Chapter

The Endemism of the Vascular Flora of Mexico Present in Comarca Lagunera, an Agricultural Region in the Chihuahuan Desert

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Abstract

A study of the distribution of 321 taxa of endemic vascular plants of Mexico distributed in Comarca Lagunera, a region of northern central Mexico within the Chihuahuan Desert, was conducted. The analysis consisted in detecting the areas of high richness and with this information propose areas for the conservation of plant biodiversity in this region. The study includes an analysis of species richness at the level of political units (municipalities), vegetation types, and grid cells of 10 × 10 km. Additionally, the corrected weighted endemism index was calculated using the grid cells. The sites with the richest taxa are located in the mountain areas; however, these do not coincide with the sites with the highest index of endemism since a high percentage of taxa have a restricted distribution to one of the proposed units. Thirty-six taxa are recognized with restricted distribution to the boundaries of Comarca Lagunera, most of them considered as microendemics, which have been described in recent years. Therefore, it is necessary to establish biodiversity conservation programs in the region since much of Comarca Lagunera territory is dedicated to agricultural and industrial activities.

Keywords: biodiversity informatics, conservation, Coahuila, corrected weight endemism index, Durango, north of Mexico, chorological analysis, semiarid vegetation

1. Introduction

Biodiversity informatics is a set of tools that allows free and rapid access to knowledge accumulated in different sources and media such as biological collections and specialized literature, which has facilitated the arrangement, management, analysis, and interpretation of biodiversity in addition to the generation of models; many of them focused on the conservation of biodiversity [1, 2]. The increase in knowledge of biodiversity is seen in a large amount of information from different databases available on the Internet, of which the Global Biodiversity Information Facility (GBIF–www.gbif.org) stands out, housing more than 1000 million records of species distribution (October 2018). This number of records continues growing, as it improves the quality control of the data hosted because more and more institutions deposit their data on that platform. Another tool that is very useful in biodiversity informatics is the Biodiversity Heritage Library (BHL—www.biodiversitylibrary.org), which allows free access to millions of published historical documents related to taxonomy, biogeography, and ecological aspects of the groups that form the biodiversity, among other items; thanks to these platforms, it is now easier to consult information that in the past was difficult to access for many research groups.

In Mexico, the National Commission for Knowledge and Use of Biodiversity (CONABIO) carried out one of the first attempts to gather and make available information to researchers about the distribution of Mexican species. Currently, the National System of Information on Biodiversity (SNIB) is one of the most reliable databases that houses information on the distribution of a large number of species of virtually all biological groups known to Mexico; this database gathers information from a large number of Mexican collections in which the taxonomic information has been reviewed, identified, and determined by specialists, and it also has a high level of quality in the revision phase of the georeferencing of the localities of distribution, so its reliability is very high [3]. The effort made by different institutions to learn about biodiversity allows Mexico to contribute to one of the objectives of the Systematic Agenda [4].

Although Mexico has a great botanical tradition and the knowledge of the flora in several regions is relatively well known, such as the north of the country and mainly the Chihuahuan Desert [5, 6], there are areas that do not still have an inventory of their flora, and therefore the distribution of the endemic elements is unknown, which is an impediment to carry out conservation plans. One of the regions in which a complete inventory of the flora is not yet made is Comarca Lagunera, a region located in the northern center of Mexico, within the Chihuahuan Desert (**Figure 1**).

The boundaries of Comarca Lagunera differ depending on the approach considered, and in this chapter, the limits proposed by Sánchez [7] are taken, which recognize that Comarca Lagunera is composed of 15 municipalities that share particular natural and socioeconomic attributes. Five of these municipalities belong to the state of Coahuila (Francisco I. Madero, Matamoros, San Pedro, Torreón, and Viesca) and

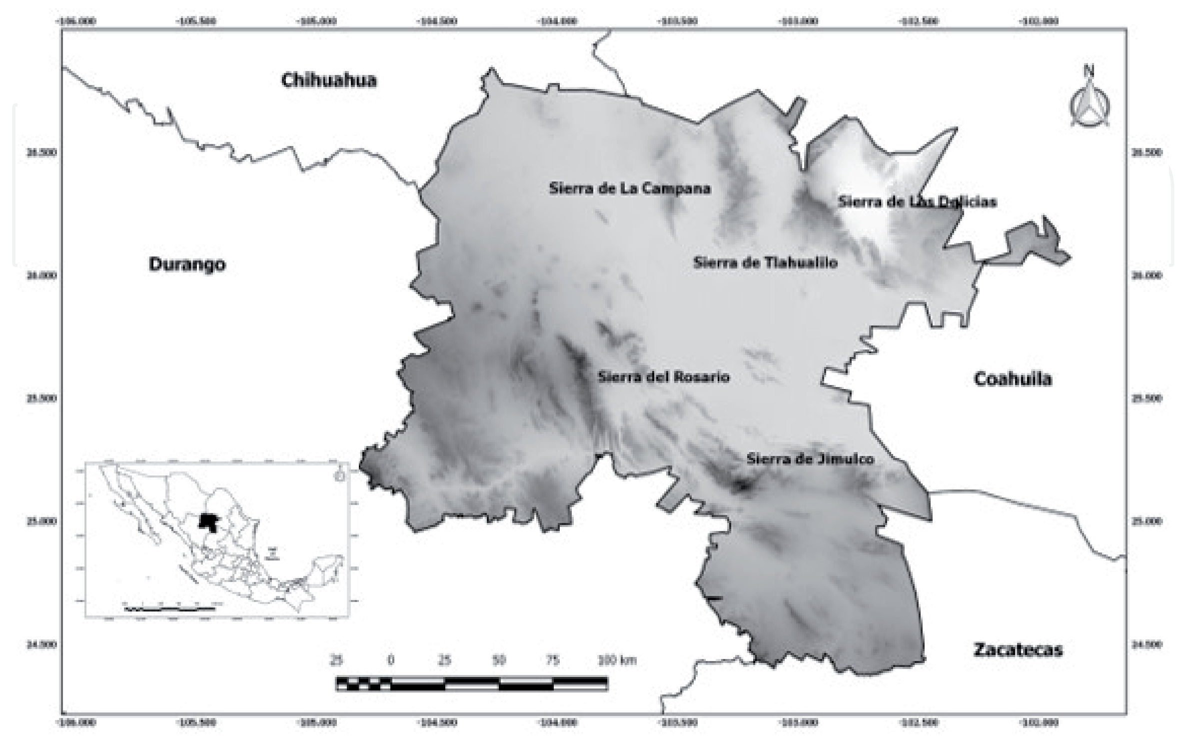

Figure 1.
Localization of Comarca Lagunera in México and its principal mountain zones.

10 to the state of Durango (General Simón Bolívar, Gómez Palacio, Lerdo, Mapimí, Nazas, Rodeo, San Juan de Guadalupe, San Luis del Cordero, San Pedro del Gallo, and Tlahualilo) (**Figure 2**). Under these limits, Comarca Lagunera covers an area of just over 43,000 km^2, which is equivalent to the total territory of Denmark.

The climate of Comarca Lagunera is semiarid to very arid, according to García [8] (**Figure 3**), with an average annual temperature of 20–22°C and an annual rainfall of 200–300 mm. The climate types are BS1hw (semiarid-semiwarm), BS1kw (semiarid-tempered), BS0hw (arid-semiwarm), BS0kw (arid-tempered), and BWhw (arid-semiwarm). The relief of the region is composed of small hills and low elevations, as well as adjacent depressions [9], among the main elevations are the mountains of Candelaria, El Rosario, El Sarnoso, España, Jimulco, La Campana, Las Cadenas, Las Delicias, Mapimí, and Tlahualilo.

Mexico has a richness flora and vegetation as a result of the great diversity of ecological conditions, which in turn has been shaped by the complex geological history of its territory. The different types of vegetation that are recognized are based on ecological, floristic, and physiognomic affinities; although some consider the edaphological, geological, and topographic aspects of greater importance [10]. The different vegetation types according to the National Institute of Statistic and Geography (INEGI) are based on [11, 12]. The land use and vegetation information elaborated by the INEGI is a reliable element in terms of information and its feasibility; therefore, they are used as a basic framework by government agencies, the private sector, and academia, and it is a basic input for the implementation of institutional programs as a reference for the preparation of reports on the state of plant cover in Mexico [13]. The diversity of types of vegetation in Mexico is so wide that it is difficult to find an equivalence with those that exist in other places [14], including those of North America in northern Mexico [15].

