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Artículo

Distribución de *Vanilla planifolia* Jacks. ex Andrews y acciones para su conservación en la Huasteca Potosina

Vanilla planifolia Jacks. ex Andrews distribution and actions for its conservation in the *Huasteca Potosina*

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Resumen

La vainilla (*Vanilla planifolia)* es una de las orquídeas más ampliamente utilizada desde la época precolombina, actualmente, su estatus de conservación corresponde a la categoría de Sujeta a Protección Especial. Los objetivos de esta investigación fueron identificar su distribución actual y potencial en la Huasteca Potosina; y diseñar acciones para su conservación. Para ello, se realizaron consultas en herbarios, recorridos de campo, entrevistas con los productores de vainilla y talleres participativos con habitantes locales. Se llevó a cabo un análisis espacial basado en sistemas de información geográfica, para conocer las características ambientales de los sitios con presencia de la especie y se modelizó su distribución potencial. En la Huasteca Potosina, se ubicaron 28 sitios con presencia del taxón bajo estudio, la mayoría en sistemas agroforestales tradicionales y, menor proporción, en los relictos de selva mediana que aún persisten en la región, anclados a los tutores que les proveen el soporte necesario. Su distribución potencial se estimó en 85.5 km^2. El germoplasma sin procesos de domesticación y adaptado a las condiciones ambientales que se identificaron, tiene posibilidades de ser conservado. Los poseedores de este recurso genético consideran que una Unidad de Manejo de la Vida Silvestre sería la forma más adecuada para lograr su conservación *in situ*.

Palabras clave: Conservación, distribución potencial, estrategias de conservación, *Maxent*, *Vanilla planifolia* Jacks. ex Andrews, Huasteca Potosina.

Abstract

Vanilla (*Vanilla planifolia*), one of the most widely used orchids since pre-Columbian times, is currently under threat and subject to special protection. The objectives of this research were to identify the current and potential distribution of wild vanilla in the *Huasteca Potosina*; and design actions for its conservation. For this purpose, consultations were made in herbaria, field trips, interviews with the vanilla producers, and participatory workshops with local inhabitants. A spatial analysis was carried out in order to get to know the environmental characteristics of the plots with the presence of vanilla, and their potential distribution was modeled. In the *Huasteca Potosina,* 28 sites were located with the presence of the taxon under study, most of them in traditional agroforestry systems and, to a lesser extent, in the relics of medium forest that still persist in the region, anchored to the tutors that provide them with the necessary support. Its potential distribution was estimated at 85.5 km^2 Germplasm without domestication processes and adapted to the environmental conditions that were identified, has the possibility of being conserved. The owners proposed wildlife management units for its conservation *in situ*.

Key words: Conservation, potential distribution, conservation strategies, Maxent, *Vanilla planifolia* Jacks. ex Andrews, *Huasteca Potosina.*

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Introduction

Vanilla (*Vanilla* spp.) is one of the most widely cultivated orchids in the world (Flanagan and Mosquera, 2016). Its demand encompasses the food, pharmaceutical, perfume and cosmetics industries (Azofeifa-Bolaños *et al.*, 2014). The most important species of this genus across the world are *Vanilla planifolia* Jacks. ex Andrews, *V. pompona* Schiede and *V. tahitensis* J.W. Moore., as they produce natural vanillin (Flores *et al.*, 2017).

Of the three species, *Vanilla planifolia* not only is the one most exploited for commercial purposes and the second natural flavoring in the food industry (Luna-Guevara *et al.*, 2016) but also is subjected to special protection by the Mexican laws (NOM-059-SEMARNAT-2010) (Semarnat, 2010). This is mainly due to the deforestation and fragmentation of its habitat (medium evergreen forests), and to the illegal extraction of individuals for the establishment of commercial plantations (Soto and Dressler, 2010). The specificity of its pollinizers and natural disseminators is an element that increases the endangerment of its populations (Salazar *et al.*, 2014).

The creation of germplasm banks, the improvement of conditions in the plantations and *in vitro* conservation are some of the most commonly utilized strategies for conserving this species (Bello-Bello *et al.*, 2015). This requires knowing the status of its populations, defining actions that incorporate commercial, biological and cultural values, and designing specific conservation strategies (Herrera-Cabrera *et al*., 2012; Salazar *et al*., 2014; Hernández-Ruíz *et al*., 2016).

One of the most relevant tools for the protection and conservation of threatened species is the application of species distribution models (SDMs) (Baldwin, 2009; Cassini, 2011; Mateo *et al*., 2011). These models, based on the occurrence of the species, allow to determine the environmental factors that delimit their distribution or redistribution (Cassini, 2011). They facilitate not only the development of conservation strategies but also the repopulation of vegetal and animal species (Loiselle *et al*., 2003; Benito and Peñas, 2007; Obregón *et al*., 2014; Figueroa *et al*., 2016).

In Mexico, SDMs have been applied for the purpose of identifying distribution patterns and establishing priority areas for the conservation of birds (Jacinto-Flores *et al*., 2017), reptiles (Paredes *et al*., 2011) and plants (Villaseñor and Téllez-Valdés, 2004; Peters *et al*., 2014).

Given the economic and cultural importance of vanilla for Mexico and the rest of the world (Hernández, 2011), this paper seeks to contribute to the knowledge of the current distribution of *Vanilla planifolia* in the northeast of the country. So far, there is no recent evidence documenting its occurrence in the state of *San Luis Potosí*, nor is there basic information available for designing actions to preserve the current germplasm.

