Technology
Arts Sciences
TH Köln

UNIVERSIDAD AUTÓNOMA DE SAN LUIS POTOSÍ

FACULTADES DE CIENCIAS QUÍMICAS, INGENIERÍA, MEDICINA

Y CIENCIAS SOCIALES Y HUMANIDADES

PROGRAMA MULTIDISCIPLINARIO DE POSGRADO EN CIENCIAS AMBIENTALES

AND

TH KÖLN - UNIVERSITY OF APPLIED SCIENCES

INSTITUTE FOR TECHNOLOGY AND RESOURCES MANAGEMENT IN THE TROPICS AND SUBTROPICS

CONNECTIVITY FOR CONSERVATION: A SYSTEMATC APPROACH TO LINK RELEVANT AREAS FOR CONSERVATION WITH THE BIOSPHERE RESERVE SIERRA DEL ABRA TANCHIPA

THESIS TO OBTAIN THE DEGREE OF

MAESTRÍA EN CIENCIAS AMBIENTALES

DEGREE AWARDED BY UNIVERSIDAD AUTÓNOMA DE SAN LUIS POTOSÍ

AND

MASTER OF SCIENCE

NATURAL RESOURCES MANAGEMENT AND DEVELOPMENT

DEGREE AWARDED BY TH KÖLN – UNIVERSITY OF APPLIED SCIENCES

PRESENTS:

COLUMBA MARCELLI SANCHEZ

CO-DIRECTOR OF THESIS PMPCA

DR.HUMBERTO REYES HERNANDEZ

CO-DIRECTOR OF THESIS ITT

DR.CLAUDIA RAEDIG

ASSESSOR:

Dr. CARLOS A. MUÑOZ ROBLES

COLOGNE, GERMANY AUGUST 25TH, 2019

PROYECTO REALIZADO EN:

UNIVERSIDAD AUTONOMA DE SAN LUIS POTOSI

COLOGNE UNIVERSITY OF APPLIED SCIENCES

CON EL APOYO DE:

CONSEJO NACIONAL DE CIENCIA Y TECNOLOGÍA (CONACYT)

DEUTSCHER AKADEMISCHER AUSTAUSCH DIENST (DAAD)

LA MAESTRÍA EN CIENCIAS AMBIENTALES RECIBE APOYO A TRAVÉS DEL PROGRAMA NACIONAL DE POSGRADOS

(PNPC - CONACYT)

Erklärung / *Declaración*

Name / *Nombre*: COLUMBA MARCELLI SANCHEZ

Matrikel-Nr. / *N° de matricula*: **11124625 (TH Köln) 286427 (UASLP)**

Ich versichere wahrheitsgemäß, dass ich die vorliegende Masterarbeit selbstständig verfasst und keine anderen als die von mir angegebenen Quellen und Hilfsmittel benutzt habe. Alle Stellen, die wörtlich oder sinngemäß aus veröffentlichten und nicht veröffentlichten Schriften entnommen sind, sind als solche kenntlich gemacht.

Aseguro que yo redacté la presente tesis de maestría independientemente y no use referencias ni medios auxiliares a parte de los indicados. Todas las partes, que están referidas a escritos o a textos publicados o no publicados son reconocidas como tales.

Die Arbeit ist in gleicher oder ähnlicher Form noch nicht als Prüfungsarbeit eingereicht worden.

Hasta la fecha, un trabajo como éste o similar no ha sido entregado como trabajo de tesis.

Köln /San Luis Potosí, den /*el* 22 DE AGOSTO 2019

Unterschrift / *Firma*: ______________

Ich erkläre mich mit einer späteren Veröffentlichung meiner Masterarbeit sowohl auszugsweise, als auch Gesamtwerk in der Institutsreihe oder zu Darstellungszwecken im Rahmen der Öffentlichkeitsarbeit des Institutes einverstanden.

Estoy de acuerdo con una publicación posterior de mi tesis de maestría en forma completa o parcial por las instituciones con la intención de exponerlos en el contexto del trabajo investigatición de las mismas.

Unterschrift / Firma: __________________

ACKOWLEDGES

I express my sincere gratitude to my supervisor Dr. Humberto Reyes and Dr. Claudia Raedig for their guidance, patience and dedication. My special gratitude also for my supervisor to Dr.Carlos Muñoz for his support and motivation.

I would like to thank to the personnel in the BRSAT Dr. Alejandro, Lic. Sandra, without their support on my field work this research could not have been possible.

A special thanks to Sandra and Marisela for their kind accompaniment during this 2 years.

To my friends and classmates in San Luis Potosi and in Germany for all the academic and personal support recived. My special thanks to Sergio for his inconditional support.

My deepest gratitude to my mother to help me achieving my goals, and to all my family for always encourage me and motivate to face new challenges.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF MAPS

LIST OF IMAGES

LIST OF ABBREVIATIONS

AHP	Analytical Hierarchy Process
BMZ	The German Federal Ministry for Economic Cooperation and Development
BRSAT	Biosphere Reserve Sierra Abra Tanchipa
CBD	Convention on Biological Diversity
CESMO	Corredor Ecológico de la Sierra Madre Oriental
CONABIO	La Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (National Comissiion for the Knowledge and Use of Biodiversity)
CONAFOR	Comisión Nacional Forestal (National Forest Commission)
CONANP	Comisión Natural de Áreas Protegidas (National Comission of Protected Areas)
FAO	Food and Agriculture Organization
GIS	Geographic Information Systems
GIZ	Deutsche Agency for Internal Cooperation
ILM	Integrated Landscape Management
INEGI	Instituto Nacional de Estadística y Geografía
INIFAP	Instituto Nacional de Investigaciones Forestales
IUCN	International Union for the Conservation of Nature
LGEEPA	Law of Ecological Balance and Environmental Protection
MBC	Mesoamerican Biological Corridor
DEM	Digital Elevation Model
NDVI	Normalized Vegetation
NGO	Non-Governmental Organization
ONU	Organización de las Naciones Unidas
PA	Protected Areas.
PES	Payment for Ecosystem Services
PNNP	National Program of Protected Areas
PROCAMPO	Programa de Estímulos a la Producción Agrícola (Subsidies to Agriculture Productivity)
PROGAN	Programa de Estímulos a la Producción Ganadera (Subsidies to Livestock Productivity)

RAMSAR	Convención Relativa a los Humedales de Importancia Internacional
RANP	Red Nacional de Areas Naturales Protegidas (National Network of Protected Areas)
SAGARPA	Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (Ministry of Agriculture, Livestock, Development Rural, Fishing and Food (
SDG	Sustainable Development Goals
SEGAM	Secretaría de Ecología y Gestión Ambiental. (Ministry of Ecology and Environmental Management)
SEMARNAT	Secretaría de Medio Ambiente y Recursos Naturales (Ministry of Environment and Natural Resources)
SMO	Sierra Madre Oriental
SNIB	National Biodiversity Information System
TNC	The Nature Conservancy – Mexico Program
TPSBC	Terrestrial Priority sites for Biodiversity Conservation
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNEP	United Nations Environment Programme
VDAC	Voluntary Destined Areas for Conservation
WCPA	World Commission on Protected Areas
WWF	World Wildlife Fund

ABSTRACT

In the last three centuries, the planet's biomes have changed. Human beings have drastically altered the quantity, pattern and composition of natural vegetation globally, fragmenting native vegetation in patches, forming a matrix composed by decreasing numbers of natural areas and growing numbers of areas modified by anthropogenic activities. When the connectivity between natural areas are altered by fragmentation, native biodiversity is threatened, because fragmentation isolates the habitat of plants and animals, preventing the movement of organisms and processes that occur in habitats of connected landscapes.

In this process, often areas designated for biodiversity conservation, the so-called Protected Areas (PA), become 'islands' surrounded by a matrix formed by anthropogenic activities. However, the conservation of biodiversity is optimized when protected areas are connected,

Due to international commitments, since 2016 Mexico, seeks to implement connectivity approaches into biodiversity conservation policies. The Biosphere Reserve Sierra Abra Tanchipa (BRSAT) is located in the mountain range Sierra Madre Oriental in northeastern of Mexico, has an exceptional landscape with an important extension of deciduous and sub-deciduous tropical forests with great biological diversity. This includes endemic and threatened taxa of plants and animals. BRSAT is surrounded by a complex fragmented landscape of agricultural activities, and land uses.

The aim of this research is to develop a systematic approach to link BRSAT with relevant areas for conservation integrating physical ecological and socio economic data of the landscape to find the most suitable areas for connectivity conservation and to explore their incorporation to a voluntary conservation scheme.

The analysis was made through mapping different criteria with Geographic Information Systems (GIS) (Arcgis 10.5) and with the Least Cost Path tool, using as a resistant layer, and the most relevant areas for conservation. Secondly, physical, ecological and socio economic data was combined to obtain a suitability map to identify the optimal areas for conservation adjacent to the connectivity route. This was achieved through an Analytic Hierarchy Process (AHP) method that considers experts weighted assessment for the elected variables. Finally, through interviews to landowners, government agents, and academia experts, to a brief look of the knowledge, motivations and constraints to establish protected areas to create connectivity under the national Mexican Scheme for 'Voluntary Destined Areas for Conservation' (VDAC) was obtained.

The routes connect BRSAT with relevant areas for conservation and go across mainly through Ejidos, with high and medium values of suitability. There were critical areas found, that could help to promote connectivity for conservation, mainly in the surroundings of BRSAT (Ejido las Pitas). In addition, areas with high suitability values for connectivity conservation were found in the south of the study area, close to Biosphere Reserve Sierra Gorda. This connectivity route has not being analyzed properly before. Moreover, according to the interviews there is a good potential establish VDCA to protect natural resources, to help to create connectivity and to generate benefits to the landowners.

This results helps to fulfill Mexican mandates to create new areas for conservation, and to reconnect to the threatened of BRSAT which otherwise would become an isolated area. Additionally, to explore among some stakeholders the potential to establish through the route, private protected areas destined voluntarily by the landowners.

Key words: Connectivity conservation – Protected Areas – Voluntarily Destined Areas for Conservation

RESUMEN

En los últimos tres siglos, los biomas del planeta han cambiado. Los seres humanos han alterado drásticamente la cantidad, el patrón y la composición de la vegetación natural a nivel mundial, fragmentando la vegetación nativa en parches, formando una matriz compuesta por un número decreciente de áreas naturales y un número creciente de áreas modificadas por actividades antropogénicas. Cuando la conectividad entre áreas naturales se ve alterada por la fragmentación, la biodiversidad nativa se ve amenazada, debido a que la fragmentación aísla el hábitat de flora y fauna, limitando el movimiento de organismos y procesos que ocurren en hábitats de paisajes conectados.

En este proceso, a menudo las áreas designadas para la conservación de la biodiversidad, las llamadas Áreas Protegidas (AP), se convierten en "islas" rodeadas por una matriz formada por actividades antropogénicas. Sin embargo, la conservación de la biodiversidad se optimiza cuando las áreas protegidas están conectadas,

Debido a los compromisos internacionales, desde 2016 México busca implementar enfoques de conectividad en las políticas de conservación de la biodiversidad. La Reserva de la Biosfera Sierra Abra Tanchipa (BRSAT) está ubicada en la Sierra Madre Oriental en el noreste de México, tiene un paisaje excepcional y una extensión importante de bosques tropicales caducifolios y subcaducifolios con gran diversidad biológica. Esto incluye taxones endémicos y amenazados de plantas y animales. BRSAT está rodeado por un complejo paisaje fragmentado de actividades agrícolas y usos de la tierra.

El objetivo de esta investigación es desarrollar un enfoque sistemático para vincular BRSAT con áreas relevantes para la conservación integrando datos físicos ecológicos y socioeconómicos del paisaje para encontrar las áreas más adecuadas para la conservación de la conectividad y explorar su incorporación a un esquema de conservación voluntario.

El análisis se realizó mediante el mapeo de diferentes criterios con los Sistemas de Información Geográfica (SIG) (Arcgis 10.5) y con la herramienta Least Cost Path (Ruta de menor coste), utilizando como capa de resistencia, las áreas más relevantes para la conservación. En segundo lugar, los datos físicos, ecológicos y socioeconómicos se combinaron para obtener un mapa de aptitud para identificar las áreas óptimas para la conservación adyacente a la ruta de conectividad. Esto se logró a través de un método de Jerarquía Analítica (AHP por sus siglas en inglés) que considera la evaluación ponderada de expertos para las variables elegidas. Finalmente, a través de entrevistas a propietarios, agentes gubernamentales y expertos de la academia, se obtuvo un breve acercamiento sobre el conocimiento, las motivaciones y las limitaciones para establecer áreas protegidas para crear conectividad bajo el Esquema nacional mexicano de 'Áreas Voluntarias Destinadas para la Conservación' (ADVC).

Las rutas conectan a la RBSAT con áreas relevantes para la conservación y atraviesan principalmente Ejidos, con valores altos y medios de aptitud. Se encontraron áreas críticas que podrían ayudar a promover la conectividad para la conservación, principalmente en los alrededores de RBSAT (Ejido las Pitas). Se encontraron áreas con altos valores de aptitud para la conservación de la conectividad en el sur del área de estudio, cerca de la Reserva de la Biosfera Sierra Gorda. Esta ruta de conectividad no se ha analizado correctamente antes. Además, según las entrevistas, existe potencial para establecer ADVC para proteger los recursos naturales, ayudar a crear conectividad y generar beneficios para los propietarios.

Este resultado puede auxiliar a cumplir con los mandatos mexicanos de crear nuevas áreas para la conservación voluntaria y para reconectar la BRSAT que de lo contrario se convertirían en un parche forestal aislado. Además, para explorar entre algunos interesados, el potencial de establecer a través de la ruta, áreas protegidas en el esquema del ADVC.

Palabras claves: Conservación para la biodiversidad - Areas Naturales Protegidas - Areas destinadas voluntariamente a la Conservación.

1 INTRODUCTION

1.1 FRAGMENTATION AND BIODIVERSITY LOSS

On a global level, fragmentation and loss of habitats are recognized as the main threats of biodiversity at a global level (Castro-Navarro et al., 2017; Fahrig, 2003; Fischer & Lindenmayer, 2007; Frost et al., 2006; Haddad et al., 2015).

The concept of fragmentation will be analyzed as a phenomenon that not only reduces the total amount of available habitat, but also isolates the remaining habitat, preventing the movement of organisms from one ecosystem to another and the respective processes that were carried out between them in previously connected ecosystems. First, the concept of fragmentation will be defined. Next, the causes and consequences of fragmentation will be listed and the relationship between this phenomenon and biodiversity loss will be clearly explained.

1.1.1 DEFINITION

The first hypotheses based on the biogeography of the oceanic islands provided a theoretical framework that allowed understanding the effects of fragmentation on species distribution. Terrestrial forest surrounded by a matrix of agricultural activities, become " islands "of natural habitat spread through a" sea "of habitat transformed by humans" (Kirkby, MacArthur, & Wilson, 1968).

In 1986, fragmentation was defined as a phenomenon that occurs in large areas of habitat, in which it is divided into increasingly smaller patches, and isolated by a matrix of habitats different from the original state of the matrix (Wilcove, McLellan, & Dobson, 1986)

Haddad (2015)adds this definition that the new matrix of habitats is the result of anthropogenic activities that modify land uses. Some authors define fragmentation as the division of a habitat (Fahrig, 2003), some others focus the definition in the influence of human activities in the process of habitat fragmentation (SEMARNAT et al., 2017b). Scientists do criticize the human impact, whereas governments usually drive fragmentation, and are shy to develop political strategies against fragmentation.

Understanding how fragmentation is influenced by human actions, allows prioritizing the protection and management of natural areas where there are options to protect large intact habitats or fragmented habitats (with the same total amount of habitat) (Loyola et al., 2019)). According to Fahring (2017)there are more authors that link biodiversity loss with habitat fragmentation "per se", despite there is no empirical evidence that supports the generalized assumption that a group of small habitat patches generally, have a lower ecological value than large patches of the same total area.

On the contrary, Fletcher (2018)specify that current literature indicate the negative ecological effects of fragmentation are not “per se”, given the unproven extrapolation of patterns and mechanisms at patch scale (size effects, patch isolation and edge effects) for purposes of habitat fragmentation at landscape scale.

Despite the different conclusions, both authors and their collaborators around the world confirm the effects of fragmentation on biodiversity and the urgency of working on solutions that minimize the causes and their effects, being undeniable that habitat fragmentation disrupts the connectivity, and is the main threat to global biodiversity (Fahrig et al., 2019).

1.1.2 CAUSES AND CONSEQUENCES OF FRAGMENTATION

Fragmentation is also a phenomenon that not only reduces the total amount of habitat available, but also isolates the remaining habitat, preventing the movement of organisms from one ecosystem to another and the respective processes that they carried out among themselves in their previously connected ecosystems. Therefore, he causes and consequences of fragmentation are related to the biodiversity loss and will be described above.

According to Fahrig (2003) fragmentation consequences can be summarize in two: habitat loss and fragmentation “per se”, being the elimination of habitat, the most common effect of the fragmentation process.

Fragmentation is linked to anthropogenic pressures. Nowadays, humans use almost half of the Earth surface to raise cattle(UNEP, CBD, & SBSTTA, 2011).When agricultural and livestock lands modify and separate fragments of natural ecosystems, these fragments are ecologically analogous to islands, - as in islands biogeography theory -, then the greater distance the islands have, the survival of biotic populations is affected. Consequently, the sustainability of ecological goods and services of forests, are at risk. This also will affect economic sectors dependent on natural resources, such as agriculture and livestock (SEMARNAT et al., 2017b

Fragmentation experiments considered by many as the most expensive and longest in ecology - have demonstrated up to 70%(Haddad et al., 2015) of the world's forest cover on the five continents is already facing some degree fragmentation this has reduced the biodiversity between 13% and 75%,(Haddad et al., 2015). This altered key ecosystem functions, especially in smaller and isolated fragments, in which the effects are magnified (Haddad et al., 2015). This changes in the matrix of the landscape, leaves fauna and flora habitat disconnected from other ecosystems (UNEP et al., 2011). Their mobility corridors are lost. (López Yela, 2017).

In the central Amazonia, forest fragments are found (ranging from one to 100 hectares,) which have undergone a great variety of ecological changes over the past 32 years. The evidenced has been registered through the “Biological Dynamics of Forest Fragments Project” or BDFFP, in which the impacts of fragmentation in the world's largest rainforest - the Amazon -, and biota are evaluated (Laurance et al., 2011)

The species richness of many organisms decreases according to the size of the fragments. For e.g, the decline in population rates is evident in flora (Aguilar & Tabarelli, 2010; Ibáñez, Katz, Peltier, Wolf, & Connor Barrie, 2014) and in fauna: insects (Habel et al., 2010), reptiles (Driscoll, 2004)birds (Ferraz et al., 2007), and primates (Boyle & Smith, 2010). For these groups, small fragments are not often able to maintain viable populations increasing edge effect that can lead to further biodiversity loss(Laurance et al., 2011).

In other cases, for some plants in mutualistic relations with ants, no significant decline in diversity was reported despite the habitat fragmentation this also influences biodiversity loss rates (Laurance et al., 2011). Extinction rates increased in some bird species and mammals that inhabits fragmented habitats have a higher probability of extinction (Crooks et al., 2017)

Land-use changes in rainforest lead to massive habitat destruction and as a consequence, fragmentation. The above mention, confirmed the effects of fragmentation, such species mobility, species extinction. Other effects can be added to the list: effect-border mortality(Lovejoy, et al., 1986), higher mortality of trees(Pütz et al., 2011), local seed loss and external seed rain, (Melo, et al., 2010), alterations in genetic flows (Drees, et al., 2011) and other population ecological process (Fischer & Lindenmayer, 2007; Pütz et al., 2011).

According to Martínez and colleagues, (2009) landscape fragmentation is “the last phase of habitat degradation process in which the forest surface decreases, the edge-effect increases and the subdivision of the habitat continues until the landscape loses its functionality ". This process occurs in two phases: 1) Habitat loss and its deterioration, without affecting the operation of the landscape; 2) Habitat loss with a surplus that leads to the isolation of habitat scraps. In the first phase, the habitat loss is hardly solvable, since in many cases it is a consequence of territorial demands for urban growth or agricultural expansion. In the second phase, the problems of fragmentation arise the need to maintain or increase connectivity between the remaining elements of the landscape(Martínez Alandi et al., 2009).

Given the growing concern and awareness of the effects of habitat fragmentation on natural systems, it is urgent to apply conservation and restoration measures to improve landscape connectivity and to reduce species high extinction rates and to maintain the ecosystem services

1.2 CONNECTIVITY AS A BIODIVERSITY CONSERVATION STRATEGY

Connectivity conservation describes actions taken to conserve landscape connectivity through conservation criteria and incorporating social and institutional dimensions(Worboys, Francis, & Lockwood, 2010). Connectivity conservation provides the methods of how to link areas for conservation purposes,

Nowadays, International Agencies like UN, FAO, UNESCO(FAO, 2017; GWS, 2018; UNEP, 2010), International NGOs IUCN, Nature Conservancy, The Wildlands Project, and World Wildlife Fund and numerous local government institutions are adopting strategies to promote connectivity(Salido Pérez, 2015); in order to maintain or regenerate population flows in fragmented ecosystems (Haddad & Tewksbury, 2006).

Connectivity is a relatively recent topic that seeks to respond to the habitat fragmentation. Reports mention, "Near 67,500 scientific articles have been published in 23 scientific journals in recent years. 328 and 352 articles had in their keywords connectivity and corridor respectively" (Guzmán Wolfhard & Raedig, 2019). Ecological corridor studies were relatively rare in 1980, but they grew prominently during the 1990.

Like any concept that arises in the field of environmental sciences, the term "connectivity" has a wide variety of definitions, interpretations, and evaluation methods (Fagan & Calabrese, 2007). Connectivity can be defined as "the ease with which plants and animals move between particular landscape elements; the number of connections between patches relative to the maximum number of potential connections" (Worboys, Francis, & Lockwood, 2010).

