DOI: https://doi.org/10.29298/rmcf.v12i63.812

Article

Distribución potencial de *Prosopis Laevigata* (Humb. e*t* Bonpl. ex Wiilld. M.C. Johnst en el estado de Hidalgo, México

Potential distribution of *Prosopis Laevigata* (Humb. e*t* Bonpl. ex Wiilld. M.C. Johnst in the state *of Hidalgo*, Mexico

Abraham Palacios Romero[1*], Edith Jiménez Muñoz[2], Rodrigo Rodríguez Laguna[3] y Ramón Razo Zárate[3]

Resumen

Prosopis laevigata (mezquite) tiene una distribución geográfica amplia en la república mexicana y es un recurso valioso en zonas áridas y semiáridas por sus funciones ecológicas y el aprovechamiento de su madera para diversos usos; sin embargo, debido a la sobreexplotación que ha tenido, su área de distribución natural se ha reducido de forma notoria. Con base en lo anterior, el objetivo de este estudio fue delimitar zonas potenciales para el establecimiento de esta especie en el estado de Hidalgo, México. Para ello, se utilizó el algoritmo *MaxEnt* ver. 3.3.3 para determinar la distribución potencial del mezquite, la cual fue validada con ayuda del análisis *ROC*. Se aplicó la prueba *Jackknife* para identificar los factores limitantes en la distribución potencial del taxón. El análisis de los datos indicó que los factores del clima: temperatura y humedad son los más relevantes para definir áreas potenciales de establecimiento; mientras que, la evapotranspiración, edafología y geología fueron menos importantes. El modelo obtenido reveló una disponibilidad de 83 438 ha donde el mezquite puede desarrollarse y se concentran, principalmente, en la región central de la entidad. Por ello, se concluye que el estado de Hidalgo posee amplias zonas en las que es factible plantar (reforestar) *P. laevigata.*

Palabras clave: Área potencial, distribución de especies, *MaxEnt*, mezquite, nicho ecológico, reforestación.

Abstract

Prosopis laevigata (*Mezquite*) has a wide geographic distribution in the Mexican Republic and is a valuable resource in arid and semi-arid zones due to its ecological functions and the use of its wood for various uses; however, due to overexploitation they have had, their natural range has been markedly reduced. Based on the above, the objective of this study was to delimit potential areas for the establishment of this species in the state of *Hidalgo*, Mexico. For this, the MaxEnt algorithm was used ver. 3.3.3 to determine the potential distribution of mesquite, which was validated with the help of ROC analysis. The Jackknife test was used to identify limiting factors in the potential distribution of the species. The analysis of the data indicated that the factors of climate type, temperature and humidity are the most relevant to define potential areas of establishment; while evapotranspiration, soil science and geology were less important. The obtained model revealed an availability of 83 438 ha where mesquite can be established and they are mainly concentrated in the central region of the state. Therefore, it is concluded that the state of Hidalgo has large areas where mesquite can be developed.

Key words: Potential area, species distribution, MaxEnt, mesquite, ecological niche, reforestation.

Fecha de recepción/Reception date: 30 de junio de 2020
Fecha de aceptación/Acceptance date: 9 de noviembre de 2020

[1]Departamento de Bioingeniería y Ciencias, Tecnológico de Monterrey, Campus Hidalgo. México.
[2]Escuela Superior de Apan, Universidad Autónoma del Estado de Hidalgo. México.
[3]Instituto de Ciencias Agropecuarias, Área Académica de Ciencias Agrícolas y Forestales, Universidad Autónoma del Estado de Hidalgo. México.
* Autor por correspondencia; correo-e: abraham.palacios@tec.mx

Introduction

A methodology developed for biological conservation research leads to the estimation of the potential distribution areas from the ecological niche modeling (Finch *et al*., 2006), since it provides information about the tolerance of the species to abiotic factors, lets the assessment of its affinity in regard to environmental factors and helps to determine the probability of presence or establishment in a geographic space (Mitov and Stoyanov, 2005). Ecological niche models are the main tool to determine the potential distribution of species (Cruz-Cárdenas *et al*., 2014) since they consider the environmental factors of the localities where the species live (Finch *et al.,* 2006). Models based on geographic information systems use data from different physical-geographic and climatic characteristics that allow delimiting optimal areas for the location of plant species, and obtaining good *a priori* results (Anderson *et al*., 2003; Téllez *et al*. 2004; Palacios *et al.,* 2016).

