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Distribution, eco-climatic characterisation, and potential growing regions of *Annona cherimola* Mill. (Annonaceae) in Mexico

Jesús Rubén Rodríguez-Núñez[1]; Eduardo Campos-Rojas[2]; Jorge Andrés-Agustín[3]; Irán Alia-Tejacal[4]; Santo Ángel Ortega-Acosta[5]; Vicente Peña-Caballero[1]; Tomás Jesús Madera-Santana[6]; and Carlos Alberto Núñez-Colín[1]*

ABSTRACT

The cherimoya (*Annona cherimola* Mill.) is a fruit crop with worldwide commercial importance. However, its distribution and potential growing regions of cherimoya are not defined for Mexico. That is why, this research aims to map the natural distribution of cherimoya and different eco-climatic regions where it is grown in Mexico as well as to map the climatic adaptability with the current climate and a prospection with the climate change scenario, all by different models of GIS. The general distribution model of cherimoya in Mexico showed that it had a chance to find cherimoya "in a natural way" in the biogeographic provinces Trans-Mexican Volcanic Belt, Sierra Madre del Sur and Highlands of Chiapas. Three eco-climatic groups were found in the distribution of cherimoya that corresponded to climates $C(m)(w)$, $(A)C(e')$, and $(A)C(e)$, respectively. Where the group with climate $(A)C(e)$ had the most restricted distribution. The potential growing regions of excellent adaptation of cherimoya were found in the biogeographic provinces of Trans-Mexican Volcanic Belt, Sierra Madre Occidental, Sierra Madre Oriental, Sierra Madre del Sur and Highlands of Chiapas. Finally, based on eco-crop modelling, it is concluded that climate change will not greatly affect areas of excellent adaptation of cherimoya in Mexico.

Keywords: Geographic Information Systems; Eco-Climatic Characterisation; Potential Growing Regions; Distribution Modelling; Annonaceae.

1 Programa de Biotecnología, Universidad de Guanajuato. Mutualismo #303, Col. La Suiza, Celaya, Guanajuato, 38060, México.

2 Departamento de Fitotecnia, Universidad Autónoma Chapingo. Km 38.5 Carretera México-Texcoco, Chapingo, Texcoco, México, 56230, México.

3 Centro Regional Universitario Centro Occidente, Universidad Autónoma Chapingo. Periférico Paseo de la República #1000, Col. Lomas del Valle, Morelia, Michoacán, 58170, México.

4 Facultad de Ciencias Agropecuarias, Universidad Autónoma del Estado de Morelos. Av. Universidad #1001, Col. Chamilpa, Cuernavaca, Morelos, 62210, México.

5 Facultad de Ciencias Agropecuarias y Ambientales, Universidad Autónoma de Guerrero. Carretera Iguala-Teloloapan S/N, Col. Ignacio Manuel Altamirano, Iguala de la Independencia, Guerrero, 40040, México.

6 Centro de Investigación en Alimentación y Desarrollo, A.C. Antigua Carretera a La Victoria. Km. 0.6 Hermosillo, Sonora, 83304 México.

* Corresponding author ✉. E-mail address: JRRN (jesus.rodriguez@ugto.mx), ECR (educamro55@gmail.com), IAT (iran.alia@uaem.mx), JAA (aajorge2000@yahoo.com.mx), SAOA (ortega.santo@colpos.mx), VPC (vicente.caballero@ugto.mx), TJMS (madera@ciad.mx), CANC (carlos.nunez@ugto.mx).

SIGNIFICANCE STATEMENT

We elucidate the different climates where cherimoya grows in Mexico and modelling of the potential regions where cherimoya can be cultivated, including a global climate change scenario. This work is the first approach to conserve the cherimoya genetic resources for Mexico.

INTRODUCTION

The family Annonaceae consists of near 108 genera and more than 2400 species, being one of the families that more contribute to the biodiversity of a lot of tropical and subtropical regions around the world (Chatrou et al. 2012). Within these genera outstand the genus *Annona*, which has species with horticultural interest mainly in the neotropics. Where most of the species of this genus grow in tropical climates and some of them in subtropical regions, like the cherimoya (*Annona cherimola* Mill.) (Segura et al. 2012).

Mexico is considered a megadiverse country, mainly in its flora (Rzedowski 1993), and in the American continent is perhaps the country with the greatest number of endemism registered (Villaseñor 2003). Because of that, a great interest of the Mexican scientific community to study and to characterize its genetic resources was generated, among them the related to the genus *Annona*; thus groups of research about this genus was generated as the Red Mexicana de Anonáceas —Mexican Annonaceae Network— (Segura et al. 2012; Andrés-Agustín and Segura Ledesma, 2014; Andrés-Agustín 2015). Where cherimoya (*Annona cherimola* Mill.) is one of the most studied species among Annonaceae species in Mexico because of its high horticultural potential (Agustín 1999; Andrés-Agustín 2002; Domínguez and Castañeda 2002). Cherimoya is the second important Annonaceae fruit crop in Mexico with 36 harvested hectares and 247.3 ton of production and a value of production of US$76,162.80 for 2019 (SIAP, 2020). Besides the current hypothesis by Larranaga et al. (2017) about the Mesoamerican origin of this species, notwithstanding the archaeological remains and the former hypothesis about its South American origin, specifically Andean (Pozorsky and Pozorsky 1997; Bonavia et al. 2004).

It explains why it is the priority the study of this species in Mexico can make good management of the cherimoya's genetic resources. To start planning about the conservation and collect of germplasm as well as its characterization and evaluation it is important to know its distribution and the different climatic variation where cherimoya grows; furthermore, to identify the potential growing regions and the possible variation because of the climatic change (Zagaja 1988). All these studies can be obtained using diverse methods of Geographic Information Systems —GIS— (Jones et al. 2002; Guarino et al. 2002; Núñez-Colín and Goytia-Jiménez 2009; Hijmans et al. 2012; Scheldeman and van Zonneveld 2011; Núñez-Colín et al. 2017). In the case of cherimoya, there are not specialized studies about this subject in Mexico, although there are for Andean regions (van Zonneveld et al. 2012) and the information about its distribution is dispersed. That is why, this research aims to generate maps of the natural distribution of cherimoya (*Annona cherimola* Mill.) in Mexico and the different eco-climatic regions where it grows (Jones et al. 2002) as well as generating maps of climatic adaptability in the country with the current climate and with a prospection according to estimated climatic change for 2050 (Scheldeman and van Zonneveld 2011) by means several GIS methods.

MATERIAL AND METHODS

Passport data of SNIB-CONABIO database (CONABIO 2015; 363 passport data, Supplementary table 1) and the Tropicos.org database (Missouri Botanical Garden 2017; 108 passport data) were used; besides, the registered optimal climatic data of cherimoya in the FAO database (FAO 2007) was used. All data formed the sources of information for the cabinet analyses.

Two different analyses based on GIS were being done. The first was made in the software Floramap 1.03 (Jones and Gladkov 1999), which consist to make probabilistic maps of the general natural distribution and the distribution of different eco-climatic regions where cherimoya grows based on a cluster analysis of the accessions that grow in different eco-climatic regions. The probability maps were calculated without weighted, that means, all the coefficients to evaluated climatic variables were equal to one. The transformation of the rain data —to match it with the temperature scale—Power Rain A transform was used with a coefficient of 0.1. Moreover, eight principal components were used, which explained 96.12% of the total variance (Jones and Gladkov 1999; Jones et al. 2002). All probabilistic maps in Floramap were calculated with a minimal probability of 75% to locate the species. The resolution for this analysis was 10 minutes of latitude per 10 minutes of longitude.