Improving connectivity can counteract the effects of fragmentation and habitat loss; resulting even more effective than focusing on targeting land-use changes. Connectivity does not require large areas to operate, or high levels of conservation, but rather a continuity of the well-planned and executed landscape (Martínez Alandi et al., 2009). While some authors conceive connectivity as "a property of the landscape as a whole", others conceive it as "a characteristic intrinsically associated with a unit of individual habitat" (Tischendorf & Fahrig, 2000)

1.2.1 LANDSCAPE CONNECTIVITY

To define the concept of landscape connectivity, it is necessary to define landscape. A landscape according to Mussi (2010) in (Guzmán Wolfhard & Raedig, 2019)is "a group of ecosystems that share flow interactions, under the influence of the same climate, with similar geomorphology, and subject to the same disturbances. From another perspective, landscape can be conceived as "a group of elements that define a geographical space where within its limits are carried out social economic and cultural interrelations with the natural environment, and with its transformations" (Manent-Bollo, 2017)

Forman and Godron (1981) and Fischer & Lindenmayer (Fischer & Lindenmayer, 2007), define three elements of the landscape: 1) The matrix, 2) The patches, and 3) The corridor, these elements can be analyzed and measured through landscape metrics to understanding the landscape process.

Landscapes are as a structural habitats, natural barriers, connectivity corridors and biological borders (Bennett, 2003). Notwithstanding landscape connectivity depends not only on the structural characteristics(Adriaensen et al., 2003).Landscape connectivity is also "the degree to which it is landscape facilitates or prevents the movement of organisms between ecological patches"(Taylor, Fahrig, & With, 2010).Is it then an “emerging property "of species' interactions with the landscape. For instance is essential for ecosystem health and biodiversity conservation (Haddad & Tewksbury, 2006; Zhang, Meerow, Newell, & Lindquist, 2019)

However, it should be consider that landscape connectivity is a human construct, which uses the word landscape to emphasize its anthropogenic nature (Fischer & Lindenmayer, 2007).

1.2.2 TYPES OF CONNECTIVITY

Fragmentation and connectivity of the landscape can be evaluated to show the distribution and land cover changes over time (Cubides Isaacs, 2011). Two types of connectivity: structural and functional can be described(Uezu, et al., 2005)

In terms of structure, connectivity can be defined as the spatial configuration of different habitat types (A. F. Bennett, 1999). Structural connectivity is related to the landscape patterns and the results of the density and complexity of the corridors, as well as the distance between patches, and the matrix (Uezu et al., 2005).

Structural connectivity does not incorporate any data on the dispersal capacity of species or the potential movement of organisms between patches (Fagan & Calabrese, 2007)In functional terms, connectivity refers to the behavioral response of individuals to the landscape structure (Bennett, 1999), the extent to which the species under study move through the landscape (Uezu et al., 2005).

Therefore, there are the two types of landscape connectivity: 1) Structural connectivity, which describes only the physical relationships between habitat patches such as habitat corridors and interconnected distances, which can be measured through a wide variety of landscape metrics and analytical-spatial approaches, and 2) Functional connectivity, which considers the response of organisms' behavior to the landscape structure (Moilanen & Nieminen, 2002).

Structural landscape connectivity increases when physical relations between habitat patches are enhanced. The use of structural connectivity strategies could improve functional connectivity for some species (Taylor et al., 2010)

1.2.3 ECOLOGICAL CORRIDORS

To optimize connectivity, there are several strategies; one is the use of ecological corridors. Linked to scientific and social contexts, the concept of ecological corridor appears in recent decades in scientific literature. An ecological corridor can be defined, as an extensive regional connections that aim to facilitate the movement of animals ecosystems and ecological processes different sections of the landscape" generally in a linear shape, which improves the ability of organisms to move between patches of their habitat", (Dobson et al.,1999; Worboys et al., 2010).

Corridors are formed by three elements: "The patches, the matrix, the corridors, all which are connected in a multidirectional form"(Guzmán Wolfhard, 2015). In recent studies, the great potential of certain land cover mixtures - for example, forests, mixed vegetation and grasslands - has been proven to provide corridors for the maximum number of species and thus allow biodiversity conservation (Ersoy, Jorgensen, & Warren, 2019).

For instance, the agriculture matrix is a concept that in recent years has been related to ecological corridors given the rise of anthropogenic activity. This matrix is an area of the landscape occupied by agricultural areas, human settlements, agroforestry, and remnant forests, and these matrices can function as habitat or as a corridor system linking distant protected areas(Wood et al., 2017).

It is essential to include the agriculture matrix if effective management is desired. Through this some species are able to migrate; although it is worth mentioning that some species, whose means of survival are found in forest areas, are unable to cross-large distances of open spaces between protected areas (Wood et al., 2017)Therefore, ecological corridors as a management strategy is complex.

There is wide variety of roles and functions that ecological corridors have for the conservation of biodiversity.

- According to the roles and functions they cover, ecological corridors can be classified as:
- Linear corridors, allowing the continuity of a habitat through level crossings, riverine vegetation or river systems.
- Stepped corridor or walkway: serves as a connection or passage between patches that are not connected, for example, small wetlands, urban parks or a sequence of islands.
- Landscape corridors, composed of a mosaic of habitats that form a connected landscape, examples of this type of corridor are mosaics of successive stadiums in a type of vegetation or a mosaic of plant communities controlled by different geologies (Bennett, 2003; Worboys et al., 2010).

Ecological corridors (in Mexico) are classified in 1) Biological Corridors, 2) Ecological Corridors, 3) Conservational Corridors and 4) Sustainable Development Corridors(SEMARNAT et al., 2017) :

- Biological corridors focus on functional and structural connectivity, for diverse taxa. This type of corridor is also known as a biodiversity corridor by some authors (Lino, 2007, cited in (Guzmán Wolfhard, 2015)
- Ecological corridors integrate the idea of landscape and patch structure in territorial entities of a larger scale with an ecosystem perspective.
- Conservation corridors are based on the concept of regional development and connectivity networks in diverse mosaics, considering the environmental aspects, the social aspects of sustainable practices and the participation of various actors
- Finally, sustainable development corridors, whose focus on the economic benefits of sustainable production and trade, are based on a governance model of inclusion, participation, cooperation and political integration

Ecological and biodiversity corridors seek to protect and conserve biodiversity through integration of different types of land use. This can be achieved by reconnecting the remaining fragments of forest areas at the regional level, thus ensuring the conservation of biodiversity and ensuring that ecosystems continue to contribute to the well-being of human populations (Worboys et al., 2010)

To do this, different methodologies can be used according to the physical or biological characteristics of the habitat, patches, and matrix and the function that will have the corridor(Panagakos, 2016) . One of the most common methods are the distances analysis tools, in Geographic Information Systems like Arcgis(Redlands, 2014). Specifically the Least Cost Path (LCP) tools(Adriaensen et al., 2003; Lee, Chon, & Ahn, 2014; Raney, 2009; Williams & Snyder, 2005; Zhang et al., 2019)

The method is a distance analysis method used to create connectivity paths (Garrido-Garduño & Vázquez-Domínguez, 2013; Penrod et al., 2006; Raney, 2009).This is the concept can be defined as the path that is drawn representing the movement with the lowest cost given through a resistance of each pixel, which is set in accordance with the objective to be achieved

It can be used, for example, to determine paths between large centers (matrices), small sites (patches) and links (corridors) (Lee et al., 2014)

This is often done by a suitability analysis; this describes areas that are characterized by a combination of certain properties. Often, the result of a suitability analysis is a suitability map. It shows which locations or areas are suitable for a specific use in form of a thematic map(GITTA, 2013)

Although, assume that corridor connectivity is the only solution to achieve biodiversity conservation, it is risky, some studies on the mobility of species through corridors are descriptive and not experimental, and the fact that some species can move from one natural area to another does not guarantee their reproduction and survival (Crooks & Sanjayan, 2006)

Nevertheless, there is a consent on some authors agrees that connect two areas, increases the mobility of species in the landscape (Beier, Majka, & Spencer, 2008; Haddad & Tewksbury, 2006; Sloan et al., 2019). The structural or physical continuity of the forest habitat will guarantee connectivity for the less mobile and more sensitive forest species to the effects of fragmentation. Once the possibility of dispersal of these is guaranteed, it is assumed that it will also be secured for the rest of the species with greater mobility (Martínez Alandi et al., 2009)

In summary, the processes of landscape modification are complex and involve human actions. There are many anthropic factors associated with the modification and fragmentation of the landscape (Fischer & Lindenmayer, 2007). The use corridors as a biodiversity conservation approach, should consider, but should include socio economic factors.

Despite this, there are few methodologies that to, considering socio-economic criteria to stablish connectivity paths or corridors. Therefore, for this research work it is proposed to follow a connectivity approach by conservation areas.

1.2.4 CONNECTIVITY CONSERVATION AREAS

Connectivity conservation areas is defined by the use of biodiversity conservation criteria, including social and institutional dimensions as "a complex natural and semi-natural lands that are spatially defined as the area subject to a connectivity conservation vision and management. It potentially includes core protected areas and a range of different land owners, land tenures and land uses" (Worboys et al., 2010)

Therefore, for the purposes of this investigation, connectivity will be considered as a systematic approach that allows the conservation of biodiversity through corridors that promote the mobility of species in a fragmented landscape, composed of natural areas and areas modified by human activities, with a multi objective vision of the landscape, through areas relevant to conservation.

1.2.5 INTEGRATED LANDSCAPE MANAGEMENT AND CONNECTIVITY

In Mexico, land use changes had dramatically reduced the forest vegetation cover in the last 60 years, interrupting the continuity of the habitat and increasing the biodiversity loss (Castillo, 2017)

There is an urgency to act, and to responds to international commitments particularly to the Strategic Plan for Biological Diversity 2011-2020 and to the Aichi targets (CDB, 2018):

"By 2020, at least 17 per cent of terrestrial and inland water areas and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services,

are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscape and seascape “ (CDB, 2018).

For this purpose, Mexico presented at the 13th Conference of the Parties in 2016(COP 13) a document called National Vision of Integrated Landscape Management (ILM) connectivity (Vision Nacional del Manejo Integrado Del Paisaje y Conectividad). With this approach, Mexico seeks to integrate ILM and Connectivity into conservation policies (SEMARNAT et al., 2017).

ILM is one approach to address interconnected social, environmental, economic and political challenges focusing on integrated solutions at landscape scales (Reed et al, 2016). Although there are many approaches on landscape territorial planning, the international community since 2012 recognize the ILM as a main strategy to reach sustainability at a landscape scales (FAO, 2017; Scherr, Shames, & Friedman, 2013)that can be defined as:

“Integrated landscape management refers to long-term collaboration among different groups of land managers and stakeholders to achieve the multiple objectives required from the landscape. These typically include agricultural production, provision of ecosystem services; protection of biodiversity, landscape beauty, identity and recreation value; and local livelihoods, human health and well-being. Stakeholders seek to solve shared problems or capitalize on new opportunities that reduce trade-offs and strengthen synergies among different landscape objectives (…)” (Scherr et al., 2013)

Therefore, ILM depends on the connectivity between different conservation schemes, managed by different stakeholders, such as Protected Areas, biological corridors and sites under sustainable forest management, fishing shelters, water reserves, among others, achieving three main aspects (SEMARNAT et al., 2017):

- The effective and equitable administration of protected areas
- The connection of protected areas
- The integration of protected areas into wider land and marine landscapes.

In conclusion, ILM proposes an approach of environmental management, based on the landscape perspective that combines the protection of biodiversity in a context of anthropic complexity. In this approach, PA represent nodes of connectivity in diverse landscapes, where zones of ecosystem relevance and high biodiversity are also integrated, not necessarily under a status of protection.

1.3 BIODIVERSITY CONSERVATION IN MEXICO

Mexico, has the fourth largest mega biodiversity after Brazil, Colombia and Indonesia (Espinosa-Organista, D.& Ocegueda-Cruz, 2008; Jiménez Sierra et al., 2014)This natural capital has suffered an alarming anthropogenic impact for centuries, which has intensified in the last 50 years (CONABIO, 2008; Espinosa-Organista & Ocegueda-Cruz, 2008; López-Barrera et al., 2017; Sarukhán et al., 2017).

Deforestation has severely affected tropical ecosystems. Land use changes, mainly due to agricultural and urban expansion, have resulted in the loss of forest areas important for biodiversity conservation (Schelhas, 2007). The Global Forest Resources Assessment conducted by FAO indicates that Mexico's deforestation rate for 2015 was −0.1% per year, compared to the 1990-2000 period that was -0.3% per year (FAO, 2015a, 2015b; López-Barrera et al., 2017)).

Although the number of hectares deforested has decreased, the primary forest area still loses up to −0.7percentage each year FAO, 2015a. In addition primary forest degradation and fragmentation has been increasing during the las 50 year, which is critical (Sarukhán et al., 2017)

The biological costs of deforestation in Mexico are reflected in the 49 taxa extinct and the numerous threatened species (Sarukhán et al., 2017(**¡Error! No se encuentra el origen de la referencia.**).

Table 1. Threatened species in NOM-059-SEMARNAT. Own elaboration. Source: (Sarukhán et al., 2017)

Category	Plants	Fungi	invertebrates	Fish	Amphibian	Reptiles	Birds	Mammals	Total
Extint	6	0	0	13	0	0	19	11	49
Critically	183	10	20	81	7	27	95	52	475
Endangered	340	28	12	80	44	142	126	124	896
Vulnerable	458	8	17	30	143	274	152	104	1186
Total	987	46	49	204	194	443	392	291	2606

This high rate on biodiversity loss has created in the Mexican environmental agencies the urgency to to protect biodiversity and the ecosystem services it provides. PAs are the key element for the conservation of biodiversity, but it should be mentioned.

1.3.1 PROTECTED AREAS

At a global level PA are the main instruments for biodiversity conservation (Saura et al., 2018).Since the mid-twentieth century, protected areas have been a cornerstone strategy to prevent deforestation, reduce habitat loss, maintain ecosystem services and preserve biodiversity (Alvarez et al., 2013; Andam et al., 2008; SEMARNAT et al., 2017). In addition, PA provide benefits to human communities through access to natural resources, raw materials, medicines, they are a mitigation tool for climate change and in many cases they are important for their cultural and educational value (UICN, 2018).

According to the World Commission on Protected Areas (WCPA), 12% of earth surface is under some category of protection (IUCN & WCPA, 2010). Although is recognized does not guarantee that they are optimally conserved areas. Biodiversity and habitats rates continue to rise (Butchart et al., 2010; Geldmann et al., 2015).

The International Union for the Conservation of Nature (IUCN) defines in (Dudley, 2008) protected areas as, "A clearly defined, recognized, dedicated and managed geographical space, through legal means or other types of effective means to achieve conservation in the long term of nature and its ecosystem services and their associated cultural values. "At the international level, the objectives of creation of the Natural Areas are very diverse and are managed by a large number of very diverse actors (Dudley, 2008; Geldmann et al., 2015)

Therefore, there are different organizations that recognize the importance of the Protection of Natural Areas and have granted different categories based mainly on the reasons for their establishment. The IUCN categories are recognized by international initiatives such as the United Nation Convention on Biological Diversity (CBD), by governments and national laws as the standard and reference of the diversity of forms of protected area management and their categorization (Dudley, 2008), to create a common understanding and international framework of reference for protected areas both between and within countries

In Mexico, the definition of Protected Areas is in the General Law of Ecological Balance and Environmental Protection (LGEEPA) in the third article section II: "Areas of the national territory (…)where the natural environments have not been significantly altered by human activity or that require preservation and restoration"(LGEEPA, 2012)

There are different categories of Protection according to their relevance and motive of creation. According to IUCN is show in Table 2

Table 2.Classification of federal protected natural areas in Mexico according to the IUCN classification. Source: (Gutiérrez-Carbonell & Bezaury-Creel, 2009)

Category	Code	Terrestial PA	Marine PA
Strict Nature Reserve	UICN Ia	ZN-RB, Sant. (APFF Islas del Golfo de California excepto Isla Tiburón)	ZN-RB, Sant.
Wilderness Area	UICN Ib	In project through voluntary certification VDAC	-
National Park	UICN II	PN	

Natural Monument or Feature	UICN III	MN, PN Arqueological	
Habitat/Species Management Area	UICN IV	-	
Protected Landscape/ Seascape	UICN V	-	
Protected area with sustainable use of natural resources	UICN VI	ZA-RB, APFF, APRN (APFF Tiburon Island)	ZA-RB-APFF
No IUCN category		PN Degradated y APRN Las Huertas	

*ZN: core zone of BR; RB: biosphere reserve; Sant. sanctuary; RN: nature reserve; VDAC: Voluntarily destined Area for Conservation; PN: national park; MN: national monument; ZA: buffer zone of BR; APFF: area of protection of flora and fauna, APRN: area of protection of natural resources. *Biosphere reserves core zone are category Ia and the buffer zone is IB.*

Convention on Biological Diversity (CBD), through an analysis of gaps and omissions of terrestrial and marine biodiversity in Mexico, determined that at least 43% of the country's surface area should be protected. Although this action would be unfeasible (Gutiérrez-Carbonell & Bezaury-Creel, 2009).PAs occupies 90 839 521 ha of the National territory which 23.6 percent corresponds to continental, freshwater and island terrestrial (SEMARNAT & CONANP, 2018).

Despite the current diversification in the PA categories and surface, it is recognized by CONANP this are by “islands of conservation” because of the lack of connectivity (SEMARNAT et al., 2017). The concept of PAs is evolving towards integrating different spaces of the countryside, with distinct characteristics, and tenure of the land where proprietors obtain benefits in conservation.

Therefore, in the National Program of Protected Areas (PNNP 2014-2018) the specific objective: “Achieve an Integrated Landscape Management of the PA, its buffer zones, through mechanisms that ensure the conservation of ecosystems, biodiversity, and ecosystem services, and the sustainable use of their natural resources through criteria of inclusion and equity. This will be evaluated by the increase in the number of Voluntary Destined Conservation Areas” (VDAC) (SEMARNAT, 2018).

1.3.2 VOLUNTARILY DESTINED AREAS FOR CONSERVATION (VDAC)

In Mexico, Protected Areas, mainly, have been promoted and established by government institutions (Semarnat, 2006). Historically, before the arrival of the Spaniards, indigenous communities have protected their natural heritage. Indigenous communities such as Milpa Alta in Mexico City, the Zapotec and Chinantec communities of the Sierra Juárez in Oaxaca; the Chimalapas zoques; the huichol communities of Jalisco or the Tepehuana communities of the South of Durango, among many others, have defended the possession of their lands and have protected their ecosystems land tenure scheme in Mexico is also a key factor in voluntary conservation.

Currently, communities and Ejidos own most of the forest areas. This is a system of communal land tenure and individual use. After the Mexican Revolution of 1910 the Mexican federal government created the Ejido, to redress long-standing land-tenure inequality(Perramond, 2008).

This permanence in land use is mainly due to the following reasons: the restrictions presented by these areas for the development of conventional agriculture and livestock; the interest of communities in protecting their forests or simply because they are lands that have not yet been given use (Anta, 2007).

In 1996, a reform of the General Law of Ecological Balance and Environmental Protection (LGEEPA, 2012) mentions the scheme of VDCA, "Indigenous peoples, social organizations, public or private persons may voluntarily allocate the properties that belong to them to actions to preserve ecosystems and their biodiversity. For this purpose, they may request the respective recognition from the Secretariat by issuing the certificate."

DEFINITION

The VDAC have a very high protection status (equivalent to Ib IUNC classification), Main criterion is that the land has to be owned which can be protected, and it is only possible in a legal process: This is also done in other countries, e.g. Brazil(Guzmán Wolfhard & Raedig, 2019) and United States(Dayer et al., 2016)

Privately protected areas are an integral and complementary approach to biodiversity conservation onto privately owned land increasingly recognized as a viable alternative of public stewardship (Dayer et al., 2016; Selinske et al., 2019)

The VDCA, are a voluntary biodiversity conservation scheme in Mexico. Those interested certify before the Ministry of Environment and Natural Resources (SEMARNAT) and CONANP properties that have characteristics of PA. Their owners, in accordance with their own management strategy (LGEEPA, 2012), will manage these areas.

The general assumption is that unprotected areas tend to have less diversity and more invasion, possibly because of more intensive management or more frequent human disturbance. On the other hand, many non-protected areas may be managed in ways that maintain plant and animal populations. In some cases, private lands have been found to support higher levels of biodiversity than PA(McCune, Van Natto, & MacDougall, 2017)

They are opposable to third parties once registered in the Public Registry of Property and Commerce, or in the National Agrarian Registry (GIZ & CONANP, 2016)

REGULATORY FRAMEWORK

The establishment, Administration and Management of Areas Destined Voluntarily to Conservation is dictated in the LGEEPA, Article 77 BIS and chapter 5 of title VII of the Regulations of the General Law of Ecological Balance and Protection of the Environment in Protected Areas (LGEEPA, 2012)

For the certification of the property, the main requirements are:

- Application format to devote Voluntary Areas to Conservation established by certificate Modality: Without identification and inclusion of features to highlight the property.
- Description of the general physical and biological characteristics of the area, specifying the present ecosystems, relevant flora and fauna species to be protected.
- Valid official identification, for individuals and legal representatives. Constitutive act in the case of a legal entity.
- Document proving the legal representation of the promoter
- Legal documents that prove ownership of the property
- Georeferenced map
- Photographs that identify the characteristics of the property to be certified
- Management strategy for the conservation of the property: a) Zoning of the area, specifying the surface of each zone, b) Actions for the protection, conservation and restoration of natural resources, c) Guidelines for the use and use of natural resources of the area property.

Properties can be certified on three distinct levels; priority areas, intermediate areas, and basic areas. This hierarchy is granted by the general physical and biological characteristics of the property: The size of the surface, the state of conservation of the ecosystems, the management strategies presented, biodiversity, presence of endemism's, development of research activities and or environmental education, among others (CONANP, 2014).