The objective of this research was to identify the current distribution sites of *Vanilla planifolia*, to model its potential distribution and to determine, together with local inhabitants, actions for its conservation in the *Huasteca Potosina*.

Materials and Methods

Study area

The *Huasteca* region, located in the state of *San Luis Potosí*, comprises two subregions: the northern *Huasteca* and the southern *Huasteca* (Inegi, 2017). The vanilla area of the state is situated in the latter, in the windward portion of the Eastern *Sierra Madre* (Reyes *et al.*, 2018) (Figure 1). The predominant climate is semi-warm subhumid, with a small warm subhumid portion to the north and northeast, and a temperate humid segment exclusively in the municipality of *Xilitla*. Annual precipitations range from 1 500 to 3 000 millimeters, and the mean annual temperature ranges between 16 and 24 °C (Inegi, 2017).

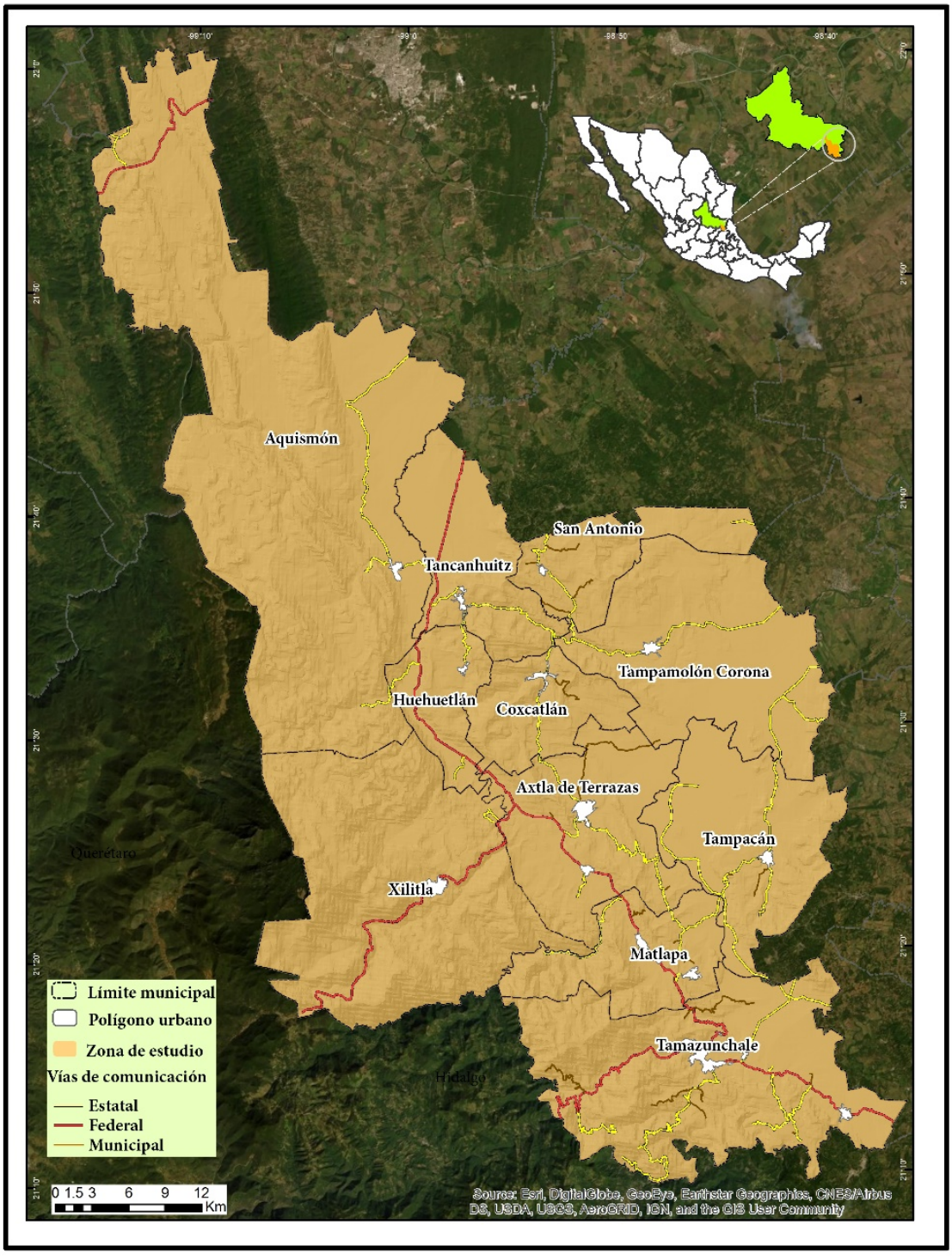

Figure 1. Vanilla region, state of *San Luis Potosí*.

Current and potential distribution

In order to define the current distribution of the species in the region, records a search was carried in the collections of the National Herbarium of Mexico (MEXU) and the *Isidro Palacios* Herbarium of the *Instituto de Investigaciones de Zonas Desérticas* (IIZD) (Desert Zones Research Institute), of the *Universidad Autónoma de San Luis Potosí* (UASLP) (Autonomous University of San Luis Potosí). The database of the *Red Mundial de Información sobre Biodiversidad* (World Network of Information on Biodiversity) was also consulted (Remib, 2018). The result was two records of *Vanilla planifolia* for *San Luis Potosí,* corresponding to the same collection, deposited in the MEXU and the IIZD.