Prosopis laevigata (Humb. *et* Bonpl. ex Willd.) M.C. Johnst. is a native species of Mexico with a wide geographical and ecological distribution and is considered a valuable resource for the inhabitants of arid and semi-arid areas of the country (Villanueva *et al.,* 2004). Several goods and services are obtained from this species such as firewood, rubber, construction materials, food, fodder, nectar for beekeeping, shade for animals, medicines, among others. In addition, it performs important ecological functions, since it is a soil fixer and, therefore, prevents and controls erosion, fixes nitrogen in the soil and provides food and shelter to wildlife (Rodríguez *et al.,* 2014).

In the state of *Hidalgo*, this species is beginning to be widely used in agroforestry projects due to its versatility (Sánchez *et al.,* 2017) and due to its high nutritional value, it can be considered as a superfood (Díaz-Batalla *et al.*, 2018). In addition, various studies indicate that, due to its rapid growth, it is a viable species for the production of food for sheep (Buzo *et al.,* 1972; Sawal *et al*., 2004), which is one of the main economic activities from the state of *Hidalgo*; at present, it is the second largest producer nationwide and the main supplier of sheep meat for Mexico City (Vélez *et al*., 2017).

Despite its great extension, it presents a high rate of decrease in surface area, especially notorious in the northern and central states of the country (Ríos *et al*., 2011). From its great nutritional potential and diversity of use forms, it is a priority to carry out management plans with this species to avoid putting wild populations at risk and promote its sustainable use. Based on the above, it is intended to define, through an ecological niche model, suitable spaces for their potential establishment in the state of *Hidalgo*.

Materials and Methods

The state of *Hidalgo* is located in the central part of the Transversal Neovolcanic Axis, and the southern part of the *Sierra Madre Oriental* of the Mexican republic (Figure 1). The predominant climates are: temperate subhumid C (w), semi-dry temperate BS1k and semi-warm humid ACf (Inegi, 2017). The annual average temperature is 16 °C, and the minimum of the coldest month (January) is 4 °C, the maximum is 27 °C. It brings together a great diversity of plant species and climates due to the regional altitudinal variation of the entity (154 to 3 350 masl) (INEGI, 2014).

Figure 1. Location of the state of *Hidalgo,* Mexico.

To model the ecological niche, data on climatic, edaphological, geological and altimetry variables were obtained. The edaphologies, from vector files of the 1: 250 000 scale coverage of the digital geological-mining chart F14-11 (INEGI, 2007); the geological ones, from the set of vector edaphological data series II of Inegi (INEGI, 2007); lastly, those of type of climate, from Inegi's "coverage of climatic units" (INEGI, 2008). The altimetry was based on Inegi's "Continuum of Mexican elevations 3.0", with a resolution of 120 m (INEGI, 2013). The climatic variables were determined with evapotranspiration data, relative humidity, soil humidity, precipitation, radiation and average temperature, coming from the Meteorological Network of del *Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias* (INIFAP).

Once the necessary information to model the potential distribution had been gathered, the raster files were generated for all the variables, since this is the only format accepted by the program with which the modeling was carried out. The variables of edaphology, climate type and geology were transformed into raster variables through the reclassification method, as well as the homogenization of cell size at 120 m. For the digital elevation model, the size of the cell was modified and it was adjusted to the size of the rest of the raster images with the Arcview "Resample" tool (Table 1).

Table 1. Climatic and environmental data used in the MaxEnt model.

Variable	Source*	Type of data (raw)	Raster conversion method
Altitude	Inegi	*Raster* image	Cell size and image adjustments
Cimate	Inegi	Vectorial polygon	Reclassification and raster conversion, cell and image size adjustment.
Edafology	Inegi	Vectorial polygon	Reclassification and raster conversion, cell and image size adjustment.
Evapotranspiration	INIFAP	Station table with georeference transformed to point vector file	Generation of semivariogram and application of Kriging
Geology	SGM	Vectorial polygon	Reclassification and raster conversion, cell and image size adjustment.
Relative humidity	INIFAP	Station table with georeference transformed to point vector file	Generation of semivariogram and application of Kriging
Soil humidity	INIFAP	Station table with georeference transformed to point vector file	Generation of semivariogram and application of Kriging
Precipitation	INIFAP	Station table with georeference transformed to point vector file	Generation of semivariogram and application of Kriging
Radiación	INIFAP	Station table with georeference transformed to point vector file	Generation of semivariogram and application of Kriging
Mean temperature	INIFAP	Station table with georeference transformed to point vector file	Generation of semivariogram and application of Kriging