The second analysis was done with the software DIVA-GIS version 7.5 (Hijmans et al. 2012) to make models of adequate growing regions of cherimoya. It is considered two scenarios, first —called current potential growing regions (CPGR) — real climatic data of

Table 1. Assumed parameters in the Eco-Crop model for cherimoya (*Annona cherimola* Mill).

Parameter	Value
Minimal growing season	240 days
Maximal growing season	270 days
Killing temperature	1 °C
Minimal temperature (No damages)	7 °C
Optimal minimal temperature	17 °C
Optimal maximal temperature	25 °C
Maximal temperature (No damages)	32 °C
Minimal rainfall	600 mm
Optimal minimal rainfall	800 mm
Optimal maximal rainfall	1200 mm
Maximal rainfall	2200 mm

50 years of the Wolrdclim database were used; while the second, it was used the CCM3 model that considers the double atmospheric CO_2 concentration for modelling the climate change effect —called future potential growing regions (FPGR)— (Govindasamy et al. 2003). The resolution for this analysis was 2.5 minutes of latitude per 2.5 minutes of longitude.

Both models were obtained using the Eco-Crop algorithm (Hijmans et al. 2001; Hijmans and Graham 2006) and the optimal climatic data for adaptation of cherimoya of the FAO database (FAO 2007; Table 1); Both models were also compared to locate the adequate regions to establish in vivo germplasm banks, mother orchards, and evaluation fields of this species with a climate change scenario.

The maps of biogeographic provinces by Morrone et al. (2017) were used for all GIS maps. Morrone et al. (2017) described 14 biogeographic provinces to Mexico: Californian, Baja Californian, Sonoran, Chihuahuan Desert, Tamaulipas, Yucatan Peninsula, Sierra Madre Occidental, Sierra Madre Oriental, the Trans-Mexican Volcanic Belt, Balsas Basin, Sierra Madre del Sur, Pacific Lowlands, Veracruzan, and Chiapas Highlands (Figure 1).

RESULTS AND DISCUSSION

Distribution in a natural way

The modelling of the distribution in natural ways of cherimoya in Mexico showed that there are high possibilities to find cherimoya in centre, south and south-eastern Mexico. The provinces with the highest probability to find germplasm (> 90%) were the Trans-Mexican Volcanic Belt, Sierra Madre del Sur, and Chiapas Highlands (Figure 2), which are mountainous temperate climate provinces. Provinces between 75 and 90% of probability to find germplasm were Veracruzan, Yucatan Peninsula, south of Sierra Madre Occidental, and centre and south of Sierra Madre Oriental (Figure 2), where two first provinces have transitional climates and others are mountainous temperate climate provinces.

The distribution results (Figure 2) agree with the reported regions by Segura et al. (2012) although these authors showed some regions in the north central of the country in these authors called as their group 1, the group of which its distribution is the northern region of central Mexico, which did not find in this research.

Eco-climatic characterization

The considered accessions in this research were divided into three eco-climatic groups (Figure 3), which showed different distributions and adaptation climates in Mexico that could be associated with the presence of three different genetic pools, which can be useful into breeding programs. In different environmental conditions, the populations and the genotypes could have genetic differences in their adaptations to these environments (Dobzhansky, 1970).

A possible practical implication of this information in breeding programs is to develop hybrid cultivars considering as parents, individuals from different genetic pools because they have higher probabilities to obtain heterosis in this cross (Wright, 1978). The climograms of the three groups (Figure 4A, 4, 4C) showed different climatic patterns.

The cluster 1 had an average elevation of 2281.6 m above sea level (masl). Besides, it showed the fewest mean temperature of the three groups (Figure 4D) with a mean temperature of 14.7 °C (Figure 4A), a temperature differential (maximal temperature minus minimal temperature) between 11.4 and 15 °C (Figure 4E). This cluster showed the minimal temperature of the coldest month was 5 °C (Figure 4A) and maximal temperature of the warmest month was 23.8 °C (Figure 4A). It also showed an average annual rainfall of 1126.3 mm (Figure 4A) where the wettest month

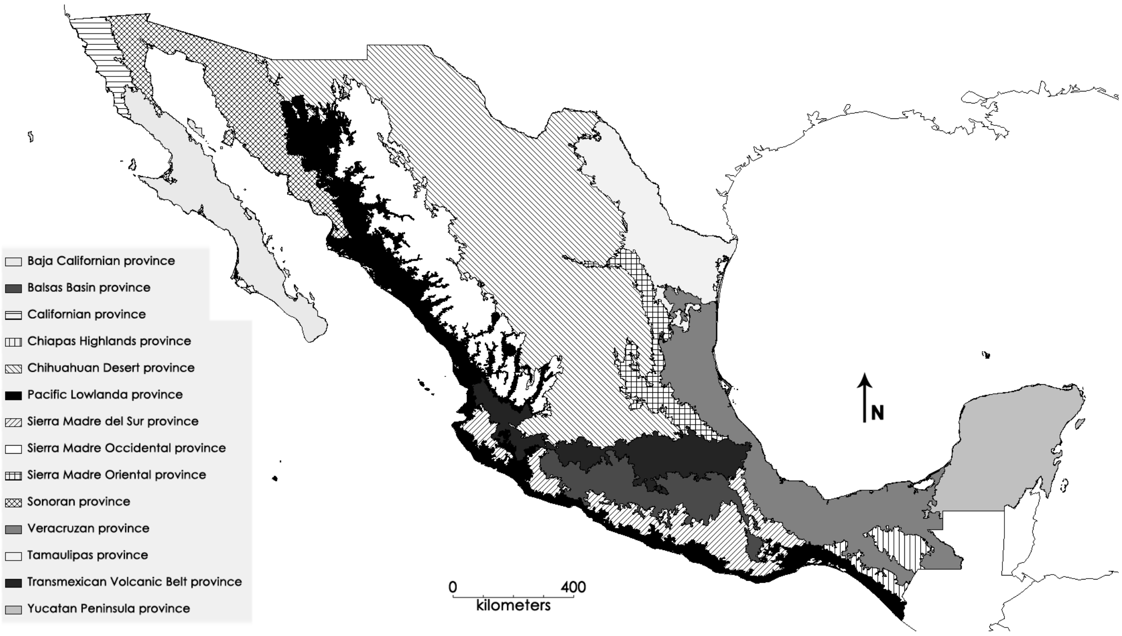

Figure 1. Biogeographic provinces of Mexico according to Morrone et al. (2017).

