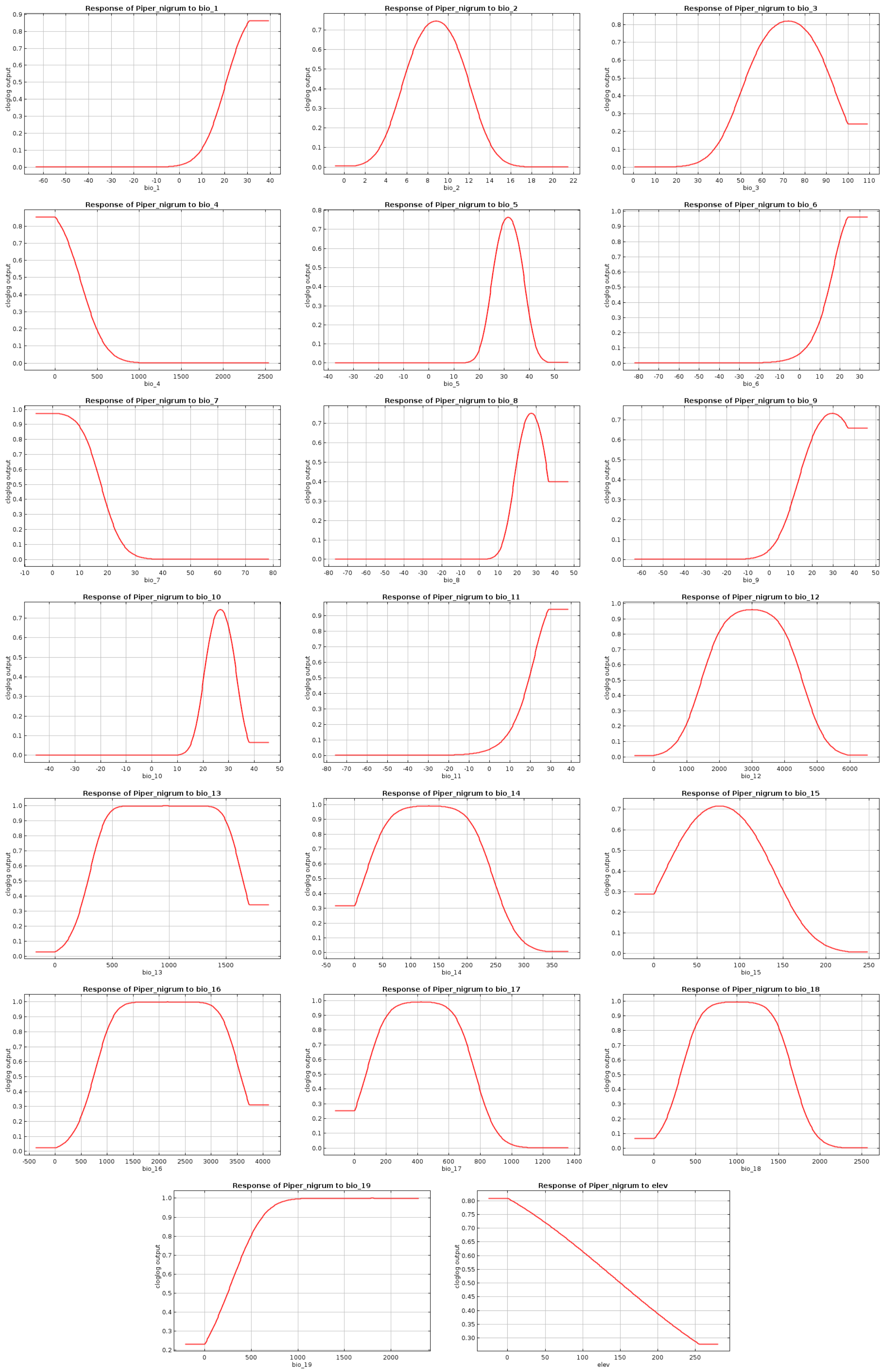

Figure 6: Response of *Piper nigrum* to the different bioclimatic variables.