The database of the "2013-2015 Applied research macro project for the strengthening of vanilla production in Mexico" provided information on producers who reported the occurrence of vanilla in relicts of the medium jungle, of secondary vegetation and of the agroforest systems of the *Huasteca* known as *te´lom* and *cuayo*. Thus, 21 farmers were identified and received a questionnaire with semi-structured questions, with the purpose of verifying (among other data of interest about the species) whether the interviewee distinguished between different types of vanilla, knew the sites where the species grows wild and was certain that these populations had not been subjected to previous management (*i.e.* were uncultivated).

For the aims of this research, and in keeping with the General Wildlife Law, wild species were defined as: *those organisms that subsist subject to natural evolutionary processes and develop freely in their habitat, including their smaller populations and individuals, whether under human control or feral* (Semarnat, 2018).

Based on the information provided, field tours were undertaken between February and September, 2014, for the purpose of verifying the presence of the species. Thus, 28 sites were identified and georeferenced with a Garmin Colorado 600 GPS. Besides the coordinates of each site, information was obtained on the type of support tree

that holds the plant, the height of the liana, the number of fruits, the percentage of shade, and the predominant environmental characteristics.

Likewise, botanical specimens were collected (Ricker, 2014) which were deposited in the IIZD Herbarium for later identification, through the use of taxonomic keys (Soto, 2003; Soto and Dressler, 2010).

The data georeferenced in the field (28) and the record obtained at the MEXU and IIZD herbariums were the basic inputs of the SDM, which was based on the maximum entropy algorithm known as Maxent. This model makes it possible to infer potential sites of occurrence of a particular species based on actual occurrence data and on the predominant environmental conditions (Cassini, 2011; Mateo *et al*., 2011). In addition to the occurrence data, the bioclimatic (BIO) layers of the database of the WorldClim-Global Climate Data (http://www.worldclim.org/), vegetation and Series V land use (VUS), altitude (MDT) and Series V edaphology (EDA) of the Inegi (https://www.inegi.org.mx/datos/) were incorporated into the SDM. All the information layers were converted to a raster format and standardized to a single cell size of 30 × 30 m (Table 1).

Table 1. Bioclimatic and physical variables used in the potential distribution model.

Clave	Variables
BIO1	Mean anual temperature
BIO2	Daytime temperature oscillation
BIO3	Isothermality
BIO4	Temperature seasonality
BIO5	Maximum mean temperature of the warmest period
BIO6	Minimum mean temperature of the coldest period
BIO7	Annual temperature oscillation
BIO8	Mean temperature of the rainiest quadrimester
BIO9	Mean temperature of the driest quadrimester
BIO10	Mean temperature of the warmest quadrimester
BIO11	Mean temperature of the coldest quadrimester
BIO12	Annual precipitation
BIO13	Precipitation of the rainiest period
BIO14	Precipitation of the driest period

BIO15	Precipitation seasonality
BIO16	Precipitation of the rainiest quadrimester
BIO17	Precipitation of the driest quadrimester
BIO18	Precipitation of the warmest quadrimester
BIO19	Precipitation of the coldest quadrimester
VUS20	Vegetation
MDT21	Land use
EDA22	Altitude

Repetitions were carried out alternating different qualitative and quantitative layers and calibrating the 25 %, 50 % and 75 % settings in order to determine the evaluation percentage (Benito and Peñas, 2007; Cassini, 2011). The main criterion for selecting the best model was a value of the ROC^2 curve above 75 % (Muñoz and Felicísimo, 2004). Given that the training AUC (0.953) and evaluation AUC (0.939) coefficients are near 1, they indicate a high confidence interval, as they are above the random prediction, ensuring the robustness of the model.

The resulting SDM was exported to the ArcGis 10.2 software and superimposed on a SPOT satellite image of February, 2016, in order to check its coincidence with the areas occupied by rainforests (the natural habitat of the species). Finally, the surface area where *V. planifolia* may potentially be distributed was estimated.

Actions for conservation

In order to get into the territory and get involved with the local population in the conservation of the species, the locality of *Jalpilla* in *Axtla de Terrazas* was selected to design conservation actions through participative processes oriented toward action and personal commitment to the protection of the environment. The selection criterion was the support of the peasants for the project to be carried out.

Participatory methodologies are tools that help to decipher the reasons why a community that has some type of resource makes its decisions and, at the same time, allows to delineate some actions for its protection (Herlihy and Knapp, 2003). These methodologies are based on the active intervention of the local inhabitants and are composed of group dynamics, socio-dramas, critical routes, maps and other means that encourage the participation, analysis and reflection of the participants. Unlike other methods, this approach does not seek representativeness, since each case study is usually unique, in addition, due to its nature - qualitative type - they do not require a statistical analysis for validation (Reyes *et al*., 2013).

The methodology used in this work included conducting participatory evaluation workshops, field trips, application of semi-structured interviews and participant observation. Both the interviews and the participant observation are complementary instruments through which it was possible to triangulate and collate the information obtained in the workshops.

In *Jalpilla*, three participative workshops were carried out, with an average attendance of 8 to 10 producers, including the owners of the plots where *Vanilla planifolia* was found.

