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Research note

Identificación de áreas potenciales para la reforestación con seis fabáceas arbóreas en Guanajuato

Identification of potential areas for reforestation with six arboreal Fabaceae in the state of *Guanajuato*

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Abstract

The loss and reduction of forest cover are related to soil degradation and the reduction of environmental services. Reforestation is a key element to fight global warming. Replanting deforested areas with native forest species increases the survival and success of the plantation. It was proposed that, according to the requirements of altitude, slope, temperature, precipitation, topography, soil type, texture and depth, and through the use of the BIOCLIM tool, it is possible to identify and quantify the potential reforestation areas in the state of *Guanajuato* by six forest species of the Fabaceae family. Based on climatic and edaphic requirements, *Prosopis laevigata* was the taxon with the largest potential area for reforestation with 278 102 ha of good and very good suitability, *Albizia occidentalis* occupied a surface area of 230 239 ha, 157 491 ha were estimated for *Acacia farnesiana* (synonym of *Vachellia farnesiana*), 149 434 ha for *Lysiloma divaricata* (synonym of *Lysiloma divaricatum*), 120 968 ha for *Leucaena esculenta*, and merely 3 633 ha for *Acacia pennatula* (synonym of *Vachellia pennatula*). The delimited areas are the zones where it is possible to plant these species and guarantee a greater probability of survival and success in reforestation works, and with it, the restoration of the landscape.

Key words: *Albizia occidentalis* Brandegee*,* BIOCLIM, forest cover *Prosopis laevigata* (Humb. & Bonpl. *ex* Willd.) M. C. Johnst., climatic requirements, edaphic requirements.

Resumen

La pérdida y reducción de la cubierta forestal están relacionadas con la degradación del suelo y la disminución de servicios ambientales. Reforestar es un elemento clave para combatir el calentamiento global. Repoblar zonas deforestadas con especies forestales nativas aumenta la supervivencia y éxito de la plantación. Se planteó que de acuerdo con los requerimientos de altitud, pendiente, temperatura, precipitación, topografía, tipo, textura y profundidad del suelo y mediante el uso de la herramienta *BIOCLIM* es posible identificar y cuantificar las áreas potenciales de reforestación en el estado de Guanajuato para seis especies forestales de la familia Fabaceae. Con base en los requerimientos climáticos y edáficos, *Prosopis laevigata* fue el taxón con mayor superficie potencial para reforestar con 278 102 ha de aptitud buena y muy buena, *Albizia occidentalis* tuvo una superficie de 230 239 ha, para *Acacia farnesiana* (sinonimia de *Vachellia farnesiana*) se obtuvo un área de 157 491 ha, *Lysiloma divaricata* (sinonimia de *Lysiloma divaricatum*) de 149 434 ha, *Leucaena esculenta* de 120 968 ha, y en el caso de *Acacia pennatula* (sinonimia de *Vachellia pennatula*) se determinaron solamente 3 633 ha. Las áreas delimitadas son las zonas donde es posible plantar estas especies y garantizar mayor probabilidad de supervivencia y éxito en trabajos de reforestación, y con ello la restauración del paisaje.

Palabras clave: *Albizia occidentalis* Brandegee, *BIOCLIM*, cubierta forestal, *Prosopis laevigata* (Humb. & Bonpl. *ex* Willd.) M. C. Johnst.*,* requerimientos climáticos, requerimientos edáficos.

Subject development

The loss and reduction of forest cover alters the functioning and capacity of forest ecosystems to provide ecosystem services such as soil erosion control, carbon capture and storage, rainwater harvesting, aquifer recharge, and food production, among others (ONUAA, 2012). In the state of *Guanajuato*, land use change, overexploitation of species, overgrazing, introduction of exotic taxa, illegal logging, and fires are the main causes of forest ecosystem degradation (SMAOT, 2021). According to Semarnat and CP (2002), environmental degradation is the deterioration of the environment due to the depletion of natural resources (air, water, soil, or vegetation), which leads to the destruction of ecosystems.