* Inegi = *Instituto Nacional de Estadística y Geografía*; INIFAP = *Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias*; SGM = *Servicio Geológico Mexicano.*

For the climatic variables, historical data were collected from the INIFAP Meteorological Network. The Kriging interpolation method was applied to these data to generate a raster image of precipitation and temperature. This method has been widely used to estimate the variation of spatial variables with local data related to climate such as precipitation and temperature (Teegavarapu and Chandramouli, 2005; Galindo *et al.,* 2010; Andrade and Moreano, 2013).

To determine the potential distribution of *P. laevigata* in the state of *Hidalgo*, the MaxEnt 3.3.3 algorithm was used, which estimates the probability that a species is found at a certain point (Drake, 2014). Georeferenced points of the species (Figure 2) were obtained in the Global Biodiversity Information Facility (GBIF, 2016), which is an international organization in charge of collecting scientific data on biodiversity, which are provided by institutions, herbaria, universities and other organizations around the world. Before introducing them to the algorithm, the sample size was reduced by means of a random selection to reduce the effect of spatial autocorrelation, and at the end 19 georeferenced points were introduced. This algorithm was chosen because its performance is considered very good. In addition, it can give adequate results with small sample sizes (Plasencia-Vázquez *et al*., 2014).

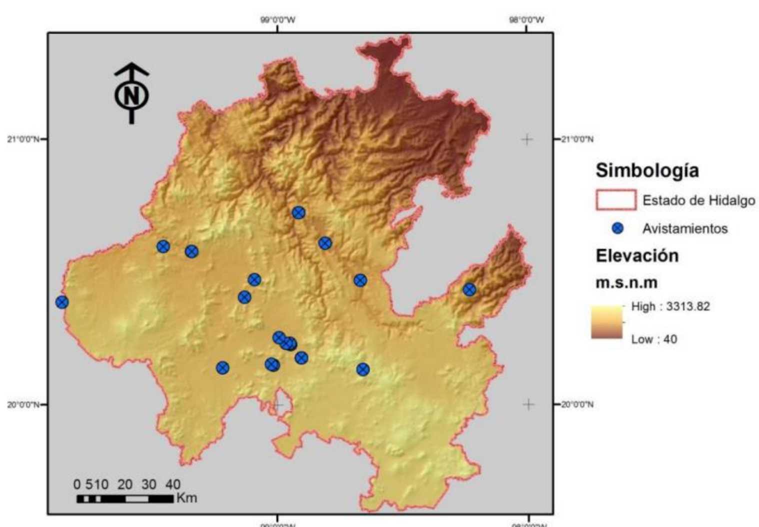

Figure 2. Geolocation of *Prosopis laevigata* (Humb. *et* Bonpl. ex Willd.) M.C. Johnst. sightings in the state of *Hidalgo*.

The selected configuration of the MaxEnt model to determine the potential distribution of *P. laevigata* was the logistic function. In the model calibration, 500 iterations were specified and the convergence limit was set at 0.00001 (default value). The regularization value was set at 1.0 (default value), as this allows the algorithm to model a more localized distribution that fits the presence records. The model was calibrated with the standard parameters that MaxEnt 3.3.3 has by default.

The analysis of the area under the curve (AUC) of the ROC (Receiver Operating Characteristic) function was used to validate the model (López and Fernández, 1998; Palacios *et al.,* 2016).The AUC curve of the ROC function is a measure that shows the discrimination capacity of the model with values that fluctuate from zero to one, in which 0.5 indicates that its adjustment is no better than one obtained at random, that is, the closer to one, the training and test data, the more correct the model is (Ávila *et al.,* 2014).

The most important climatic variables associated with the species were determined with the Jackknife test, based on which a graph of the contributions of each of the variables to the model is generated.