By 2019, there are 348 certified areas distributed in 24 states, with a total surface of 549,078 ha. Oaxaca has 124,098 ha certified surface, Campeche and Guerrero with 104,314 and 57,918 ha, respectively (CONANP, 2014). In San Luis Potosi, there is no certified area under this modality yet.

BENEFITS OF CERTIFYING A VDAC

At 19 years of the certification of the first VDAC, CONANP has verified benefits of the conservation scheme as mention in the Table 1

Table 3.Benefits of VDAC. Source: Own elaboration. Source: (CONANP, 2014

Benefits of certifying a property as an VDAC		
Economic	**Social**	**Environmental**
• Sustainable use of natural resources. • Shielding against land use changes. • Added value to products or services.	• Sustainable development model • Contribution to food security • Territory cultural identity planning • Strengthening the local and regional governance	• Mitigation and adaptation to climate change effects • Improvement of infiltration, quality and quantity of water • Contributes to the fulfillment international commitments

Therefore, the possibility that communities and ejidos, and private owners may have the opportunity to establish their own conservation areas voluntarily and that this scheme be recognized and stimulated by government institutions and society, is of particular importance. The potential for its establishment new conservation areas should be analyzed

1.3.3 BIOLOGICAL CORRIDORS IN MÉXICO AS PROTECTED AREAS

Although Biological Corridors in Mexico are promoted by federal institutions such as CONABIO and CONANP, have not a protection category status itself. Although they can be protected, if they link areas with a protected status. This is the case of Biological corridor of Chichinautzin in Puebla. It is categorized according to Mexican status as an "Area of Protection of Flora and Fauna" (SEMARNAT, 2018). Since many years different proposals to recognize diverse corridors have been proposed, e.g, in the south of Mexico 9 biological corridor were recognized for its relevance to biodiversity conservation(CONABIO, 2015)

In addition, international initiatives have been made for the establishment of corridors. Mesoamerican Biological Corridor (MBC) has the goal of connect PAs in a multinational scale, to maintain biodiversity thus biological connectivity and conservation measures. Albeit the relevance of MBC is high (CONABIO, 2012). Work at this scale requires considerable efforts of institutional coordination, territorial management and high budgets; which difficult achieving the objectives of its creation, as is the case of the Sierra Madre Oriental Ecological Corridor (CESMO by its acronym in Spanish).

1.3.4 ECOLOGICAL CORRIDOR IN THE SIERRA MADRE ORIENTAL

Created with the support of the Deutsche Agency for International Cooperation (GIZ), The German Federal Ministry for Economic Cooperation and Development (BMZ) and CONANP. The CESMOs objectives were the creation of an ecological corridor to improve connectivity between the area's ecosystems and strengthen management both in the conservation areas themselves and in the buffer zones in the Sierra Madre Oriental (SMO).

In 2012, an area of over 4 million hectares, 5 states and over 250 municipalities align to shared vision and began a project to develop strategies for sustainable regional management through the approach of integrated landscape management and connectivity(GIZ, 2012).

Although the CESMO´s objectives was not completely fulfilled, it left important precedents for achieving connectivity in the area, through relevant sites for conservation, protected areas, and including different stakeholders and landowners needs, in order to minimize fragmentation and its effects on biodiversity. According to Reyes-Hernandez (2009), a severe case of habitat fragmentation could be observed in this SMO region.

SMO is an area of great biological, cultural and socio-economic importance for achieving connectivity in the area. Particulary, the Biosphere Reserve Sierra del Abra Tanchipa is located in the SMO region in the State of San Luis Potosí. This is recognized internationally ((GWS, 2018) for being an important area, not only by the extension of deciduous and sub-deciduous tropical forests in a great state of conservation, but also in by the numerous animal and plants species, wide valuable in biological diversity(SEMARNAT, 2014). BRSAT and surroundings had been studied before as a relevant site for conservation (CONABIO, CONANP, & TNC, 2008; GIZ, 2012; Terán-Valdez, 2013).

Through diverse methodologies has been proven high fragmentation in the surrounding of RBSAT and need to connect the fragmented landscape has been reported in different region's studies (Castro-Navarro et al., 2017; GIZ, 2012; Reyes et al., 2016; Terán-Valdez, 2013)(Errejón et al., 2018).

The problems mentioned in this introductory chapter on fragmentation and lack of connectivity and its consequences for biodiversity, the isolation of natural protected areas and the fragility of the remaining habitats, evidences the urgency to counteract this effects and to connect the relevant areas for biodiversity conservation

1.3.5 PAYMENT OF ECOSISTEM SERVICES IN MEXICO

Payments for environmental services (PES) are policy instruments for forest conservation. PES programs are recognized internationally as an efficient strategy for the conservation of the services provided by ecosystems (Bommarco, Vico, & Hallin, 2018; Wood et al., 2017). In Mexico, PES, grants a payment per hectare to forest owners, with the purpose that they preserve their lands in order to obtain the benefits from the forest like, the recharge of the aquifers, forest conservation, climate regulation among others(Bezaury-Creel, 2009; SEMARNAT & CONANP, 2018). The payment for environmental services is promoted by CONAFOR

The areas eligible for PES are based on the degree of conservation of forest ecosystems, and this subsidy is frequently used by CONANP to focus resources to PAs. It is a recognized subsidy at the rural level, although some authors mentions that payment made by CONAFOR does not guarantee the conservation of forests or the provision of ecosistem services in the long term. However, exist great demand to obtain it. PSA usually lasts for 5 years, and it can be renewed a limited number of times, so CONAFOR promotes the VDCA scheme at the end of the period of access to the subsidy, and vice versa, CONAFOR and CONANP promote the establishment of VDCA to access PSA subsidies.

1.4 JUSTIFICATION

Despite the existence of Protected Areas, biodiversity continues to decline (Butchart et al., 2010)(Butchart et al., 2010). Given this, the different land uses of the national territory and the abundance of fragmented landscapes make it difficult to conserve large areas or land, caused by an abundant array of human activities, different land tenures' interests among others. Connecting fragments of relevance to landscape conservation is a quite viable option(García Quiroga & Abad Soria, 2014).

In Mexico, derived from anthropogenic pressures. In the portion of the Sierra Madre Oriental belonging to San Luis Potosí, which BRSAT belongs? 13% of the area with natural cover is susceptible to Land Use Changes; is estimated that in 6 years this values could be triplicate (Sahagún-Sánchez, Reyes-Hernández, Flores Flores, & Vargas, 2011).This area constitutes a natural biological corridor of high biological and cultural diversity and importance(Luna, Morrone, & Espinosa, 2004)

The methodologies used for the creation of corridors in many cases do not incorporate the heterogeneity of social and economic factors or the interests of landowners(Terán-Valdez, 2013).

In addition, there is no category of protection for biological corridors in Mexico. New ways to connect the sites relevant to the conservation in the landscape where matrix has become incompatible with the wildlife movement(Beier et al., 2008) should be and explore new sites with conservation possibilities that had not previously been considered for being in fragmented matrices

There is a national mandate to create VDCA; it should be used to seek connectivity. To this end, this study will work to smaller scale, to provide a systematic approach to link BRSAT through relevant areas for conservation with other PA of the region, considering physical biological social and economic elements of the fragmented landscape and explore the incorporation of relevant sites for conservation to VDCA scheme.

2 OBJECTIVES

2.1 GENERAL OBJECTIVE

- To analyze landscape connectivity in the BRSAT and the incorporation of new conservation areas for connectivity corresponding to a Private Conservation Area scheme in Mexico (Voluntarily Destined Areas for Conservation).

2.2 SPECIFIC OBJECTIVES

- To determine the study area based on its structural connectivity with two adjacent biosphere reserves.
- To identify connectivity paths to link BRSAT with other protected areas through areas relevant areas for conservation.
- To obtain suitability maps for connectivity conservation incorporating physical, ecological, anthropogenic pressure and socio-economic criteria.
- To explore the incorporation of VDACs as a possible connectivity conservation strategy in the study area.

3 STUDY AREA

3.1 GENERAL CHARACTERISTICS

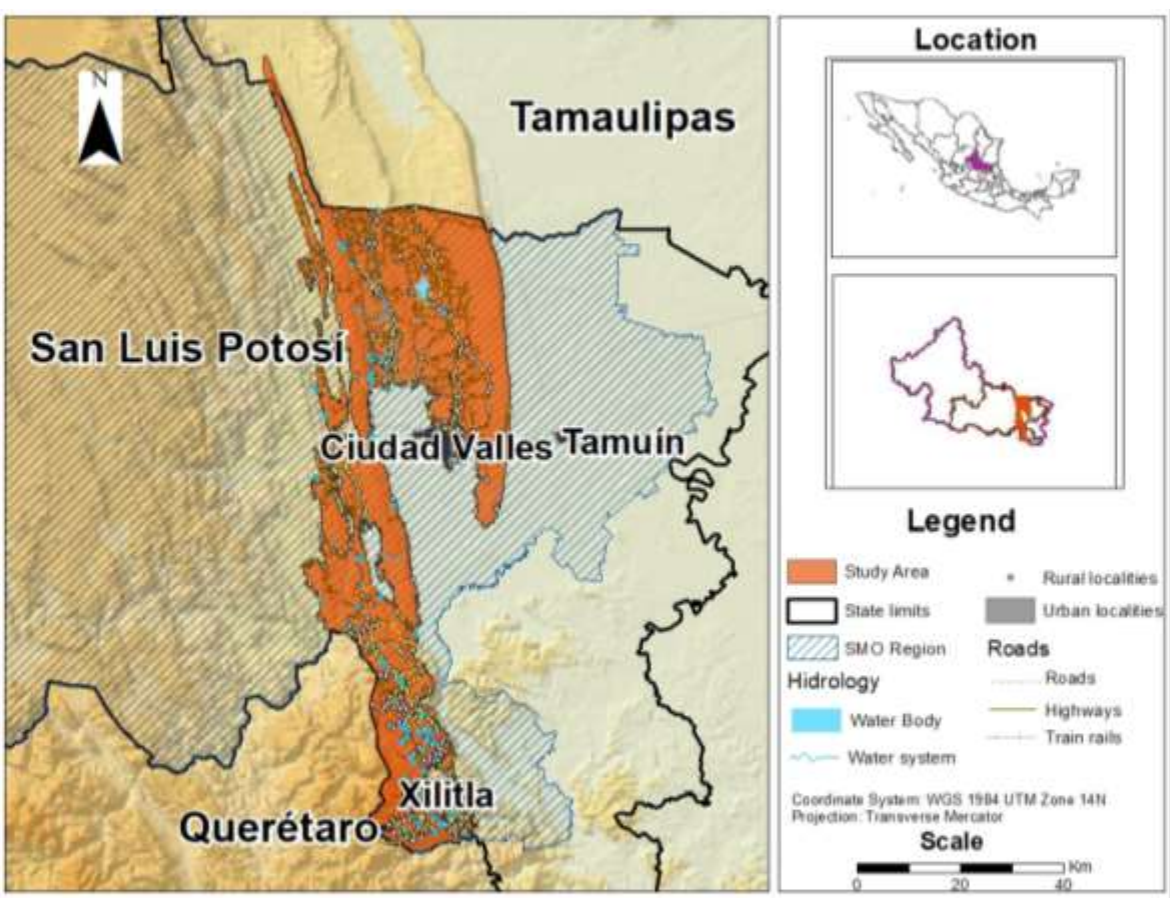
Several studies recognize BRSAT importance for biodiversity conservation(Castro-Navarro et al., 2017; GIZ, 2012; López Báez & Santos Reynoso, 2016; Luna et al., 2004; Suárez-Mota et al., 2017).

To find connectivity paths with other PA of San Luis Potosi, first the connectivity at a larger scale was assessed. BRSAT is located between two other important biosphere reserves, El Cielo in the north (State of Tamaulipas) and Sierra Gorda in the south (State of Queretaro). Ecological importance, and need of creating a “corridor” among this areas has been reported before (Errejón Gómez et al., 2018) This process is explained in methodology chapter in

Map 21.

The study area was limited to the area lined in orange in (

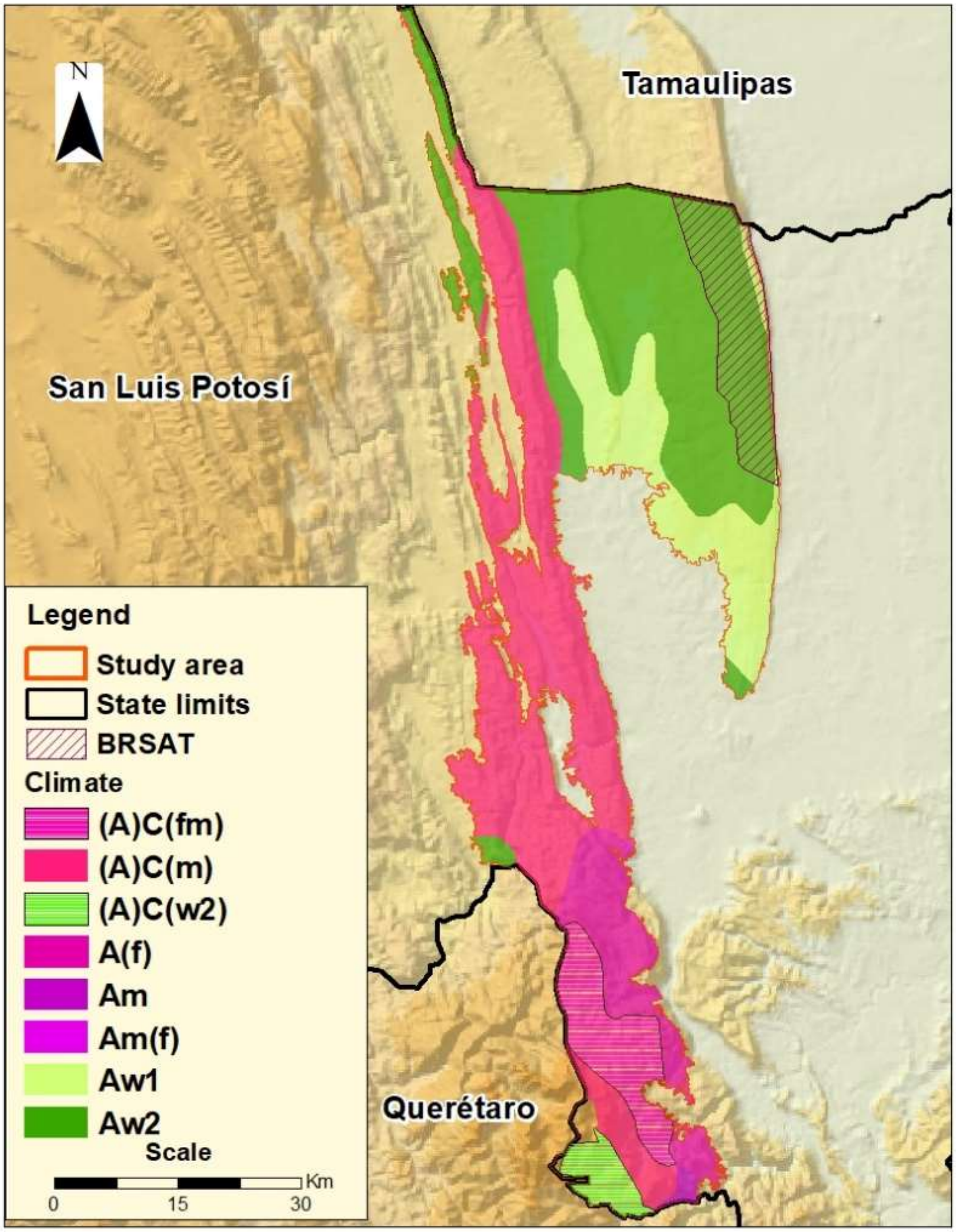
Map 1).



Map 1. Study Area Localization. Own Elaboration. Source: (INEGI, 2018)

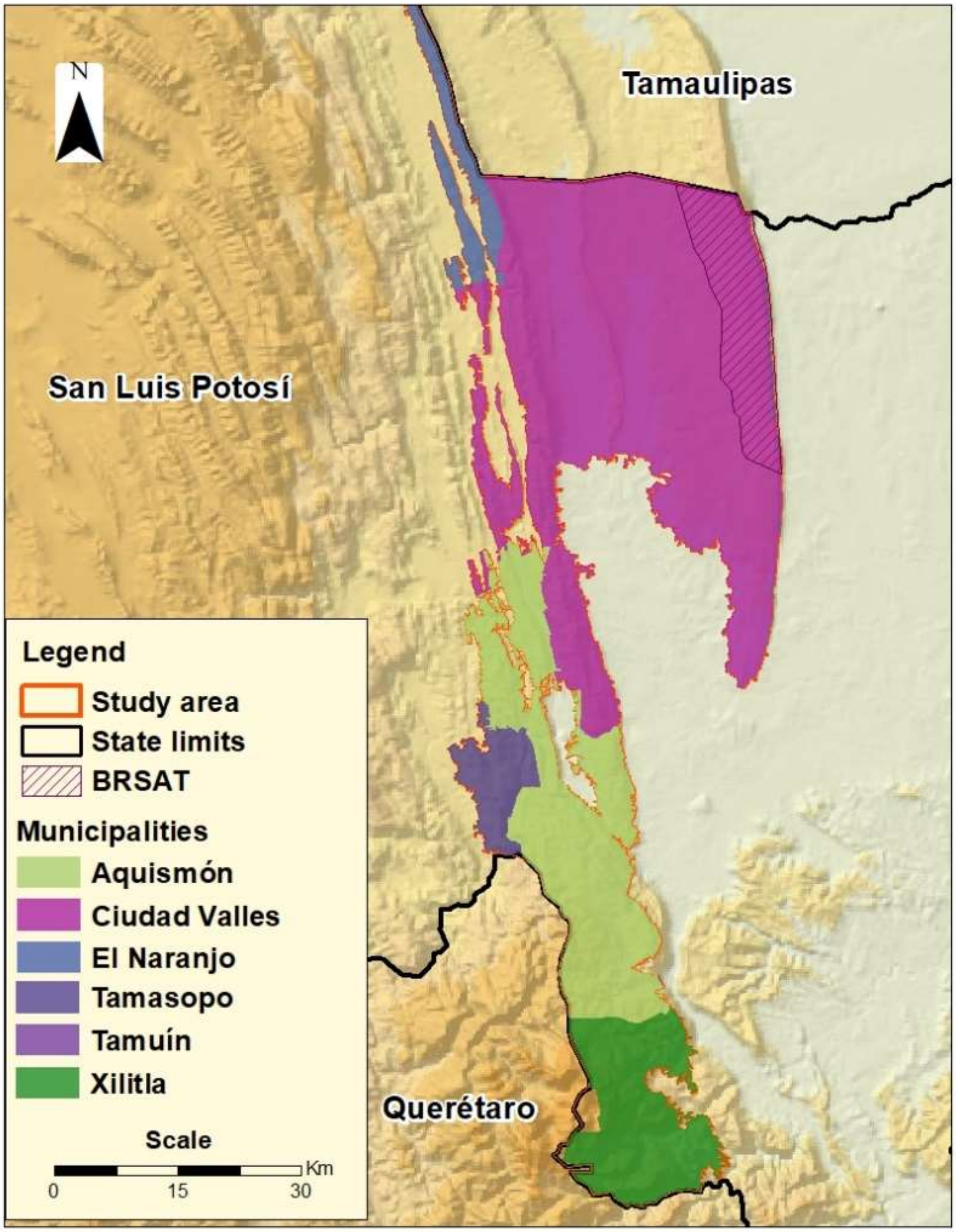
LOCATION

The study area is located in the Sierra Madre Oriental (SMO) (Map 1).This is vast mountain system located at the northeast-southeast from the south of the Rio Grande and the Gulf of Mexico to the Eje Neovolcánico Mexicano (22°40´N y 99 40' W hasta 21° 08' N y 98 50’).



