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Article

Potencial agroecológico de *Moringa oleifera* Lam. para el estado de Veracruz

Agroecological potential of *Moringa oleifera* Lam. for the state of *Veracruz*

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Resumen

Moringa oleifera (moringa) es una especie multipropósito con aplicaciones alimentarias y medicinales. El objetivo de esta investigación fue delimitar las áreas con potencial agroecológico para el cultivo de moringa en el estado de Veracruz, México. Para ello, se utilizó una zonificación agroecológica que integra datos científicos y georreferenciados sobre sus requerimientos agroclimáticos, los usos de suelo y la localización de comunidades urbanas, mediante Sistemas de Información Geográfica (SIG). Los requerimientos agroclimáticos para el cultivo de moringa derivaron de dos fuentes de datos: una bibliográfica, con publicaciones científicas y bases de datos oficiales; y otra que integró datos georreferenciados, entrevistas semiestructuradas y recolecta de muestras de suelo. Se definieron los criterios para la identificación de áreas potenciales y se construyó un SIG para generar los mapas de las áreas con potencial agroecológico para el cultivo de moringa con cinco categorías: Muy alto, Alto, Medio, Bajo y Muy Bajo. Los mapas del potencial agroecológico incluyeron solo la superficie categorizada por el Instituto Nacional de Estadística y Geografía como de uso agropecuario. Los resultados indican que el espacio territorial con muy alto potencial tiene una extensión de 1 008 119 ha, equivalente a 18 % del territorio total disponible en 37 % de los municipios de la entidad. Se concluye que el estado de Veracruz tiene condiciones agroecológicas óptimas para el cultivo de *M. oleifera* en gran parte de su territorio, y que la incorporación de la información obtenida de los productores locales es importante para definir las áreas con potencial para su plantación.

Palabras clave: Especie multipropósito, *Moringa oleifera* Lam., productores locales, requerimientos agroclimáticos, Sistemas de Información Geográfica, zonificación agroecológica.

Abstract

Moringa oleifera (*Moringa*) is a multipurpose species with food and medicinal applications. The purpose of this research was to delimit the areas with agroecological potential for the cultivation of *Moringa* in the state of *Veracruz*, Mexico. For this, an agroecological zoning was used integrating scientific and georeferenced data on agroclimatic requirements of this species, land uses and the location of urban communities, through Geographic Information Systems (GIS). The agroclimatic requirements for the *Moringa* crop were derived from two data sources. The first, of a bibliographic type, with scientific publications and official databases. The second, integrated georeferenced data, semi-structured interviews and collection of soil samples. The criteria for the identification of potential areas for cultivation were defined and then a GIS was built to generate the maps of the areas with agroecological potential, using five categories: Very high, High, Medium, Low and Very Low, according to their potential for *Moringa* cultivation. The agroecological potential maps included only the surface area categorized by the National Institute for Statics and Geography as for agricultural use. The results indicate that the territorial space with very high potential has an area of 1 008 119 ha, equivalent to 18 % of the total territory available in 37 % of the municipalities of the entity. It is concluded that the state of *Veracruz* has optimal agroecological conditions for the cultivation of *Moringa oleifera* in vast areas of its territory and that the incorporation of the information obtained from local producers is important to define the areas with potential for its cultivation.

Key words: Multipurpose species, *Moringa oleifera* Lam., local producers, agroclimatic requirements, Geographic Information Systems, agro-ecological zoning.

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Introduction

Moringa oleifera Lam. (*Moringa*) is an arboreal species not native to Mexico, but in its territory there are ideal conditions for its cultivation (Olson and Fahey, 2011). This plant from the southern Himalayas has been part of the diet and traditional medicine in South Asia for centuries. Possibly, it reached national territory in the Nao of China and since then it has been part of the Pacific horticulture (Olson and Alvarado-Cárdenas, 2016).

For ten years, interest in the cultivation of *Moringa* has increased in the country; however, it is currently enjoying a new heyday, as in the rest of the world, due to two recent laboratory findings, such as its high protein content and its anticancer properties (Olson and Alvarado-Cárdenas, 2016). The most recent figures from the Mexican Agrifood System (SIAP, 2020) indicate that *Moringa* is cultivated in eight municipalities of four states (*Michoacán, Oaxaca, Puebla* and *Quintana Roo*), with a total area of 411 planted hectares, and an annual production of 1 328 tons of leaves, with a sales value of 8 thousand Mexican pesos per ton, which represents an annual income of around 13.5 million Mexican pesos.