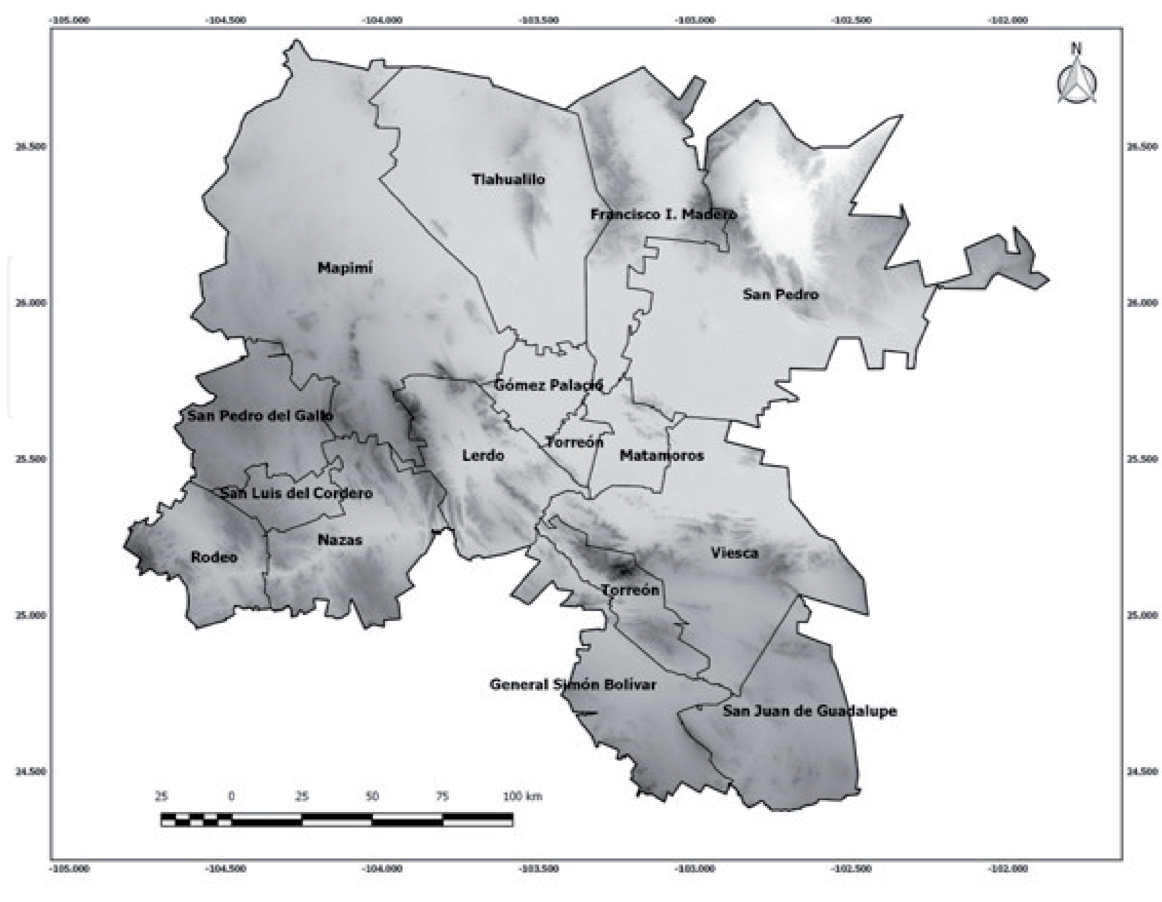

Figure 2.
Municipalities that form Comarca Lagunera, according to Sánchez [7].

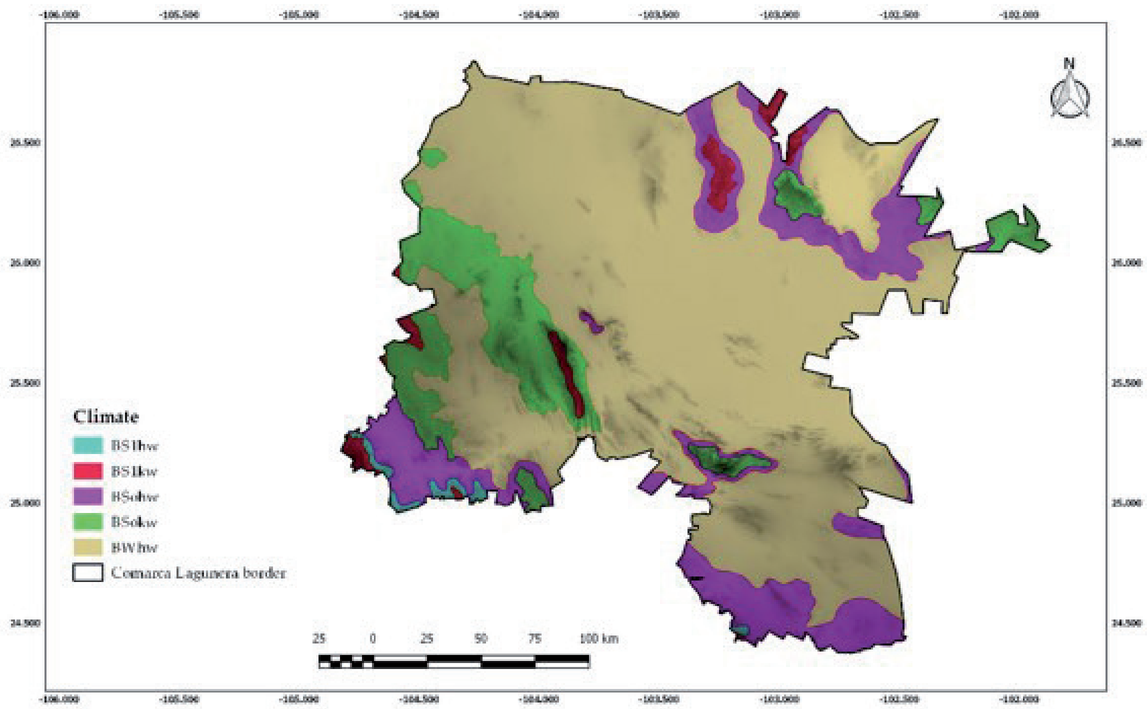

Figure 3.
Climates in Comarca Lagunera according to García [8].

According to the National Institute of Statistic and Geography (INEGI) [13], the land use and vegetation types in the area are 17. The description of the types of vegetation exceeds the objective of this work so only listed below, in parentheses are the most important genera that are present in each of them: chaparral (*Arctostaphylos* Adans., *Ceanothus* L., *Cercocarpus* Kunth, *Eriogonum* Michx., *Heteromeles* M. Roem., *Mimulus* L., *Quercus* L., *Rhamnus* L., and *Yucca* L.), crasicaule scrub (*Acacia* Mill., *Brickellia* Elliot, *Buddleja* L., *Celtis* L., *Dalea* Juss., *Larrea* Cav., *Mimosa* L., *Opuntia* Mill., *Prosopis* Burkart, *Rhus* L., *Stenocereus* (A. Berger) Riccob., and *Yucca*), gallery vegetation (*Acacia*, *Chilopsis* Don, *Mimosa*, *Prosopis*, *Salix* L., and *Senecio* L.), gypsophile vegetation (*Dicranocarpus* A. Gray, *Flaveria* Juss., *Helianthemum* Mill., *Petalonyx* A. Gray, *Sartwellia* A. Gray, *Selinocarpus* A. Gray, and *Stipa* L.), halophile grassland (*Distichlis* Raf., *Hilaria* Kunth, *Spartina* Schreb. ex Gmel., *Sporobolus* R.Br., and *Uniola* L.), halophile xerophile vegetation (*Atriplex* L., *Batis* L., *Frankenia* L., *Spartina*, and *Zostera* L.), induced grassland (*Andropogon* L., *Aristida* L., *Bouteloua* Lag., *Bromus* L., *Buchloe* Engelm., *Calamagrostis* Adans., *Cathestecum* C. Presl, *Deschampsia* P. Beauv., *Erioneuron* Nash, *Festuca* L., *Hilaria*, *Lycurus* Kunth, *Muhlenbergia* Schreb. ex Gmel., *Stipa*, *Trachypogon* Nees, and *Trisetum* Pers.), microphile desertic scrub (*Acacia*, *Cercidium* Tul., *Condalia* Cav., *Chilopsis*, *Flourensia* DC., *Fouquieria* Kunth, *Hymenoclea* Torr. & A. Gray, *Larrea*, *Lycium* L., *Olneya* A. Gray, *Opuntia*, and *Prosopis*), mesquite forest (*Prosopis*), natural grassland (*Bouteloua*), oak forest (*Quercus*), oak-pine forest (*Quercus*, *Pinus* L.), pine forest (*Pinus*), rosetophile desertic scrub (*Agave* L., *Dasylirion* Zucc., *Euphorbia* L., *Hechtia* Klotzsch, *Parthenium* L., and *Yucca*), submontane scrub (*Acacia*, *Agave*, *Aristida*, *Bouteloua*, *Capparis* L., *Cordia* L., *Euphorbia*, *Flourensia*, *Gochnatia* Kunth, *Karwinskia* Zucc., *Leucophyllum* Humb. & Bonpl., *Mimosa*, *Mortonia* A. Gray, *Neopringlea S. Watson*, *Pithecellobium* Mart., *Rhus*, *Tridens* Roem. & Schult, and *Zanthoxylum* L.), vegetation of sandy desert (*Ambrosia* L., *Atriplex*, *Ephedra* L., *Larrea*, *Opuntia*, *Prosopis*, and *Yucca*), and xerophile scrub (*Acacia*, *Agave*, *Dasylirion*, *Euphorbia*, *Flourensia*, *Fouquieria*, *Larrea*, *Opuntia*, *Prosopis*, and *Yucca*). A considerable part of the territory of the region is occupied for agricultural and livestock activities (**Figure 4**).