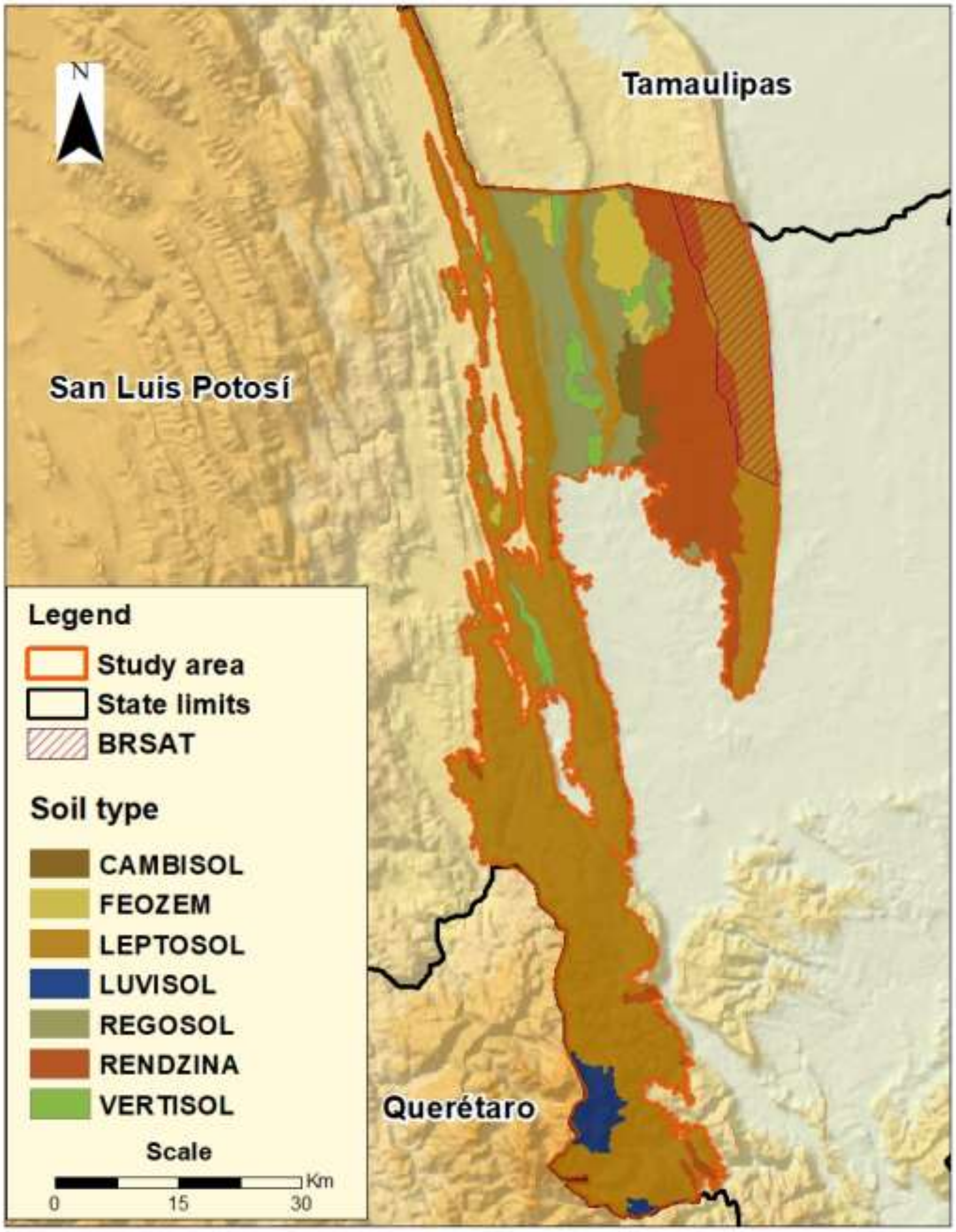
Map 2. Climates in in the study area. Own elaboration. Source: (CONABIO, 2019a)

Being approximately 800km long and 100km wide, it comprises an area of around 70,000 km^2 with heights ranging from 150 to more than 3000m (Castro-Navarro et al., 2017; Ortíz-Rodríguez, Muñoz-Robles, & Borselli, 2019)



Map 3. Municipalities in the study area. Own elaboration. Source: (CONABIO, 2019a)

The predominant climates (Map 2). According to Köppen modified by Garcia, are mostly temperate, semi-arid, humid and sub-humid (A) C, warm humid and sub humid (Am, Af and Aw) (Hernández-Cerda & Carrasco-Anaya, 2004). The temperature ranges in 2 main groups: warm (22 ° and 26 ° C), semi warm (18 ° and 22 ° C) (CONABIO, 2019a; Hernández-Cerda & Carrasco-Anaya, 2004).



Map 4. Soil types in the Study area. Own elaboration. Source: (CONABIO & INIFAP, 1995)

The climatic and orographic diversity in the SMO combined with the interaction of the Tropical and Neotropical biogeographic provinces favors the presence of different biomes, and high biological diversity (Luna et al., 2004; Suárez-Mota e al., 2017) The heterogeneity of ecosystems is also high: coniferous and oak forests, cloud forests, and evergreen tropical forest can be found. This abundance of diversity of habitats leads to the presence of a large number of species from all taxonomic groups (Luna et al., 2004). The vegetation in the study area is heterogeneous (Table 4). The land uses (Map 5), shows a fragmented landscape by agricultural areas

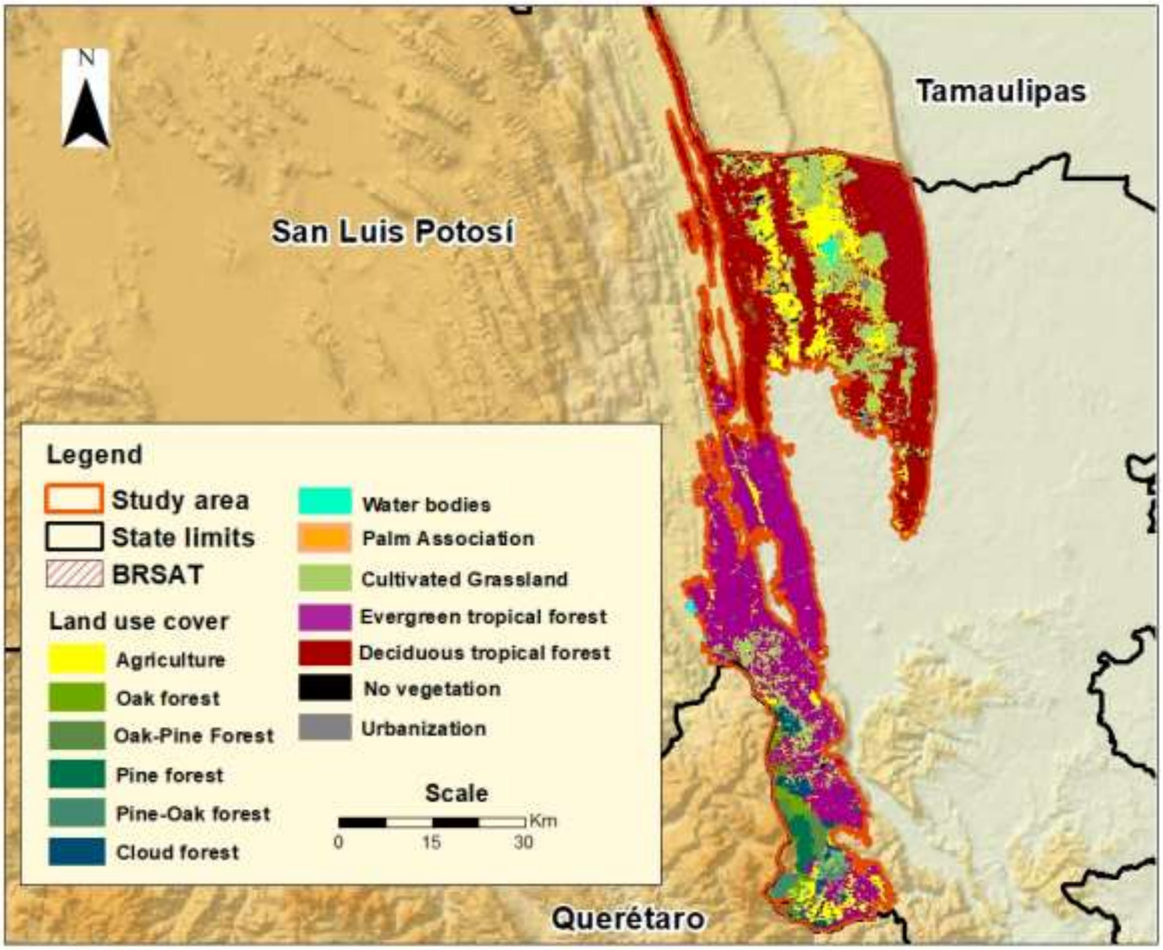
The study area has a surface 75, 9732 km2 distributed in 6 municipalities of the state of San Luis Potosí: Aquismón, Ciudad Valles, El Naranjo, Tamasopo, Tamuín and Xilita (Map 5).

According to CONABIO and INIFAP(1995), the soil types in the area are predominantly Leptosols (FAO, 2008). In the area also were classified Rendzina, Vertisol, regosoles, luvisoles, feozem, cambisoles, (Map 4).

Table 4.Land Use in the Study Area. Own elaboration. Source: (CONAFOR 2012)

Vegetation	Hectares
Agriculture	333743.62
Oak forest	4243.46
Oak-pine forest	3005.17
Pine forest	2741.78
Pine Oak forest	2583.86
Cloud forest	4114.43
Water bodies	1426.73
Palm association	815.01
Cultivated grassland	35065.81
Evergreen tropical forest	88192.52
Deciduos tropical forest	8908.78
No vegetation	26157.03
Urbanization	333743.62

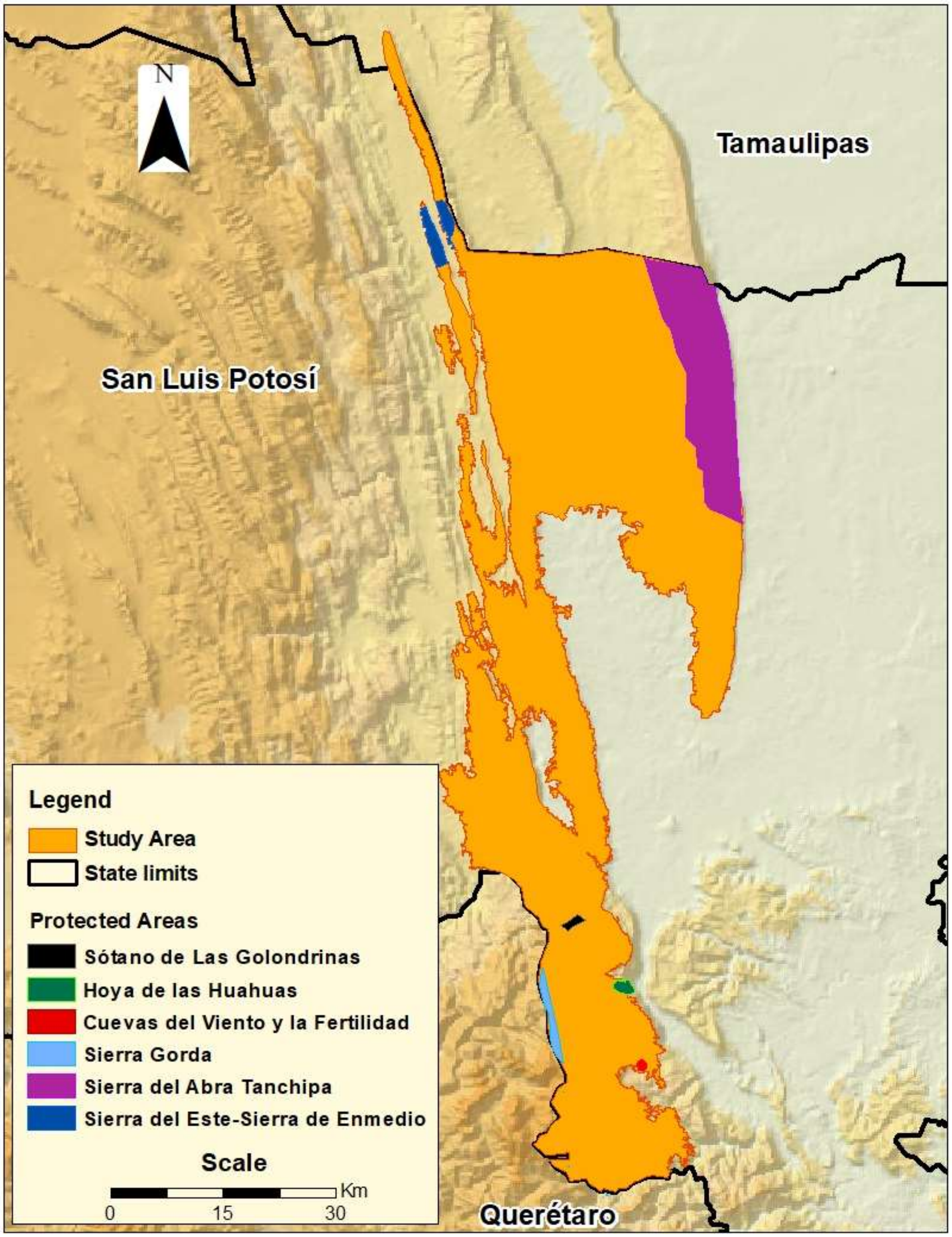
Nevertheless, the diversity of ecosystems highlights its importance and the urgency for its conservation. In particular, the deciduous forest is considered the most diverse among the dry tropical forests of the world (Rzedowsky, 2006; SEMARNAT & CONANP, 2014).



Map 5. Land use cover in the study area. Own elaboration. Source: (CONAFOR, 2012)

3.2 REGIONAL PROTECTED AREAS

There are five PA in the study area. BRSAT has a federal status protection, and the other four have state protection status. In addition, the limits of the Biosphere Reserve Sierra Gorda was considerate as a destination for connectivity paths. This limit is located in the border between San Luis Potosi and Queretaro (Map 6).



Map 6.Protected Areas in the Study Area. Own Elaboration. Source:(CONANP, 2018a; RANP, 2018)

Sierra de Emedio and Sierra del Este state reserves have a high biological diversity and for being a wildlife refuge in the region. Studies reported 127 of vertebrate species and more than 200 vascular plants (SEGAM, 2018b) El Sótano de las Golondrinas is a habitat for numerous species from the high jungle, and species of secondary vegetation (SEGAM, 2016a). La Hoya de las Huahuas is an important area of nesting and refuge sites for wild fauna, particularly for birds and bats that play important roles in the regional ecology (SEGAM, 2018a).

Las Cuevas Del Viento y La Fertilidad in addition to being a site of cultural and ethnobotanical importance in the region is a relic of deciduous forest important for the conservation of the fragmented landscape (SEGAM, 2016b)

The program Man and the Biosphere (MAB) (UNESCO, 2018) also recognize the BRSAT. In its extension of 21,464.44 hectares, in BRSAT have been registered near 269 plants and animals species of 69 families and 196 genera (Rzedowsky, 2006; SEMARNAT, 2014).

More than 2,500 vascular plants, 532 birds species, 207 amphibians and reptiles species, and more than 200 mammals species have been recorded in the SMO, including (*Panthera onca*) (Sahagún-Sánchez et al., 2011). Regarding wildlife, particularly for the BRSAT about 19 publications consulted for the elaboration of the Reserve Management Program summarize a total of 728 vertebrate species (723 terrestrial), of which 142 are mammals, 458 birds, 80 reptiles, 25 amphibians and four aquatic species (SEMARNAT, 2014). Some species of fauna and flora are threatened, some of them endemic (Table 5)

Table 5. BRSAT Threatened Species. Own Elaboration. Source: SEMARNAT 2014.

	Common name	Scientific name	Category
Fauna	Musaraña orejillas mexicana	*Cryptotis nelsoni*	EN
	Ardilla de Peter	*Sciurus oculatus*	EN
	Meteoro de Jalapa	*Microtus quasiater*	SP
	Murciélago hocicudo de Curazao	*Leptonycteris curasoae*	T
	Murciélago trompudo	*Choeronycteris mexicana*	T
	Jaguar, tigre	*Panthera onca*	EN
	Tigrillo	*Leopardus wiedii*	EN
	Ocelote	*Leopardus pardalis*	EN
	Leoncillo	*Herpailurus yagouaroundi*	T
	Guacamaya verde	*Ara militaris*	EN
	Loro Tamaulipeco	*Amazona viridigenalis*	EN
	Víbora de Cascabel, Chilladora	*Crotalus molossus*	SP
Flora	Colorín	*Erythrina coralloides*	T
	Cedro Rojo	*Cedrela odorata*	SP
	Soyate	*Beaucarnea inermis*	T (e)
	Santorum, Flor de Muerto	*Laelia gouldiana*	Ex (e)
	Laelia de mayo, flor de Lirio	Laelia speciosa	SP (e)
	Torito Morado	*Stanhopea tigrina*	T (e)
	Tempequiste	*Sideroxylon capiri*	T
	Tejo Mexicano, romerillo	*Taxus globosa*	SP
	Palma de dolores	*Dioon edul*e	EN (e)
	Chamalillo	*Zamia fischeri*	EN(e)
	-	*Diospyros riojae*	EN
	-	*Ceratozamia kuesteriana*	EN(e)

Ex = probably extinct in the wild; EN = In danger of extinction; T = threatened, SP = subject to special protection, (e) = endemic, according to the Official Mexican Norm Nom-059-Semarnat-2010, Environmental protection-Wild species of flora and fauna native to Mexico-Risk categories and specifications for their inclusion, exclusion or change-List of species in risk(SEMARNAT & CONANP, 2014)

The high levels biological diversity and the low values of fragmentation make the site highly relevant for conservation and an important area to connect (Ortega Huerta, 2007). The vegetation reported in the Sierra del Abra Tanchipa represent an ecological corridor between the states of San Luis Potosí and Tamaulipas (SEMARNAT & CONANP, 2014).

3.3 SOCIOECONOMIC CHARACTERISTICS OF THE STUDY AREA

Except for Ciudad Valles, the 5 out of 6 municipalities in the study area are considered rural areas. (INEGI, 2010).The 76 municipalities share various characteristics on their socioeconomic profiles. The primary productive sector, in almost all cases surpassed 50% of the activities of the economically active population.

Table 6.Socioeconomic characteristics. Own elaboration. Source: INEGI (2010) Censo Nacional de Población y vivienda and CONAPO (2011). Marginalization Index by federative entity and municipality 2010

Municipalities	Population	% Indigenous Population	Degree of Marginalization	% Access to health insurances	Economic activities
Ciudad Valles	167,713	*	*	72.02	1. Retail trade 2.Manufacturing 3.Agricultural activities
Aquismón	47,423	72.39	Very High	81.93	1. Agricultural activities 2. Retail trade 3.Construccion
El Naranjo	20,495	*	High	76.50	1. Agricultural activities 2. Retail trade 3 Manufacturing
Tamasopo,	28,848	12.91	High	69.64	1. Agricultural activities 2. Retail trade 3.Construction
Tamuín	37,956	*	*	77.85	1. Agricultural activities 2. Retail trade 3. Manufacturing
Xilitla	51,498	51,498	High	51,498	1. Agricultural activities 2. Retail trade 3.Construction

*There is no information

The high and very high grade of marginalization describe the social condition in which these people live. As for the grade of marginalization and lack of access to health services, indigenous groups were predominant (CEP, 2018)

The indigenous language speaking population is diverse, in Aquismón the predominant languages are Pame and Huasteco, In Huehuetlán, Tamuín, and in Ciudad Valles, Huastecos and Nahual, in Tamasopo, Pame and Nahual, and in Naranjo and Xilitla, Nahual and Huasteco (CONAPO, 2002)as shown in Table 6.

3.4 MANAGEMENT OF THE PROTECTED AREA

Twenty-four years after its creation, the biosphere reserve faces new challenges, such as fortifying its legal framework, increasing the connectivity of its ecosystems and between populations of its wild species, fostering the creation of new VDAC towards the approach of ILM among many others.

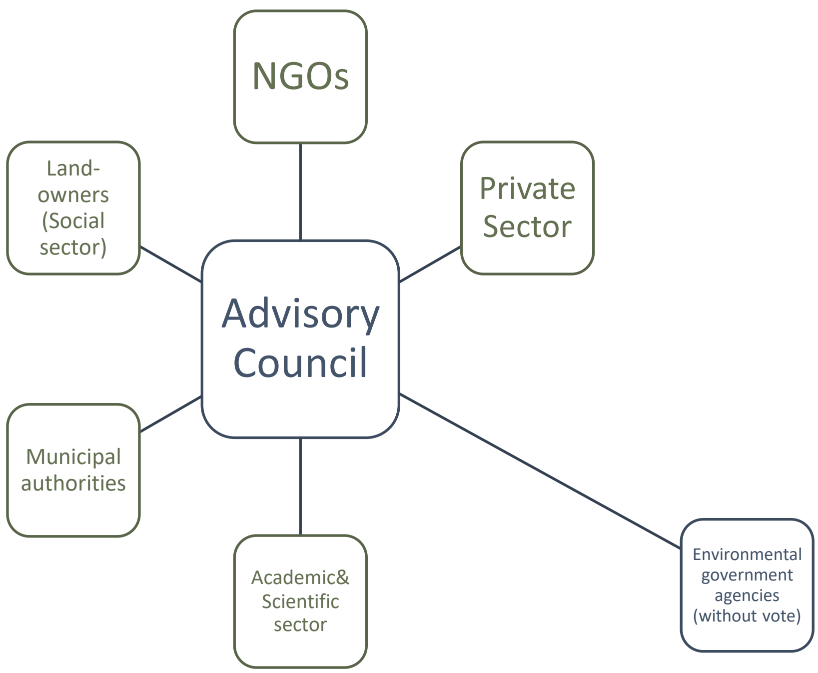


Figure 1. Structure of the Advisory Council. Own Elaboration. Adapted from: (CONANP, 2018b)

The Abra Tanchipa is managed by CONANP. For the completion of the conservation goals, an advisory council was formed. This is an organ of citizen participation with representation of diverse sectors of society with the function of advising and supporting the direction of the BRSAT in the actions of conservation and sustainable development (Figure 1).

The composition of the advisory council reveals the stakeholders that have an influence over the operative actions for the biosphere reserve. These members can be affected or affect the actions related to conservation that would be implemented in the BRSAT. -

This structure is relevant in order to identify the stakeholders involved in BRSAT decision-making process.