In the last decade, more than 250 000 ha have been reforested in Mexico to counteract the negative effects of deforestation and degradation (Burney *et al.*, 2015). Reforestation allows the latter to be reversed, changing moderate-degradation areas to a low-degradation status (Semarnat and CP, 2002). However, in the best of cases, the survival rate in these plantations barely exceeds 60 % (Burney *et al.*, 2015), and in some entities it is less than 40 % due, among other things, to the use of species that are poorly adapted to the environmental conditions of the plantation site, the lack of protection of these areas, and their conversion to agricultural land (Torres, 2021).

Ecological niche modeling by means of Geographic Information Systems (GIS) and ecological niche algorithms is a tool for assessing the actual or potential spatial distribution of species (Soberón *et al.*, 2017) and generating land suitability maps for its development, which in turn are the basis for determining potential areas for reforestation, restoration, or taxon conservation (Garza-López *et al.*, 2016; Manzanilla-Quijada *et al.*, 2020).

Genetic (GARP), climate envelopes' (BIOCLIM), and maximum entropy (MaxEnt) algorithms are used to model the ecological niche; these utilize ecogeographic variables such as latitude, longitude, altitude, slope, climate, and soil in the form of raster layers (Guisan and Zimmermann, 2000; Castellanos-Acuña *et al.*, 2018).

Prosopis laevigata (Humb. & Bonpl. *ex* Willd.) M. C. Johnst., *Albizia occidentalis* Brandegee, *Acacia farnesiana* (L.) Willd. (synonym of *Vachellia farnesiana* (L.) Wight & Arn.), *Lysiloma divaricata* (Jacq.) J. F. Macbr. (synonym of *Lysiloma divaricatum* (Jacq.) J. F. Macbr.), *Leucaena esculenta* (DC.) Benth. and *Acacia pennatula* (Schltdl. & Cham.) Benth. (synonym of *Vachellia pennatula* (Schltdl. & Cham.) Seigler & Ebinger) are tree legumes native to the state of *Guanajuato* that can be used in reforestation programs. Therefore, the objective of this research was to identify and quantify the areas susceptible of reforestation with these species through the modeling of the ecological niche with Geographic Information Systems and the BIOCLIM analysis system, according to their environmental requirements.

The study covered the entire surface of the state of *Guanajuato*, located between 20°50'22" and 19°54'46" N, and 99°40'17" and 102°05'49" W. From a political-administrative point of view, the entity is made up of 46 municipalities and has a territorial area of 30 460 km^2 (Inegi, 2017). *Guanajuato* has a rugged landscape with mountains and plateaus, which is why it is part of three physiographic provinces: the Eastern *Sierra Madre*, the Central Plateau, and the Transversal Neovolcanic Axis (Inegi, 2017). According to García's (2004) classification, the predominant climates are semi-warm sub-humid (type (A)C(w_0)), semi-arid temperate (BS_1kw), and sub-humid temperate (C(w_1)).

The following activities were carried out for the development of the work: (a) Description of the habitat with data provided by the *Comisión Nacional Forestal* (National Forest Commission) (Conafor, 2018) for reforestations in the last ten years in areas of *Guanajuato*, Mexico, (b) Bibliographic review of the requirements of forest species with respect to the altitude and slope of the terrain, precipitation and mean annual temperature, soil type, texture and depth, (c) Construction of a database of the environmental requirements of each taxon with the information obtained in steps (a) and (b), (d) Stratification of digital layers of environmental information according to the requirements of each species, (e) Using the BIOCLIM algorithm with the DIVA GIS software version 4 (Hijmans *et al.*, 2004) to generate an ecological interval and the potential distribution of the taxa, and (f) Editing of the resulting layers and generation of the maps of potential suitability of the territory for each species, excluding agricultural areas, bodies of water, and urban areas of the state.