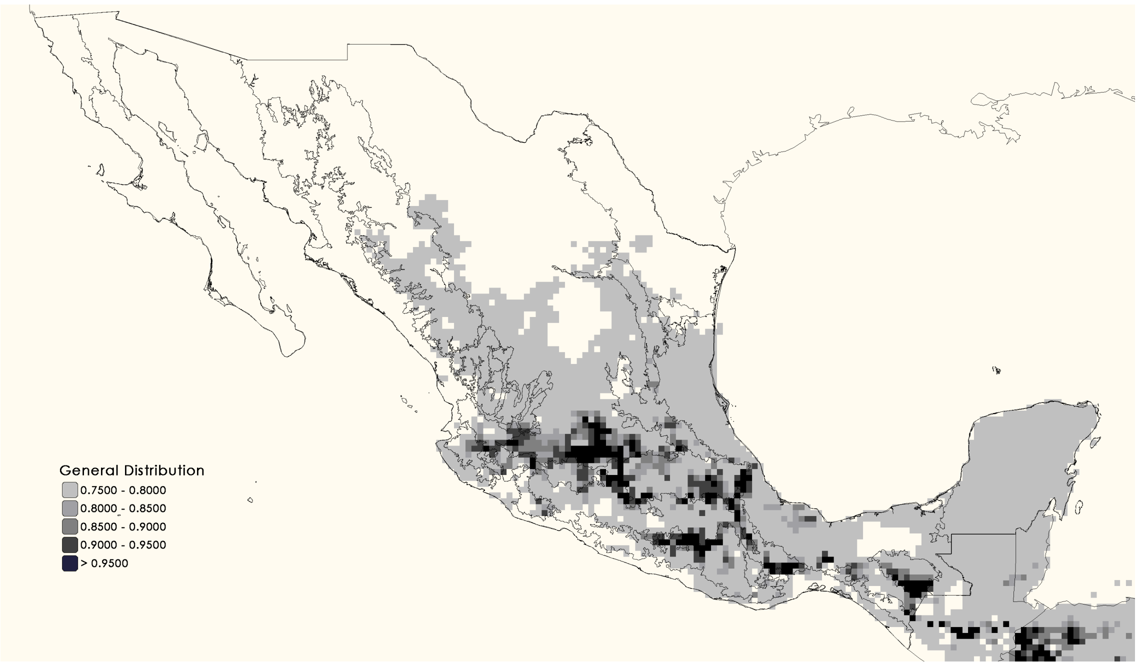

Figure 2. General distribution in natural way of cherimoya (Annona cherimola Mill.) in Mexico divided in the biogeographic provinces reported by Morrone et al. (2017).

showed precipitation of 209.4 mm (Figure 4F) and the driest of 21.8 mm (Figure 4F). These climatic traits according to Köppen classification modified by García (2004) corresponded with a *C(m)(w)* climate (wet temperate with summer rainfall).

The cluster 2 had an average elevation of 1241.2 masl. Moreover, it showed the highest mean temperature, although with similar values to cluster 3 (Figure 4D) with a mean temperature of 21 °C (Figure 4B), a temperature differential between 11.5 and 16.2 °C (Figure 4E). This cluster showed the minimal temperature of the coldest month was 10.4 °C (Figure 4B) and maximal temperature of the warmest month was 30.7 °C (Figure 4B). It also showed an average annual rainfall of 1079.3 mm (Figure 4B) where the wettest month showed precipitation of 208.7 mm (Figure 4F)

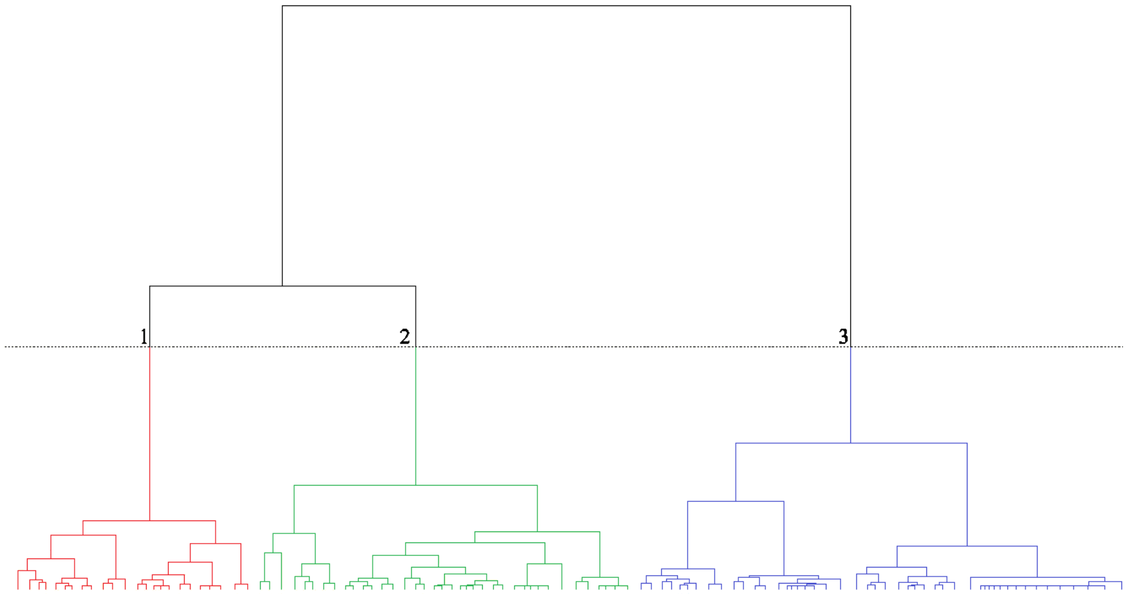

Figure 3. Dendrogram of the accessions of cherimoya (*Annona cherimola* Mill.) by means the climatic traits of its distribution using the method of Ward.

and the driest of 8.8 mm (Figure 4F) and showed 3.42% of winter rainfall. These climatic traits are according to Köppen classification modified by García (2004) corresponded with an *(A)C(e')* climate (very extreme semi-warm of the temperate group with summer rainfall).

The cluster 3 had an average elevation of 1146.4 masl. Furthermore, it showed similar mean temperature values to cluster 2 (Figure 4D) with a mean temperature of 19.7 °C (Figure 4C), a temperature differential between 8.7 and 10.9 °C (Figure 4E). This cluster showed the minimal temperature of the coldest month was 12.2 °C (Figure 4C) and maximal temperature of the warmest month was 26.7 °C (Figure 4C). It also showed an average annual rainfall of 1703.8 mm (Figure 4C) where the wettest month showed precipitation of 294.7 mm (Figure 4F) and the driest of 39.2 mm (Figure 4F) and showed 7.42% of winter rainfall. These climatic traits according to Köppen classification modified by García (2004) corresponded with an *(A)C(e)* climate (extreme semi-warm of the temperate group with summer rainfall).