4 METHODOLOGY

Methods used to address the specifi with the specific objectives are shown in the Figure 2

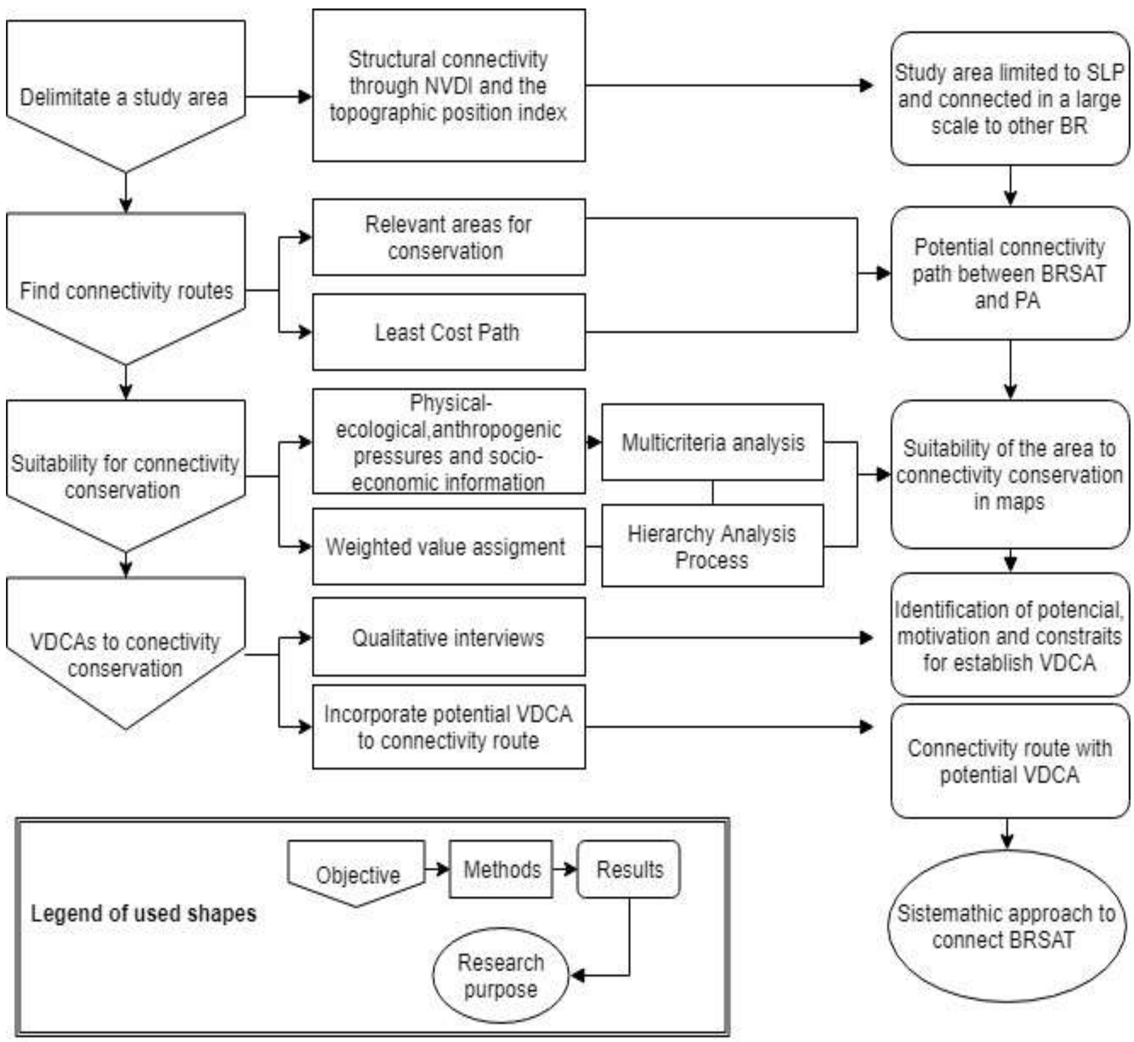


Figure 2. Overview of the methodology followed in the study. Own elaboration

4.1 DELIMITANTION OF THE STUDY AREA

The study area was delimitated from four Landsat vr.8 images (february-april 2018). A polygon was created to adjoining BRSAT with biosphere reserve of el Cielo y Sierra Gorda. through a the surface that was structurally connected (vegetation and/or morphology). This was made by calculating the Topographic Position Index (TPI), and the Normalized Difference Vegetation Index (NDVI) with an ArcGIS 10.5 extension tool and tool respectively. TPI measures topographic slope positions and automate landform classifications and NDVI helps to improve discrimination between the vegetation and other surfaces(Aguayo, 2013; De Reu et al., 2013)

In addition, the polygon was manually adjusted to include PAs of the region, eliminating isolated small polygons in the limits and agricultural areas that disrupt connectivity. Finally, the polygon was adjusted to the state limits of San Luis Potosí due to the operational limitations of the BRSAT administration (See results Map 21).

4.2 CONNECTIVITY PATHS TO LINK BRSAT AND OTHER PROTECTED AREAS

Structural connectivity between the BRSAT and other PNs was determined in 2 phases: identification of appropriate conservation sites for the preparation of a suitability map, and a least-cost path analysis.

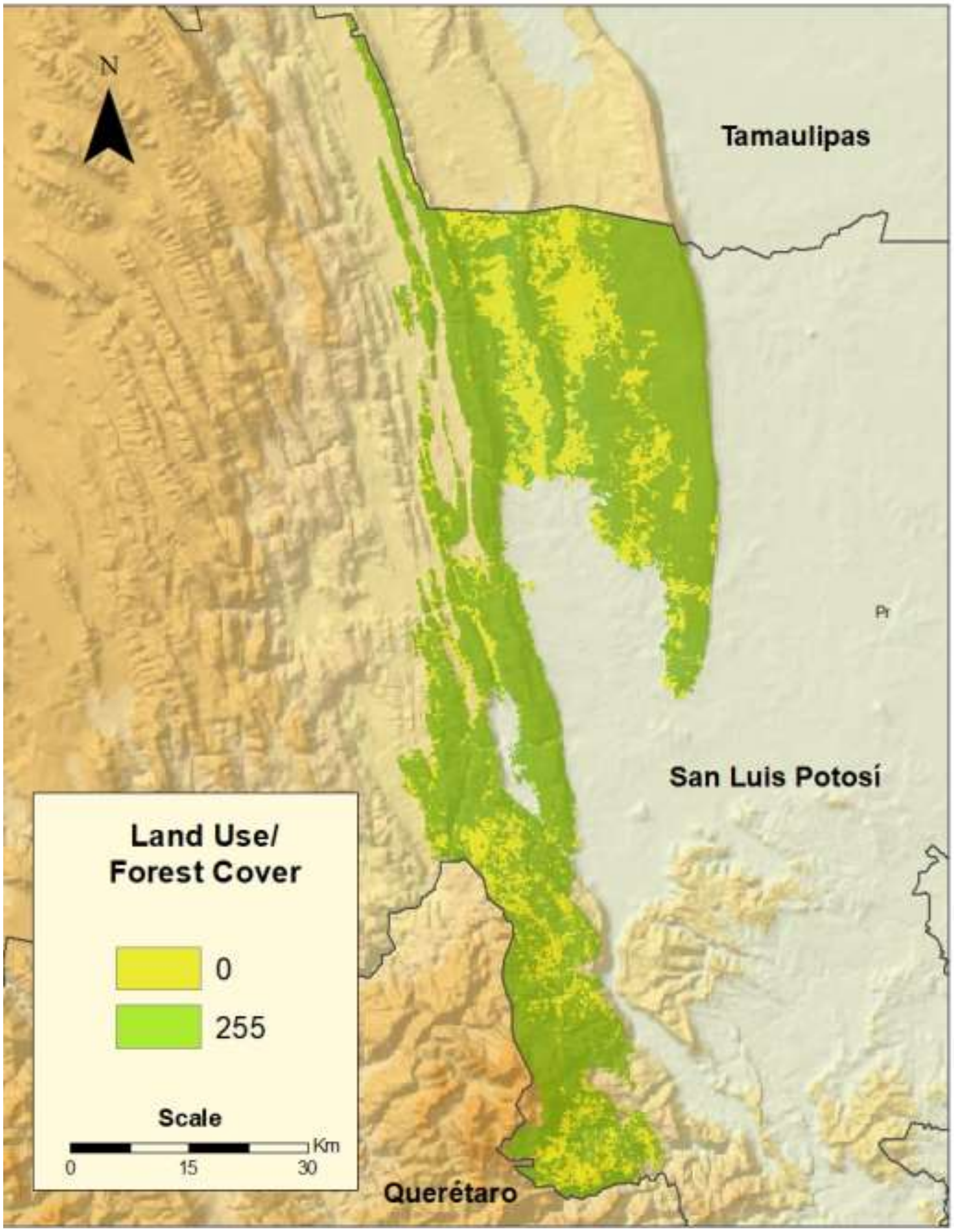
4.2.1 PHASE 1: RELEVANT AREAS FOR CONSERVATION (Resistance/Cost Layer)

DATA GATHERING

A map was drawn to identify sites that would be relevant for conservation, to serve as a suitability map for selecting connectivity paths. Cartographical information was summarized in a single final layer that shows the relevant areas for conservation. The process will be detailed below. They were identified on the map in ArcGIS version 10.5:

- Forest land use – woody vegetation
- Fauna records
- Terrestrial priority sites for biodiversity conservation
- Distance to protected areas

For the analysis, the data in all layers were standardized to the same scale with comparable units. A scale of 0–255 was employed, where zero represents the minimum value (least relevant for conservation) and 255 the most relevant for conservation. For this first phase, these values were assigned weights determined according to information from the bibliography.



Map 7. Classified forest cover. Own elaboration. Source (CONAFOR, 2015) Values: 0 minimum-255 maximum relevance for conservation

All geographic data layers were standardized in raster format, with the following attributes: 30 m spatial resolution, and UTM projection, zone 14N using the WGS84 datum. The process of data reclassification and standardization and the source for each criterion is described in the following.

Forest land use (woody vegetation)

The geographical distribution of forest resources and land use in the state of San Luis Potosí was obtained from 1:50,000 scale vector maps from the National Inventory of Land Use and Vegetation (CONAFOR, 2015). The information was reclassified into two broad groups: Forest areas (with woody vegetation) and Non-forest (bodies of water, agricultural land, natural and induced pasture, palm groves and areas without evident vegetation) (Map 7).

Terrestrial priority sites for biodiversity conservation (TPSBC)

The data were prepared by the National Commission for Biodiversity Knowledge and Use (CONABIO), the National Commission of Protected Natural Areas (CONANP), The Nature Conservancy – Mexico Program (TNC) and Pronatura (CONABIO, CONANP, & TNC, 2008).

TPSCB are spatial units determined by an analysis of information on threatened animal and plant communities due to deforestation and forest degradation. These areas are urgent priorities for conservation, so they are assigned the highest value (255) while the remaining area is assigned a value of zero. (Map 8)

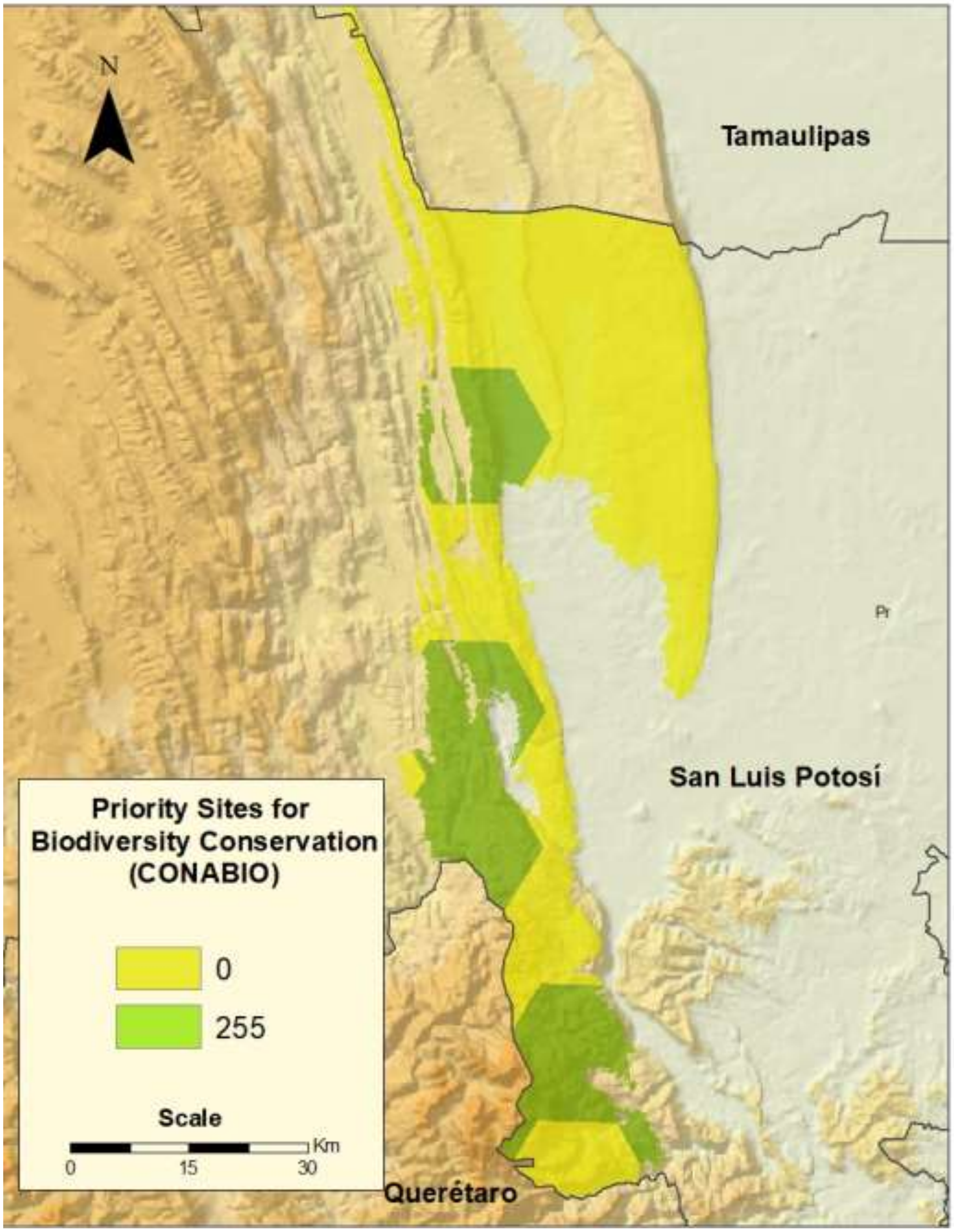
Distance to protected areas

The map of protected areas in San Luis Potosí is made up of federal (CONANP, 2018a), state, and municipal protected areas (CONANP, 2018a; RANP, 2018). The Euclidean distance was calculated for each PA polygon using the ArcGIS 10.5 Euclidean Distance tool. This tool generates a raster that estimates the linear distances between a polygon and the rest of the field (Garrido-Garduño & Vázquez-Dominguez, 2013) (Map 9).

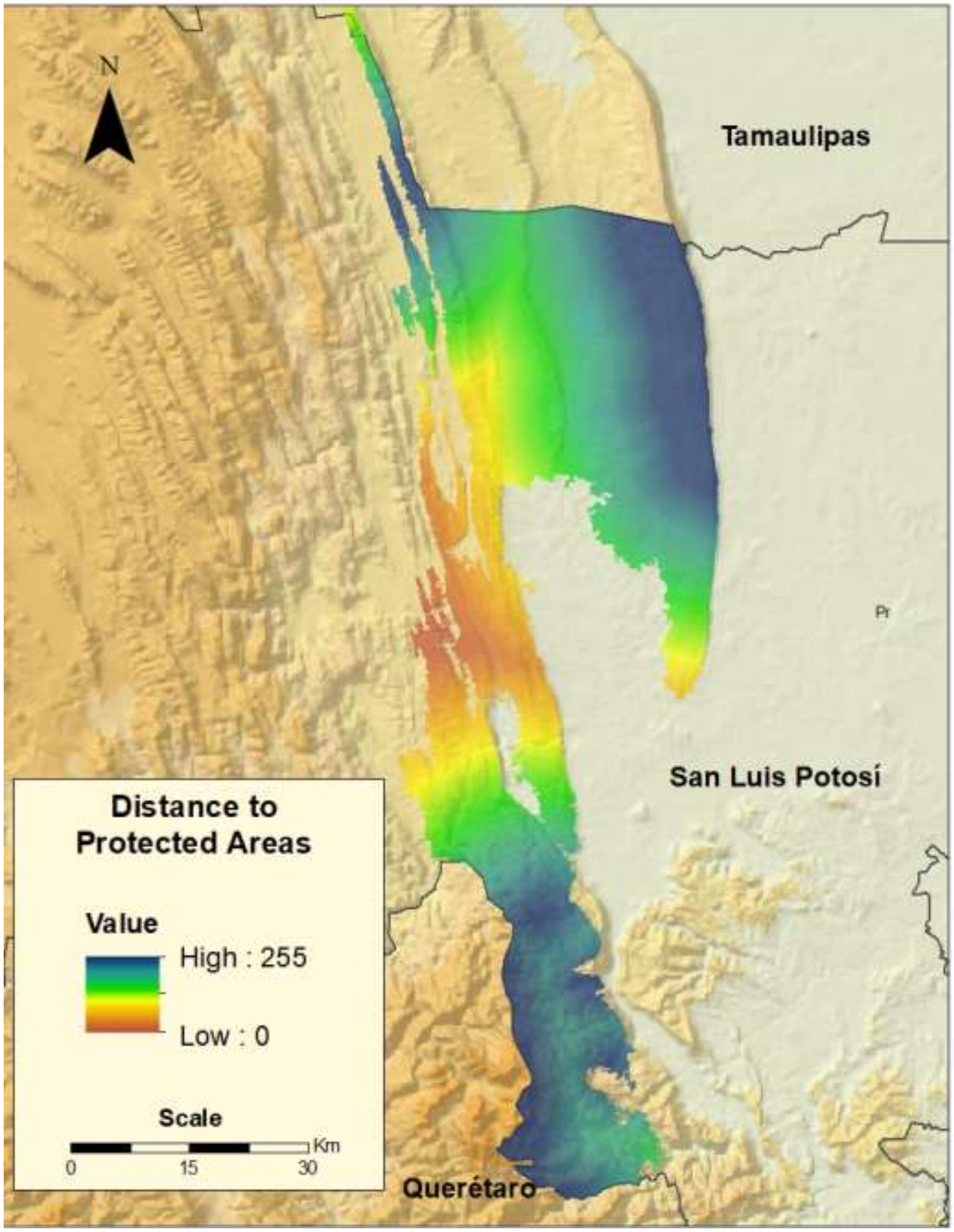
For the standardization, a linear formula was used, which incorporates interactions between the characteristics of the variables by assigning a high value of suitability to the favorable or unfavorable qualities for the present study (255) (Eastman, 2012). This operation was carried out with the help of the ArcGIS 10.5 Map Algebra tool and the Euclidean distance layer:

Standardization = 255 × ((Data layer − (minimum distance)) / (maximum distance − (minimum distance)))

In this case, the closest areas of the PA were considered the most suitable (255) because the areas located outside the protected polygons and those surrounding them (zones of influence) include ecological and biological characteristics similar to those that protect the PA, but with some degree of anthropogenic pressure, which was the reason they were excluded from the areas (Dominguez, 2009). It has been proposed that deterioration and loss of biodiversity could be avoided, diminishing the edge effect by creating connectivity in buffer zones (Dominguez, 2009) (Schelhas, 2007)(Martínez Alandi, Múgica de la Guerra, Castell Puig, & de Lucio Fernández, 2009).



Map 8. Classified Terrestrial priority sites for biodiversity conservation. Own elaboration. Source: (CONABIO et al., 2008) *Values: 0 minimum-255 maximum relevance for conservation.*



Map 9. Classified Distance to PA. Own elaboration. Source: (CONANP, 2018a; RANP, 2018) Values: zero minimum-255 maximum relevance for conservation.

Fauna records

Structural and functional connectivity is based on creating paths that enable the mobility of species and processes (Ersoy et al., 2019). All sighting records of four taxonomic groups contained in the databases of the National Biodiversity Information System (SNIB) of the National Commission for Biodiversity Use and Knowledge (CONABIO) were included. Table 7

Table 7.Fauna Registries by Taxonomic groups. Own elaboration. Source :(CONABIO, 2019a)

Taxonomic groups	Registries	Number of Species
Mamals	479	84
Reptiles	270	80
Birds	3130	309
Amphibians	396	32

The Map 10 shows records of individuals obtained from databases developed, validated or financed by CONABIO; this makes this data layer robust and reliable. (CONABIO, 2019c, 2019b, 2019e, 2019d).

The data obtained was contained in CSV (comma-separated values) files for UTM Region 14. Subsequently, vector data was added in ArcGIS 10.5, a cut was applied to the study area and the data for each taxonomic group and for each species was reclassified according to its category of protection in the IUCN Red List as described in the following Figure 3.

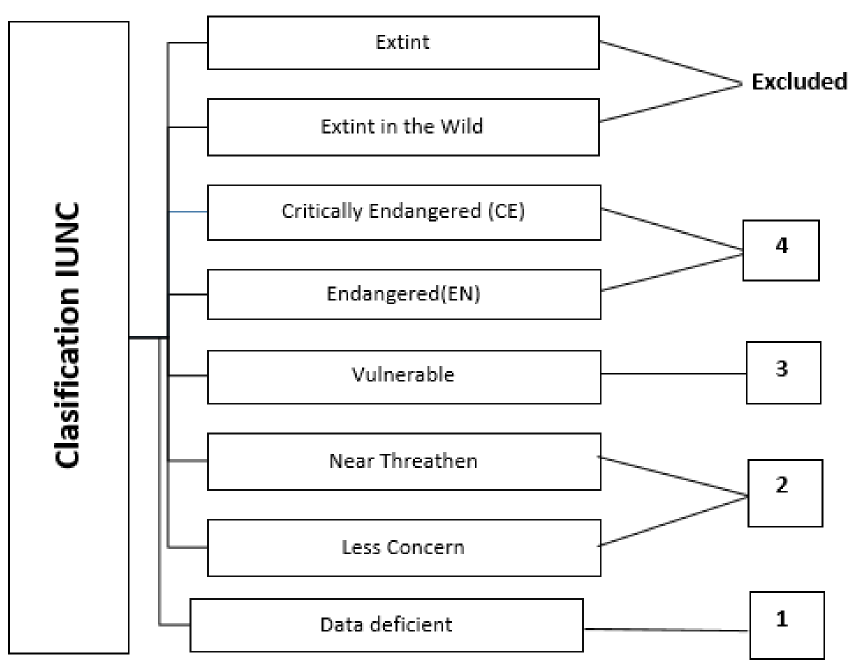


Figure 3. Reclassification of threatened species. Own elaboration adapted from (UICN, 2008).

The kernel density estimator was used to analyze the vector data. Essentially, intervals of fixed amplitude are constructed around each observation according to the attributes of each data vector using the function to fit a smooth conical surface at each point (Salgado Ugarte, 2002).Using the Kernel Density tool, the kernel density was calculated for each taxonomic group, which indicated the density of observation records (observations/km2).