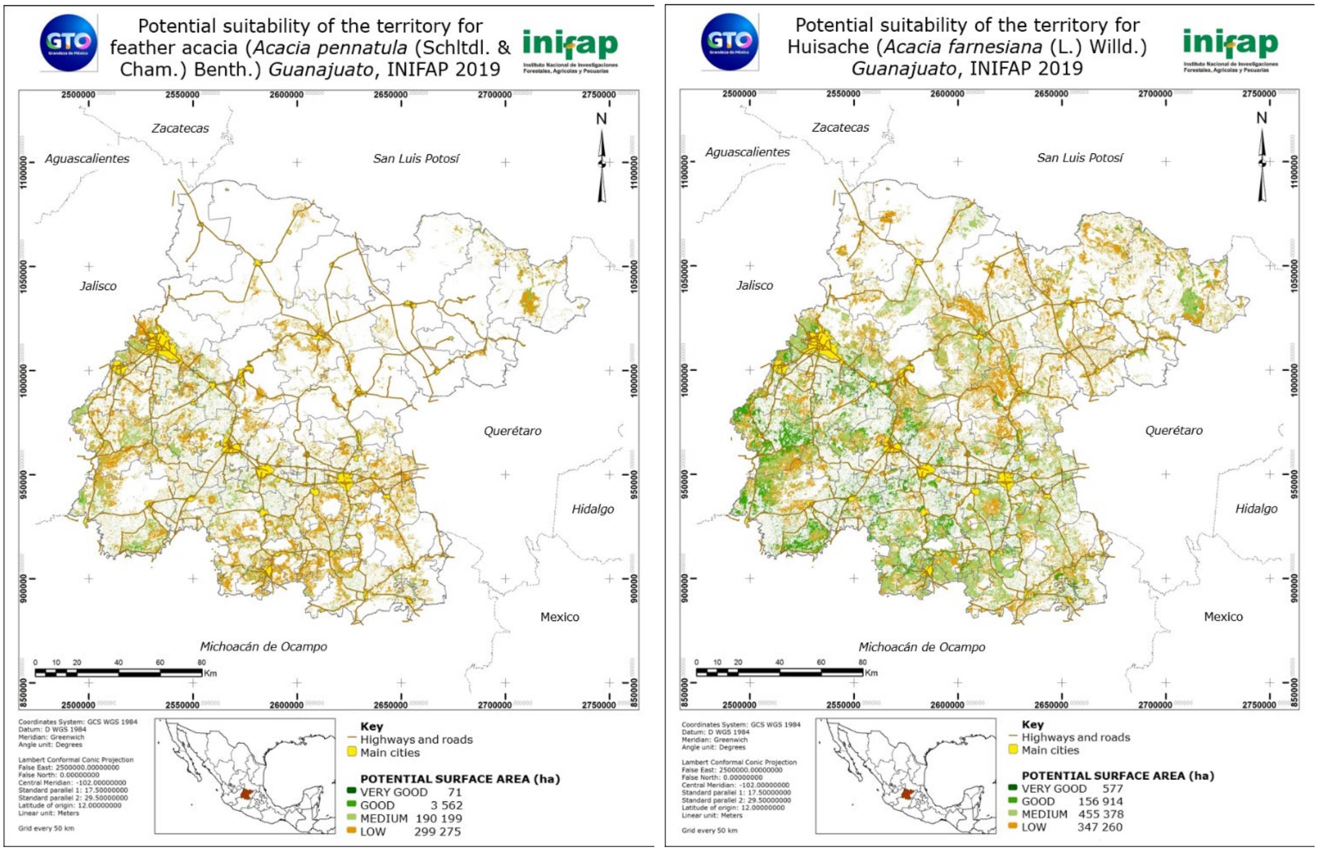
Table 1 describes the environmental variables and intervals used in the identification and quantification of potential areas for reforestation with the six tree taxa. Figure 1 shows the maps generated based on BIOCLIM.