In recent years in the state of *Veracruz*, small producers have emerged growing *Moringa* and transforming the harvested leaves into finished products, such as capsules, granules and infusions, among others, and whose target market is the food and natural products industry (Salas- Martínez and Valdés-Rodríguez, 2018). However, for this federal entity, the Agrifood and Fisheries Information System does not record sales or production records (SIAP, 2020); in addition, an assessment of the territorial aptitude or the agroecological potential for its cultivation in the state is not known.

At present, there are different systems for identifying the agroecological land potential for several purposes, including Geographic Information Systems (GIS). The purpose of GIS is to capture, analyze, store, edit and represent georeferenced data as a result of the integration of computer technology, human resources and geographic information (Olaya, 2014).

The application of GIS to determine the areas of the state of *Veracruz* with agroecological potential for *Moringa* cultivation will provide a tool for land use planning and crop management (Jiménez *et al*., 2004). Additionally, in previous studies on the agroecological potential of other states for cultivation, such as the one carried out by Espinosa *et al.* (2013) in *Chiapas*, the agronomic practices used by local producers and the national information generated on *Moringa* cultivation have not been integrated.

For this reason, the aim of this research was to delimit the areas with agroecological potential for the cultivation of *Moringa oleifera* in the state of *Veracruz*, Mexico, through agroecological zoning that integrates the available information on optimal agroclimatic requirements for the species, the knowledge of local producers, as well as land uses and the location of urban communities, through Geographic Information Systems.

Materials and Methods

The study was carried out in the state of *Veracruz*, located in the central part of the Gulf of Mexico, between 22°28' and 17°09' N, and 93°36' to 98°39' W. It borders five states, to the north with *Tamaulipas*; to the west with *San Luis Potosí, Hidalgo* and *Puebla;* to the southwest and south with *Oaxaca* and to the southeast with *Chiapas* and *Tabasco* (Sedecop, 2018).

The average annual temperature is 25.4 °C and the accumulated state average rainfall is 1 516 mm per year. The soil groups with the greatest presence are Vertisol, Feozem, Luvisol, Acrisol and Andosol, which together occupy 67 % of the state surface, of which Vertisol stands out, with 27 %. Soils with a clay texture cover 46 % of the land and are represented by the Vertisol, Acrisol and Luvisol groups; in general, these support cattle pastures and sugarcane crops (Soto and Geissert, 2011).

Information sources

To determine the areas with agroecological potential for the cultivation of *Moringa*, soils requirements of this plant were found from two data sources. The first includes those published in several databases on the species in the country. From them, the characteristics of soil type, precipitation and temperature were obtained, which were spatially located using the Inegi cartography (2018).

The second source included interviews with local producers, georeferenced data, and soil sample collections at cultivation sites. To do this, *Moringa* producers from the state of *Veracru*z were identified through an Internet search. Four producers were located in four municipalities: *Emiliano Zapata, Cosamaloapan, Soledad de Doblado* and *Tierra Blanca*; only three of them agreed to cooperate with the interview and field visits, which were carried out between November 2019 and March 2020. These producers have an average of 0.5 ha of planted area. A soil sampling was carried out in the plots with *Moringa* to analyze texture and pH in the Soil Laboratory of the National Institute of Ecology (Inecol), through the methodology indicated in NOM-021-RECNAT-2000 (Semarnat, 2002).

The variables to establish the agroclimatic potential were: climate (temperature and precipitation, annual minimums and maximums), soils (pH and texture) and altitude. The temperature and precipitation data were taken from the Climate Atlas of Mexico (Centro de Ciencias de la Atmósfera, 2018), which include the 1902-2015 period.

The information for the characteristics of the soils comes from the digitized edaphic charts and soil units of the Inegi (2018), and additionally, from the results of the soil samples taken in the plots of the *Moringa* producers. On the other hand, the information for the altitude variable was taken from the Inegi Digital Elevation Model (2018) in raster format.