The first, a "recognition" workshop sought to identify the owners of the plots where the species was located and obtain general information on its uses, economic importance and production system. The second, a "conservation" workshop, had had the aim of recognizing the perception of the participants regarding the conservation and the actions implemented to preserve the species. The objective of the third workshop, on "actions for conservation", was to identify and determine priority sites for the preservation of the species through several schemes and their discussion with the inhabitants.

In addition, the participants were trained in the assessment of the genetic resources, the importance of the local biodiversity, and the possibilities offered by the new conservation schemes.

As a result of the intervention, workshop participants proposed and defined by consensus, exclusion areas as the main measure to protect the species. For this, it was

necessary to have the consent of the legal holders of said lands and their consent to implement the previously agreed actions. In order to establish the boundaries of the proposed areas more accurately, these were georeferenced in the field with a Garmin Colorado 600 GPS. Finally, all the information was represented in a SPOT satellite image of February, 2016, printed in true color and shown to the group for validation of the results.

Results

Current and potential distribution of *Vanilla planifolia*

The only record of *Vanilla planifolia* reported by the consulted herbaria for S*an Luis Potosí* corresponds to the locality of *Tanjasnec*, *San Antonio*. It was carried out on May 4, 1979, by Janis Alcorn in a medium evergreen forest. In this research, the presence of the species was identified in 28 sites belonging to the 17 localities (*Tanjasnec* included) belonging to the municipalities of *Aquismón*, *Axtla*, *Huehuetlan*, *Matlapa*, *San Antonio*, *Tancanhuitz*, and *Tamazunchale* in the *Huasteca Potosina* (Figure 2).

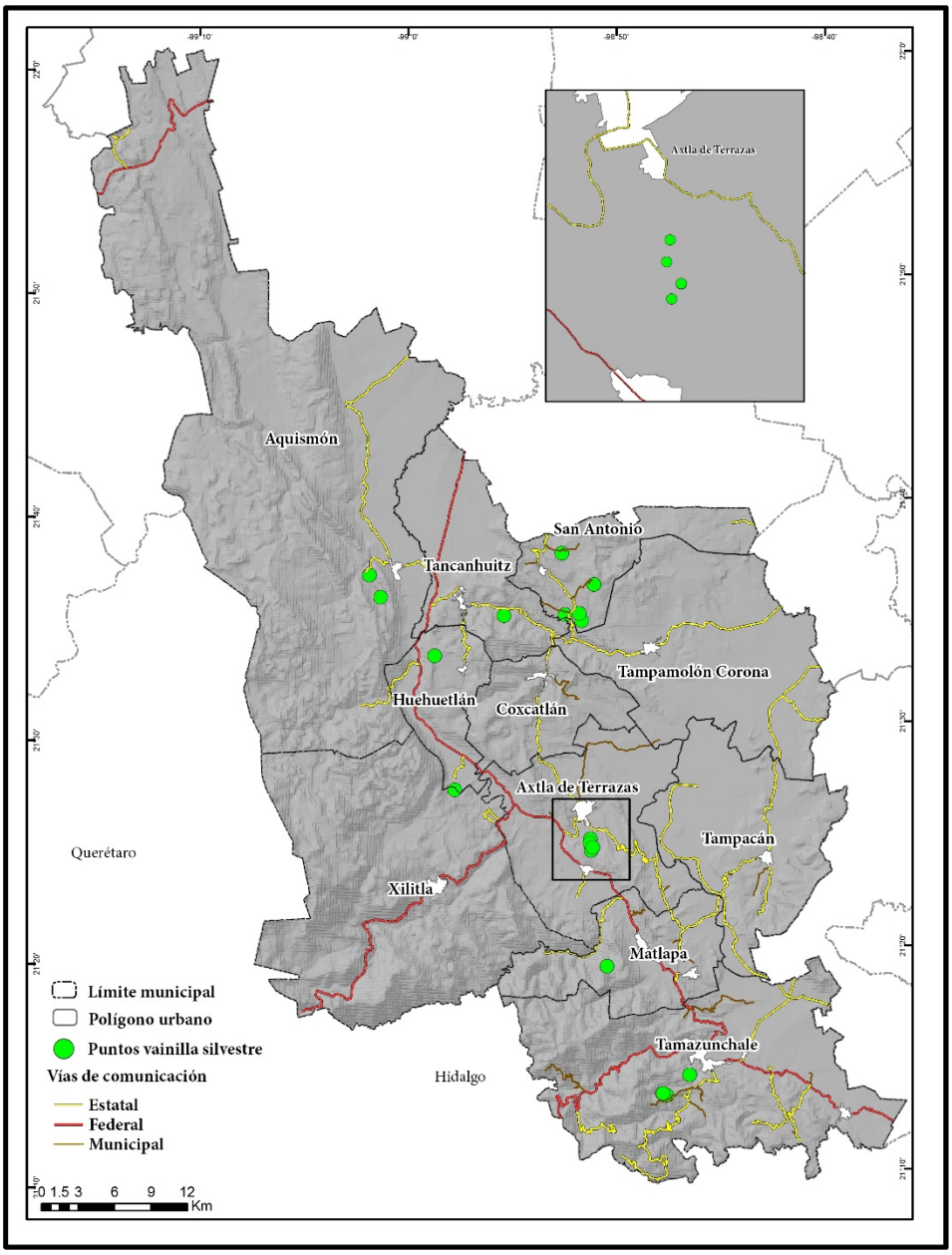

Figure 2. *Vanilla planifolia* Jacks. ex Andrews plots in the *Huasteca Potosina*.