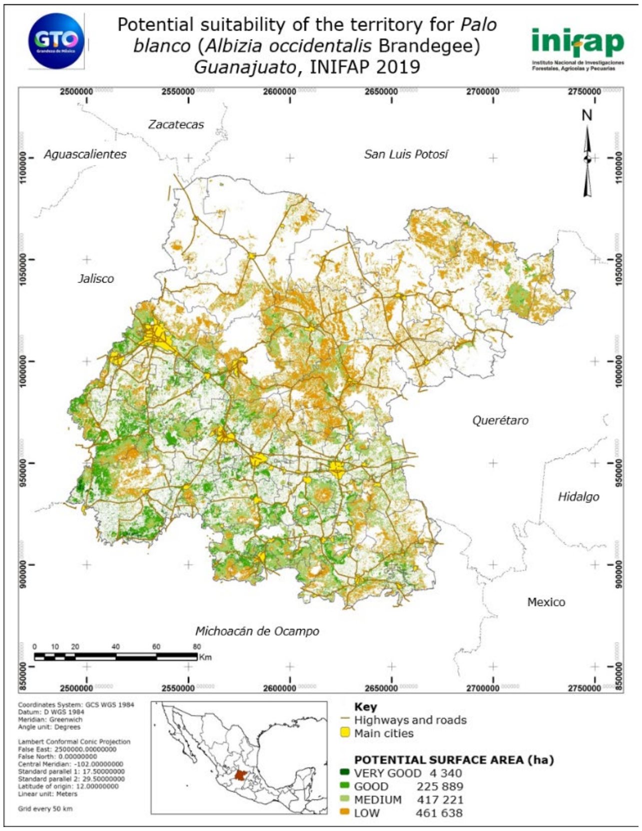
Table 1. Climatic variables for each forest species.

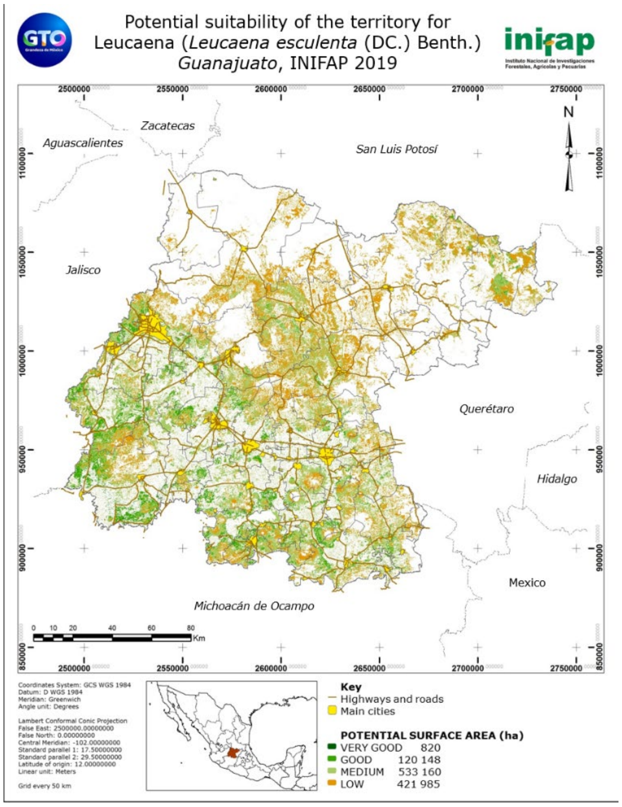
Environmental variable		Species					
		***Acacia farnesiana* (L.) Willd.**	***Acacia pennatula* (Schltdl. & Cham.) Benth.**	***Albizia occidentalis* Brandegee**	***Leucaena esculenta* (DC.) Benth.**	***Lysiloma divaricata* (Jacq.) J. F. Macbr.**	***Propsopis laevigata* (Humb. & Bonpl. *ex* Willd.) M. C. Johnst.**
Altitude (masl)	Minimum	36	0	600	0	0	0
	Optimal	392	1 200	850		900	1 900
	Maximum	2 500	1 700	2 100	1 000	1 400	2 300
Slope (%)	Excelent	25-35	20-30	20-30	18	25	0-30
Rainfall (mm)	Minimum	400	500	539	500	800	552
	Optimal	868	1 300	846	1 200	1 000	900