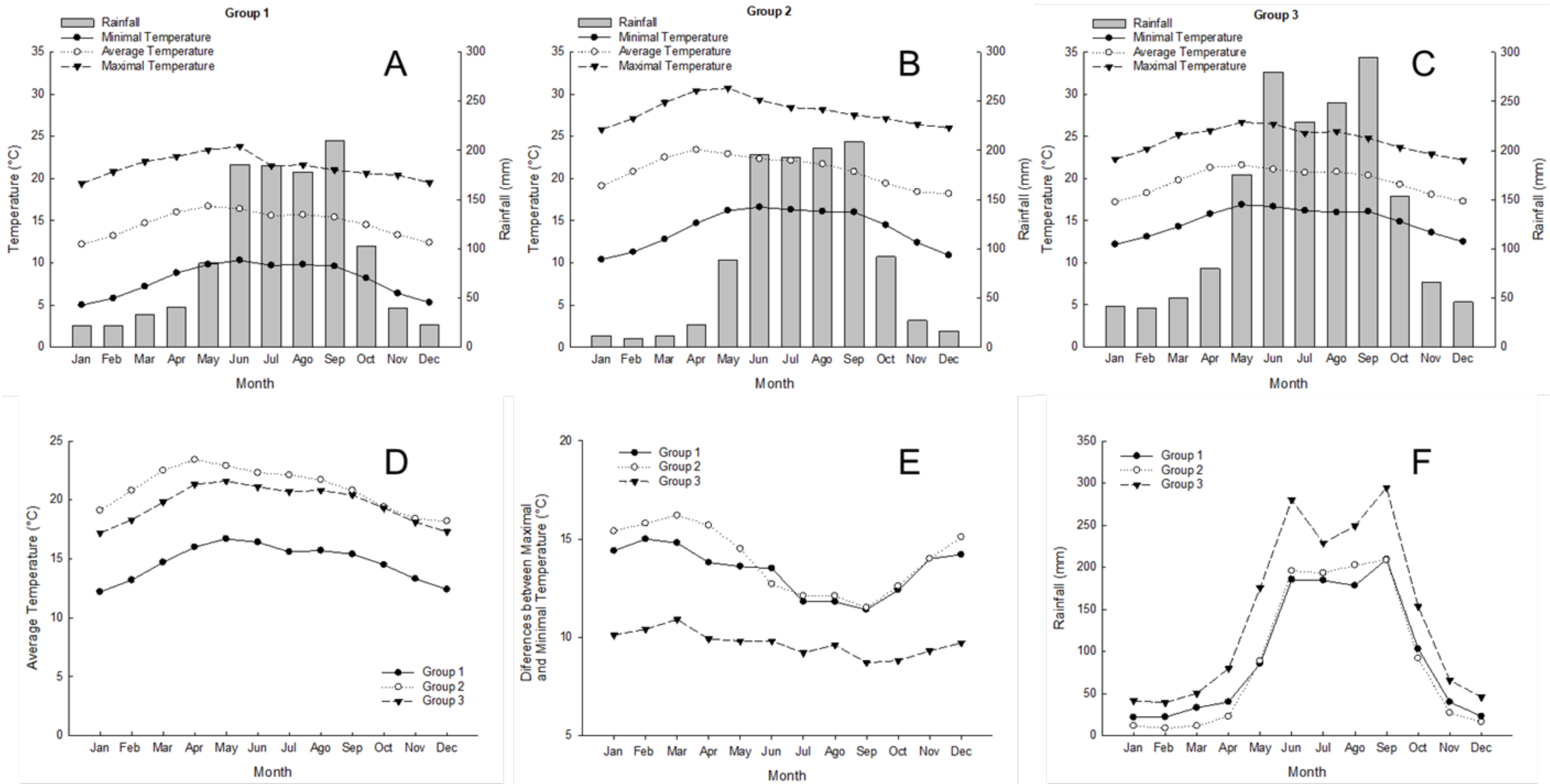

Figure 4. Climograms of the three eco-climatic groups of cherimoyas (*Annona cherimola* Mill.) (4A, 4B, and 4C, respectively) and the comparison of these groups into mean temperature (4D), temperature differential (4E), and rain (4F).

The distribution of cluster 1 was mainly located in the eastern Trans-Mexican Volcanic Belt, northern Sierra Madre del Sur, and north region of the Chiapas Highlands (Figure 5). These regions correspond to the south of the state of Queretaro in the border to Guanajuato, the northern State of Mexico, southern Hidalgo, Tlaxcala, west central Puebla, northeaster Oaxaca, and North of Chiapas Highlands.

Meanwhile, the distribution of cluster 2 was mainly located in centre, south, and west of Sierra Madre del Sur, western Trans-Mexican Volcanic Belt, south region of Chiapas Highlands with important zones in the extreme regions in the south of the Pacific Lowlands (Figure 6). These regions correspond to the west and south-eastern Jalisco, southern Guanajuato, north and eastern Michoacán, west and centre of Oaxaca, and centre of Chiapas.

Finally, the distribution of cluster 3 was strictly located, almost exclusivity, for the region where converge the Trans-Mexican Volcanic Belt, Veracruzan, Sierra Madre Oriental, and Sierra Madre del Sur provinces, and also, although with lesser probability, in some parts of eastern Yucatan Peninsula (Figure 7). These regions correspond to central east of Puebla, central west of Veracruz and Quintana Roo.

When comparing the climatic factors of the three groups where cherimoya germplasm grows in Mexico constitutes an important reference to select specific genotypes for each climatic group because the benefits that represent their satisfactory adaptation and their competitivity mainly considering the presence of creole materials in each one of the eco-climatic regions where cherimoya is distributed (Zagaja 1988). For instance, guava (Psidium guajava L.) had two genetic pools, one tropical and other subtropical (Cázares-Sánchez et al. 2010), and it is shown that tropical accessions have a higher sensibility to frost (Mondragón-Jacobo et al. 2010). Rajan et al. (2007) indicated that to improve crops it is necessary to have a gene pool, which is protected in a natural way in the genetic diversity of each species. In this sense, the cultivars could not have a good adaptation to more than one eco-climatic region (Núñez-Colín and Goytia-Jiménez 2009; Cazares-Sánchez et al. 2010). Therefore, to select and to identify specific cherimoya accessions for each eco-climatic region of their distribution will allow to find desirable genes to incorporate into cultivars such as tolerance or resistance to plagues, diseases, and abiotic stresses as well as to improve fruit quality and productivity (Quamme and Stushnoff 1988; Sistrunk and Moore 1988; Callahan 2003).

The distribution of the eco-climatic groups presented here disagree to the results by Segura et al. (2012) —who used similar GIS analyses but there did not specify weights of the variables nor coefficient of rain transform— because it was found here more eco-climatic groups and they were distributed in different regions those reported by these authors.

The soil type is not a determinant limiting for the growth of this plant, because chirimoya adapts to various types of soil, such as sandy, sandy clayey, clayey, or stony soil. What they need is a soil with good drainage, as they do not resist flooding soils. The most suitable soil pH is between 6.0 and 7.5 (Rosell García et al., 1997).

Something important in this crop is the frequent lack of potassium, with the appearance of foliar margins with discolorations that evolve to necrosis (Navia and Valenzuela, 1978). It has been observed that the demand for nitrogen increases with the plant's own development (George, 1984). Calcium and magnesium requirements are important, especially in the last phase of fruit growth, prior to maturation. It is proposed that *A. cherimola* depends on mycorrization for optimal growth, above all favourable results are highlighted with the use of *Glomus deserticola*. This mycotrophic character of *A. cherimola* has been described by several authors (Azcón-Aguilar et al., 1994a, 1994b), therefore the wide range of soil type in which the plant adapts.

According to Morín (1983) establishing a plantation of Annona should be borne in mind that agro-climatological conditions —which are suitable for the normal development of the crop— considers that the climate is the most important aspect than the soil type.

The soil distribution of Chirimoyo in Mexico is characterized by the different ranges mountains which presented in mayor percentage the soil type called Feozem, mainly along the Transmexican Volcanic Axis, the Sierra Madre Occidental, the Yucatan Peninsula, and Southern of Chihuahuan Desert; it can be presented in any type of relief and climate, except in rainy tropical regions or very desert areas. It is the fourth most abundant soil type in Mexico, and is characterized by having a dark, soft surface layer, rich in organic matter and nutrients and variable depth. The second type of soil where chirimoya is found is the regosol characterized by light colours and poor in organic matter. In Mexico, they constitute the second most important type of soil by their extension. They are often associated with litosoles and with rock outcrops or tepetate. They are often shallow, their fertility is variable, and their productivity is conditioned on depth and stoniness. And thirdly, the soils in which chirimoya develops are vertisol soils, which present as their main characteristic a little differentiation of their horizons, due to internal movements of materials and the formation of large cracks in the summer periods, which have their origin in a high content in expansive clays. They develop in