The highest density is therefore observed where the concentration of records was highest and in turn, where the threat category for each species was highest, which was thus assigned the highest suitability value of 255. Subsequently, the Raster Calculator tool was used to add and superimpose the information of each taxonomic group. (Map 10)

RESISTANCE/COST LAYER ELABORATION (RELEVANT AREAS FOR CONSERVATION)

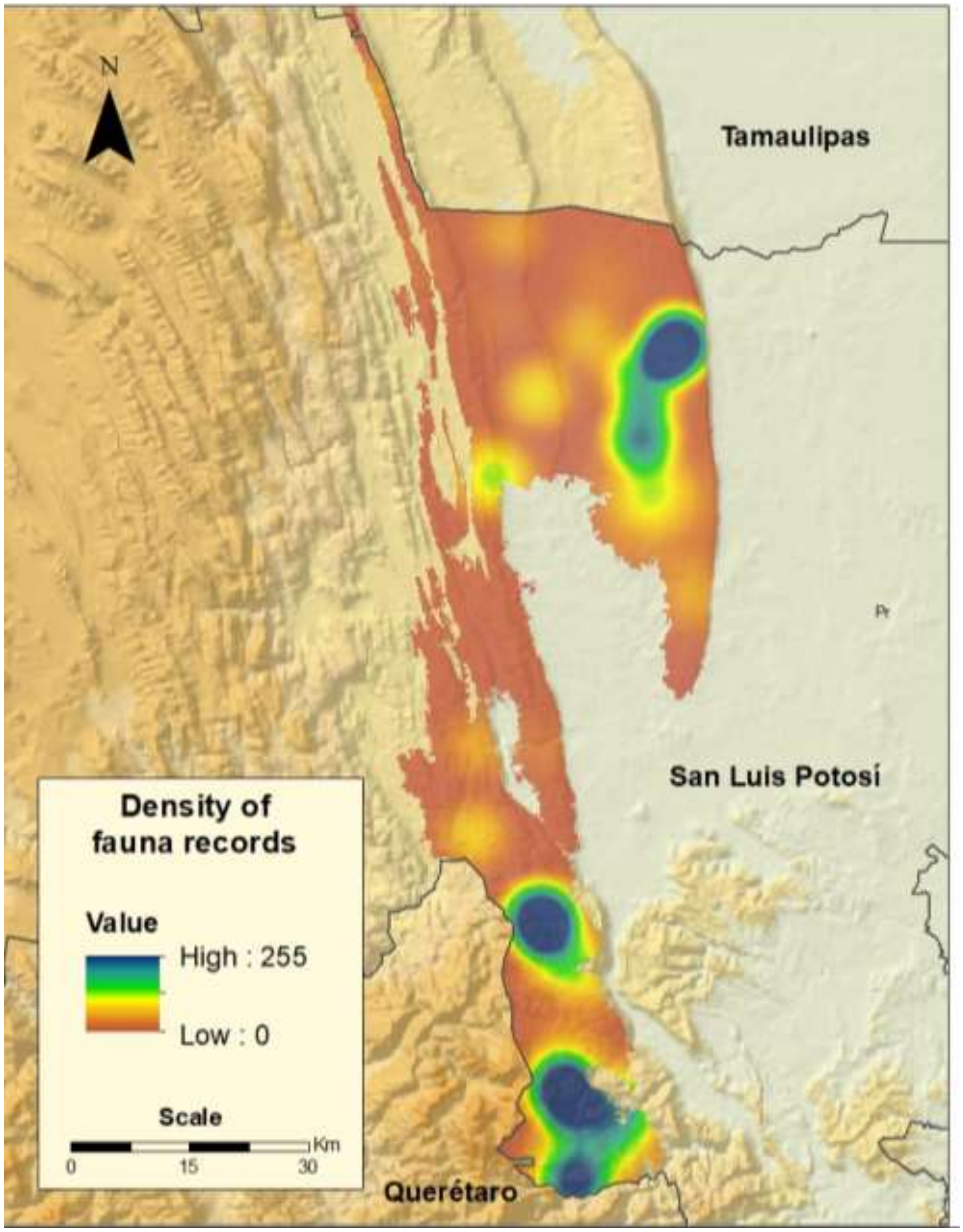
The Weighted Sum tool was used, enabling interaction between the characteristics of the different variables to be expressed by means of a unit sum that overlays the information from each layer with a weight. The weight used for the criteria was .25 because the expected result incorporates all criteria with equal importance. Map 24

4.2.2 PHASE 2: CONNECTIVITY PATH

LEAST COST PATH

Connectivity paths were drawn connecting the BRSAT to other PA. The paths were obtained using the ArcGIS 10.5 LCP tool frequently used in structural connectivity studies. LCP has been recognized as one of the best for finding paths that connect elements within a landscape structure (Adriaensen et al., 2003; Beier et al., 2008; Lee et al., 2014).

To obtain the LCP from the BRSAT (origin) to the six different destinations PAs (destinations), can be obtained through four steps (Figure 4.). Once the source and destinations are elected, the Cost Distance tools and the Backlink Cost tools helps to obtain the shortest weighted distance from each cell to the nearest source and the least costly path from the source point over the cost distance surface respect respectively (ESRI).”From this process, two raster layers are obtained (Cost Distance and Back link rasters). The LCP tool used these layers, the resistance layer, and the destinations to connect them through the cheapest cost.



Map 10. Classified density of fauna records. Own elaboration: (CONABIO, 2019b, 2019c, 2019d, and 2019a). Values: zero minimum-255 maximum relevance for conservation.

LCP Algorithm operates as follows: "given a source and a cost surface, named resistance layer, finds an LCP from the source to each cell that does not exceeds any path from any source cell to that cell. The result is a raster surface of accumulated least cost" (Shirabe, 2018).

To stablish the LCP, in the resistance layer, the values (0-255) were reclassified with this Arcgis 10.5 tool, in order to guarantee that zero means the major resistant, the less optimal for the path and 255 the cheapest and optimal values for the path

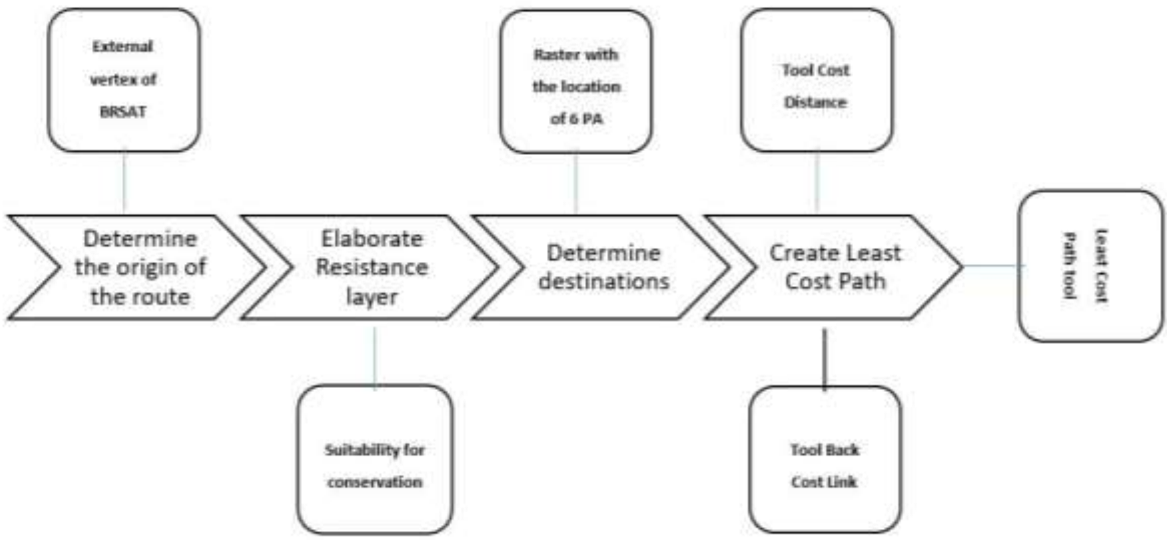


Figure 4. Least Cost Path Process. Own Elaboration.

4.3 SUITABILITY MAPS FOR CONNECTIVITY CONSERVATION

The suitability for conservation was identified through a multicriteria analysis using a weighted linear combination(Chávez et al., 2015; Terán-Valdez, 2013). With this method, the interaction between different criteria can be included by multiplying each value on a common scale and a range of weights (Malczewski, 1999)

4.3.1 PHASE 1: CHOICE OF COMPONENTS AND CRITERIA

it is recognized in studies on conservation the influence of environmental, biophysical and socio-economic factors at the landscape level is recognized (Beier et al., 2008; Chávez González et al., 2015; Torres Acosta,et al., 2019)

Given this, the specific criteria for each component were chosen following two basic principles; their influence for conservation and for the establishment of connectivity paths, and that the data could be spatially represented (Figure 5).

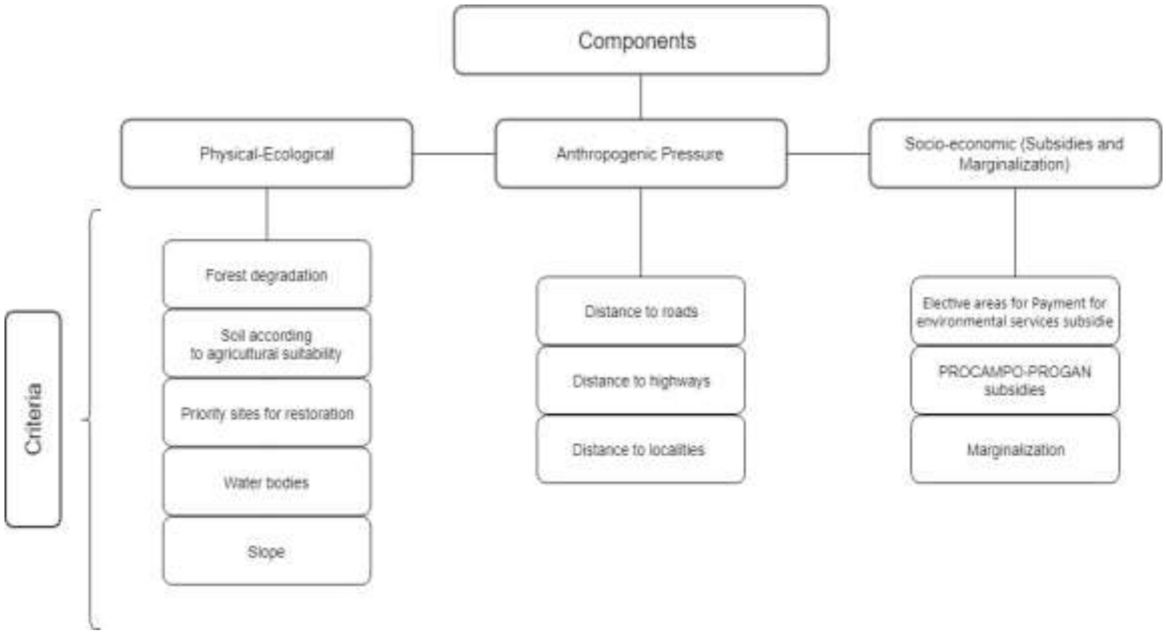


Figure 5. Components and criteria. Own elaboration.

Each criterion was represented in a layer of raster map data, 11 layers; with a cell, size of 30 meters, with WGS84 UTM 14N coordinates, was standardized on a scale of values from zero to 255 according to their suitability for conservation.

4.3.2 PHASE 2: DATA GATHERING: CRITERIA RECLASIFICATION AND STANDARIZATION

PHYSICAL-ECOLOGICAL COMPONENT

Degree of Forest degradation

Vegetation structure is one of the most important aspects of a forest system, since it is related to the stability of the forest stand, productivity, soil conservation, and morphology of the landscape, and determines the microclimatic conditions and the presence of habitat for many species of animals, plants and fungi

Table 8. Forest Cover Classification. Own elaboration. Source: (CONAFOR, 2015)

Sucesional state	Suitability Values
Non-forestry areas	0
Secondary Herbaceous Vegetation	160
Secondary Vegetation Shrubby	190
Secondary Tree Vegetation	200
Primary forests	255

The dynamics of change of the forest cover not only indicate the loss of forest area when it is converted to other uses, but also reflect changes in the structure and composition of forest stands(CONAFOR, 2012)(Map 11)

Data from the National Forest and Soil Inventory (CONAFOR, 2012) was used. The data was reclassified according to the level of degradation of forest vegetation, which was inferred from the observed successional state. The values assigned to each category are listed below Table 9

Soil according to agricultural suitability

Soil data was obtained from a map of Mexico on a 1:1,000,000 scale (CONABIO & INIFAP, 1995).Soils in the state of San Luis Potosí were reclassified according to their physical characteristics. The soils agricultural potential was assigned according to the soil physical characteristics that favor agricultural activities; this was made by an expert (Muñoz, 2019).

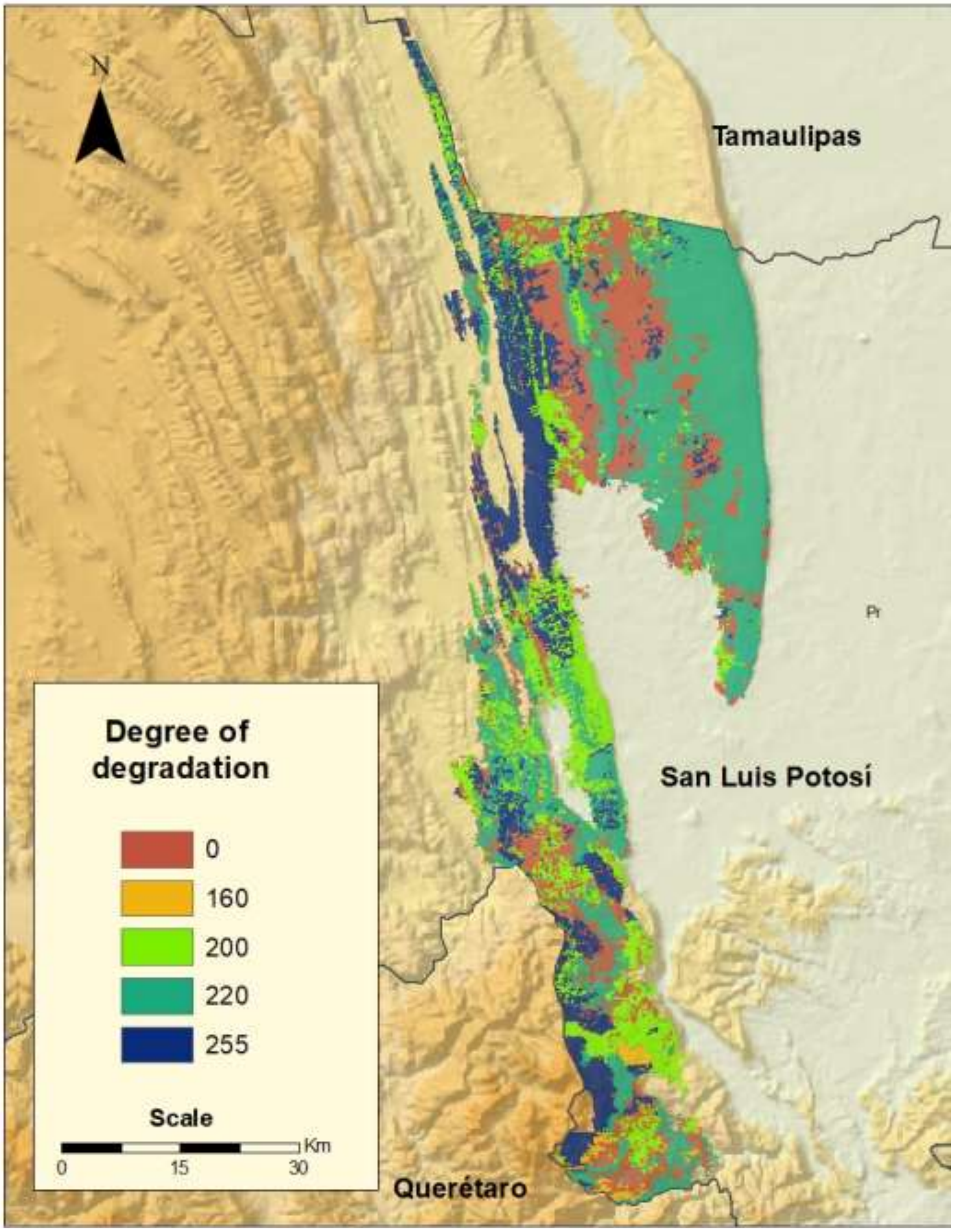
Table 9. Soil according to agricultural suitability classification. Own elaboration. Source: (CONABIO AND INIFAP, 1995)

Soil Type	Suitability Values
Leptosols	80
Feozem	100
Regosol	130
Rendzina	180
Luvisol	200
Cambisol	230
Vertisol	255

The value associated with the highest suitability was assigned to soils with the best agricultural potential (Map 12). This is because it is recognized that soils with agricultural potential are more prone to changes in land use. Fertile soils for agriculture have caused high rates of deforestation in the area (Sahagún-sánchez & Reyes-hernández, 2018).

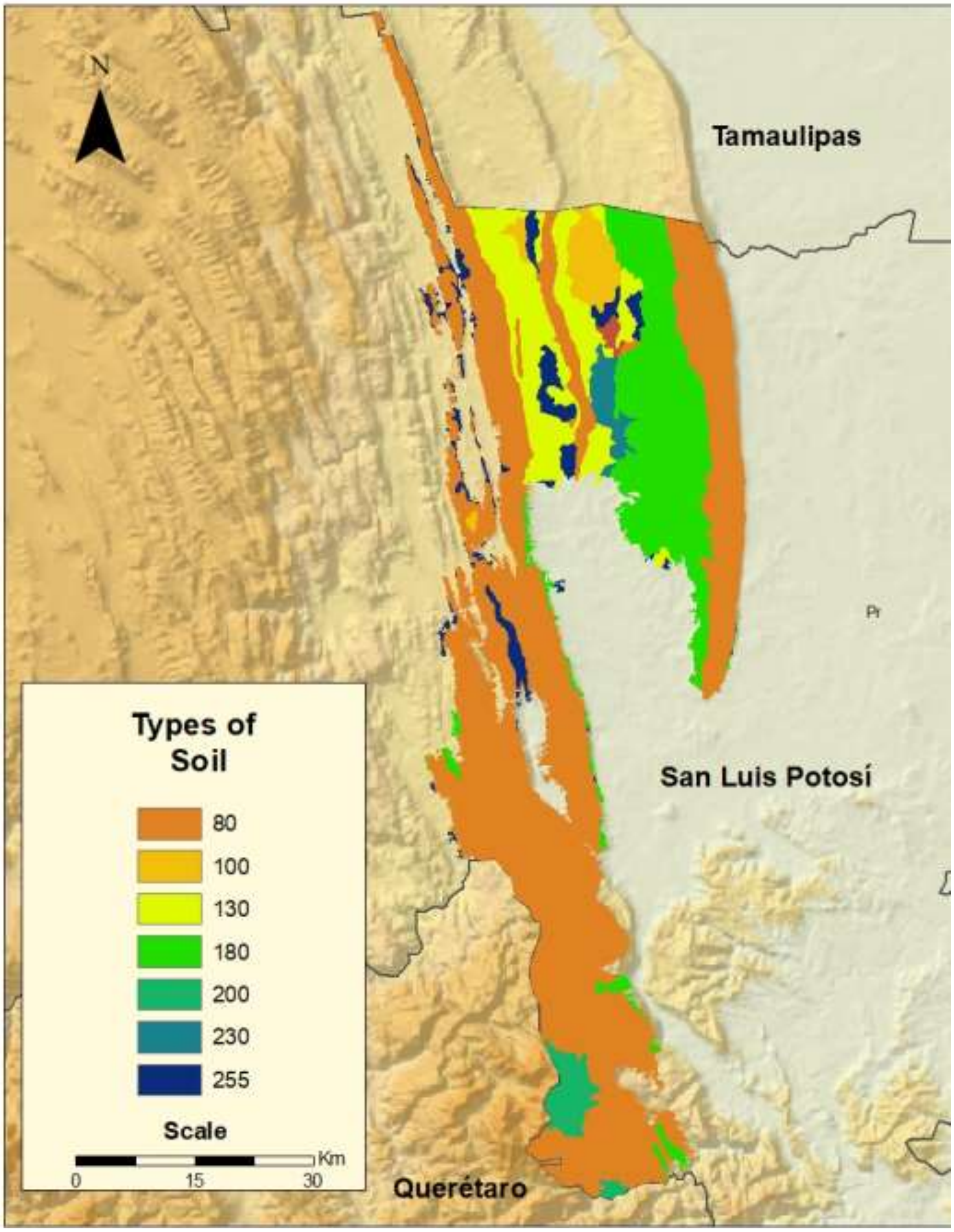
Priority Sites for Restoration (PSR)

PSRs were designed to identify areas of high biological value that require restoration to ensure long-term persistence of their biodiversity, ecological functions and the ecosystem services they provide, as well as to increase ecosystem connectivity and habitat recovery of the most vulnerable species (CONABIO, 2019f)



Map 11. Classified degree of degradation. Own elaboration. Source: (CONAFOR, 2015)
Values = 0 minimum-255 maximum suitability for conservation