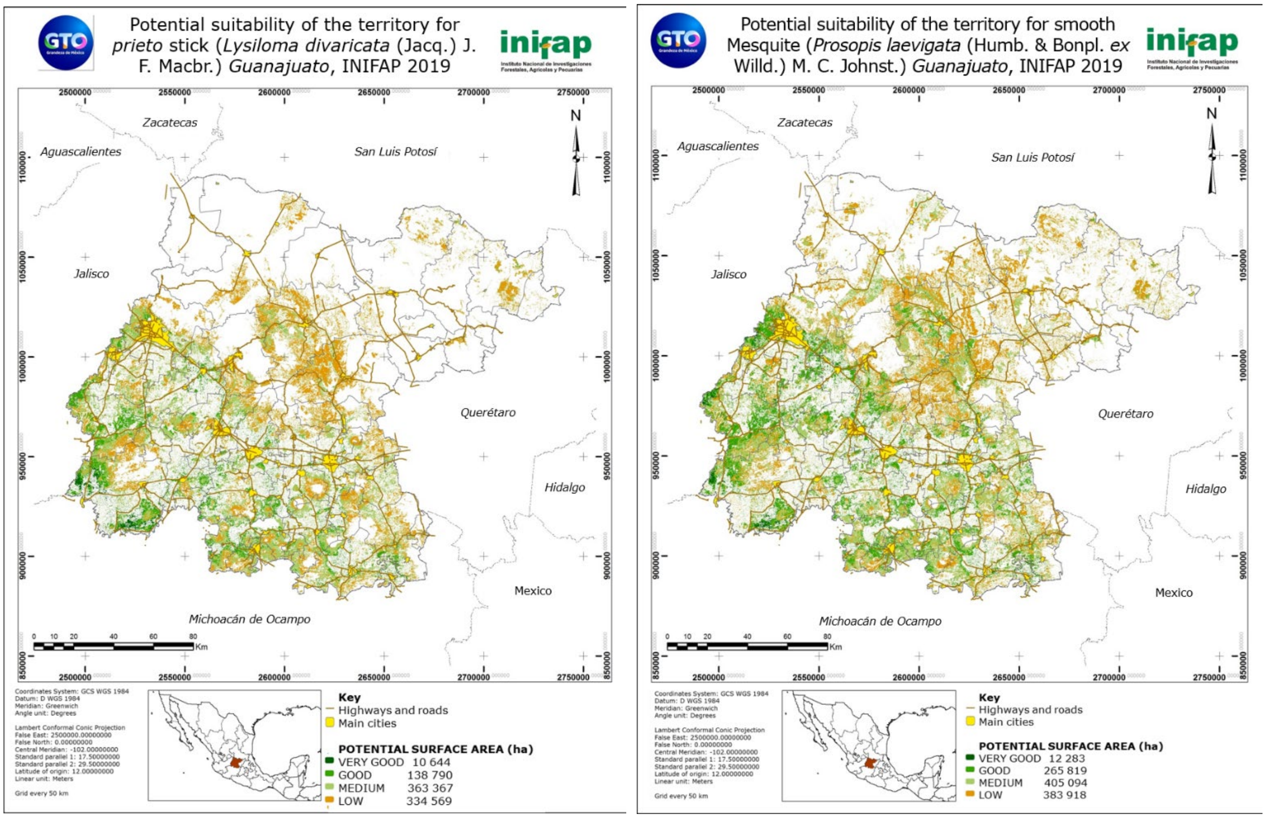
	Maximum	1 500	2 500	1 506	2 000	1 800	1 200
Temperature (°C)	Minimum	13.5	5.0	0.2	-1.0	0.0	13.5
	Optimal	24.7	20.0	22.3	27.0	19.0	20.5
	Maximum	28.5	46.0	40.5	46.0	30.0	28.5
Soil texture		Loamy clayey	Loamy clayey	Loamy clayey	Loamy clayey	Loamy clayey	Sandy, clayey-sandy
Soil type		Regosol	Andosol	Regosol	Regosol	Vertisol	Yermosol
Soil depth (cm)		50	100	50-100	30	150	>50

Acacia farnesiana (L.) Willd. (synonym of *Vachellia farnesiana* (L.) Wight & Arn.), *Acacia pennatula* (Schltdl. & Cham.) Benth. (synonym of *Vachellia pennatula* (Schltdl. & Cham.) Seigler & Ebinger), *Lysiloma divaricata* (Jacq.) J. F. Macbr. (synonym of *Lysiloma divaricatum* (Jacq.) J. F. Macbr.).