Within the territory of Comarca Lagunera, five areas have been decreed for the protection of biodiversity: a protected natural area at the federal level (Reserva de la Biósfera Mapimí), one at the state level (Parque Estatal Cañón de Fernández), one

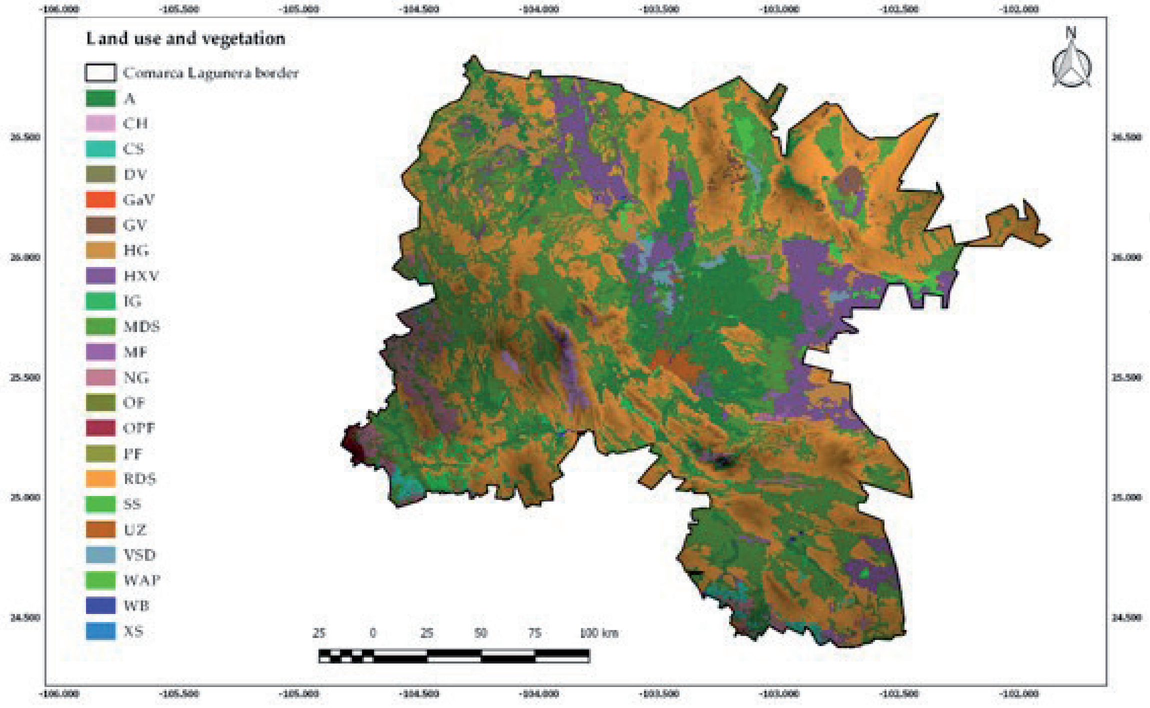

Figure 4.
Land use and vegetation types in Comarca Lagunera according to INEGI [10]. A = agricultural; CH = chaparral; CS = crasicaule scrub; DV = depleted of vegetation; GaV = gallery vegetation; GV = gypsophile vegetation; HG = halophile grassland; HXV = halophile xerophile vegetation; IG = induced grassland; MDS = microphile desertic scrub; MF = Mesquite forest; NG = natural grassland; OF = Oak forest; OPF = Oak-pine forest; PF = Pine forest; RDS = rosetophile desertic scrub; SS = submontane scrub; UZ = urban zones; VSD = vegetation of sandy desert; WAP = without apparent vegetation; WB = water body; and XS = xerophile scrub.

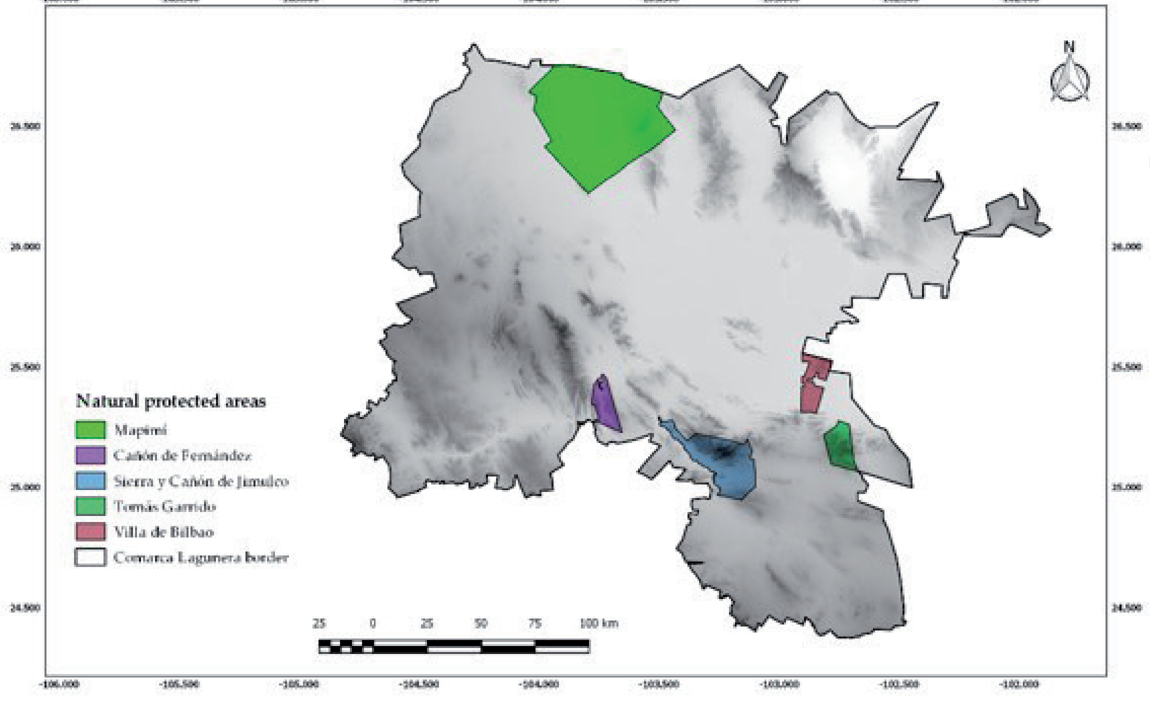

Figure 5.
Protected natural areas decreed in Comarca Lagunera.

municipal (Sierra de Jimulco), and two at ejidal level (Dunas de Bilbao and Ejido Tomás Garrido) (**Figure 5**).

The objective of the present study is to analyze the distribution and abundance of the taxa of the endemic flora of Mexico distributed in Comarca Lagunera in order to recognize potential sites for their conservation.

2. Methods

The search for information regarding the distribution of vascular plants in the SNIB database was carried out, where the records of the collected specimens in Comarca Lagunera were compiled. Considering the political limits of the 15 municipalities that form this region of Mexico, an exhaustive literature search was conducted in the BHL to detect nonregistered taxa, as well as verify the distribution of the taxa and addition of sites of collection not reported in the SNIB databases.

The information of the protologue of most of the taxa was reviewed, mainly those that have been described as new in the last decades, as well as the sites of register of collection of these taxa. The information published in various inventories at the state or regional level for both the flora as a whole or for specific groups was also consulted [6, 16–26], in addition to the review of the specimens deposited in the Interdisciplinary Research Center for Regional Integral Development (CIIDIR) herbarium.

Based on the information collected, a database with the records of the different taxa distributed in the boundaries of Comarca Lagunera was constructed. The nomenclatural information to avoid synonyms was based on the consultation of databases on the Internet of the International Plant Name Index (IPNI) (https://www.ipni.org), The Plant List (http://www.theplantlist.org), Tropicos (http://www.tropicos.org), and mainly in Villaseñor [27], which is so far the work that brings together the most extensive knowledge about the distribution of the flora of Mexico, where the author mentions that there are about 23,314 species and 1,414 subspecific categories.