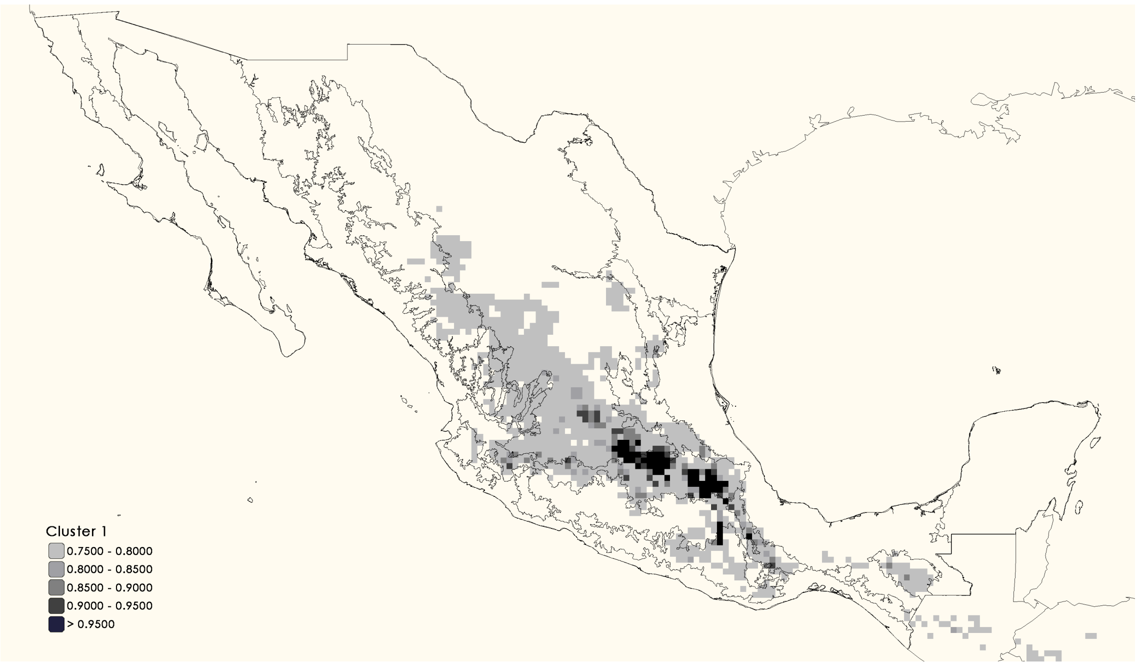

Figure 5. Distribution of the group 1 (climate $C(m)(w)$) of cherimoya (*Annona cherimola* Mill.) in Mexico divided in its biogeographic provinces reported by Morrone et al. (2017).

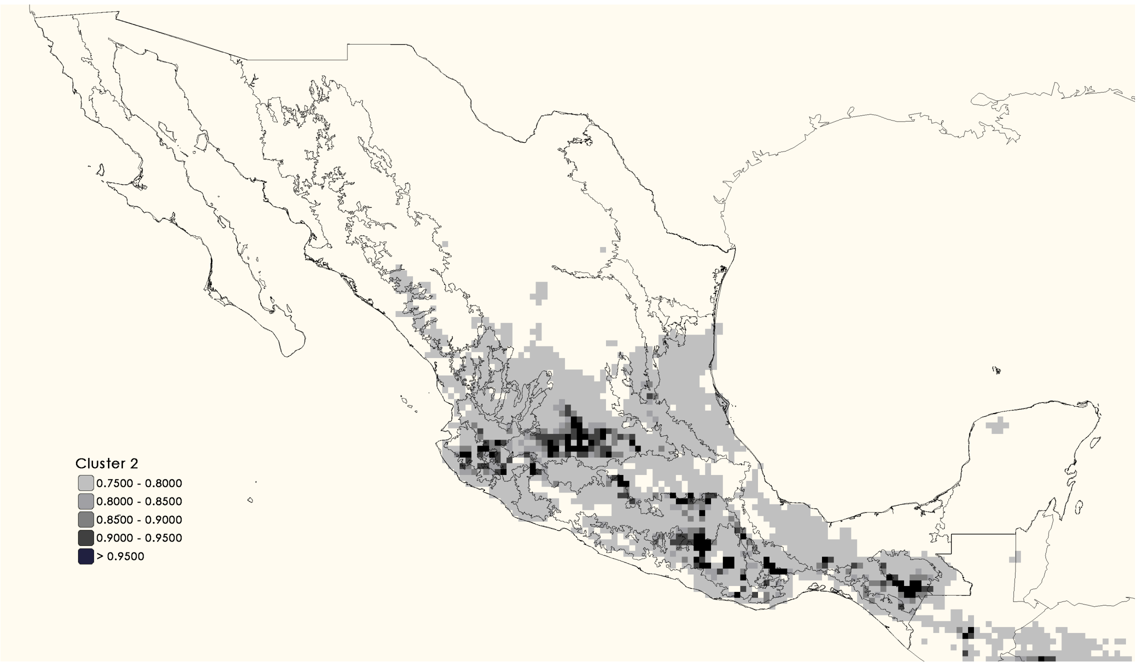

Figure 6. Distribution of group 2 (climate $(A)C(e')$) of cherimoya (*Annona cherimola* Mill.) in Mexico divided in its biogeographic provinces reported by Morrone et al. (2017).

flat or slightly inclined reliefs and on loamy materials or tertiary loamy limestone (Rzedowski, 1993; Andrés Agustín, 2015, INEGI, 2008).

To prove the inference about the existence of different genetic pools, according to the reported eco-climatic clusters, it is necessary morphological and molecular characterization studies to be certain of these different genetic pools. Furthermore, the importance to collect germplasm of the three eco-climatic clusters for preservation and to the management of cherimoya genetic resources should be a priority to corroborate the possible Mesoamerican origin of this

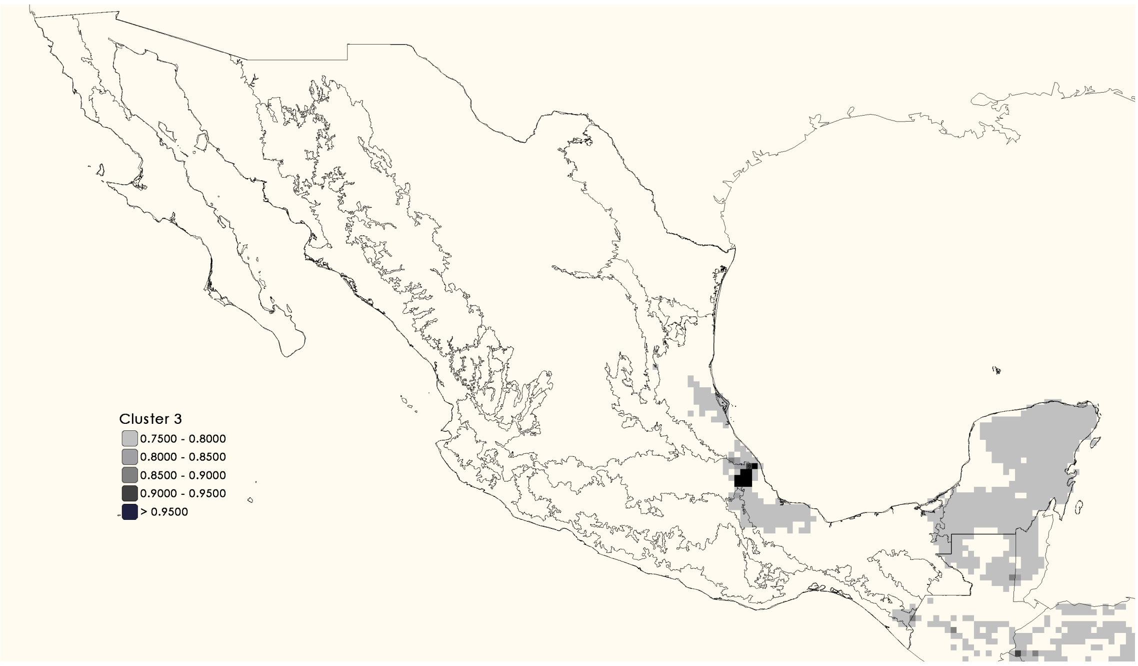

Figure 7. Distribution of group 3 (climate $(A)C(e)$) of cherimoya (*Annona cherimola* Mill.) in Mexico divided in its biogeographic provinces reported by Morrone et al. (2017).

species proposed by Larranaga et al. (2017). Besides, it would be advisable to develop an ethnobotanical study to know the role of the human being in the distribution of the cherimoya in the three eco-climatic regions found in this work.