The main characteristics of these places indicate that the species develops at altitudes of 100 to 767 m, in plots with slight (5 %) to moderate (>10 %) slopes. The minimum temperature ranges between 5 and 14 °C, and the maximum temperature, between 26 and 36°C. The annual precipitation ranges from 1 600 to 2 500 mm. The predominant vegetation type in all the sites is medium (evergreen and subdeciduous) forest (Figure 3).

Figure 3. Specimens of *Vanilla planifolia* Jacks. ex Andrews, located in forest relicts (1) and agroforest systems (2).

The main support trees associated to vanilla were: wild coffee (*Psychotria* sp.), angelica tree (*Dendropanax arboreus* (L.) Decne. & Planch.), avocado (*Persea Americana* L.), bay cedar (*Guacima ulmifolia* Lam.) and black cherry (*Prunus serotina* Ehrh.). In average, a single liana was found per tree, with a length of five meters. Only two plants with visible fruits were found during the entire exploration. The botanical file of the collected specimens can be consulted on the virtual page of the *Isidro Palacios* Herbarium of IIZD. (http://slpm.uaslp.mx/DetalleEjemplar.aspx?id=8Uky0ajgzwU=).

The distribution model indicates that this species may inhabit a potential area of 85.5 km^2 (Figure 4), the area with the highest probability of occurrence (71-87 %) being the central portion of the municipalities of *Matlama* and *Tamazunchale*, the central portion of *Coxcatlán* and *San Antonio* and *Tancanhuitz*, the west of *Huehuetlán*, and the southeast of *Aquismón*.

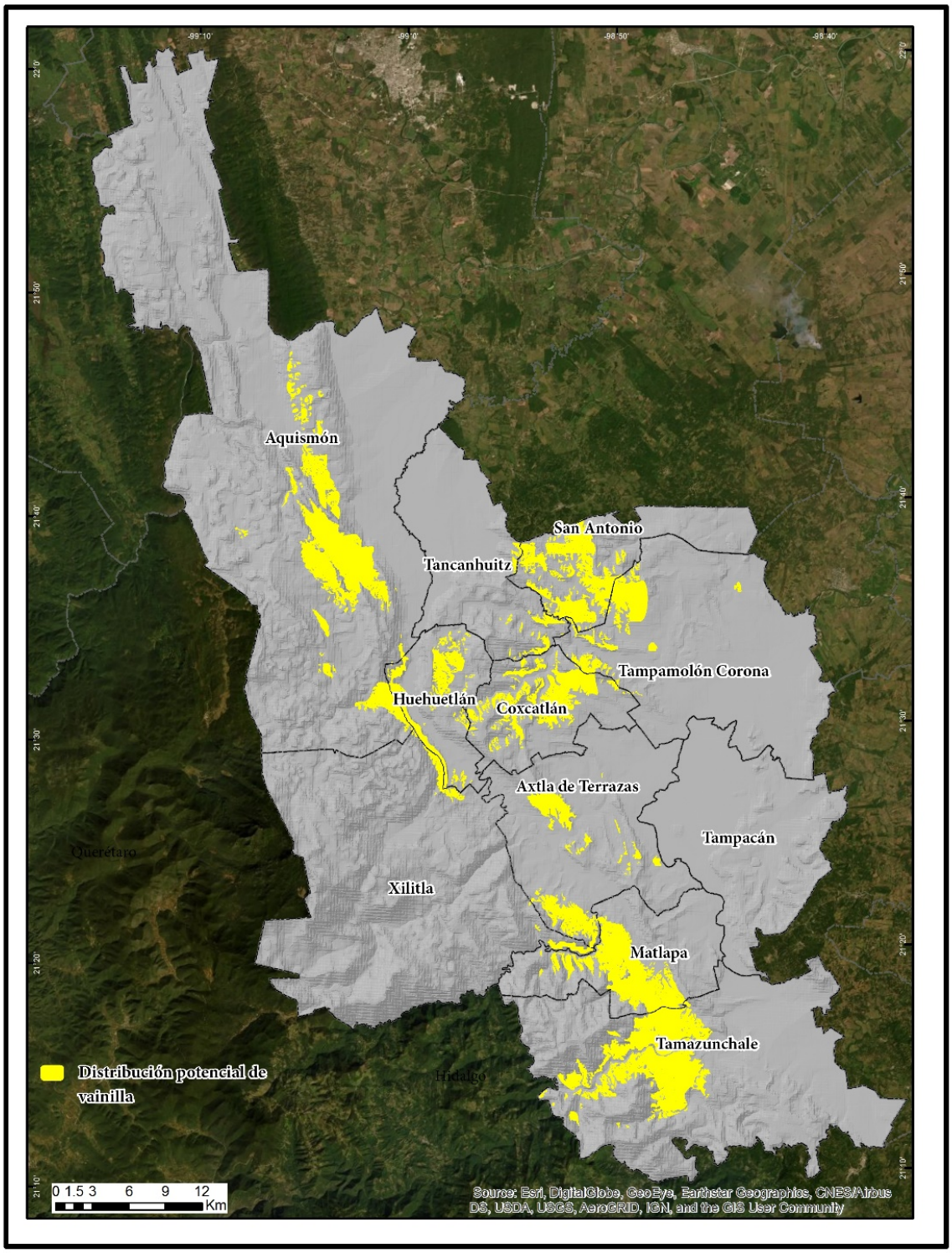

Figure 4. Potential distribution of *Vanilla planifolia* Jacks. ex Andrews in the *Huasteca Potosina*.