In this study, the classification used by Villaseñor [27] for higher taxonomic categories is followed, which is based in turn mainly on the classification of Angiosperm Phylogeny Group [28]. The constructed database was refined to identify duplicate records and errors in the georeferencing. The records without geographic reference or with errors in it were georeferenced with the help of the topographic charts of INEGI scale 1:250,000 and 1:50,000 (www.inegi.org.mx). For maps elaboration, the digital model of the continuum of Mexican elevations (http://www.beta.inegi.org.mx/app/geo2/elevacionesmex) was used, in addition to the cartography related to land use and vegetation types for the region [13] and natural protected areas at the federal [29], state, municipal, and ejidal level [30]. All maps were created in the software QGIS 2.18.23 [31].

In order to perform the chorological analysis, the following were used as Operational Geographical Units (OGUs): the municipalities that are part of Comarca Lagunera, vegetation types, and a grid cell of 10 × 10 km latitude/longitude. Species richness was measured as the total count of species within each of the proposed units. In the analyzes at the municipal level, the criteria suggested by Dávila-Aranda et al. [32], with modifications due to the number of municipalities of Comarca Lagunera, to classify the level of restriction in the distribution of the species in scarcely distributed (taxa registered only in one municipality), closely distributed (2–4 municipalities), normally distributed (5–7 municipalities), and widely distributed (8 or more municipalities) were employed. Using these study units, a species accumulation curve was constructed, and with the aid of the nonparametric Chao2 estimator, the approximate number of endemic taxa, which are still unknown in Comarca Lagunera, was determined.

The vegetation types recognized by INEGI [13] for Comarca Lagunera were used; in each type of vegetation, the contribution of the endemic species of Mexico was evaluated. The information of the presence records was used to perform a cluster analysis, for which an absence-presence matrix was constructed to carry out a similarity analysis applying the Jaccard index, which was preferred over other indexes due to the fact that it does not consider shared absences. Once the similarity matrix was obtained, a grouping analysis (UPGMA) was carried out, to determine the floristic similarity among vegetation types. The corresponding phenogram was generated with the average linkage or UPGMA using the SAHN-clustering command in the NTSYSpc version 2.0 program [33].

Since the municipality size of Comarca Lagunera is not uniform and the area occupied by the different vegetation types is extremely different, it was necessary to carry out an alternative chorological analysis with units of standardized size. For this reason, a grid cell of 10 km per side was constructed to reduce the effect of the differences in the size of the units used for the analysis according to Crisp et al. [34]. An analysis of richness and endemism was also carried out following the proposal of Crisp et al. [34] and Linder [35], and this analysis called corrected weighted endemism index (CWEI) was applied for the first time to analyze the endemic elements of the flora of Australia and later in Africa. In Mexico, it has been applied in the analysis of diverse groups of flora and fauna, mainly to detect species-rich sites and a high level of endemism in order to propose sites for the conservation of biodiversity [36–39].

The CWEI [34, 35] is a methodology that calculates the relationship of taxa richness with weighted endemism. For this index, the presence of the taxon in an OGU is considered, and the abundance is omitted. It consists of three basic steps: in the first one, the index of endemism is calculated for each one of the taxa which is the result of the amplitude of its distribution, so it is calculated as the reciprocal of its distribution, and therefore, a species with restricted distribution to a single OGU (in this case grid cells) is assigned an index of "1," a species that is distributed in two OGUs is assigned an index of "0.5," and so on in such a way that the index will be lower as its distribution increases, so it is weighted with a higher value for species with restricted distribution; the second step is to calculate the weighted endemic index (WEI) for each of the OGUs, this is achieved by summing the values of the endemism index of each of the taxa that are distributed in each OGU; while the third step consists in dividing the WEI by each one of the OGUs among the richness of species that are distributed in it, in this way, we obtain the CWEI for each one of the OGUs; OGUs with the highest scores are recognized as centers of endemism.

Finally, a complementarity analysis was carried out [40] to detect the minimum number of grid cells needed to conserve most of the endemic species that inhabit this area of Chihuahuan Desert. The method consists in selecting the areas to be protected based on the total species richness from the following procedure: the grid cell with the highest number of taxa is selected, this is the grid cell with priority 1, the species registered in it are eliminated from the analysis, and then the selection of the grid cell with the highest number of remaining taxa (complement) that have not yet been selected in the previous step is repeated; if two or more grid cells have the same number of taxa, the first grid cell identified is selected, and the procedure ends when all the taxa have been selected.

3. Results and discussion

The richness of endemic plants of Mexico represented in Comarca Lagunera consists of 59 families, 184 genera, 300 species, and 21 infraspecific taxa (8 subspecies and 13 varieties) totaling 321 taxa (**Table 1**). Thirty-six taxa possess known distribution only for the area corresponding to Comarca Lagunera (Appendix), 21 more taxa are known only from the Chihuahuan Desert (*sensu* Villarreal-Quintanilla et al. [41]), 33 more taxa only occur in the states of Coahuila and Durango, and the rest of the taxa is restricted to the territory of Mexico but with a greatly wide distribution. This diversity of endemic taxa corresponds to approximately 10% of the total endemic species of Mexico [27] and to about 30% of the flora known for Comarca Lagunera [González-Zamora & Pérez-Morales, *in prep*.].

The families with the highest number of endemic taxa in Mexico distributed in Comarca Lagunera are Asteraceae and Cactaceae, which collectively account for approximately 35% of the total, this percentage is consistent with the results of Villareal-Quintanilla et al. [41] for the endemic flora of the Chihuahuan Desert, as well as for other semi-desert regions of central Mexico. The first six families with the highest number of endemic taxa represent about 54% of those reported for this region of Mexico and 36% of the taxa restricted to Comarca Lagunera (**Table 2**).

Of the 10 genera with 5 or more endemic species of Mexico, 4 correspond to the family Cactaceae, 2 to Asteraceae, 1 to Lamiaceae, 1 to Asparagaceae, 1 to Caryophyllaceae, and 1 to Fabaceae (**Table 3**). *Corynopuntia* F.M. Knuth and *Gaillardia* Foug. are the best represented genera; since in the study area, five of the seven species and five of the six species reported as endemic to Mexico, respectively, are distributed, including *Corynopuntia halophila* D. Donati which until now has only been reported as restricted to the territory of Comarca Lagunera [42], the same case is presented for *Salvia jessicae* B.L. Turner [43] and *Drymaria jenniferae* Villarreal & A.E. Estrada [44].

In the distribution by political entities, it was found that in general terms, the municipalities corresponding to the state of Coahuila have greater richness

Taxonomic group	Families	Genera	Species	Infraspecific taxa
Ferns	2	3	3	
Gymnosperms	1	1	1	
Angiosperms	56	180	296	21
Monocots	6	18	30	1
Eudicots	50	162	266	20
Total	**59**	**184**	**300**	**21**

Table 1.
Number of taxa of endemic vascular plants of Mexico in Comarca Lagunera.

Family	Taxa	Percentage with respect to the total	Genera represented	Endemic taxa of Comarca Lagunera
Asteraceae	69	21.5	38	6
Cactaceae	43	13.4	15	2
Fabaceae	27	8.4	16	3
Asparagaceae	13	4.0	7	1
Poaceae	10	3.1	6	
Lamiaceae	10	3.1	2	1
Total	**172**	**53.5**	**84**	**13**

Table 2.
Families with the highest number of endemic taxa of Mexico in Comarca Lagunera.

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Genus (Family)	Species in Mexico	Species endemics of Mexico	Endemic taxa of Mexico in Comarca Lagunera
Coryphantha (Engelm.) Lem. (Cactaceae)	46	37	8
Mammillaria Torr. & A. Gray (Cactaceae)	169	145	8
Salvia L. (Lamiaceae)	328	258	8
Agave L. (Asparagaceae)	159	133	5
Brickellia Elliott (Asteraceae)	85	57	5
Gaillardia Foug. (Asteraceae)	12	6	5
Corynopuntia F.M. Knuth (Cactaceae)	10	7	5
Opuntia Mill. (Cactaceae)	91	62	5
Drymaria Willd. ex Schult. (Caryophyllaceae)	38	23	5
Dalea Ulbr. (Fabaceae)	146	92	5

Table 3.
Genus with the highest number of endemic taxa in Mexico with distribution in Comarca Lagunera.

compared to those of Durango. Torreón concentrates the highest number of taxa with 105 (32.7%), followed by Lerdo with 93 (29.0%) (**Table 4**). This may be due, in the first place, to the fact that the mountainous chains with greater extension and higher altitude are located mainly in these municipalities, which is conducive to the development of a large amount of endemism, as has been documented for other mountainous areas of Mexico in which the conditions of humidity and temperature allow the development of temperate vegetation [45–47], as well as in the Chihuahuan Desert [41] which shows that the diversity in this area of the country is not distributed homogeneously; and second, that the efforts to carry out floristic inventories in the semiarid zones of Coahuila have been greater; however, in the part corresponding to Durango, several inventories are in the process of being elaborated that will undoubtedly increase the knowledge of the flora.