Based on these plant requirement variables, an overlay of the shape and raster images was made for each variable. The Land Use and Vegetation chart at scale 1: 250 000 Series VI of Inegi (2018) was used to identify the areas occupied by urban areas, as well as by forest use, protected areas and water bodies, which were discarded from the selection model for being considered essential for the provision of essential goods and services for sustainable economic and social development. In this way, only the areas used for agriculture and livestock were included.

In order to obtain the source maps, the tools of the ArcGis program Version: 10.7.1 were used; the values with the best fit in the raster images were interpolated, the values for the variables were classified and the shape images were generated for the minimum and maximum annual temperature, and the minimum and maximum annual precipitation in the appropriate interval for *Moringa* cultivation. in the state of *Veracruz*.

The agroecological potential for *Moringa* cultivation was classified into five categories: Very High, High, Medium, Low and Very Low. The definition of each category was based on the evaluation of five variables: soil type, land use, interval of minimum and maximum annual precipitation, interval of maximum and minimum temperature, and altitude. These categories were established upon the number of variables that met the conditions or suitable intervals for the crop. The areas with Very High potential met the requirements for the five variables, those with High, four, and so on until those with Very Low potential, with only one variable out of the total of five (tables 1 and 2). The category of greatest interest for this study was that of Very High agroecological potential.

Table 1. Categories for the identification of areas with agroecological potential for *Moringa oleifera* Lam. cultivation.

Number of variables	Category				
	Very low	Low	Medium	High	Very high
1	X	X	X	X	X
2		X	X	X	X
3			X	X	X
4				X	X
5					X
Total	1	2	3	4	5

Table 2. Example of Determination of categories by compliance with variable(s) for five municipalities in the state of *Veracruz.*

Uso de suelo	*UsoValor*	*Altitud* (msnm)	AltValor	Pp (mm)	PpValor	Tem (°C)	TemValor	*Suelo*	*Suelo Valor*	ApTerValor	Región	CVE_Mun	*Municipio*	GM_2015	*Potencial*	ha
Agricultura	1	10-827	1	880-1 310	1	17.6-27.6	1	Phaeozem	1	5	Capital	004	Actopan	Medio	Muy alto	39.376
Agricultura	1	10-827	1	880-1 310	1	17.6-27.6	1		0	4	Huasteca Baja	160	Alamo Temapache	Alto	Alto	1 349.9
Agricultura	1	10-827	1		0	17.6-27.6	1		0	3	Olmeca	108	Minatitlán	Bajo	Medio	51.849
Agricultura	1	10-827	1		0		0		0	2	Huasteca Alta	121	Ozuluama de Mascareñas	Alto	Bajo	56.899
Agricultura	1		0		0		0		0	1	Huasteca Baja	072	Huayacocotla	Alto	Muy bajo	44.719

† *UsoSuelo* = Land use; *Altitud* = AltValue; Pp = Precipitation; Tem = Temperature; *Suelo* = Type of soil; *Región* = Administrative Region; CVE_MUN = Municipality key; GM_2015 = Position within range (top, middle, bottom); Aptitud = Category; *Potencial* = Potential; ha = Hectarea; ±Value within the range = 1; Value out from the range = 0

With the interaction of the climatic and edaphic variables, two maps were elaborated: 1) Agroecological potential for the cultivation of *Moringa* based on bibliographic references and 2) Agroecological potential for the cultivation of *Moringa* based on the agroclimatic conditions of three producing municipalities in the state of *Veracruz*, Mexico.

For the second map, the information provided by the producers of the entity and the characteristics of the variables analyzed were used, in the location sites of their *Moringa* plantations.

Results and Discussion

Table 3 shows the optimal values of the agroclimatic variables for the cultivation of *Moringa* from bibliographic data. Table 4 summarizes these same variables, but with georeferenced data, interviews and soil samples in the *Moringa* cultivation sites of the interviewed producers.

Table 3. Optimal agroclimatic requirements for the cultivation of *Moringa oleifera* Lam. from bibliographic references.