It is important to emphasize that, although favorable environmental conditions for the development of *Vanilla planifolia* exist in the south of the *Huasteca Potosina*, the scarcity of areas with native arboreal vegetation —due to the fragmentation of forests in the region— prevents the development of the species.

The variables that contribute in a smaller proportion to explain the potential distribution model of the species in the *Huasteca Potosina* are: i) annual precipitation (76.7 %), ii) type of vegetation (9.4 %), and iii) type of soil (6.3 %). The rest of the variables contributed less than 5 %.

Actions for the conservation of *Vanilla planifolia*

At *Jalpilla*, all the producers agreed that the species has inhabited the area in its wild form for more than 100 years. The plants were discovered by their grandparents, who collected them occasionally in order to sell the pods at the local markets. They also pointed out that the first vanilla producers promoted its development in the traditional agroforest systems "*te´lom*" (Teenek) and "*cuayo*" (Nahuatl), which harbored a large amount of wild specimens.

For vanilla producers, to conserve is to allow the preservation of the individuals without ceasing to use them. 80 % of the producers select certain individuals, take care of these and subsequently reproduce them in order to exploit them. However, they allow the original clone to persist in its wild condition, without managing or harming it.

The creation of exclusion areas where agricultural activities are forbidden in order to avoid the depredation of the *V. planifolia* populations is one of the main actions for protecting the species.

The four proposed areas measure a total of 12.8 ha and are located in plots that are barely accessible to the producers; although this is a limiting factor for agricultural exploitation, it has turned out to be a strength in terms of the conservation of the species at a local scale (Figure 5).

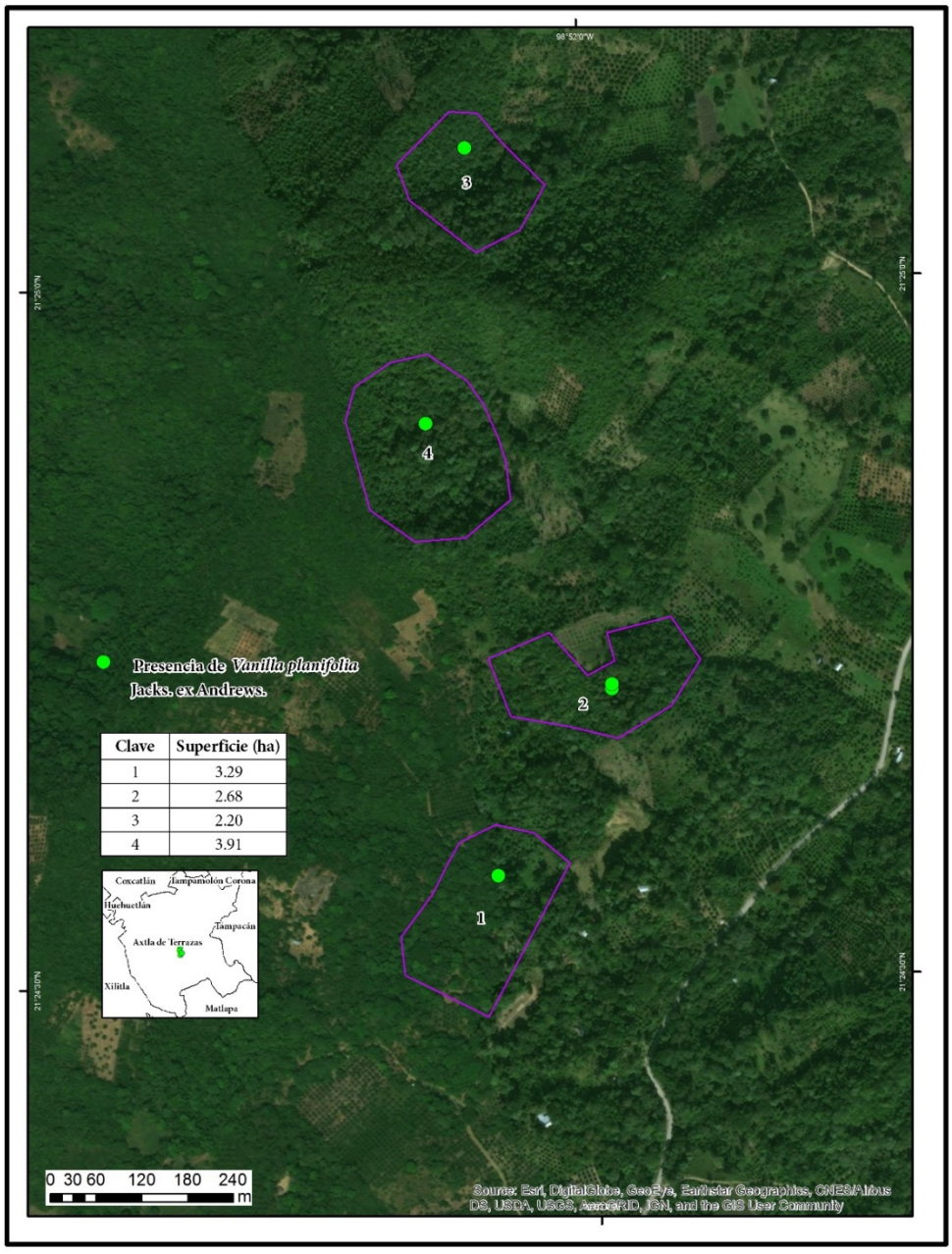

Figure 5. Proposed exclusion and protection areas of *Vanilla planifolia* Jacks. ex Andrews, in *Jalpilla*, *Axtla*, *San Luis Potosí*.