Potential suitability of the territory for *Palo blanco* (*Albizia occidentalis* Brandegee) *Guanajuato*, INIFAP 2019
Zacatecas
Aguascalientes
San Luis Potosí
Jalisco
Querétaro
Hidalgo
Mexico
Michoacán de Ocampo
N
0 10 20 40 60 80 Km
Coordinates System: GCS WGS 1984
Datum: D WGS 1984
Meridian: Greenwich
Angle unit: Degrees
Lambert Conformal Conic Projection
False East: 2500000.00000000
False North: 0.00000000
Central Meridian: -102.00000000
Standard parallel 1: 17.50000000
Standard parallel 2: 29.50000000
Latitude of origin: 12.00000000
Linear unit: Meters
Grid every 50 km
Key
Highways and roads
Main cities
POTENTIAL SURFACE AREA (ha)
VERY GOOD 4 340
GOOD 225 889
MEDIUM 417 221
LOW 461 638


Potential suitability of the territory for Leucaena (*Leucaena esculenta* (DC.) Benth.) *Guanajuato*, INIFAP 2019
Zacatecas
Aguascalientes
San Luis Potosí
Jalisco
Querétaro
Hidalgo
Mexico
Michoacán de Ocampo
N
0 10 20 40 60 80 Km
Coordinates System: GCS WGS 1984
Datum: D WGS 1984
Meridian: Greenwich
Angle unit: Degrees
Lambert Conformal Conic Projection
False East: 2500000.00000000
False North: 0.00000000
Central Meridian: -102.00000000
Standard parallel 1: 17.50000000
Standard parallel 2: 29.50000000
Latitude of origin: 12.00000000
Linear unit: Meters
Grid every 50 km
Key
Highways and roads
Main cities
POTENTIAL SURFACE AREA (ha)
VERY GOOD 820
GOOD 120 148
MEDIUM 533 160
LOW 421 985



Acacia farnesiana (L.) Willd. (synonym of *Vachellia farnesiana* (L.) Wight & Arn.), *Acacia pennatula* (Schltdl. & Cham.) Benth. (synonym of *Vachellia pennatula* (Schltdl. & Cham.) Seigler & Ebinger), *Lysiloma divaricata* (Jacq.) J. F. Macbr. (synonym of *Lysiloma divaricatum* (Jacq.) J. F. Macbr.).

Figure 1. Potential areas for reforestation with the six studied tree species.

With the BIOCLIM ecological niche model, it was possible to determine the potential distribution of the six taxa analyzed, which are similar to the species studied by Martínez-Méndez *et al.* (2016). The areas of potential distribution identified in the state correspond to areas of lowland rainforest, scrubland, and grasslands. The similarity in the delimitation of the potential areas responds to the fact that species such as *Acacia farnesiana*, *Prosopis laevigata*, *Albizia plurijuga* (Standl.) Britton &

Rose, *Eysenhardtia polystachya* (Ortega) Sarg., *Lysiloma microphylla* Benth. and *Senna polyantha* (Moc. & Sessé *ex* Collad.) H. S. Irwin & Barneby are associated with the plant formations present in the entity (Guevara-Escobar *et al.*, 2008).

The largest potential area was for *P. laevigata*, due to its wide adaptive capacity, which agrees with the results obtained by Palacios *et al.* (2016) and Palacios *et al.* (2021). According to Rodríguez-Sauceda *et al.* (2019), it is tolerant to drought and to soils of low physical and chemical quality. Furthermore, from an environmental point of view, its inclusion in reforestation activities is key due to its great capacity to retain soil and improve its fertility, which helps to prevent desertification.

The mapping generated is a useful tool for planning reforestation strategies that consider the six native Fabaceae. In this sense, according to Guevara-Escobar *et al.* (2008), the percentage of survival in reforestation activities increases if the ecological niche factor is taken into account.

Of the six species considered in the study, *Prosopis laevigata* has the largest area suitable for use in reforestation programs.

The mapping generated for each of the six species is a guide to direct reforestation actions that will guarantee the increase of their survival and thus, the success of the plantations.

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Conflict of interest

The authors declare that they have no conflict of interest.

Contribution by author

Ricardo Rivera Vázquez: development of the research, interpretation of the results, editing of the manuscript; Andrés Mandujano Bueno: interpretation of results, editing of the manuscript.

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