Variable	Optimal	Source
Temperature (°C) intervals	15-27	Olson and Fahey (2011); Vázquez-León *et al*. (2017)
Altitude (msnm)	0-600	Olson and Fahey (2011); Vázquez-León *et al*.(2017)
Accumulated annual precipitation intervals (mm)	297-1500	Valdés *et al.* (2014); SIAP (2017); Espinosa *et al*. (2013); Pérez *et al*. (2010); Egea *et al*. (2015)
Soil types	Luvisol, Phaeozem, Regosol	Espinosa *et al*. (2013)

Soil pH	6.3-7.1	Espinosa *et al*. (2013); Pérez *et al*. (2010); Goss (2012); Price (2007)
Soil texture	Sandy-loam	Valdés *et al.*(2014)

Table 4. Agroclimatic characteristics from georeferenced data, interviews and soil sample collection in municipalities where *Moringa oleifera* Lam. is growing in *Veracruz.*

Variable	***Emiliano Zapata***	***Soledad de Doblado***	***Cosamaloapan***
Temperature (°C) intervals	19-30	19-32	22-32
Altitude (masl)	827	103	10
Accumulated annual precipitation intervals (mm)	894	887	1307
Soil types	Phaeozem	Phaeozem	Vertisol
Soil pH	6.15-6.83	7.63-7.99	6.6-6.9
Soil texture	Sandy-clay	Sandy-clay	Clay

Sources: Temperature, altitude, precipitation and soil type of the locations (INAFED,2020); pH and soil texture (results of the analysis performed at *Instituto Nacional de Ecología* laboratories.

Based on the agroclimatic characterization carried out for the state of *Veracruz*, 75 % of the territory of the entity meets the optimal conditions of temperature intervals for the cultivation of *Moringa* (15-27 °C), data that Espinosa *et al*. (2013). However, there are some regions to the west, adjacent to *Puebla* and *Hidalgo* also reported, with temperatures outside the optimal range, thus they are considered inappropriate for this purpose. These are regions with cold and semi-cold climates with average temperatures that vary between 12 and 18 °C.

As stated by Pérez *et al.* (2010), *Moringa* is resistant to cold for a short time at temperatures not below 3 °C and at those below 14 °C, it does not flower. On the other hand, Olson and Alvarado-Cárdenas (2016), and Navarro (2015) considered that the ideal average temperature for *Moringa* ranges between 21 and 23 °C. However, they recommended that the absolute minimum temperature should not be lower than 15 °C; since this climatic variable is the one that takes the plant to the limit of its tolerance and seems to be the most important factor for its performance. Therefore, the temperature in these regions constitutes a limitation for the productivity of *Moringa* and they are inappropriate for the cultivation of the species.

From the optimal altitude (0-600 masl), 75 % of the territory is suitable for the described purpose, as also confirmed by Espinosa *et al*. (2013); however, there are high regions to the west, adjacent to the states of *Hidalgo* and *Puebla*, located between 1 600 and 3 800 m that are not suitable for cultivation because it is a tropical plant that thrives best below 500 meters above sea level and grows very little when it develops above 1 500 m (Olson and Alvarado-Cárdenas, 2016).

Precipitation is one of the variables that greatly influenced the determination of the agroecological potential of the studied areas. According to the recommendations of optimal total annual rainfall for *Moringa* (297-1 500 mm), 45 % of the *Veracruz* territory is suitable for cultivation because it falls in this rainfall interval, according to Espinosa *et al.* (2013) and Pérez *et al.* (2010); however, there are some regions in the state with values outside this range, which were considered unsuitable. In this case, an extensive region located to the northeast and southeast of the entity, bordering *Oaxaca, Chiapas, Tabasco* and the Gulf of Mexico; another of smaller extension to the northwest, contiguous with *Puebla* and *Hidalgo*; and finally, another to the northeast, with the Gulf of Mexico, turned out to be unsuitable for cultivation.

The criterion applied to define the optimal precipitation conditions is supported by Olson and Alvarado-Cárdenas (2016), who mentioned that the plant grows better in places with less than 970 mm of rain per year. However, Egea *et al.* (2015) and Wangcharoen and Gomolmanee (2013) suggested a wider precipitation range for the cultivation of Moringa, from 250 to 1 500 mm; but although the plant is resistant to drought, water stress can decrease its productivity.