Of all the presented and discussed options for the formal conservation of vanilla, the establishment of a Wildlife Conservation Management Unit (UMA, for its acronym in Spanish) has proven to be the most viable. Although the type of exploitation (intensive or extensive) was not determined, the critical route for carrying out this initiative in the medium term was established (Figure 6).

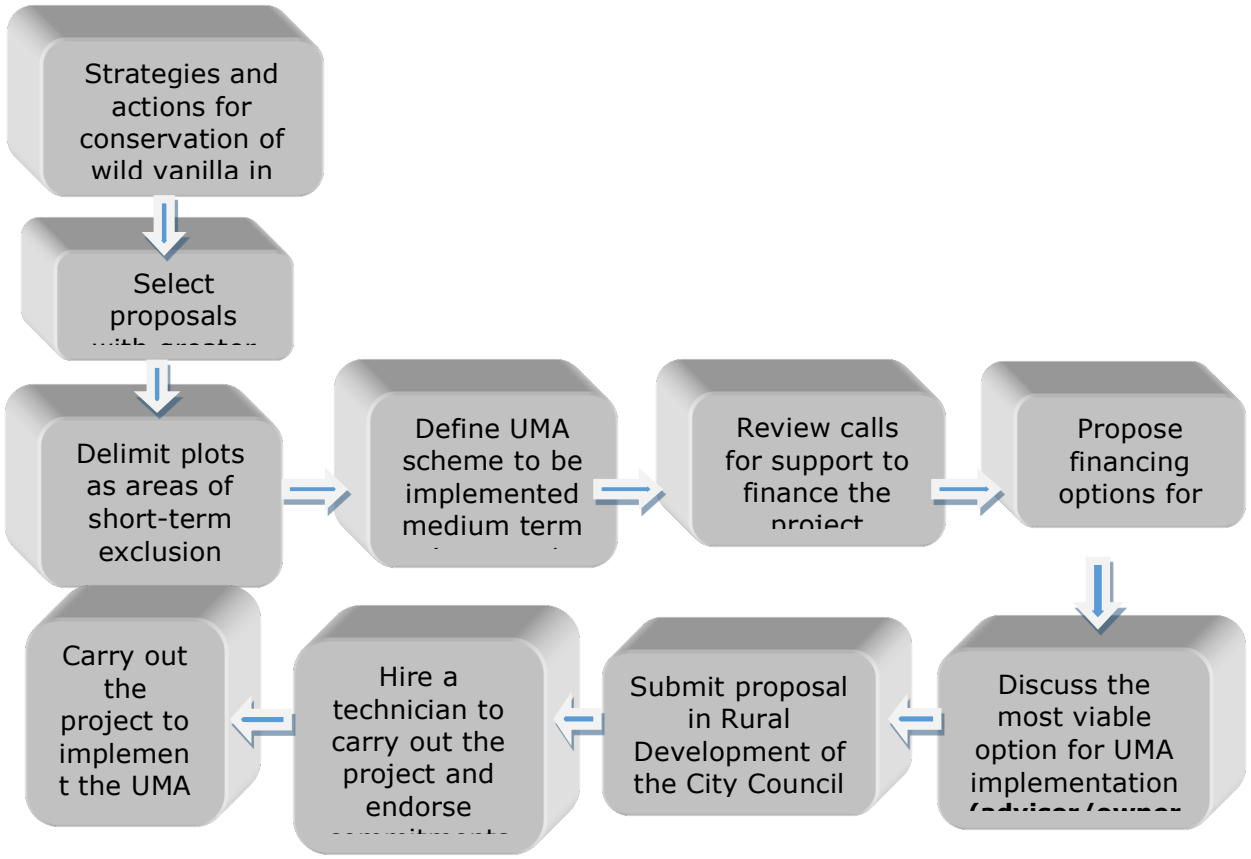

Figure 6. Critical path for the implementation of a proposed AMU as a local conservation strategy for the protection of *Vanilla planifolia* Jacks. ex Andrews, in *Jalpilla, Axtla, San Luis Potosí*.

Discussion

The culture of *Vanilla planifolia* has become more important in the *Huasteca Potosina* due to its economic value in the market since the year 2003 (Sedarh, 2012; Reyes *et al*., 2018). However, so far there are few initiatives for conserving it. The main threats that this species faces are the plundering of its wild populations to establish new plantations and deforestation (Soto and Dressler, 2006; Flanagan and Mosquera, 2016).

The reduction or disappearance of its wild populations is greater particularly in those places where its culture was intensified, where severely fragmented habitats are predominant, or where other crops have been established (Azofeifa-Bolaños *et al*., 2014; Flores *et al*., 2017).