Results and Discussion

The choice of the best model was made according to its validation, since it was sought that the training and data curves of the ROC analysis described a similar and close fit to each other. This indicates that the fit of the model is optimal and that there are no errors of omission (Figure 3), since, the closer the training and test lines are, the model is more able to describe reality (de Pando and Peñas, 2007).

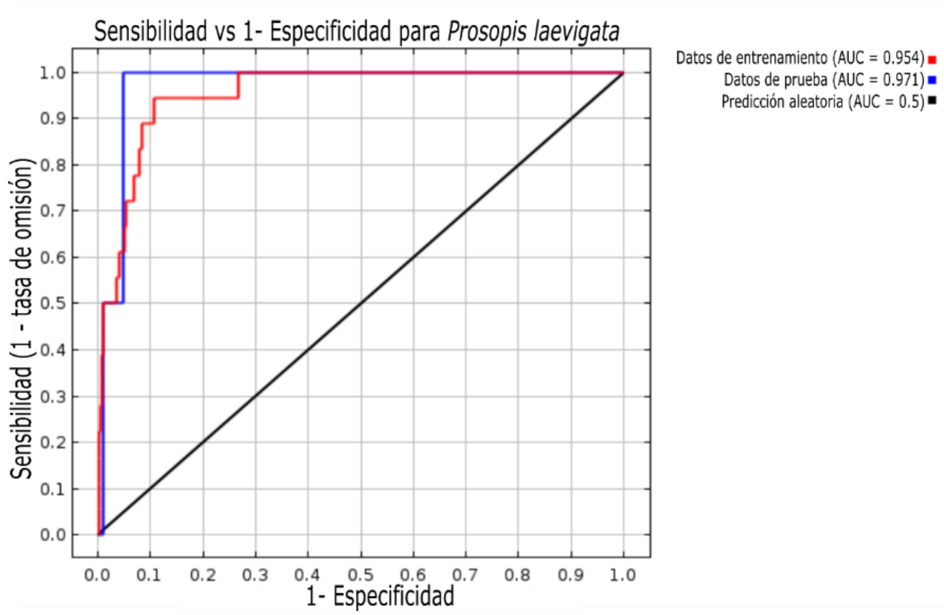

Figure 3. Results of the area under the curve (*ROC*) analysis.

The AUC value of the test was 0.954 for the training data and 0.971 for the test data (Figure 3), which is interpreted as an excellent fit, since statistically, the model defines a precise distribution for this species. These results are similar to those from Contreras-Medina *et al*. (2010) and Ávila *et al* (2014) who recorded AUC values of 0.997 and 0.971 for *Taxus globosa* Schltdl. and *Pinus herrerae* Martínez, respectively, and concluded that their results were accurate.

According to the Jackknife test, the variables of edaphology, evapotranspiration and geology contribute less to the model, because with the individual use, the gain is very low, and in edaphology it becomes negative. In addition, by eliminating out edaphology and evapotranspiration, the model has a greater gain, compared to the use with the other variables (Figure 4). This is confirmed by the ecological information of the species since, being native in large areas of Mexico, few problems would be expected to adapt to different types of soil and variating evapotranspiration conditions (Rodríguez *et al.,* 2014); therefore, these variables are expected to have little relevance in the analysis.