Modelling of potential growing regions of the cherimoya

The modelling done by the Eco-crop algorithm showed the regions where the cherimoya can have excellent, very suitable, suitable, marginals, and very marginal the growing conditions in Mexico considering as main limiting factors the minimal temperature and rainfall during the growing season.

The CPGR model, using the Worldclim climatic database —real climatic data— (WC; Hijmans et al., 2005) in the Eco-crop algorithm, showed that the cherimoya had excellent adaptation regions in centre and west of the Trans-Mexican Volcanic Belt, western Sierra Madre Occidental, centre and south of Sierra Madre Oriental and all Sierra Madre del Sur and all Chiapas Highlands provinces including the region of the Pacific Lowlands province between the two parts of Chiapas Highlands (Figure 8). Also, very suitable regions were in the Yucatan Peninsula, Veracruzan, and the Pacific Lowlands provinces (Figure 8).

Meanwhile, the FPGR model, using CCM3 climatic database —simulating the effect of climatic change— (Govindasamy et al., 2003) in the Eco-crop algorithm, showed that the cherimoya retains most of the excellent adaptation regions of the CPGR model, but loss the region of the Pacific Lowlands province between the two parts of Chiapas Highlands and also loss very suitable regions in the Veracruzan, Pacific Lowlands and Yucatan Peninsula provinces (Figure 9).

Nevertheless, it was shown that the climate change does not significantly affect the regions with excellent growing conditions for cherimoya in Mexico.

With the modelling potential growing regions results, it is possible to promote an extension of the current growing regions of cherimoya, which now still are very smalls orchards or backyard orchards in Mexico, although it is important to make a study of the types of soil before planting in some regions because of Annonaceae species, one of the factors with the greatest impact on their adaptation and acclimatization is a good drainage soil (Andrés Agustín and Nieto Ángel 1997; Agustín 1999; Andrés-Agustín et al. 2004; Andrés Agustín 2002, 2015). The potential of cherimoya has been studied in South America (Morales Astudillo et al. 2004; Pinto et al. 2005; Vanhove and Van Damme 2013) and the Caribbean region (González Vega 2013) as well as the economic importance of this fruit in Spain, which was reported since '90s (Farré and Hermoso 1997), thus cherimoya could be an alternative fruit crop for some of these regions. These results also showed that Mexico can be a potential producer of cherimoya because have many potential growing regions to cultivate this fruit.

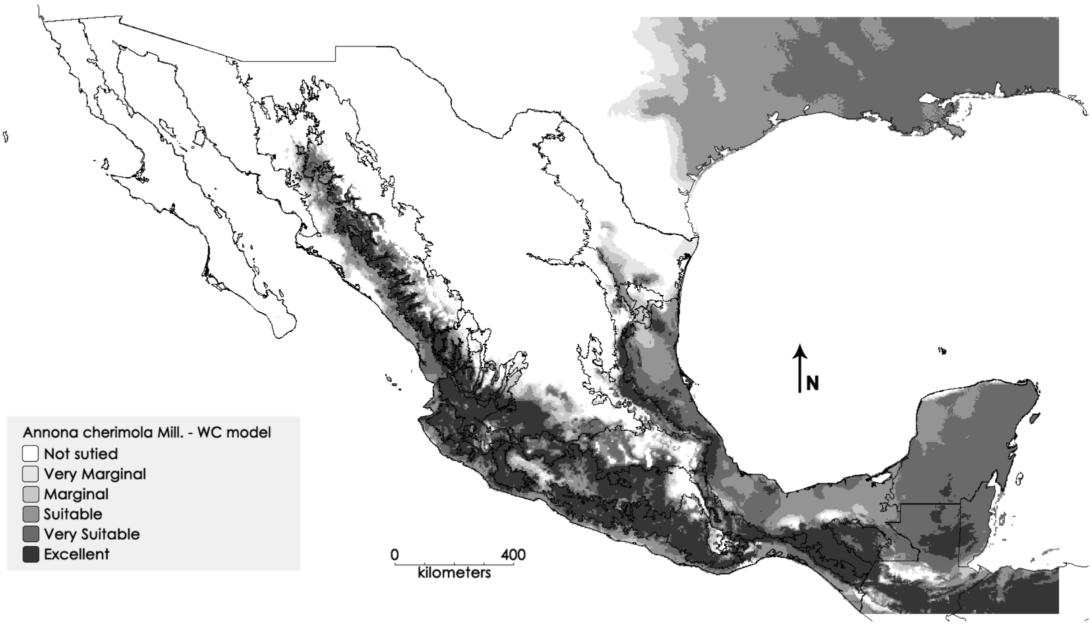

Figure 8. Eco-Crop model to know the potential growing areas of cherimoya (*Annona cherimola* Mill.) in Mexico using the Worldclim climatic database (Hijmans et al., 2005) presented in a map divided in the biogeographic provinces reported by Morrone et al. (2017).

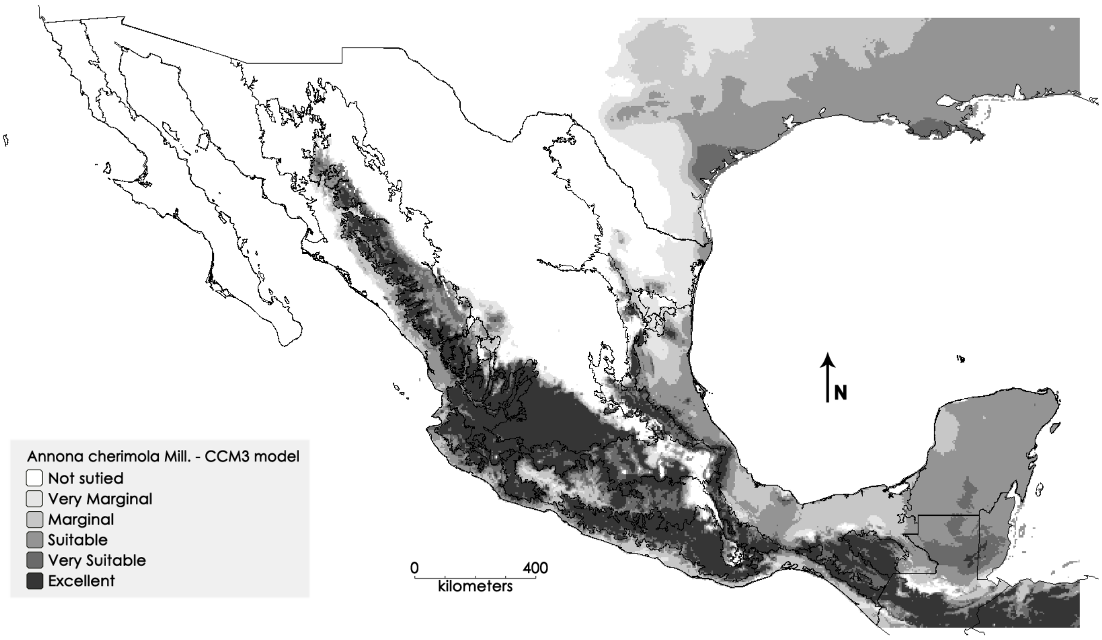

Figure 9. Eco-Crop model to know the potential growing areas of cherimoya (*Annona cherimola* Mill.) in Mexico using the model climatic database CCM3 (Govindasamy et al., 2003) presented in a map divided in the biogeographic provinces reported by Morrone et al. (2017).