At the national level, the records of *V. planifolia* correspond to the states of *Oaxaca*, *Chiapas* and *Quintana Roo* (Schlüter *et al*., 2007; Conabio, 2010). One of the last collections in the field, carried out between 2008 and 2014 by Flores *et al.* (2017) locate most of the records in *Quintana Roo*. Although two collections are registered in *San Luis Potosí* (*Vanilla planifolia* and *V. odorata*), both are herbarium records. Although the authors do not indicate to which herbariums the collections correspond, it is very probable that the record of *Vanilla planifolia* is the same as *Tanjasnec* found in MEXU. The above is deduced from the geographical location of the site (*Huasteca* region) in the corresponding cartography. The opposite occurs with *V. odorata,* whose position in the mapping places it in the arid zone of the state, where the environmental conditions of the region make the presence of this species in the wild impossible.

It is important to highlight that in the research documented here, copies of *V. planifolia* were found in 28 sites after 33 years of the first record (Figure 2); although its presence is very scarce. In addition to the sites, there is a potential area of more than 85 km^2 with environmental characteristics that are favorable to the species, according to the SDM obtained (Figure 4). These figures contrast with the number of records and with the huge surface area reported for *Oaxaca* (17 139 km^2), with a good to moderate quality for harboring this species (Hernández-Ruíz *et al.*, 2016). This could be explained due to the high degree of fragmentation and degradation of the forests of the *Huasteca* region (Reyes *et al*., 2006).

Hernández-Ruíz *et al.* (2016) point out that the precipitation of the rainiest quadrimester plays an essential role in the prediction of the model, in a similar way to the results obtained in this research. In this regard, the link existing between the amount of precipitation in the rainy season and the presence of a clearcut dry period (mid-summer heat wave or mid-summer drought) is decisive for the productivity of vanilla (Exley, 2011).

Although the main interest of the inhabitants in vanilla is economic, an economic-cultural relationship dating back to at least two centuries ago may be inferred (Alcorn, 1983; Moreno-Calles *et al*., 2013). According to the results obtained, most of the populations without human management, destined for conservation and recollection, are in the *te´lom*/*cuayo*. These "agroforests" safeguard an ancestral knowledge of the management of the natural resources (Moreno-Calles *et al.*, 2013) and at the same time harbor the largest number of wild specimens, compared to the rest of the production systems.

In this regard, there is a broad consensus in that both *in situ* and *ex situ* strategies must be applied in order to achieve conservation and sustainable use of the wild relatives of a species. The world strategy for the conservation of vegetal species states that, in addition to conserving these species, the associated indigenous and local knowledge must be respected, preserved and maintained (FAO, 2017).

In this sense, the conservation model known as "*circa situm*" or "peasant-based conservation", allows the provision of the habitat and the flow of genes in altered agricultural landscapes, but within the native sphere of the species (Boshier *et al*., 2004; Dawson *et al.*, 2013). This model, proposed in countries like Colombia (Flanagan and Mosquera; Flanagan *et al.*, 2018) could be an alternative to protect *Vanilla planifolia* and contribute to strengthen rural livelihood, as in the case of the conservation program for the vanilla germplasm in the region of *Totonacapan*, *Veracruz* (Herrera-Cabrera *et al*., 2012; Salazar *et al*., 2014).

In Mexico, the strategies for the conservation of wild vanilla are not enough(March *et al.*, 2009). Certain *in situ* and *ex situ* conservation initiatives led by higher education institutions stand out. The National System of Phytogenetic Resources (Sinarefi, for its

acronym in Spanish) proposed conservation schemes that included the building of capacities and the use and potentiation of vanilla. However, they have all had little participation by the local inhabitants.

Peasant-based *in situ* conservation combined with exploitation schemes such as the UMAs may be applied to strengthen the livelihoods, culture and local production systems (Salazar *et al.*, 2014). Considering that *V. planifolia* would be present in a large portion of the southern *Huasteca Potosina*, where the production of vanilla is concentrated (Reyes *et al.*, 2018), this scheme could be the most adequate.

In addition to promoting social participation for wildlife conservation, an UMA would improve the economic standard of living of the local inhabitants through an orderly exploitation of the resources. At the same time, it seeks to empower the local inhabitants through the collective management of biodiversity (Conafor, 2009).

The new worldwide conservation schemes, such as the voluntary guidelines for conservation and the sustainable use of wild relatives of cultivated species, may provide an opportunity for the local farmers who have safeguarded the *V. planifolia* populations for centuries (FAO, 2017).

Conclusions

This paper documents, for the first time after forty years, the presence of *Vanilla planifolia* in *San Luis Potosí*, in 28 sites belonging to 17 localities of eight municipalities of the *Huasteca Potosina*. Besides the 28 georeferenced sites, a potential area of more than 85 km^2 with favorable environmental characteristics for the development of the species was identified and quantified. The relationship between the economy, the culture and the conservation of this species in the region dates back to at least two centuries ago. Although the inhabitants carry out an empirical management of the vanilla populations, this must be supplemented with scientific knowledge allowing a better conservation of the species. Furthermore, promotion of regulated exploitation schemes allowing to strengthen the local livelihoods and, at the same time, to diversify of the traditional production systems is required.

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Conflict of interests

The authors declare that they have no conflicts of interest.

Contribution by author

Karina L. Trinidad García: herbarium consultation, field work, development of the SDM, drafting of the document; Humberto Reyes Hernández: design of the study, support in the field work, data analysis, editing of the document; Rosa I. Martínez Salazar: support in the field tours, conduction of workshops; Erika Galarza Rincón: design of maps.

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