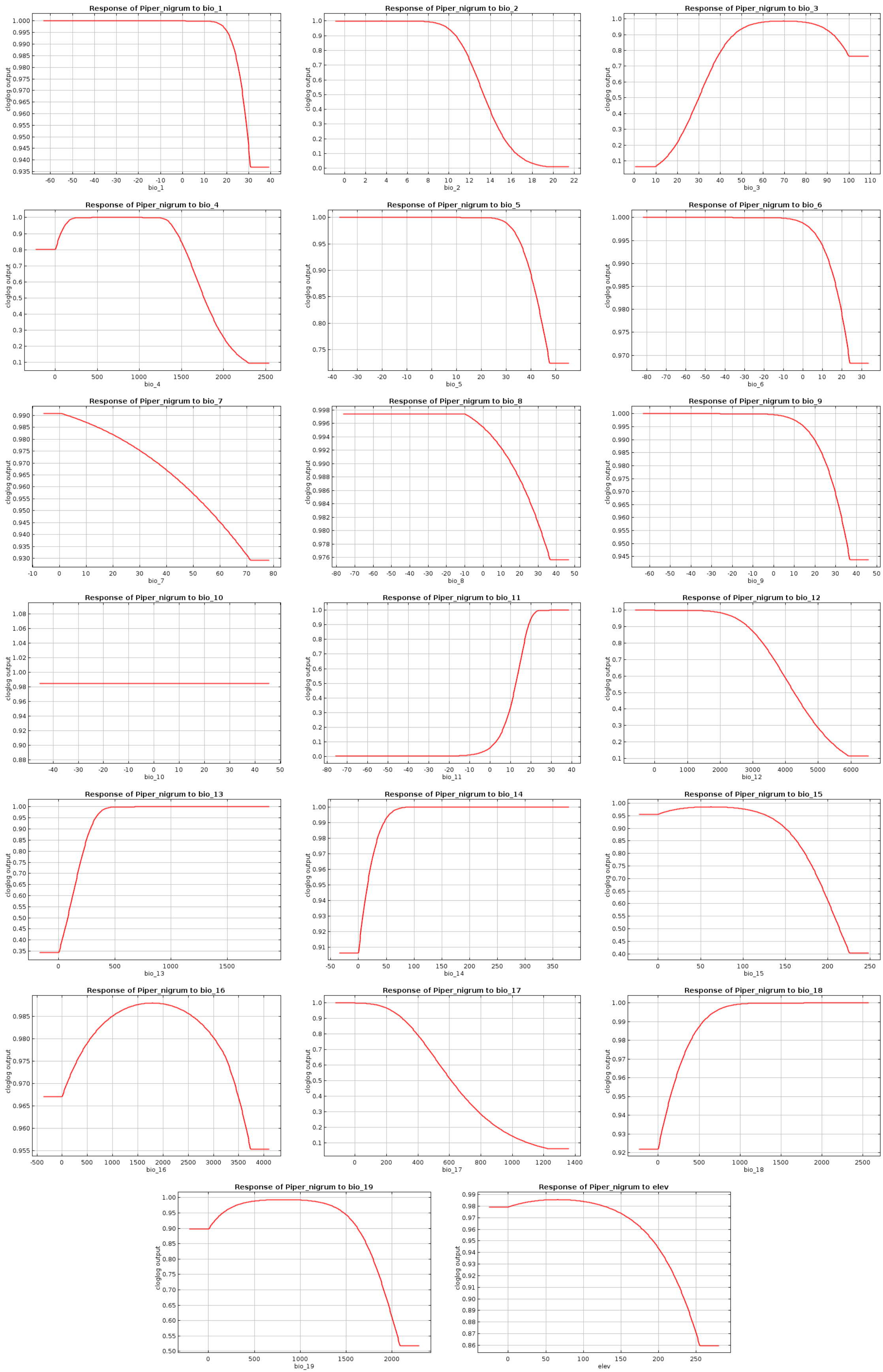

Figure 7: Response of *Piper nigrum* to the different bioclimatic variables according to ecological niche model.