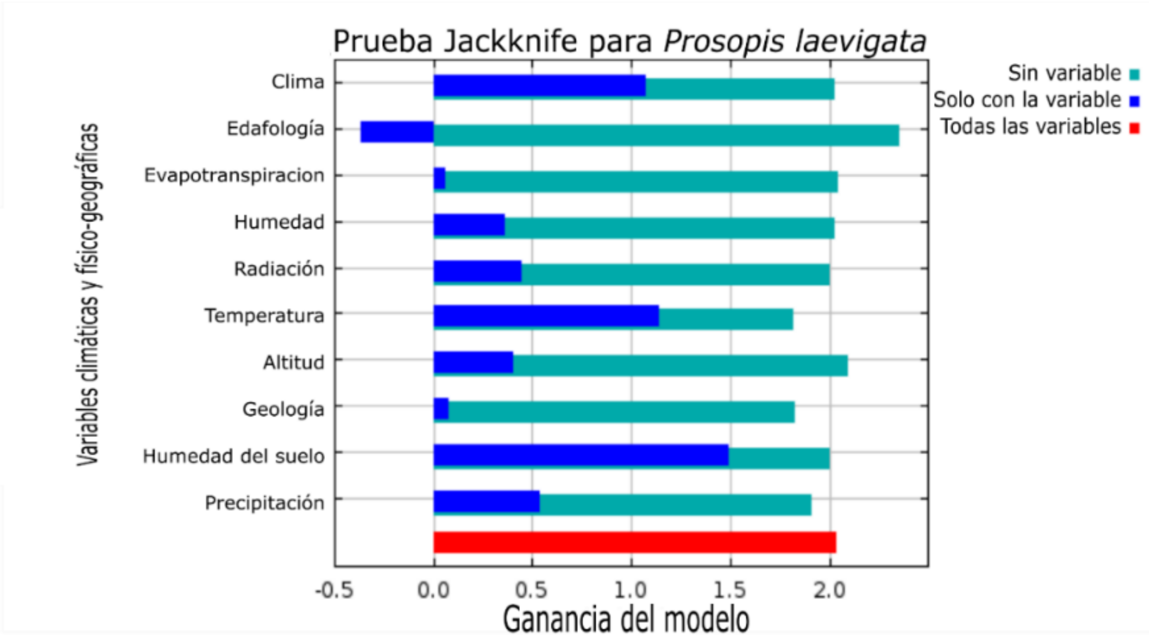

Figure 4. Contributions of the variables used to the model.

The most important variables in the Jackknife test were: soil moisture, temperature and type of climate, since they are the ones that individually have the highest gain in the model. This is attributable to the fact that the species is typical of arid and semi-arid areas, so its physiological mechanisms of absorption and conservation of water are affected in environmental conditions different from those prevailing in the regions from which they come (Villanueva *et al*., 2004).

Altitude did not have a great impact on the potential distribution of this species (Figure 4), which can be explained from the wide altitudinal range in which mesquite is distributed (from 0 to 2 200 masl) (Rodríguez *et al.,* 2014).

The final map of the potential distribution of mesquite indicates that the suitable areas are located mainly in the central part of the state, which corresponds to the east of the region known as *Valle del Mezquital*, which amount to a total of 83 437 574 ha (probability> 0.70) (Figure 5).

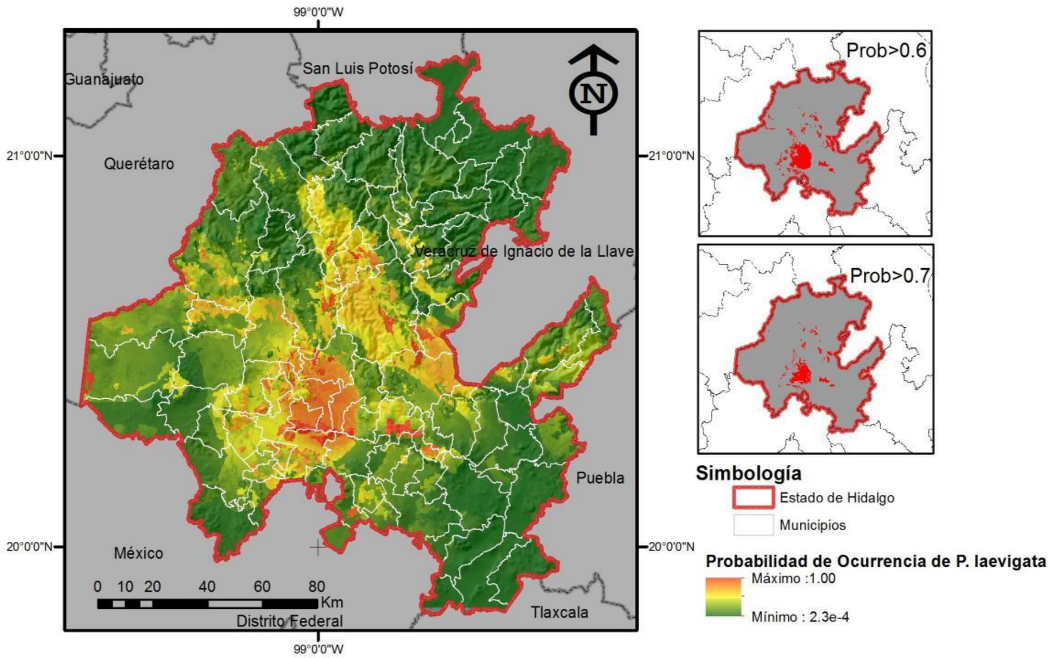

Figure 5. Potential geographic distribution of *Prosopis laevigata* (Humb. *et* Bonpl. ex Willd.) M.C. Johnst. in the state of *Hidalgo*.