CONCLUSION

In conclusion, there were located three eco-climatic clusters of the cherimoya distribution in Mexico that correspond to climates $C(m)(w)$, $(A)C(e')$ and $(A)C(e)$, respectively. Where cluster 3 showed the most restricted distribution.

The potential excellent growing regions of cherimoya were located in the Trans-Mexican Volcanic Belt, Sierra Madre Occidental, Sierra Madre Oriental, Sierra Madre del Sur, and Chiapas Highlands provinces.

When comparing the models with Worldclim data with CCM3 model data, there were not significant different. That is why, the climatic change does not significantly affect the excellent growing regions of Cherimoya in Mexico.

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DATA AVAILABILITY

The data used to support the findings of this study are available from the corresponding author upon reasonable request.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

CONTRIBUTION STATEMENT

Conceived of the presented idea: CANC, ECR
Curated and validated of the data: IAT, SAOA, JAA, CANC
Carried out the data analysis: CANC, VPC
Wrote the first draft of the manuscript: JRRN, TJMS, CANC
Review and final write of the manuscript: CANC, TJMS, JRRN, ECR
Supervision: CANC

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Additional Files

Add File 1. Project and source of the passport data of Annona cherimola Mill. used in the GIS analysis from the SNIB-CONABIO database of the Comisión Nacional de Biodiversidad (CONABIO), Mexico.

Project	**Source**	**Cite of the project**	**Number of used data**
115	REMIB-AZ herbarium	Mc Laughlin, P. S. 2003. Herbario de la Universidad de Arizona, EUA (ARIZ). Universidad de Arizona. EUA. Bases de datos SNIB-CONABIO. México, D.F.	2
138	REMIB-HINTON	Hinton, G. 2012. Colección particular Hinton. Herbarium of Geo. B. Hinton. Bases de datos SNIB-CONABIO. México, D.F.	4
AA002	AA002 E008 K004 P026 U021	Lorea-Hernández, F., Peredo, M. y C. Durán. 2014. Actualización de las bases de datos del Herbario XAL. Fase III. Instituto de Ecología, A. C.	76
AA007	AA007 L282	Contreras Jiménez, J. L. 2005. Actualización e incremento de la base de datos del Herbario de la Benemérita Universidad Autónoma de Puebla. Benemérita Universidad Autónoma de Puebla DIHMO.	10
AC002	AC002	Zamora Crescencio, P., Sánchez-González, Ma. C. y L. Aragón-Axomulco. 2005. Formación del banco de datos del herbario (UCAM). Universidad Autónoma de Campeche. Centro de Investigaciones Históricas y Sociales.	1
AS014	AS014	Chávez León, G. 2006. Inventario florístico y faunístico del Parque Nacional Barranca del Cupatitzio, Michoacán. Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación. Instituto Nacional de Investigaciones	1
B123	B123	Diego Pérez, N. 1997. Lista florística de la Costa Grande del estado de Guerrero. Universidad Nacional Autónoma de México. Facultad de Ciencias. Bases de datos SNIB-CONABIO proyecto No. B123. México, D.F.	1
B133	B133	Luna Vega, M. I. 1997. Florística y biogeografía de algunos bosques mesófilos de la Huasteca Hidalguense: Fase I (Tenango de Doria y Tlanchinol). Universidad Nacional Autónoma de México. Facultad de Ciencias. Bases de datos SNIB-CONABIO. Proyecto No. B133. México, D.F.	3
BC002	T031	Cuevas Sánchez, J. A. 2006. Computarización de la base de datos del Banco Nacional de Germoplasma Vegetal - Fase 2. Universidad Autónoma Chapingo.	10
BC003	BC003	Chávez Rendón, C. 2006. Actualización e incremento del banco de datos de la colección de herbario del Jardín Etnobotánico de Oaxaca. Centro Cultural Santo Domingo. Bases de datos SNIB-CONABIO proyecto No. BC003. México, D.F.	3
BC007	BC007	Fernández Nava, R., Reyes Toledo, B. y M. Casales Gómez. 2007. Computarización del Herbario ENCB, IPN. Fase IV. Base de datos de la familia Pinaceae y de distintas familias de la clase Magnoliopsida depositadas en el Herbario de la Escuela Nacional de Ciencias Biológicas-IPN	29

BE005	BE005	Reyes-García, A., Sousa Sánchez, M. y M. E. León Velasco. 2006. Inventario Florístico de la Reserva de la Biósfera La Sepultura del Corredor Biológico Sierra Madre del Sur. Fase II. Universidad Nacional Autónoma de México. Instituto de Biología. Bases de datos SNIB-CONABIO proyectos No. BE005 y Y003. México, D.F.	1
BK004	BK004	Salas Morales S. H. y A. Nava Zafra. 2007. Composición florística del Parque Nacional Huatulco. Sociedad para el Estudio de los Recursos Bióticos de Oaxaca, A. C. (SERBO). Bases de datos SNIB-CONABIO proyecto No. BK004. México, D.F.	1
BK029	BK029	Téllez Valdés, O. 2011. Base de datos de la distribución de la flora de la Reserva de la Biosfera Tehuacán-Cuicatlán. Universidad Nacional Autónoma de México, Facultad de Estudios Superiores Iztacala. Bases de datos SNIB-CONABIO, proyecto No. BK029. México D. F.	1
CC010	V050 CC010	Escobar Ocampo C. y J.J. Castillo Hernández. 2007. Sistematización de la colección entomológica y actualización de la colección del herbario CHIP del Instituto de Historia Natural y Ecología (IHNE), Chiapas. Secretaría de Medio Ambiente, Vivienda e Historia Natural. Bases de datos SNIB-CONABIO Plantas, proyectos No. CC010, V050_plantas y H297. México, D.F.	7
DC013	DC013	Vázquez-Torres, M. y L. H. Bojórquez G. 2011. Base de datos computarizada del herbario CIB, Instituto de Investigaciones Biológicas, Universidad Veracruzana. Universidad Veracruzana. Instituto de Investigaciones Biológicas.	4
F019	F019	González Espinosa, M. 1998. Árboles de Chiapas: registro georreferenciado de los ejemplares depositados en el herbario de la Academia de Ciencias de California (CAS). El Colegio de la Frontera Sur. Bases de datos SNIB-CONABIO proyecto No. F019. México, D.F.	11
gbif	11520	Netherlands Centre for Biodiversity Naturalis, section National Herbarium of the Netherlands, Nationaal Herbarium Nederland (accessed through GBIF data portal, http://data.gbif.org/datasets/resource/11520, 2012-12-04	2
gbif	12084	Missouri Botanical Garden, Missouri Botanical Garden (accessed through GBIF data portal, http://data.gbif.org/datasets/resource/12084, 2012-12-04	12
gbif	14128	California Academy of Sciences, CAS Botany (BOT) (accessed through GBIF data portal, http://data.gbif.org/datasets/resource/14128, 2012-12-04	2
gbif	1429	US National Plant Germplasm System, United States National Plant Germplasm System Collection (accessed through GBIF data portal, http://data.gbif.org/datasets/resource/1429, 2012-12-04	1
gbif	14346	Field Museum, Field Museum of Natural History (Botany) Seed Plant Collection (accessed through GBIF data portal, http://data.gbif.org/datasets/resource/14346, 2012-12-04	9
gbif	1496	University of Vienna, Institute for Botany - Herbarium WU, Herbarium WU (accessed through GBIF data portal, http://data.gbif.org/datasets/resource/1496, 2012-12-04	1
gbif	7900	University of Arizona Herbarium, UA Herbarium (accessed through GBIF data portal, http://data.gbif.org/datasets/resource/7900, 2012-12-04	3
H076	H076	Martínez, M. 1999. Flora acuática de Querétaro. Universidad Autónoma de Querétaro. Facultad de Ciencias Naturales. Bases de datos SNIB-CONABIO proyecto No. H076. México, D.F.	1