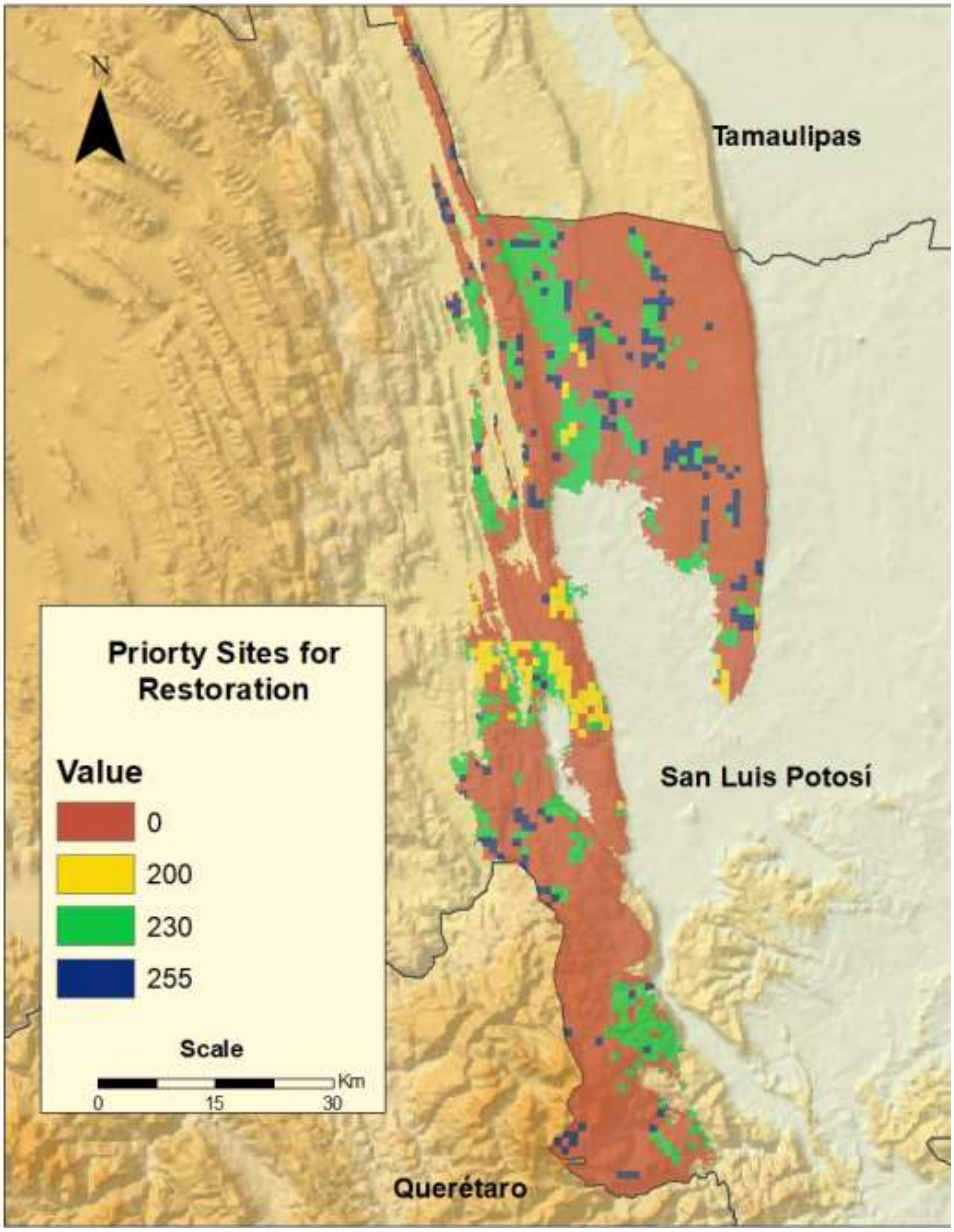
Since many priority areas for biodiversity conservation are affected by human activities, it is essential to have an accurate map indicating these areas to guide and focus restoration activity (CONABIO, 2019e). This information is classified according its priority for restoration, very high, high, medium and not considered the areas highlighted as PSRs were standardized giving the maximum value (255) to the highest relevance, 230 to the high relevance and 200 to the medium values. The rest of the study polygon was assigned the minimum value (0). (Map 13)



Map 12.Classified Soil according to suitability for agriculture. Own elaboration. Source: (CONABIO & INIFAP, 1995).Values = 0 minimum-255 maximum suitability for conservation

Hydrography

The hydrography layer displays bodies of water, springs, and streams and rivers. Data on bodies of water and springs was obtained from the series III vector data set of topographic data at a 1:50,000 scale (INEGI, 2018)contained in maps F14A69, F14A79, F14A89, F14B71, F14B81, F14C19, F14C29, F14C39, F14D11 and F14D31.

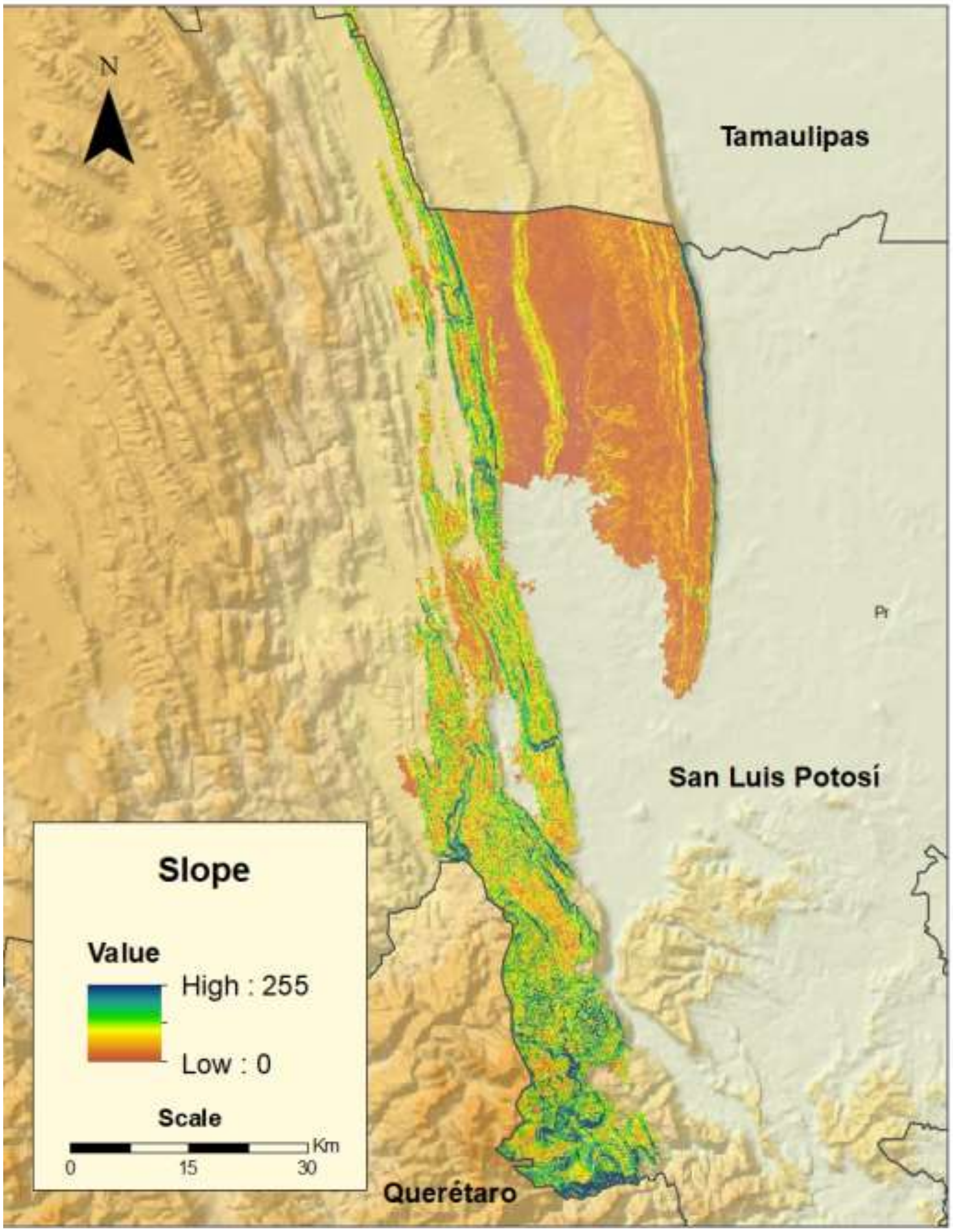


Map 13. Classified priority Sites for Restoration. Own elaboration. Source: (CONABIO, 2019e). Values = 0 minimum-255 maximum suitability for conservation

Euclidean distance was used for standardization of the bodies of water, streams and rivers layer, and kernel density was used for the vector data on springs and the weighted linear combination formula as described above. Areas closest to bodies of water were considered to be the most optimal for conservation with 255 value assigned and for the contrary zero to those areas with no water bodies.

Slope

Slopes were calculated from the MDE of the state of San Luis P*otosí*(INEGI, 2017), using the Slope tool in ArcGIS 10.5. It was considered that the steeper the slope, the greater the potential for conservation (Map 14).



Map 14. Classified Slope. Own elaboration. Source:(INEGI, 2017)
Values = 0 minimum-255 maximum suitability for conservation

The physical and biotic conditions of the montane environment induce a high degree of diversity, speciation, and endemism, important elements for the conservation of biodiversity (Chaverri-Polini, 1998). Nevertheless, the isolation of these populations due to fragmentation, and the potential for erosion on slopes, in addition to high vulnerability due to human-generated changes, makes montane conservation a priority (Chaverri-Polini, 1998)

ANTHROPOGENIC PRESSURE COMPONENT

The criteria that make up this component are anthropogenic actions that have fragmented the landscape and have been mapped.

Distance to roads, distance to highways and distance to localities.

The data were obtained from the same set of vector data as the topographic information used for construction of the hydrography layer(INEGI, 2010). To calculate the distance to roads, highways and localities, the Euclidean Distance tool described above was used.

A potential area for conservation was considered more optimal if it was located at a greater distance from anthropogenic pressures with the value of 255(Torres Acosta et al., 2019). This standardization was done using an inverse linear formula in ArcGIS 10.5. The results are in the Map 15, Map 16 and Map 17.

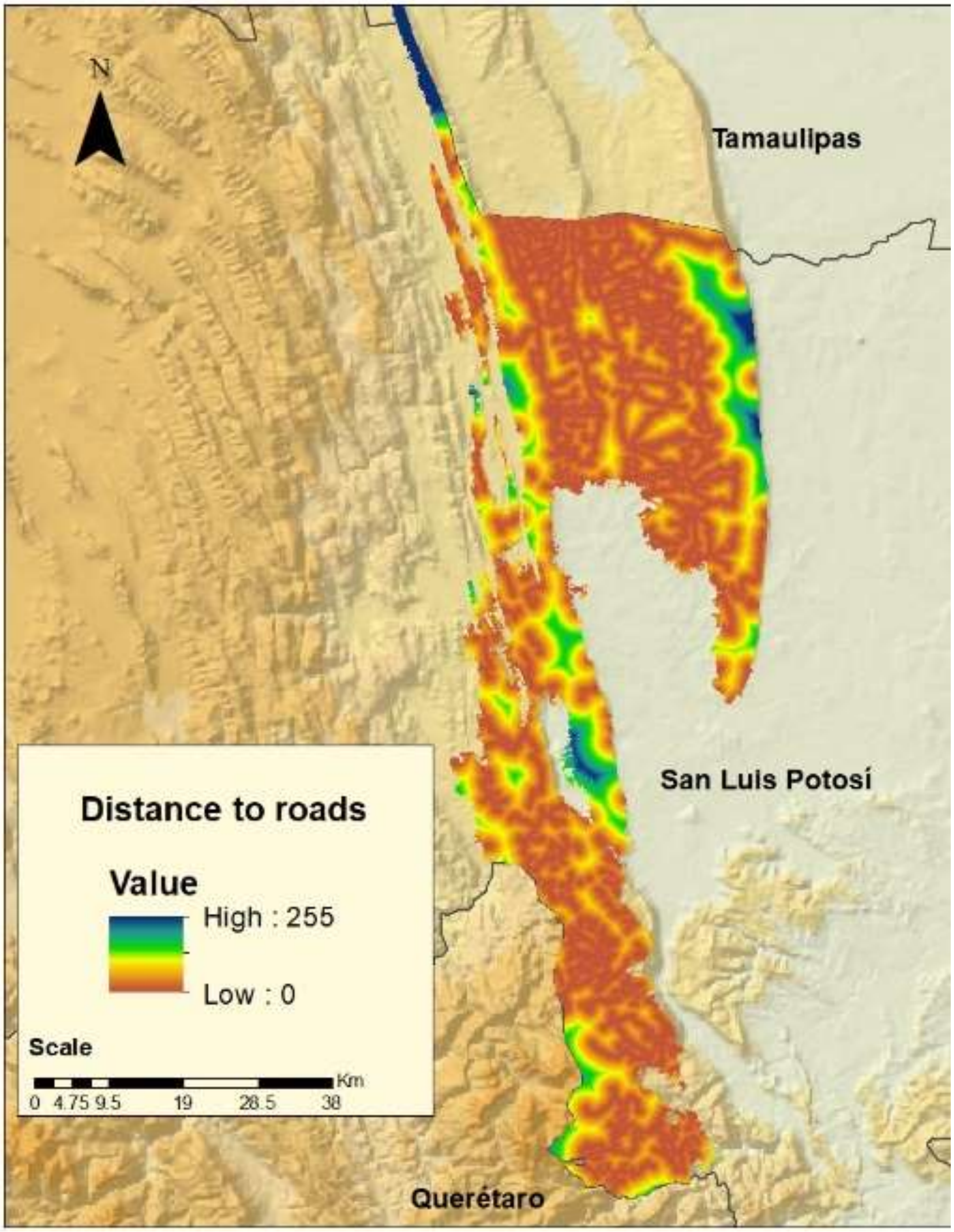
Inverse standardization=−255 ((Data layer − (minimum distance)) / (maximum distance − (minimum distance))) × 255

SUBSIDIES AND MARGINALIZATION COMPONENT

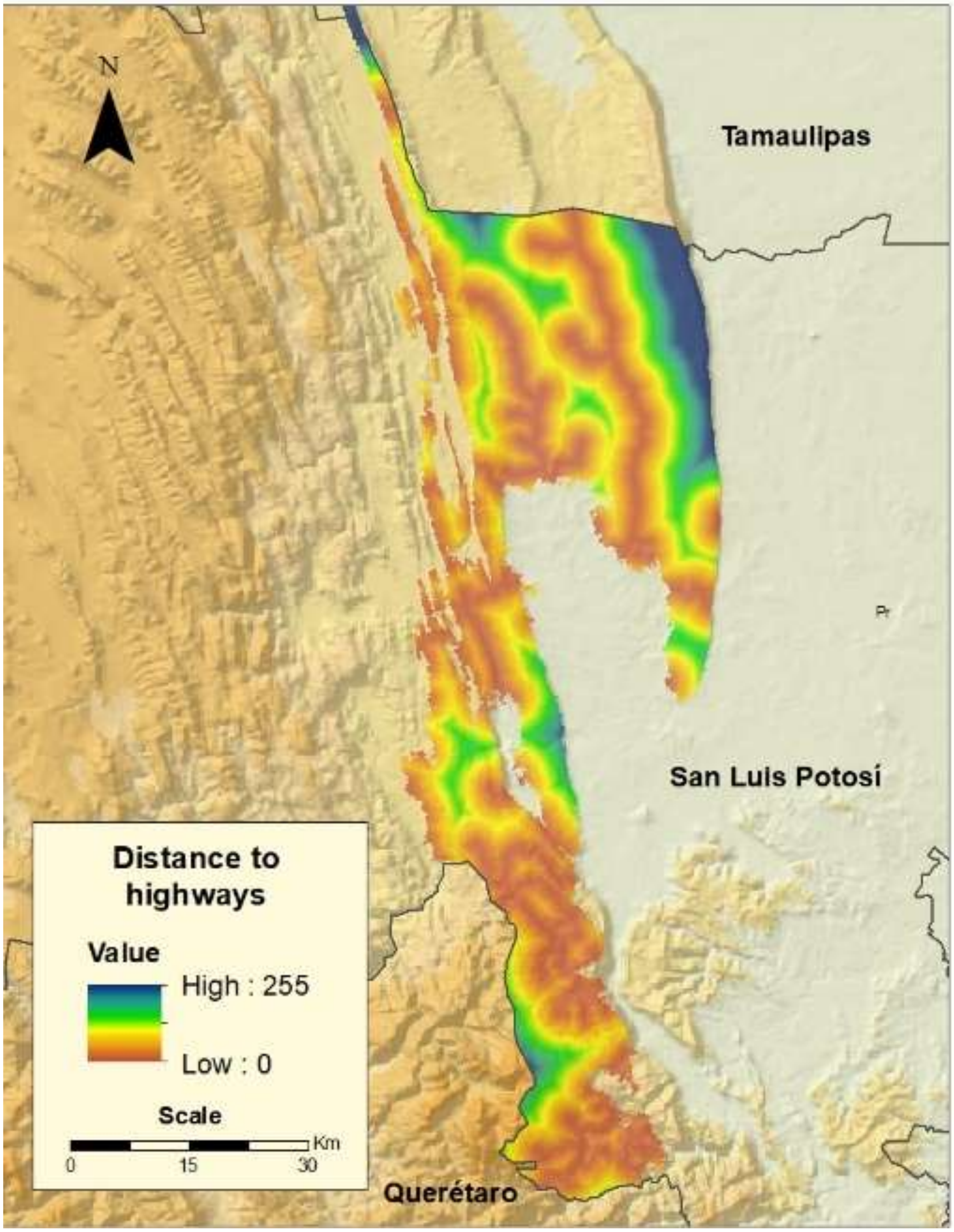
Data from two federal government subsidy programs were used to configure this component. These programs encourage the conservation of ecosystem services and agricultural activities (Map 18).

Payment for environmental services (PES) subsidy

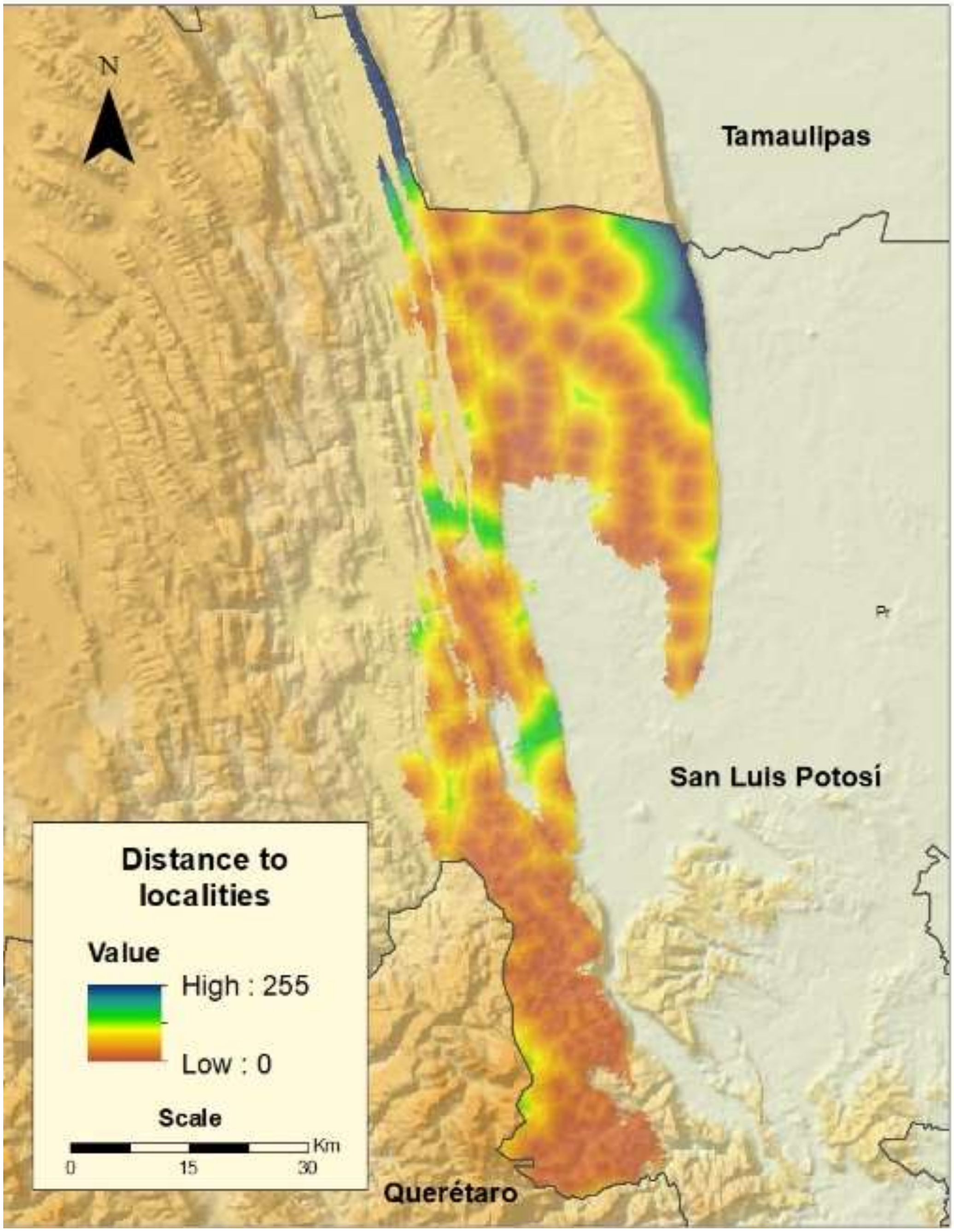
The PES is a system in which external beneficiaries of environmental services pay local communities or landowners to manage their properties with the goal of conserving them, either by restoring or protecting them (Wood et al., 2017). In Mexico, the National Forestry Commission selects the areas for conservation based on their importance for the conservation of environmental services (CONAFOR, 2019).