Traditionally, mesquite plants are considered able to adapt to a great variety of climates, so in a first approach, it would be strange that the optimal potential distribution area in the state of *Hidalgo* is so restricted. However, Guevara *et al.* (2008) indicate that *P. laevigata* may require much more specific conditions than other species of the genus.

When comparing the potential distribution shown in the present study with the natural distribution referred to by Palacios (2006), there is agreement between the observed and the calculated one, which confirms that this type of model is capable of effectively predicting the territorial disposition of the species. Also, the results obtained are supported by the work of Palacios *et al* (2016), since the authors approached the same species but in a wider area (three physiographic provinces).

In *San Salvador, Actopan, Francisco I. Madero, Santiago de Anaya, Metztitlán, El Arenal, San Agustín Metzquititlán, Ajacuba, Mineral del Chico, Cardonal, Atotonilco El Grande* and *Eloxochitlán* municipalities are located the largest areas with a high suitability of establishment of the species (P> 0.7) (Table 2). These municipalities have arid and semi-arid climates (Chávez *et al.* 2001), so they show that the model is consistent with reality, since all the records of the species correspond to regions with this type of climate (Villanueva *et al*. ., 2004).

Table 2. Municipalities of greatest potential area for *Prosopis laevigata* (Humb. *et* Bonpl. ex Willd.) M.C. Johnst.

Municipality	Potencial hectareas	Municipality %
San Salvador	14 103.20	39.77
Actopan	9 441.06	34.77
Francisco I. Madero	8 722.03	82.96
Santiago de Anaya	8 664.01	33.85
Metztitlán	5 834.09	7.27
El Arenal	4 386.30	32.46
San Agustín Metzquititlán	4 346.95	17.56
Ajacuba	4 325.43	17.11
Mineral del Chico	4 006.69	20.82
Cardonal	3 063.32	5.16
Atotonilco el Grande	2 987.33	6.58
Eloxochitlán	2 102.17	8.81
Mixquiahuala de Juárez	1 806.89	15.71
San Agustín Tlaxiaca	1 724.14	5.71
Mineral del Monte	1 344.27	24.90
Tolcayuca	1 089.45	9.24
Progreso de Obregón	737.21	8.12
Tlahuiltepa	725.00	25.35
Omitlán de Juárez	422.01	5.33

Conclusions

The results obtained in this study allow us to conclude that *P. laevigata* can be ideally established in 83 437 ha in the state of *Hidalgo*. Most of these extensions are located in the central region of the state.

Conflict of interests

The authors declare no conflict of interests.

Contribution by author

Abraham Palacios Romero: research development, analysis and interpretation of results; Edith Jiménez Muñoz: data analysis, structure and design of the manuscript; Rodrigo Rodríguez Laguna: interpretation and analysis of the obtained results, as well as correction of the manuscript; Ramón Razo Zárate: data interpretation correction of the manuscript.

References

Anderson, R. P., D. Lew and A. Townsend Peterson. 2003. Evaluating predictive models of species' distributions: criteria for selecting optimal models. Ecological Modelling 162(3):211–232. Doi: 10.1016/S0304-3800(02)00349-6.

Andrade C., L. S. y R. Moreano. 2013. Sistema de información para la interpolación de datos de temperatura y precipitación del Ecuador. Revista Politécnica 32 (1): 70-75.

Ávila, R., R. Villavicencio G. y J. A. Ruiz C. 2014. Distribución potencial de *Pinus herrerae* Martínez en el occidente del estado de Jalisco. Revista Mexicana de Ciencias Forestales 5(24):92–109. Doi:10.29298/rmcf.v5i24.322.

Buzo, J., R. Ávila y F. O. Bravo. 1972. Efecto de la substitución Progresiva de sorgo por vaina de mezquite en la alimentación de los borregos. Revista Mexicana de Ciencias Pecuarias 20:16–23.