H102	H102	Luna Vega, M. I. 1999. Florística y biogeografía de algunos bosques mesófilos de la Huasteca Hidalguense: Fase II (Tlahuelompa y Eloxochitlán). Universidad Nacional Autónoma de México. Facultad de Ciencias. Bases de datos SNIB-CONABIO. Proyecto No. H102. México, D.F.	2
H304	H304	García Ruíz, I. 1999. Flora del Parque Nacional Pico de Tancítaro, Michoacán. Instituto Politécnico Nacional. Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional-Michoacán. Bases de datos SNIB-CONABIO proyecto No. H304. México, D.F.	1
HA005	EC009 HA005	Pérez-Farrera, M. A., Martínez-Camilo, R., Martínez-Meléndez, N. y M. Martínez-Meléndez. 2011. Integración de bases de datos, actualización y sistematización de la colección de flora del Herbario Eizi Matuda (HEM). Universidad de Ciencias y Artes de Chiapas	6
HA008	ECO11 HA008	Serrano, Valentina. 2012. Base de datos del Herbario de Querétaro 'Dr. Jerzy Rzedowski' (QMEX). Fase II. Universidad Autónoma de Querétaro. Facultad de Ciencias Naturales. Bases de datos SNIB-CONABIO, proyectos No. HA008 y EC011. México D. F.	9
HA016	BA006	Hernández Aguilar S. 2014. Depuración de la colección y base de datos del Herbario CICY. Fase IV". CICY. Centro de Investigación Científica de Yucatán A.C.	2
HE008	BE018	Dávila, A. P., Rodríguez A.I. y R. L. García. 2012. Conservación "ex situ" de germoplasma vegetal de las regiones áridas y semiáridas de México. Fase 4. FES Iztacala, UNAM. Banco de Semillas FESI UNAM. Bases de datos SNIB-CONABIO, proyectos No. HE008, GE002, EE024 y BE018. México D. F.	1
INFyS2010	INFyS. 2010	CONAFOR. 2011. Base de datos del Inventario Nacional Forestal y de Suelos 2004 - 2009, Comisión Nacional Forestal y de Suelos, Zapopan, Jalisco, México	16
J063	J063	Reygadas Prado, D. D. 1999. Sistema de apoyo a la toma de decisiones para la reforestación rural en México. Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación. Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias	4
J084	J084	Batis Muñoz, A I., Alcocer Silva, M. I., Gual Díaz, M., Sánchez Dirzo, C. y C. Vázquez Yanes, 1999. Árboles mexicanos potencialmente valiosos para la restauración ecológica y la reforestación. Universidad Nacional Autónoma de México. Instituto de Ecología	24
L057	L057	Vega Aviña, R. 2000. Catálogo y base de datos preliminar de la flora de Sinaloa. Universidad Autónoma de Sinaloa. Facultad de Agronomía. Bases de datos SNIB-CONABIO proyecto No. L057. México, D.F.	2
L091	L091	Luna Vega, M. I. 2000. Florística y biogeografía de algunos bosques mesófilos de la Huasteca Hidalguense: Fase 3 (Chapulhuacán y Pisaflores). Universidad Nacional Autónoma de México. Facultad de Ciencias. Bases de datos SNIB-CONABIO. Proyecto No. L091. México, D.F.	1
M001	M001	Berlin, B. 1999. La etnobiología de los recursos nutritivos en las comunidades Tzeltales en los Altos de Chiapas. El Colegio de la Frontera Sur. Bases de datos SNIB-CONABIO proyecto No. M001. México, D.F.	20
P140	P140	Gutiérrez Garduño, M. V. 1999. Sistematización del Herbario Nacional Forestal Biól. Luciano Vela Gálvez. Secretaría de Agricultura, Ganadería y Desarrollo Rural. Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias.	7

P143	P143	Carnevali Fernández, G. y R Durán. 2009. Depuración de la Colección y del Banco de datos del Herbario CICY. Fase III. Centro de Investigación Científica de Yucatán A.C. Bases de datos SNIB-CONABIO Proyectos No. DC002, BA006 y U009. México. D. F.	6
Q017	Q017	Rzedowski, J. y S. Zamudio. 2001. Etapa final de la captura y catalogación del Herbario del Instituto de Ecología, AC, Centro Regional del Bajío.	27
R031	R031	Diego Pérez, N. y M. Martínez Gordillo. 2001. Base de datos del Municipio General Heliodoro Castillo, Guerrero (120. Sierra Madre del Sur). Universidad Nacional Autónoma de México. Facultad de Ciencias. Bases de datos SNIB-CONABIO proyecto No. R031. México, D.F.	1
SI-BMM	SI-BMM	Gual, D. M.; Rendón, C. A.; Alamilla, F. L.; Cifuentes, R. P. & Lozano, R. A. T. 2013. Bosque Mesófilo de Montaña de México. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad.	20
T015	T015	Dávila Aranda, P. y R. Lira Saade. 2001. La flora útil de dos comunidades indígenas del Valle de Tehuacán-Cuicatlán: Coxcatlán y Zapotitlán de las Salinas, Puebla. Universidad Nacional Autónoma de México. Facultad de Estudios Superiores Iztacala. Bases de datos SNIB2013-CONABIO proyectos No. T015, Q014-Flora útil y P091-Flora útil. México, D.F.	1
U008	E004 L188	Jiménez Ramírez, J, y M. Martínez Gordillo. 2003. Fusión y actualización de las bases de datos del Herbario de la Facultad de Ciencias, UNAM (FCME), Guerrero. Universidad Nacional Autónoma de México. Facultad de Ciencias. Bases de datos SNIB-CONABIO proyectos No. U008, R031-Municipio H. Castillo, L188, L092 y E004. México, D.F.	4
U011	U011	Santana-Michel, F. J., Cuevas Guzmán, R. y Guzmán Hernández, L. 2003. Actualización de la base de datos sobre la flora de la Reserva de la Biósfera Sierra de Manantlán, Jalisco-Colima, México. Universidad de Guadalajara. Centro Universitario de la Costa Sur. Bases de datos SNIB-CONABIO proyectos No. U011 y A007. México, D.F.	3
U048	U048	Guízar Nolazco, E. 2004. Banco de datos florísticos del Herbario CHAP. Universidad Autónoma Chapingo. División de Ciencias Forestales.	11