For Comarca Lagunera, 175 taxa are recognized as scarcely distributed, that is, their representation is restricted to a single municipality, this corresponds to more than 54%, while only five taxa (1.6%) are registered in seven municipalities or more of the municipalities (**Table 5**), the above shows what in other studies has been mentioned as the arid and semiarid zones of Mexico have a high proportion of taxa with very restricted distribution [26, 48]; that in this case can be attributed possibly to the geological changes that have occurred in the Chihuahuan Desert and that have been apparently stabilized since the Miocene (15 million years) [49], so that it could be about neo-endemic taxa in the process of expansion of their populations.

In this case, 20 of the 36 taxa recognized as endemic to Comarca Lagunera are scarcely distributed (Appendix), highlighting the case of *Henricksonia mexicana* Turner, which is the only known species of the genus so far, which means that so far *Henricksonia* Turner is the only endemic genus of the flora of Comarca Lagunera. The

State/municipality	Number of taxa	Percentage with respect to the total	State/municipality	Number of taxa	Percentage with respect to the total
Durango	163	50.8	**Coahuila**	243	75.7
Lerdo	93	29.0	Torreón	105	32.7
Mapimí	57	17.8	San Pedro	87	27.1
Tlahualilo	46	14.3	Viesca	76	23.7
Rodeo	48	14.9	Francisco I. Madero	60	18.7
Nazas	18	5.60	Matamoros	18	5.6
San Pedro del Gallo	18	5.6			
General Simón Bolívar	15	4.7			
San Juan de Guadalupe	13	4.0			
Gómez Palacio	10	3.1			
San Luis del Cordero	4	1.2			

Table 4.
Number of endemic taxa of Mexico and their distribution by municipality in Comarca Lagunera.

Status	Number of taxa	Percentage
Scarcely distributed	175	54.5
Closely distributed	119	37.1
Normally distributed	22	6.9
Widely distributed	5	1.6

Table 5.
Frequency of endemic taxa of Mexico according to their distribution in the municipalities of Comarca Lagunera.

restricted distribution of the mentioned taxa means that the populations have a very small number of individuals, and therefore, it is necessary to make a greater collection effort to locate them in other places, as well as ecological studies that allow to properly characterize these populations, which will allow to have solid elements for their possible inclusion within NOM-059-ECOL-2010 [50], which is the official list in Mexico for the species that present some degree of vulnerability. Until this moment not a single taxon of the 36 taxa registered as restricted to Comarca Lagunera is included in the official list NOM-059-ECOL-2010, so it is of great importance to carry out actions that allow its conservation in the face of the increase in surface occupied for anthropogenic activities.

Coryphantha durangensis (Runge ex K. Schum.) Britton & Rose is the taxon with the widest distribution since up to now it has been registered in nine municipalities; its distribution slightly exceeds the area of Comarca Lagunera so it can be considered as quasiendemic of the region; this species is listed in NOM-059-ECOL-2010 in the status of subject to special protection (Pr), that is, “that could be threatened by factors that negatively affect its viability, which is why the need to promote its recovery and conservation is determined, or the recovery and conservation of populations of associated species,” likewise this species appears in the red list of the International Union for the Conservation of Nature (IUCN) in the category of Least Concern (LC) [51]. Another 23 taxa are listed in NOM-059-ECOL-2010 and 36 taxa in the red lists of the IUCN (**Table 6**) among which *Echinocereus mapimiensis* E.F. Anderson, W. Hodgs. & P. Quirk is the only taxon restricted to the region that is included in the IUCN in the category of vulnerable (VU) [52]; *Turbinicarpus mandragora* (Fric ex A. Berger) A.D. Zimmerman and *Mammillaria pennispinosa* Krainz stand out and are distributed in Coahuila and Durango, respectively, and which according to the IUCN are in the category of critically endangered (CR) [53, 54].

The curve of accumulation of species (**Figure 6**) and the nonparametric estimator of Chao2 calculated show that the richness of endemic taxa of Mexico present in Comarca Lagunera is well known, since the result of the Chao2 estimator indicates that it is necessary to locate only eight taxa, and these data agree with the results of González-Elizondo et al. [5] for the flora of northern Mexico who mention that the flora of this region is practically well known and there are few species to be discovered; however, this value should be considered with caution since there are several sites, mainly those located in the higher mountain areas where access is complicated, in addition to the riparian zones that have not yet been documented. Likewise, the knowledge of the taxa with restricted distribution to the limits of Comarca Lagunera used in the present study has increased in the last 10 years in which 8 out of the 36 endemic taxa have been described (Appendix).

Among the vegetation types where the endemic taxa are distributed, the rosetophile desert scrub stands out, in which 192 taxa are distributed, followed by the microphile desert scrub with 147 and chaparral with 76 (**Table 7**). Furthermore, a considerable number of taxa (81) are in what has been classified as agricultural areas, so the risk of losing this part of biodiversity is considerably high; however, many of these areas have been abandoned due to the decrease in the sale prices of some products, the lack of water, the advance of desertification, and among other factors [55]. Although due to the high technology use for agriculture and the opening of sites for the breeding of various types of livestock, it cannot be ruled out that some time they are enabled again for this type of activities. A similar situation occurs in the areas that have been classified as urban in which the presence of 45 taxa has been registered, most of these localities do not present a high population density; however, the opening of new industries mainly those dedicated to mining and food production promotes the change of land use, which puts the conservation of the region's biodiversity at risk [56].

In the phenogram obtained from the cluster analysis, from the similarity matrix, three groups can be observed (**Figure 7**). In the first group appear the desert scrubs, both microphile and rosetophile, together with the chaparral and the submontane scrub, the second group is formed by the crasicaule scrub and the natural grassland, while the third group is formed by the halophile grassland, gypsophile vegetation, halophile xerophile vegetation, and vegetation of sandy deserts. It was found that the values of similarity between the different vegetation types are very low, since the microphile and rosetophile desert scrub, which are the vegetation types with the highest level of similarity, share only 41% of the taxa. The low similarity values obtained mean that the taxa represented in Comarca Lagunera have very marked preferences for the environmental conditions that prevail in each of the sites, that is, the beta diversity is very high for the set of species included in the analysis. In analysis were excluded vegetation of gallery, agricultural areas, and urban zones.

The territory of Comarca Lagunera was divided into 535 grid cells, and of these, 206 grid cells include at least one record. The average number of grid cells occupied by taxa is 3, the median is 2, and the mode is 1 (140 taxa), that is, 43.6% of the taxa have a very small distribution within Comarca Lagunera. The taxa distributed in more grid cells were *Coryphantha durangensis* (21), *Randia pringlei* (S. Watson) A. Gray (20), and *Calanticaria brevifolia* (Greenm.) E.E. Schill. & Panero (18), none of these three species restricts its distribution to Comarca Lagunera.

Taxon	Category IUCN	Category NOM-059-ECOL-2010
Agave victoriae-reginae T. Moore	LC	P
Ariocarpus kotschoubeyanus (Lem.) K. Schum.	NT	Pr
Astrophytum myriostigma Lem.	LC	A
Corynopuntia bulbispina (Engelm.) F.M. Knuth	EN	
Corynopuntia moelleri (A. Berger) F.M. Knuth	LC	
Corynopuntia vilis (Rose) F.M. Knuth	LC	
Coryphantha delaetiana (Quehl) A. Berger	LC	
Coryphantha echinus (Engelm.) Britton & Rose	LC	
Coryphantha poselgeriana (A. Dietr.) Britton & Rose	LC	A
Coryphantha gracilis L. Bremer & A. B. Lau	LC	P
Coryphantha durangensis (Runge ex K. Schum.) Britton & Rose	LC	Pr
Coryphantha longicornis Boed.	LC	
Coryphantha pseudonickelsiae Backeb.	LC	
Cylindropuntia imbricata subsp. *cardenche* (Griffiths) U. Guzmán	LC	
Cylindropuntia anteojoensis (Pinkava) E.F. Anderson	VU	Pr
Dalea melantha S. Schauer	LC	
Dalea melantha var. *pubens* Barneby	LC	
Dyssodia pinnata (Cav.) B.L. Rob.	LC	
Echinocereus mapimiensis E.F. Anderson, W. Hodgs. & P. Quirk	VU	
Echinocereus primolanatus A.F. Schwarz ex N.P. Taylor	LC	
Echinocereus stramineus subsp. *occidentalis* (N.P. Taylor) N.P. Taylor	LC	
Echinomastus unguispinus subsp. *durangensis* (Runge) U. Guzmán		A
Ephedra compacta Rose	LC	
Ferocactus pilosus (Galeotti ex Salm Dyck) Werderm.	LC	Pr
Fouquieria shrevei I.M. Johnst.		Pr
Grusonia bradtiana (J.M. Coult.) Britton & Rose	LC	
Leuchtenbergia principis Hook.	LC	A
Mammillaria coahuilensis (Boed.) Moran	EN	A
Mammillaria grusonii Runge	LC	Pr
Mammillaria lenta K. Brandegee	LC	A
Mammillaria mercadensis Patoni	LC	Pr
Mammillaria pennispinosa Krainz	CR	Pr
Mammillaria pennispinosa subsp. *nazasensis* (Glass & R. Foster) D.R. Hunt		Pr
Mammillaria stella-de-tacubaya Heese		Pr
Mammilloydia candida (Scheidw.) Buxb.	LC	
Manfreda brunnea (S. Watson) Rose		A
Manfreda potosina (B.L. Rob. & Greenm.) Rose		Pr
Opuntia leucotricha DC.	LC	
Physalis patula Mill.	LC	