Contreras-Medina, R., I. Luna-Vega y C. A. Ríos-Muñoz. 2010. Distribución de *Taxus globosa* (Taxaceae) en México: modelos ecológicos de nicho, efectos del cambio del uso de suelo y conservación. Revista Chilena de Historia Natural 83:421–433 Doi: 10.4067/S0716-078X2010000300009.

Cruz-Cárdenas, G., J. L. Villaseñor, L. López-Mata, E. Martínez-Meyer y E. Ortiz. 2014. Selección de predictores ambientales para el modelado de la distribución de especies en Maxent. Revista Chapingo, Serie. Ciencias Forestales y del Ambiente 20(2):187–201. Doi: 10.5154/r.rchscfa.2013.09.034.

Chávez S., E., R. Sousa G., J. Quintela F., S. Montiel R., J. J. Domínguez T., V. Richards E., A. Conde A., F. Chávez A., L. Serrano P., A. Cuevas M., A. Gómez R., H. García M., P. Camarillo, J. Nájera R., F. A. Damían G. y A. de J. Damían G. 2001. Ordenamiento ecológico territorial del Estado de Hidalgo. Pachuca, Hgo., México. 400 p.

De Pando, B. B., y J. Peñas de G. 2007. Aplicación de modelos de distribución de especies a la conservación de la biodiversidad en el sureste de la península ibérica. GeoFocus Revista Internacional de Ciencia y Tecnología de la Información Geográfica (7):100–119 http://www.geofocus.org/index.php/geofocus/article/view/113/275 (2 de enero de 2020).

Díaz-Batalla, L., J. P. Hernández-Uribe, A. D. Román-Gutiérrez, R. Cariño-Cotés, J. Castro-Rosas, A. Téllez-Jurado and C. A. Gómez-Aldapa. 2018. Chemical and nutritional characterization of raw and thermal-treated flours of mesquite (*Prosopis laevigata*) pods and their residual brans. *CYTA*-Journal of Food 16(1):444–451. Doi: 10.1080/19476337.2017.1418433.

Drake, J. M. 2014. Ensemble algorithms for ecological niche modeling from presence-background and presence-only data. Ecosphere. 5(6):1–16. Doi:10.1890/ES13-00202.1.

Finch, J. M., M. J. Samways, T. R. Hill, S. E. Piper and S. Taylor. 2006. Application of predictive distribution modelling to invertebrates: Odonata in South Africa. Biodiversity & Conservation 15(13):4239–4251. Doi:10.1007/s10531-005-3577-z.

Galindo, E., E. M. Otazo, L. R. Reyes, S. M. Arellano, A. Gordillo, y C. A. González. 2010. Balance hídrico y afectaciones a la recarga para el año 2021 en el acuífero Cuautitlan Pachuca. GeoFocus Revista Internacional de Ciencia y Tecnología de la Información Geográfica (10):65–90.

Global Biodiversity Information Facility (GBIF). 2016. GBIF Occurrence http://api.gbif.org/v1/occurrence/download/request/0001958-160509122628363.zip (1 de octubre de 2016).

Guevara E., A., E. González S., H. Suzán A., G. Malda B., M. Martínez, D. M. Gómez S., Y. Hernandez S., L. Pantoja H. y D. Olvera V. 2008. Distribución potencial de algunas leguminosas arbustivas en el altiplano central de México. Agrociencia. 42:703–716.

Instituto Nacioal de Estadística y Geografía Informática (INEGI). 2007. Carta edafológica Serie II, Escala 1:250 000. Formato vectorial. https://www.inegi.org.mx/app/mapas/default.html?t=0150006000000000&ag=28 (1 de septiembre de 2017).

Instituto Nacional de Estadística y Geografía (INEGI). 2008. Conjunto de datos vectoriales escala 1:1 000 000. Unidades climáticas. https://www.inegi.org.mx/app/biblioteca/ficha.html?upc=702825236182 (1 de septiembre de 2017).

Instituto Nacional de Estadística y Geografía (INEGI). 2013. Continuo de Elevaciones Mexicano 3.0, CEM 3.0. Aguascalientes, Ags., México. http://www.inegi.org.mx/geo/contenidos/datosrelieve/continental/continuoelevaciones.aspx (1 de septiembre de 2017).

Instituto Nacioal de Estadística y Geografía Informática (INEGI). 2014. Anuario estadístico y geográfico de Hidalgo 2013. INEGI. Pachuca, Hgo., México. 583 p.