According to the values of the variables considered in this study (Table 3), the areas where *Moringa* is currently grown in *Veracruz* meet the precipitation parameters of Egea *et al.* (2015). It is important to mention that the producers interviewed use pruning as a practice to obtain a greater production of leaves, as well as drip or sprinkler irrigation to increase the general productivity of the plant. This indicates that the demand for water for a good response requires greater rainfall than the 250 mm proposed in the literature (Egea *et al*, 2015; SIAP, 2017).

In regard to soil types, Espinosa *et al*. (2013) defined the optimal soils for *Moringa* cultivation as Phaeozem, Regosol and Luvisol. Based on this recommendation, 40 % of the *Veracruz* territory is suitable for its cultivation. Two suitable regions were located: the first, to the southwest and southeast of the entity, bordering the states of *Oaxaca*, *Chiapas, Tabasco* and the Gulf of Mexico; the second, in the central part of the state, in the northwest, between the states of *Puebla* and *Hidalgo* and to the northeast with the Gulf of Mexico.

Vertisol is a soil not suitable for the described purpose; however, one plantation was recorded on this type of soil. The owners indicated that the substrate is very hard in the dry season and plastic in the wet season, which makes tillage difficult, except during the short transition periods between the two seasons, but with good management it remains very productive. This was confirmed by Reyes (2006), who mentioned that vertisols are not the most favorable soils for *Moringa* cultivation, but that this restriction can be overcome with proper management. In the same way, Pérez *et al.* (2010) and Valdes *et al.* (2018) considered that *Moringa* is a species of great ecological plasticity, with the ability to adapt to different soil conditions.

In relation to soil acidity, Reyes (2006) stated that soils with a pH between 4.5 and 8 are appropriate for *Moringa* cultivation, regardless of the type of soil, except for heavy ones, where the plant has difficulties to grow. The pH values in the soils of the producers' lands (6.15-7.9) are within the recommended interval (4.5-8.0) by Espinosa *et al.* (2013) for the cultivation of the species; although some authors argue that the plant can tolerate a wider interval (5-9), growing well in alkaline conditions with pH values up to 9.0 (Price, 2007). On the other hand, in acidic conditions, Goss (2012) indicates that a pH below 5.0 hinders the absorption of nutrients by the plant, prevents the correct growth of the roots, and therefore, not only can affect its growth and productivity, but even their survival.

Based on the above and on the results of the soil analyzes carried out in the *Moringa* cultivation sites of the interviewed producers, it was estimated that heavy soils may be suitable for growing the plant, when it is well managed; for example, if it is planted on land with enough slope to avoid waterlogging.

Table 5 shows the total area suitable for *Moringa* cultivation according to the defined categories of agroecological potential. It is observed that when integrating the data provided by the producers (surface B), the suitable area for cultivation is increased, compared to that obtained from the data from the bibliographic review (Surface A). An increase of 2 % (144 000 ha) was determined in the Very High category and a significant decrease of 27 % (1 450 132 ha) in the High category. The rest of the categories increased by 18 % (972 000 ha) Medium, 5 % (270 000 ha) Low and 2 % (116 000 ha) Very Low. The results were caused by the expansion of the intervals in temperature (19-30 °C) and altitude (10-827 masl), as well as the incorporation of another type of soil and texture, which are the conditions under which the interviewed local producers are located.

Table 5. Estimated potential area for the *Moringa oleifera* Lam. plantation in the state of *Veracruz*.

Agroecological potential	**A Surface* (ha)**	**%**	**B Surface ** (ha)**	**%**
Very high	863 743	16	1 008 119	18
High	3 042 607	56	1 592 475	29
Medium	1 087 659	20	2 059 793	38
Low	369 713	7	639 212	12
Very low	54 676	1	170 555	3

Total	5 418 397	100	5 470 154	100

*Estimated area based on bibliographic references; **Estimated area based on data provided by local producers.

Temperature and altitude had a great impact on the distribution of areas with agroecological potential for *Moringa* cultivation. García (2003) explained this based on the fact that the species is distributed in a wide range of temperatures (6 to 38 °C) and altitudes (up to 1 800 masl). These results determine that there is an extensive territory with very high potential for Moringa cultivation in the state of *Veracruz*. Table 6 lists the municipalities grouped into economic regions with very high agroecological potential for this purpose.