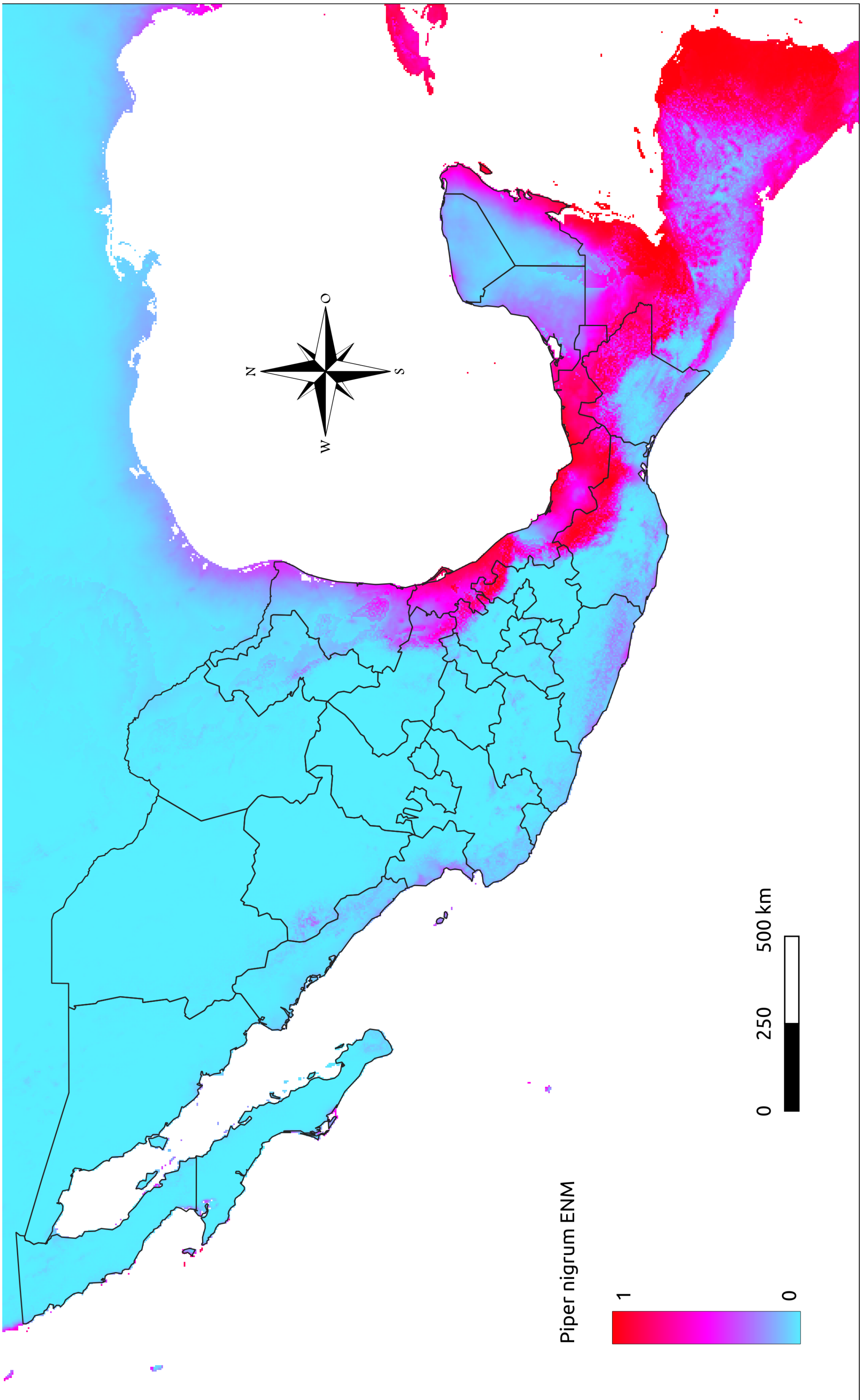

Figure 8: Projection of *P. nigrum* ecological niche on mexican territory.

References

[1] Fielding, A. H. and Bell, J. F. (1997). A review of methods for the assessment of prediction errors in conservation presence/absence models. *Environmental conservation*, 24(1):38–49.

[2] HAO, C.-y., Rui, F., Ribeiro, M. C., TAN, L.-h., WU, H.-s., YANG, J.-f., ZHENG, W.-q., and Huan, Y. (2012). Modeling the potential geographic distribution of black pepper (piper nigrum) in asia using gis tools. *Journal of Integrative Agriculture*, 11(4):593–599.

[3] Lane, M. A. and Edwards, J. L. (2007). The global biodiversity information facility (gbif). *Systematics Association special volume*, 73:1.

[4] Phillips, S. J., Anderson, R. P., and Schapire, R. E. (2006). Maximum entropy modeling of species geographic distributions. *Ecological modelling*, 190(3-4):231–259.

[5] Sen, S., Gode, A., Ramanujam, S., Ravikanth, G., and Aravind, N. (2016). Modeling the impact of climate change on wild piper nigrum (black pepper) in western ghats, india using ecological niche models. *Journal of plant research*, 129(6):1033–1040.

[6] Sillero, N. (2011). What does ecological modelling model? a proposed classification of ecological niche models based on their underlying methods. *Ecological Modelling*, 222(8):1343–1346.

[7] Soberon, J. and Peterson, A. T. (2005). Interpretation of models of fundamental ecological niches and species' distributional areas.

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