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Taxon	Category IUCN	Category NOM-059-ECOL-2010
Quercus vaseyana Buckley	LC	
Thelocactus bicolor subsp. *bolaensis* (Runge) Doweld		A
Thelocactus heterocromus (F.A.C. Weber) Van Oost		A
Thelocactus rinconensis subsp. *nidulans* (Quehl) Glass	LC	A
Turbinicarpus mandragora (Fric ex A. Berger) A.D. Zimmerman	CR	A

Table 6.
Endemic taxa of Mexico with distribution in Comarca Lagunera listed in some risk category. A = Threatened; CR= Critically Endangered; EN= Endangered; LC= Least Concern; NT= Near Threatened; P = In danger of extinction; Pr= Subject to special protection; VU= Vulnerable.

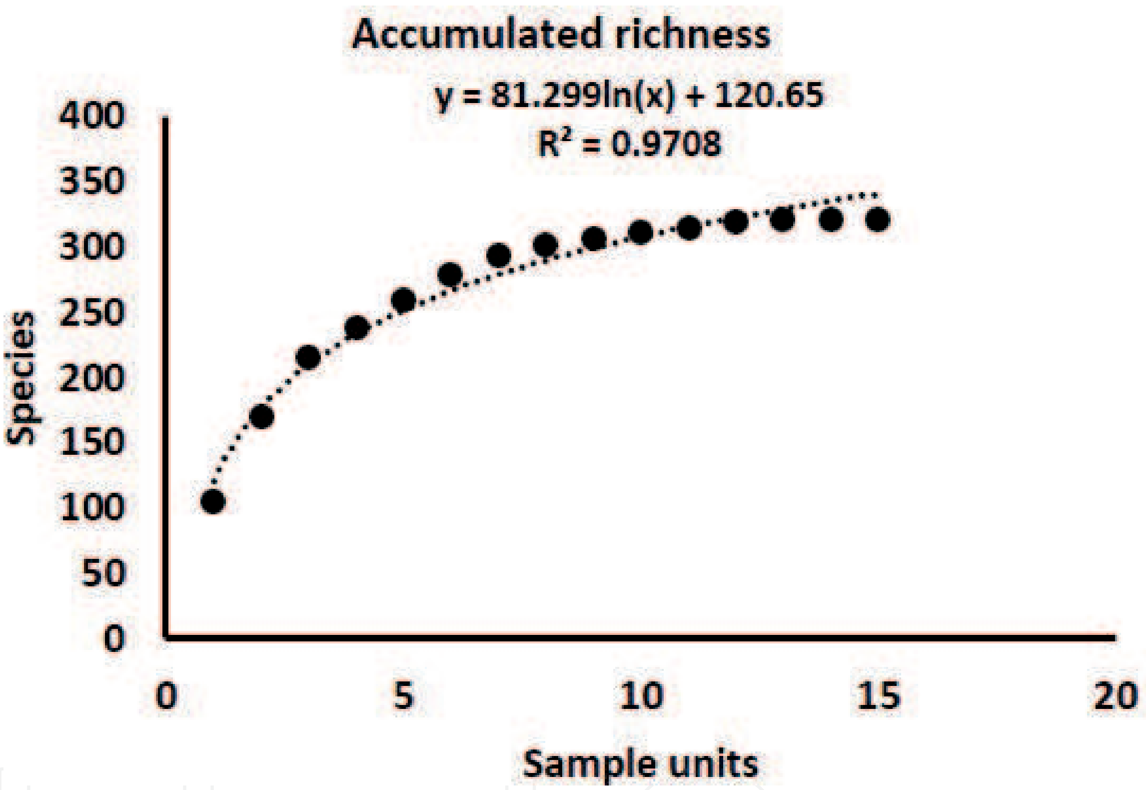

Figure 6.
Curve of accumulation of endemic taxa of Mexico with distribution in Comarca Lagunera.

The grid cells with the richest taxa were concentrated in some of the most important mountain ranges in the region. In Sierra de Jimulco (Torreón), we found two, one of them with 58 and the other one with 48 taxa, followed by Sierra de Las Delicias (San Pedro) presenting one in which 36 taxa are distributed and Sierra del Rosario (Lerdo) with one containing 31 taxa (**Figure 8**). The results obtained in the analysis of grid cells agree with the analysis at the level of municipalities mentioned above.

The grid cells with the highest WEI scores correspond with the grid cells presenting the highest taxa richness, and this is a consequence of the number of taxa rather than the values of endemism, as suggested by Crisp et al. [34]. However, the grid cells, where the highest values of the CWEI are presented, do not match with the grid cells with the greatest richness, since the highest values occur in places with few taxa. In addition, these grid cells have values of 1 for this index, in fact, there are 14 grid cells with this value, out of which 13 have a single registered taxon, and moreover, these are the only grid cells where those taxa are distributed. *S. jessicae* is the only species with restricted distribution to Comarca Lagunera and that is also

Type of vegetation	Number of taxa
Vegetation of gallery	1
Vegetation associated with bodies of water	5
Without apparent vegetation	5
Vegetation of sandy deserts	8
Induced grassland	10
Crasicaule scrub	11
Submontane scrub	19
Halophile grassland	21
Halophile xerophile vegetation	26
Gypsophile vegetation	26
Natural grassland	25
Chaparral	76
Microphile desertic scrub	147
Rosetophile desertic scrub	192

Table 7.
Distribution of taxa by type of vegetation and land use in Comarca Lagunera according to INEGI (2016).

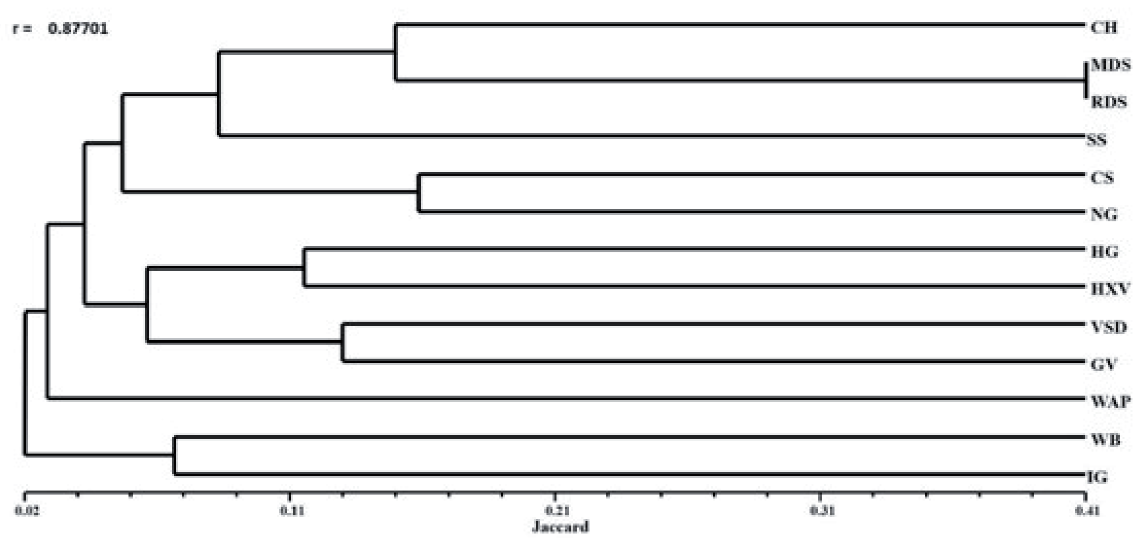

Figure 7.
Phenogram showing the relationships of the vegetation types in Comarca Lagunera based on the distribution of the endemic taxa of Mexico. CH = chaparral; CS = crasicaule scrub; GV = gypsophile vegetation; HG = halophile grassland; HXV = halophile xerophile vegetation; IG = induced grassland; MDS = microphile desert scrub; NG = natural grassland; RDS = rosetophile desert scrub; SS = submontane scrub; VSD = vegetation of sandy deserts; WAP = without apparent vegetation; and WB = vegetation associated with bodies of water.

the only taxon that has been registered in that grid cell, that is, this species can be considered as microendemic of this region of the country. If grid cells with a value of 1 are excluded from the analysis, three grid cells can be identified with a CWEI value of more than 0.750, which is the next highest value; these grid cells are located in sites that have been classified as agricultural (**Figure 9**).