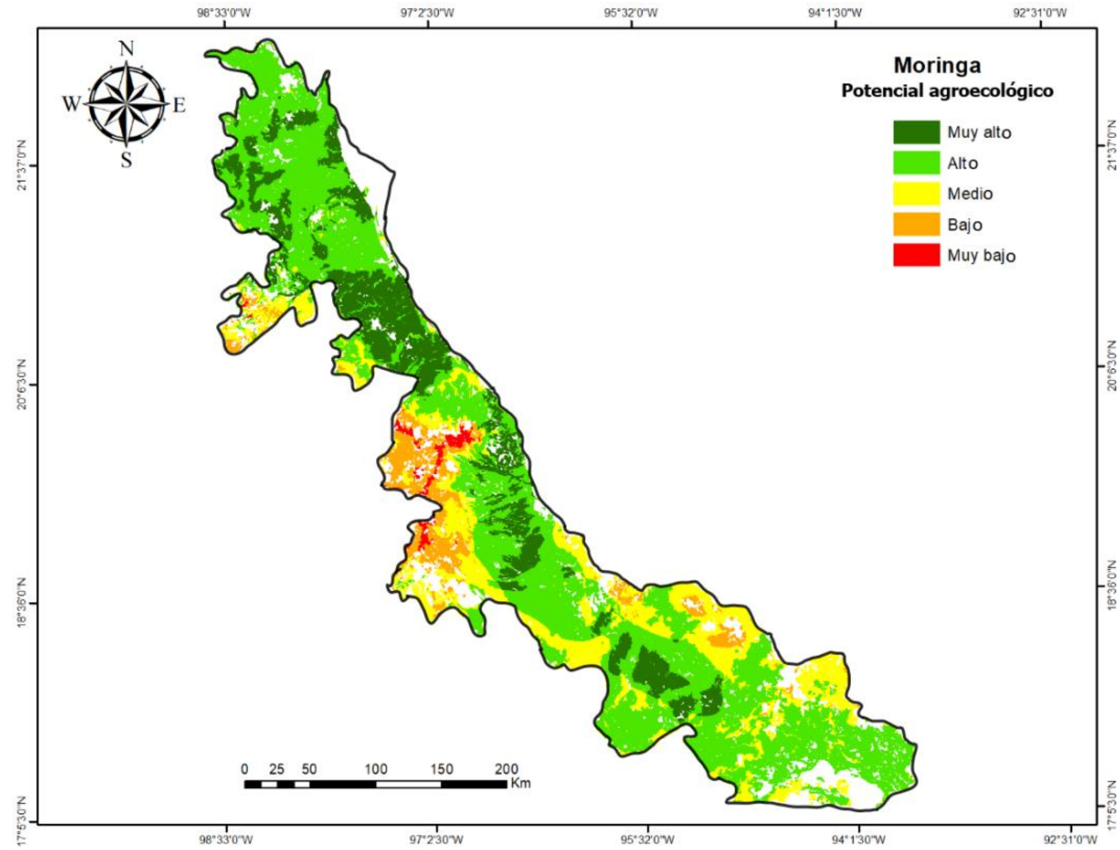
Table 6. Municipal surface, by administrative region, with agroecological potential of the Very high category for the *Moringa oleifera* Lam. cultivation in the *Veracruz* State.

Region	Municipalities	Surfaces (ha)	%†
Totonaca	*Cazones de Herrera, Papantla, Tihuatlán, Poza Rica de Hidalgo.*	33 273	3.300
Huasteca Alta	*Pánuco, El Higo, Tempoal, Ozuluama de Mascareñas, Tantoyuca, Platón Sánchez, Pueblo Viejo, Tampico Alto, Tantima, Chalma.*	445 795	44.221
Papaloapan	*Isla, Juan Rodríguez Clara, Tierra Blanca, José Azueta.*	76 606	7.599
Huasteca Baja	*Ixcatepec, Chicontepec, Álamo Temapache, Tepetzintla, Tuxpan, Ixhuatlán de Madero, Benito Juárez, Castillo de Teayo, Tuxpan, Clitlaltepétl, Chontla, Cerro Azul.*	147 638	14.645
Sotavento	*Manlio Fabio Altamirano, Soledad de Doblado, Paso de Ovejas, Úrsulo Galván, Tlalixcoyan, Veracruz, La Antigua, Medellín de Bravo*	168 403	16.705