Instituto Nacioal de Estadística y Geografía Informática (INEGI). 2017. Anuario estadístico y geográfico de Hidalgo 2017. Anuario estadístico y geográfico Hidalgo 2017. http://cuentame.inegi.org.mx/monografias/informacion/hgo/ (1 de septiembre de 2018).

López de U., G. I., y P. Fernández S. 1998. Curvas ROC. Cad Atención Primaria 5(4):229–235.

Mitov, P. G. and I. L. Stoyanov. 2005. Ecological profiles of harvestmen (Arachnida, Opiliones) from Vitosha Mountain (Bulgaria): A mixed modelling approach using gams. The Journal of Arachnology 33(2):256–268.

Palacios A., R. 2006. Los mezquites mexicanos : biodiversidad y distribución geográfica. Boletín de la Sociedad Argententina de Botánica 41(1–2):99–121.

Palacios R., A., R. Rodríguez L., M. de la L. Hernández F., E. Jiménez M. y D. Tirado T. 2016. Distribución potencial de *Prosopis laevigata* (Humb. *et* Bonpl. ex Willd) M. C. Johnston basada en un modelo de nicho ecológico. Revista Mexicana de Ciencias Forestales 7(34):35–46. Doi: 10.29298/rmcf.v7i34.81.

Plasencia-Vázquez, A. H., G. Escalona-Segura y L. G. Esparza-Olguín. 2014. Modelación de la distribución geográfica potencial de dos especies de psitácidos neotropicales utilizando variables climáticas y topográficas. Acta Zoológica Mexicana 30(3):471–490. Doi:10.21829/azm.2014.30372.

Ríos S., J. C., J. A. López H., R. Rosales S., R. Trucíos C. y A. G. Valles G. 2011. Conservación y manejo de germoplasma del mezquite. P. 220. *In:* Ríos S., J. C., R. Trucíos C., L. M. Valenzuela N., G. Sosa P. y R. Rosales S. (eds.). Importancia de las poblaciones de mezquite en el Centro-Norte de México. INIFAP. Gómez Palacio, Dgo., México. pp. 79-105.

Rodríguez S., E. N., G. E. Rojo M., B. Ramírez V., R. Martínez R., M. de la C. Cong H., H. H. Piña R. y S. M. Medina T. 2014. Análisis técnico del árbol del mezquite (*Prosopis laevigata* Humb. & Bonpl. ex Willd.) en México. Ra Ximhai 10(3):173–193.

Sánchez H., M. Á., E. Hernández A., D. Cristóbal A., M. Uribe G., P. Díaz V. y A. Lara B. 2017. Sistema agroforestal coquia-mezquite establecido en suelos del Distrito de Riego Tulancingo, Hidalgo, México. Revista Mexicana de Ciencias Agrícolas (16):3207. Doi: 10.29312/remexca.v0i16.390.

Sawal, R. K., R. Ratan and S. B. S. Yadav. 2004. Mesquite (*Prosopis juliflora*) pods as a feed resource for livestock - a review. Asian-Australasian Journal of Animal Science 17(5):719–725. Doi: 10.5713/ajas.2004.719.

Teegavarapu, R. S. V. and V. Chandramouli. 2005. Improved weighting methods, deterministic and stochastic data-driven models for estimation of missing precipitation records. Journal of Hydrology 312(1–4):191–206. Doi: 10.1016/j.jhydrol.2005.02.015.

Téllez V., O., Y. M. Chávez H., A. Gómez-Tagle C. y M. V. Gutiérrez G. 2004. Modelado bioclimático como herramienta para el manejo forestal: Estudio de cuatro especies de *Pinus*. Ciencia Forestal en México. 29(95):61–82.

Vélez, A., J. A. Espinosa, L. De la Cruz, J. Rangel, I. Espinoza and C. Barba C. 2017. Caracterización de la producción de ovino de carne del estado de Hidalgo, Mexico. Archivos de Zootecnia 65(251):425. Doi:10.21071/az.v65i251.70.

Villanueva D., J., R. Jasso I., E. H. Cornejo O. y C. Potisek T. 2004. El mezquite en la Comarca Lagunera. Su dinámica, volumen maderable y tasas de crecimiento anual. Agrofaz. 4(2):633–648.