The results obtained in the complementarity analysis show that seven grid cells are required to conserve at least 50% of the endemic flora of Mexico in this region (**Figure 10**); however, because a high percentage of taxa presents a distribution in

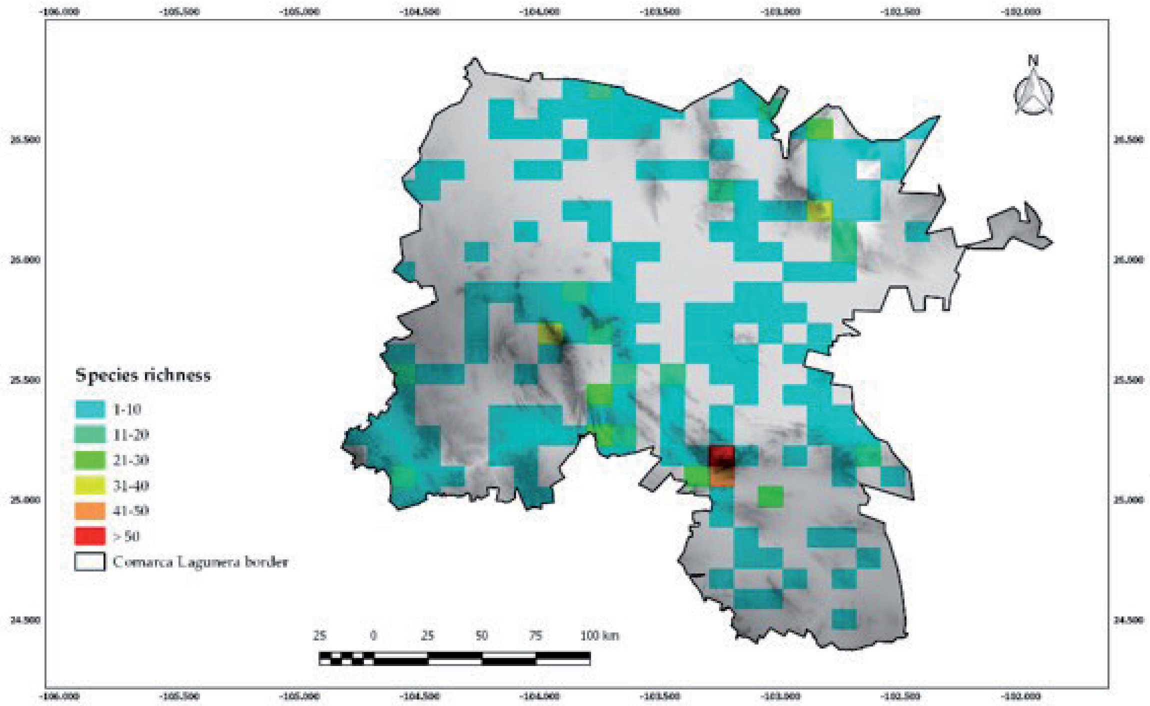

Figure 8.
Species richness in Comarca Lagunera based on the distribution in grid cells of 10 × 10 km.

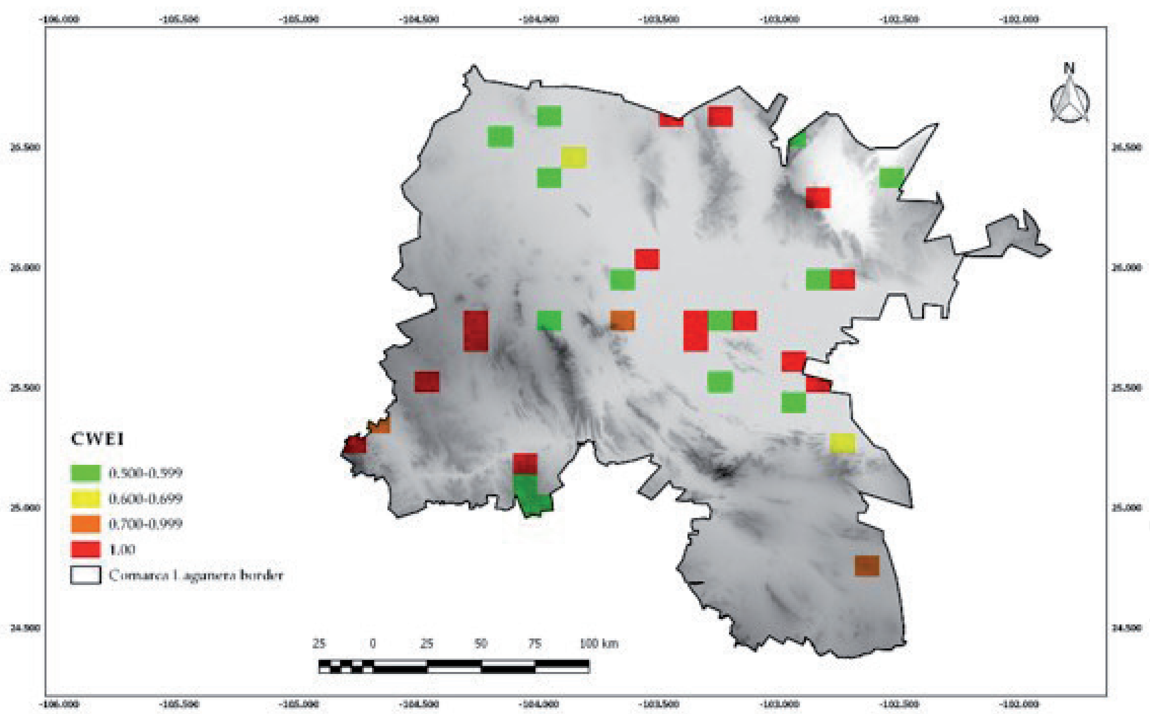

Figure 9.
Grid cells with the highest values of corrected weighted endemism index.

only one grid cell, about 90% of them is required to preserve the total of the flora included in this analysis. The previous results show that the conservation strategy that allows the protection of the endemic flora of Mexico represented in this region will be a complicated task due to the economic activities on which Comarca Lagunera depends.

Finally, the data shown here represent a first approach to the knowledge of the endemic flora present in this region of the country, and with a greater collection effort, it would probably increase. It has been reported that the causes of endemism in the