Nautla	*Juchique de Ferrer.*	24	0.002
Capital	*Actopan, Alto Lucero de Gutiérrez Barrios, Apazapan, Xalapa, Emiliano Zapata, Naolinco, Jalcomulco, Coatepec.*	92 892	9.214
Olmeca	*Acayucan.*	19	0.002
Las Altas Montañas	*Tlaltetela, Comapa, Zentla, Paso del Macho, Carrillo Puerto, Camarón de Tejeda, Cuitláhuac*	30 117	2.987
Los Tuxtlas	*Hueyapan de Ocampo*	13 352	1.324
Total		1 008 119	100

†% = Total percentage of the Very High category.

Figure 1 shows the final map of the distribution of areas with agroecological potential for the establishment of *Moringa oleifera* Lam. in the state of *Veracruz* based on bibliographic data. Four regions with very high potential were obtained, which, in order of magnitude, are located as follows: the first in the northwest, which borders the state of *Puebla* (329 026 ha); the second in the central part of the entity, between the state of *Puebla* and the Gulf of Mexico (184 827 ha); the third to the southwest, bordering the state of *Oaxaca* (182 818 ha); and the fourth region to the north of the state (167 064 ha).



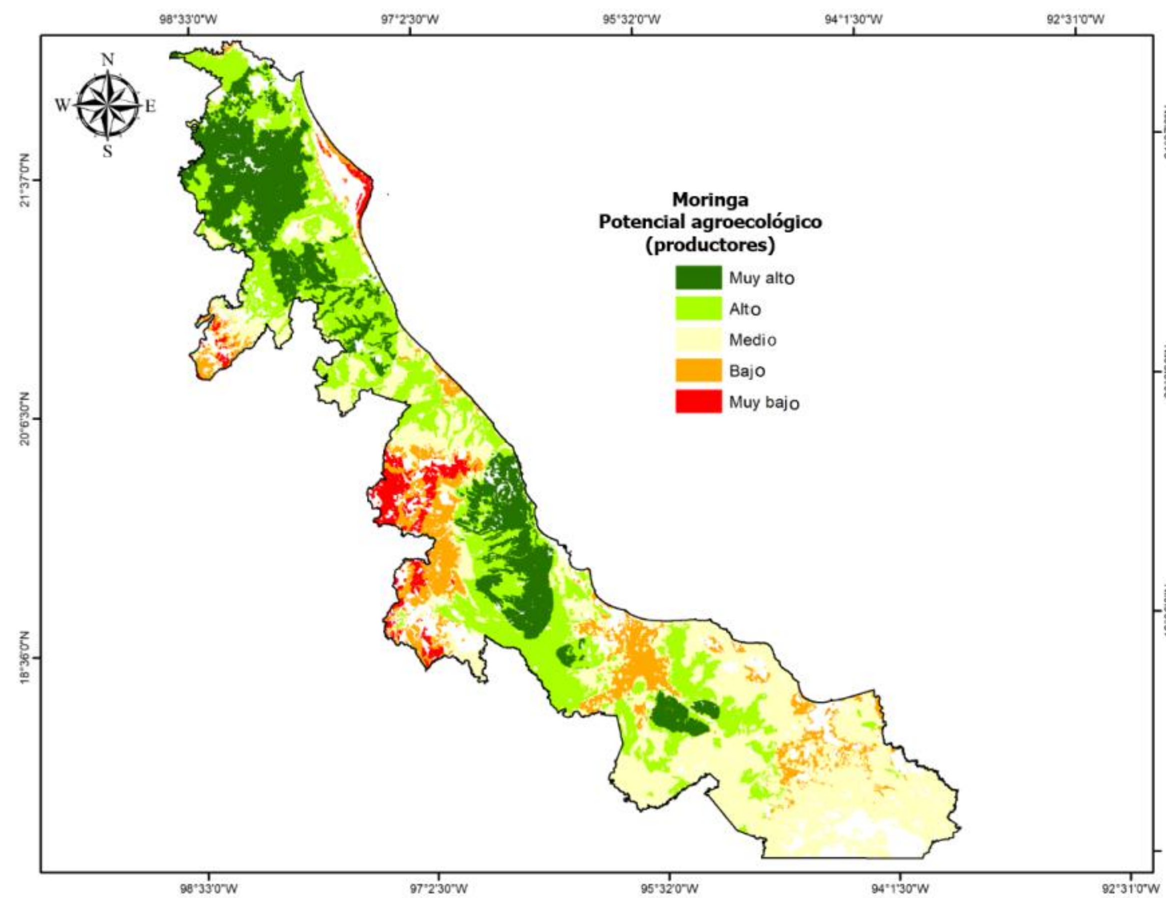
Potencial agroecológico = Agroecological potencial; *Muy alto* = Very high; *Alto* = High; *Medio* = Medium; *Bajo* = Low; *Muy bajo* = Very low.

Elaboration: de la Rosa-Portilla (2021).

Figure 1. Agroecological potential for the optimal establishment of *Moringa oleifera* Lam. in the state of *Veracruz*, Mexico based on bibliographic references.

The four regions add up to a total of 863 742 ha. When contrasting these results with Olson and Alvarado-Cárdenas (2016), it was determined that the area of 34 100 ha that these authors consign as suitable for *Moringa* cultivation in the state of Veracruz is much lower than that estimated in this study (863 742 he has). However, there is agreement in the location of one region within the category of Very high potential, identified in the central part of V*eracruz* State.

Figure 2 shows the final map based on the data provided by local producers. Three important regions categorized as having Very High Agroecological Potential were found. The first, with an extension of 626 706 ha, located to the northwest of the entity towards the states of *Hidalgo* and *San Luis Potosí*. The second, with an area of 291 436 ha, located in the central part of the entity, bordering *Puebla* to the northwest and the Gulf of Mexico to the northeast. The third, with an area of 89 997 ha, between the state of *Oaxaca* and the Gulf of Mexico.



Potencial agroecológico (*producores*)= Agroecological potencial (producers); *Muy alto* = Very high; *Alto* = High; *Medio* = Medium; *Bajo* = Low; *Muy bajo* = Very low.

Elaboration: de la Rosa-Portilla (2021).

Figure 2. Agroecological potential for the optimal establishment of *Moringa oleifera* Lam. in the state of *Veracruz*, Mexico based on data provided by local producers.

The information on the agroecological potential for the cultivation of *Moringa* can be useful as a reference for decision-making by farmers or government institutions regarding the planting of this species in areas with the right conditions for its cultivation, as pointed out by Olson and Alvarado-Cardenas (2016).

Finally, although cultivation is focused on the use of leaves among local producers, *Moringa* is a plant that adapts perfectly to the *Veracruz* tropics and has a variety of uses and properties that still need to be explored (Pérez *et al.,* 2010).

Conclusions

The state of *Veracruz* has a large extension of its territory (18 %) with very high agroecological potential for *Moringa oleifera* plantations, and, if the areas with high potential are also considered, this surface is extended to almost half of the surface available in the state (47 %).

The information from local producers and the agroclimatic conditions of their plantations allows us to estimate an expansion of 144 000 ha in the Very High Potential category, in relation to that estimated with bibliographic sources. In addition, the incorporation of these local experiences allowed to provide a more comprehensive vision adjusted to reality than that achieved if only bibliographical references are used when studies are carried out to categorize areas with potential for the establishment of *M. oleifera*.

The maps obtained in the present study are a useful tool for planning and decision-making related to the establishment of *Moringa,* both for government authorities and for producers, by ensuring that the productive alternatives are consistent with the reality of rural areas. of *Veracruz.*

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Conflict of interests

The authors declare no conflict of interest.

Contribution by author

Juan Manuel Carrión Delgado: development of the research and writing of the manuscript; Ofelia Andrea Valdés Rodríguez: methodological concept, analysis, writing and review of the manuscript; Felipe Gallardo López: review of the manuscript; Olivia Margarita Palacios Wassenaar: review of the manuscript.

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