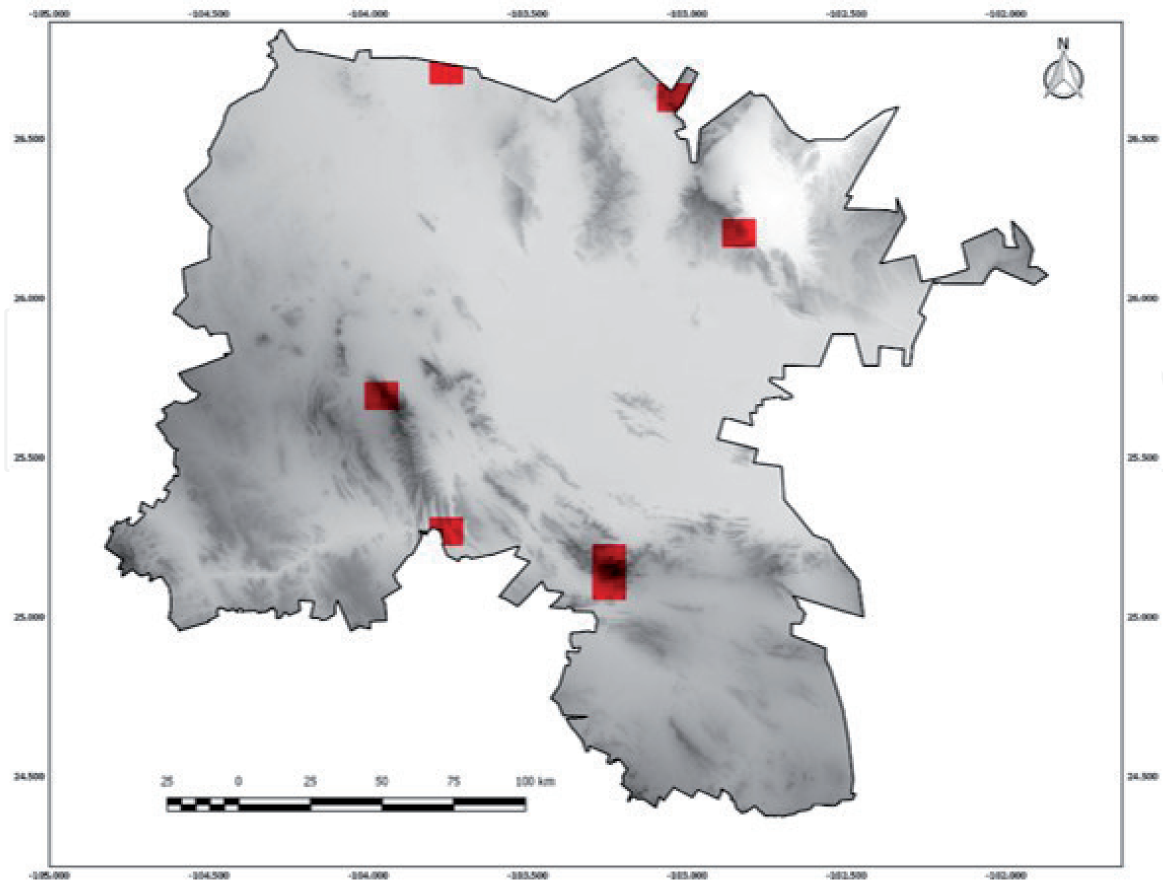

Figure 10.
Grid cells needed to conserve at least 50% of the flora in Comarca Lagunera.

arid and semiarid zones of Mexico, mainly in the Chihuahuan Desert, are frequently determined by habitat, as is the case of halophyte and gypsophyte taxa [41] and by geographic isolation mainly in the mountain areas; however, in this case, it seems that this rule is not fulfilled possibly due to the alteration of the habitats that has been caused by the different anthropogenic activities. What is a fact is that the endemic flora registered in Comarca Lagunera differs from the floristic elements found in other sites such as Cuatrociénegas and Parras de la Fuente, two localities near Comarca Lagunera, that present higher humidity and lower temperatures, since many of the known taxa of these last two sites are not represented in Comarca Lagunera [44].

4. Conclusions

The SNIB has allowed access to many researches of Mexican biodiversity in entities where there are no collections or infrastructure to house them, and they can have access to information available in scientific collections that sometimes is not available for various reasons, mainly because it is found in foreign collections, as information that is more and more strictly curated by specialists from several of the main research centers in the country; this represents one of the clearest advances in biodiversity knowledge and the cooperation of several Mexican scientific institutions, a process that began almost 30 years ago with the creation of CONABIO and later with the development of the World Net of Biodiversity Information (REMIB) that set a precedent not only in Mexico but also in various countries. Nowadays, with the development of applications in smart mobile devices such as the Naturalista platform (https://www.naturalista.mx), another huge step is taken that will allow us to know even more about the diversity of Mexico.

The present study represents an example of the value of the records of collections available in electronic media as a basis for biodiversity informatics; however, most of the available databases only present the distribution data, but lack the images of copies, so it is still necessary to review the physical specimens deposited in the collections, which have a special value since a thorough review of them and the support of the original descriptions allow the updating of the identities and the appropriate georeferencing of the specimens of a given locality [57].

In Mexico, as in other countries, conservation decisions are made taking into account political borders instead of natural criteria [32]. In this regard, the case of Comarca Lagunera is not an exception. However, in this case, efforts should be made at more local levels due to the area used in agroindustrial activities and mining exploitation. For example, some ejidos are making efforts for conservation from the scheme called payment for environmental services to which several Mexican official institutions, at different levels, contribute funds for the knowledge and subsequent conservation of biodiversity. A specific case in Comarca Lagunera is the ejido Barreal de Guadalupe, Torreón, where this type of action has been carried out successfully for a couple of years, which has impacted on the welfare of the population; however, efforts must be increased to conserve a greater surface of the semidesert zones of the north of Mexico.

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Conflict of interest

The authors declare that they have no conflicts of interest.

Notes/thanks/other declarations

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A. List of endemic taxa of Comarca Lagunera

Taxon	Year of description	Distribution
Monocots		
Order Asparagales		
Family Asparagaceae		
Agave victoriae-reginae subsp. *swobodae* Halda	2000	General Simón Bolívar, Lerdo, Nazas, San Pedro, Torreón, Viesca

Taxon	Year of description	Distribution
Order Poales		
Family Bromeliaceae		
Hechtia mapimiana López-Ferrari & Espejo	2013	Lerdo
Eudicots		
Order Fabales		
Family Fabaceae		
Coursetia insomniifolia Lavin.	1986	San Pedro
Dalea melantha var. *pubens* Barneby.	1977	Lerdo, Torreón
Pomaria fruticosa (S. Watson) B.B. Simpson.	1998	Francisco I. Madero, Lerdo, Matamoros, San Pedro, San Pedro del Gallo, Torreón, Viesca
Order Malpighiales		
Family Euphorbiaceae		
Euphorbia cressoides M.C. Johnst.	1975	Torreón
Order Sapindales		
Family Anacardiaceae		
Cotinus chiangii (Young) Rzed. & Calderón.	1999	Lerdo
Order Malvales		
Family Malvaceae		
Batesimalva lobata Villarreal & Fryxell.	1990	Torreón
Order Brassicales		
Family Brassicaceae		
Dryopetalon stenocarpum Al-Shehbaz	2013	Mapimí, Viesca
Nerisyrenia johnstonii J.D. Bacon.	1978	Francisco I. Madero, San Pedro
Order Caryophyllales		
Family Amaranthaceae		
Atriplex monilifera S. Watson.	1874	Matamoros, Tlahualilo, Viesca
Family Polygonaceae		
Eriogonum henricksonii Reveal	1989	San Pedro
Family Caryophyllaceae		
Drymaria elata I.M. Johnst.	1940	Francisco I. Madero, San Pedro
Drymaria jenniferae Villarreal & A.E. Estrada	2008	Viesca
Family Cactaceae		
Corynopuntia halophila D. Donati	2017	Francisco I. Madero, San Pedro
Echinocereus mapimiensis E.F. Anderson, W. Hodgs. & P. Quirk	1998	Tlahualilo
Order Cornales		
Family Loasaceae		

Taxon	Year of description	Distribution
Eucnide durangensis H.J. Thomps. & Powell	1981	Lerdo, Rodeo, Torreón
Order Ericales		
Family Primulaceae		
Samolus dichondrifolius Channell	1958	San Pedro
Order Gentianales		
Family Rubiaceae		
Hedyotis teretifolia (Terrell) G.L. Nesom	1988	Francisco I. Madero, San Pedro
Machaonia pringlei A. Gray	1886	Torreón, Viesca
Family Apocynaceae		
Matelea greggii (Vail) Woodson	1941	Mapimí
Order Boraginales		
Family Boraginaceae		
Lithospermum jimulcense I.M. Johnst.	1952	Torreón, Viesca
Order Solanales		
Family Solanaceae		
Solanum johnstonii M. D. Whalen	1976	Lerdo, Torreón, Viesca
Order Lamiales		
Family Plantaginaceae		
Mabrya coccinea (I.M. Johnst.) Elisens	1985	Francisco I. Madero, Matamoros, San Pedro
Family Scrophulariaceae		
Leucophyllum coahuilensis Henr.	2004	Francisco I. Madero
Family Lamiaceae		
Salvia jessicae B.L. Turner	2013	Francisco I. Madero
Family Acanthaceae		
Justicia decurvata Hilsenb.	1990	Lerdo
Ruellia jimulcensis Villarreal.	1998	Lerdo, Matamoros, Torreón
Siphonoglossa durangensis Henr. & Hilsenb.	1979	Lerdo
Siphonoglossa linearifolia Henr. & Hilsenb.	1979	Lerdo
Order Asterales		
Family Asteraceae		
Haploesthes hintoniana B.L. Turner	2013	Francisco I. Madero
Henricksonia mexicana B.L. Turner	1977	Lerdo, Nazas, Torreón
Flaveria intermedia J.R. Johnst.	1903	Tlahualilo
Gaillardia candelaria B.L. Turner var. *candelaria*	2007	San Pedro
Gaillardia candelaria var. *mikemoorei* B.L. Turner	2013	Francisco I. Madero
Marshalljohnstonia gypsophila Henrickson.	1977	San Pedro

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