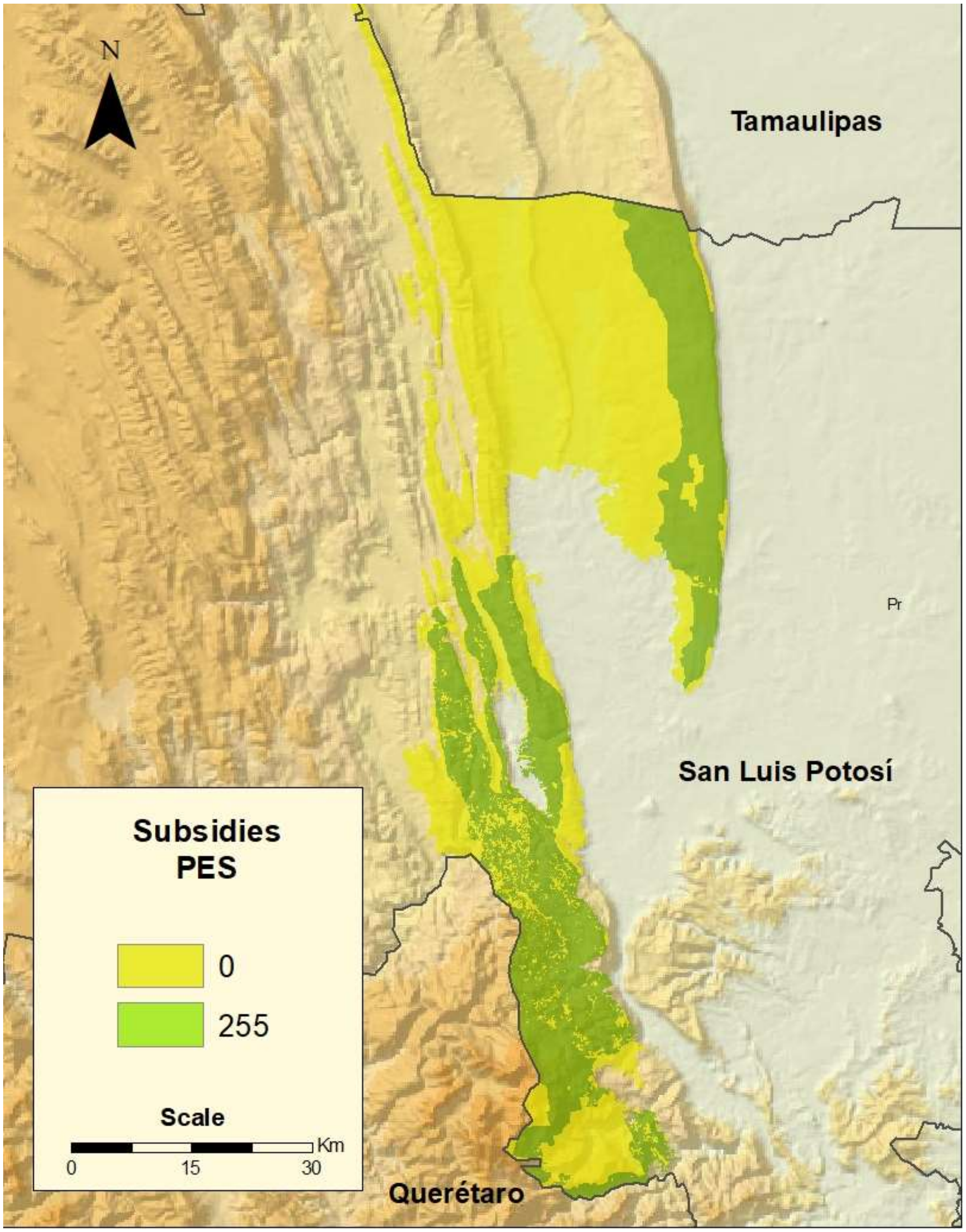
Map 15. Classified distances to Roads. Own elaboration. Source: (INEGI, 2018) Values = 0 minimum-255 maximum suitability for conservation



Map 16. Classified distances to Highways. Own elaboration. Source: (INEGI, 2018) Values = 0 minimum-255 maximum suitability for conservation



Map 17. Classified distances to localities. Own elaboration. Source: (INEGI, 2018 Values = 0 minimum-255 maximum suitability for conservation)



Map 18. Classified elective areas for Payment for Ecosystems Services. Own elaboration. Source (CONAFOR, 2019) Values = 0 minimum-255 maximum suitability for conservation

The study region includes polygons classified as "electives" for 2019. They were taken into account since in addition to being important ecosystems for biodiversity; the subsidy is a financing mechanism for conservation projects such as the VDCA. The maximum value of suitability was given to the elective areas and the zero value to the rest of the areas (Map 18)

PROCAMPO and PROGAN subsidies

These financial support mechanisms, which promote crop and livestock farming (PROCAMPO, PROGAN; respectively) were used as spatial restrictions to determine conservation sites, because they tend to promote deforestation and the creation of pastures (Turner et al., 2001)

Table 10. PROCAMPO-PROGAN surfaces subsidized

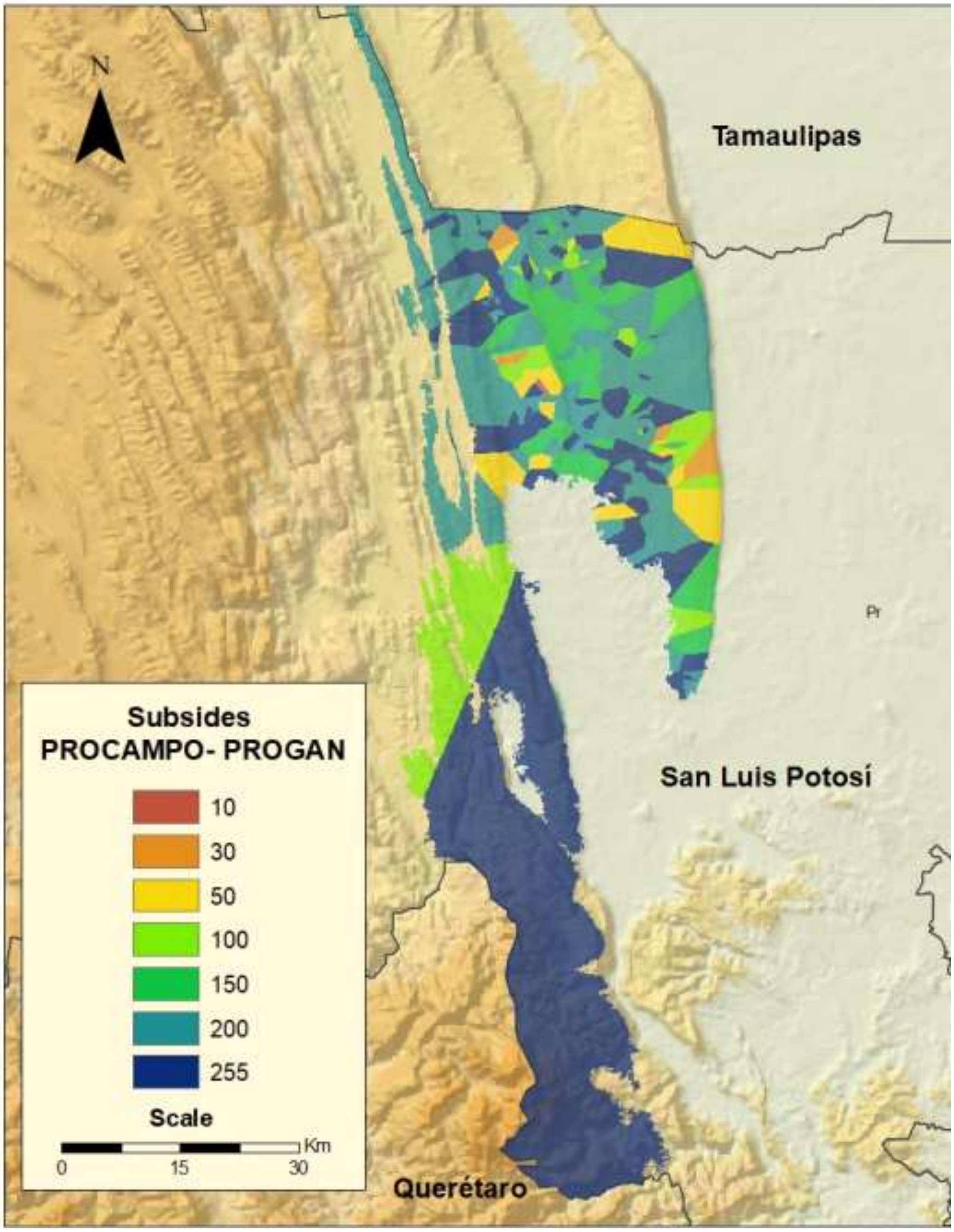
PROCAMPO-PROGAN surfaces subsidized	
Hectares	**Suitability Values**
0-15	10
16-50	30
51-100	50
101-150	100
151-300	150
300-450	200
+450	255

The vector data was reclassified according to the number of hectares that received support (Table 10). The greater the subsidized area, the lower the suitability for conservation (Map 19)

Marginalization index

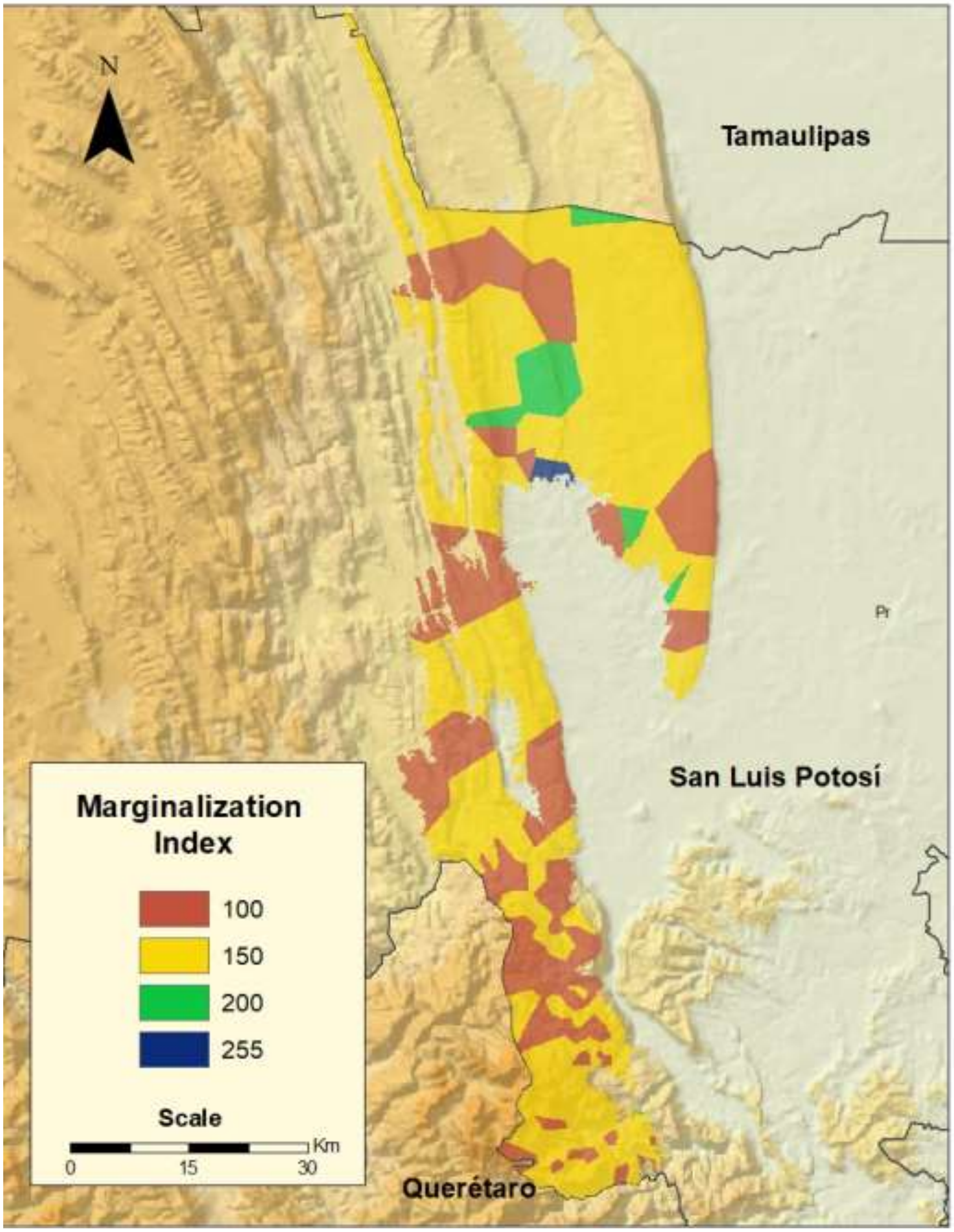
The marginalization index is a robust set of indicators based on education, housing and the availability of goods that summarizes the wellbeing of the inhabitants of the area(CONAPO, 2011)

.The data was reclassified into 4 categories according to the degree of marginalization (1 low, 2 medium, 3 high, 4 very high) and sites with high marginalization were considered not the most optimal for conservation, with a value of 0 (Map 20).



Map 19. Classified hectares subsidied by PROCAMPO AND PROGAN. Own elaboration. Source: Data bases from SAGARPA Values = 0 minimum-255 maximum suitability for conservation

The vector data on population centers was analyzed using the Create Thiessen Polygons tool. This tool is used to divide an area covered by point features into zones of proximity. The zones are areas where any location within the zone is closer to its associated point than to any other point (ESRI).



Map 20. Classified Marginalization Index. Own elaboration. Source: (CONAPO, 2011)
Values = 0 minimum-255 maximum suitability for conservation

For each of the three components (physical/ecological, anthropogenic pressure, and supports and subsidies), a suitability map was drawn using the Weighted Sum tool, as described for the first phase above. For this stage, experts determined the importance of each criterion to conservation

4.3.3 PHASE 3: ASSIGMENT OF WEIGHTS

Experts in the area determined the importance value of each criterion for the choice of potential conservation sites. This expert were chosen according to the stakeholders members of the Advisory Council (Figure 1) Fifteen consultations were held, with five governmental environmental agencies five representatives from academia, and 5 landowners from social sector, and private sector and NGOs.

The results were analyzed according to the analytical hierarchy process (AHP) method. Through a paired comparison, each actor uses his or her expertise to assign each component an importance value on a scale of 1 to 9 and Inconsistency in the pairwise comparisons is tolerable only if the inconsistency is less than 0:1 (Saaty, 2008). Subsequently, a geometric average of all criteria and all components is calculated.

A questionnaire for obtaining the data (AHP method) was adapted for the fieldwork, in order to obtain low values of inconsistencies, to minimize the subjectivity and to make it more understandable for the fifteen experts interviewed. The questionnaire was divided in three sections according to each selected criterion.

Forest degradation, Soils according to agricultural suitability, priority sites of conservation, water bodies, and slope layers shown in this chapter were combined according to the weight assigned to create the Physical and ecological map through a Weighted Sum in Arcgis 10.5.

The same was done for Anthropogenic Pressures Component (Distance to roads, highways and localities) and for the Subsidies and marginalization component (PES elective areas, PROCAMPO-PROGAN Subsidies and Marginalization index). The resulting maps will be shown in the results chapter

4.3.4 PHASE 4: SUITABILITY MAPS ELABORATION

Once the suitability maps of each component (physical and ecological, anthropogenic pressure and subsidize and marginalization component) were obtained, they were combined into a single map using a weighted sum, again according to the weighted given by the experts. These maps show the suitability for connectivity conservation for the study area. The maps will be shown in the results section

4.4 INCORPORATION OF THE VDAC SCHEME

4.4.1 PHASE 1: INTERVIEWS ABOUT THE VDAC CONSERVATION SCHEME

The interviews are used to know the perspective of social actors to understand through the words of the interviewees and appropriate the meaning they give them in the natural environment where they carry out their activities (Bernard & Ryan, 2010; Sautu et al., 2006). Being a voluntary scheme, it is necessary to know the perspective and interest of people about adopting voluntary conservation schemes for their own properties. In San Luis Potosí, there is not yet a certified ADVC property.

Semi-structured interviews were conducted. A questionnaire with 17 questions was elaborated (ANNEX) according to the presented in other studies on private conservation areas that included the perception of the landowners (Guzmán Wolfhard, 2015; Peña Azcona, 2015).

30 interviewees were conducted. The interviewed were selected representing the same groups previously identified in the Advisory council; 8 from the government sector, 7 from the academy and 15 landowners (ejidatarios and private owners). The questions were categorized into four groups:

- *Knowledge*
  Procedures and responsibilities in the certification of properties as VDAC
- *Potential*
  For the VDAC conservation schema for connectivity
  To generate economic income to the proprietors of the land
  For the sustainable conservation and management of forest resources
  To solve socio-environmental problems
- *Motivation*
  Motivations to certify their property
  Incentives for certification
  Interest of the proprietors of the land over the certification of their property
- *Constraints*
  Main limitations, advantages and disadvantages in the process of VDAC certification

The collected information, for its analysis was ordered according to the following steps, adapted from. (Guzmán Wolfhard, 2015)(Bernard & Ryan, 2010)

- Identification of the most relevant answers (themes)
- Categorization of answers

- Reduction of data to numeric answers
- Tabulation of information
- Quantification of numeric codes, generation of frequencies through transformation to percentage (30 interviewed = 100%)
- Creation of tables and/or figures

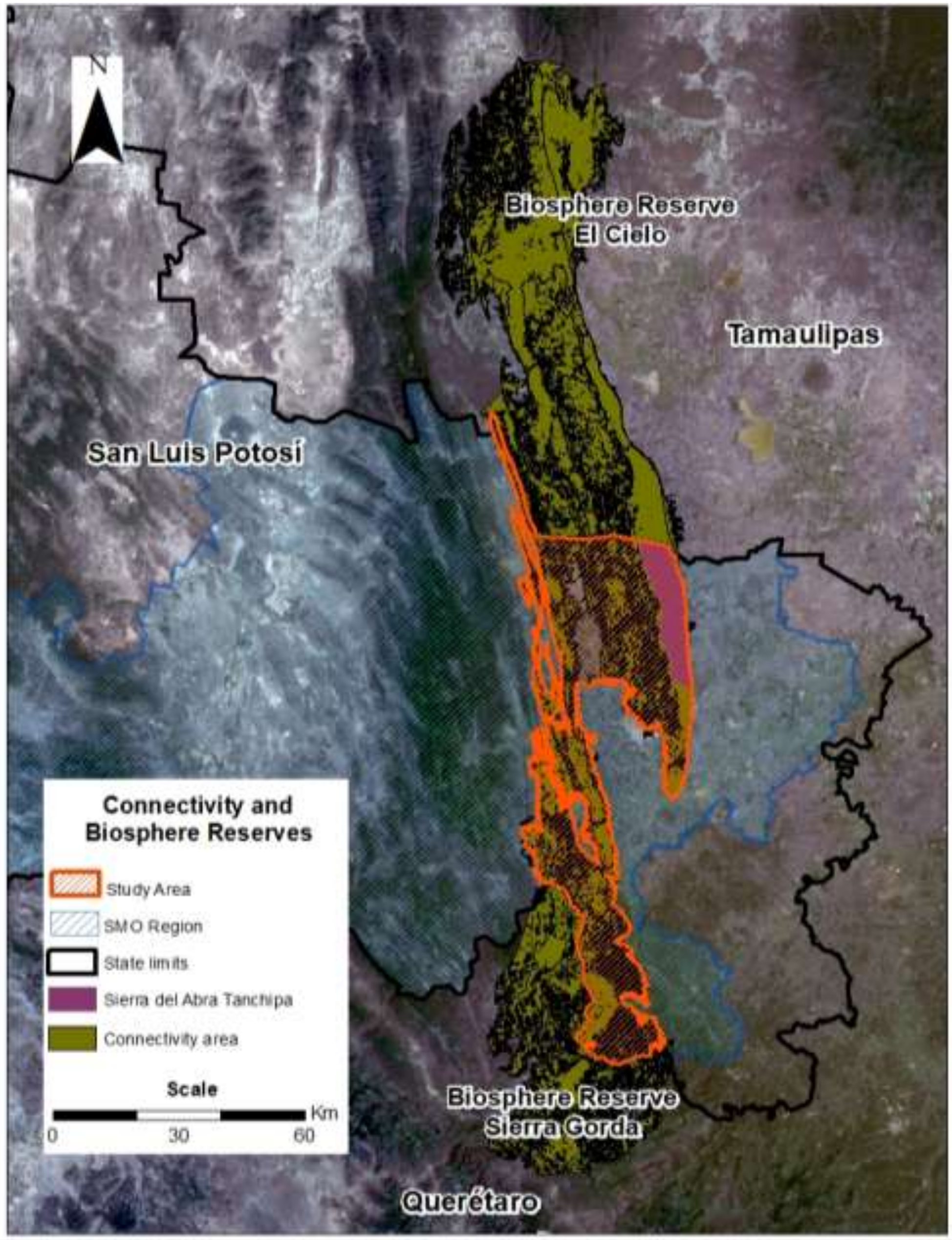
The analisys will be presented in the results chapter

4.4.2 PHASE 2. INCORPORATION OF POTENTIAL VDAC TO THE CONNECTIVITY PATH

Georeferenced information over the location of two properties whose proprietors displayed an interest in certifying them as VDAC was obtained. They were incorporated as destination points to the main path obtained from the Cost Path and traced again to incorporate them.

5 RESULTS

DELIMITATION OF THE STUDY AREA



Map 21. Delimitation of the study area. Own elaboration: Source (CONANP 2019,INEGI 2018)
*SMORegion Sierra Madre Oriental Region

The

Map 21 shows the Biosphere reserve el Cielo and the biosphere reserve Sierra Gorda despite fragmentation still linked by vegetation or morphology. This is relevant for the study area because the connectivity paths obtained could be linked to a major area. The delimitation of the study, area was verified through the NDVI and topographic position index. The study area is connected to a larger area.

CONNECTIVITY PATHS TO LINK BRSAT AND OTHER PROTECTED AREAS

PHASE 1: RELEVANT AREAS FOR CONSERVATION (Resistance/Cost Layer)

DATA GATHERING

According to the criteria established, the relevant areas for conservation are located in the south of the study area, close to the Protected Areas, Sótano de las Golondrinas, Hoya de las Huahuas and Cuevas de la Fertilidad. With the lowest values corresponds to agricultural areas, the presence of an extensive agricultural matrix is evident. The Abra Tanchipa it is isolated from other areas of relevance for conservation. Sierra de Enmedio y Sierra del Este, are in the same situation (Map 22).

Nevertheless, this area is also close to the BRSAT. The relevance for conservation in the study area is mostly conformed of medium values. A high influence of the values from TPSBC and Fauna record is evident. The Abra Tanchipa it is isolated from other areas of relevance for conservation

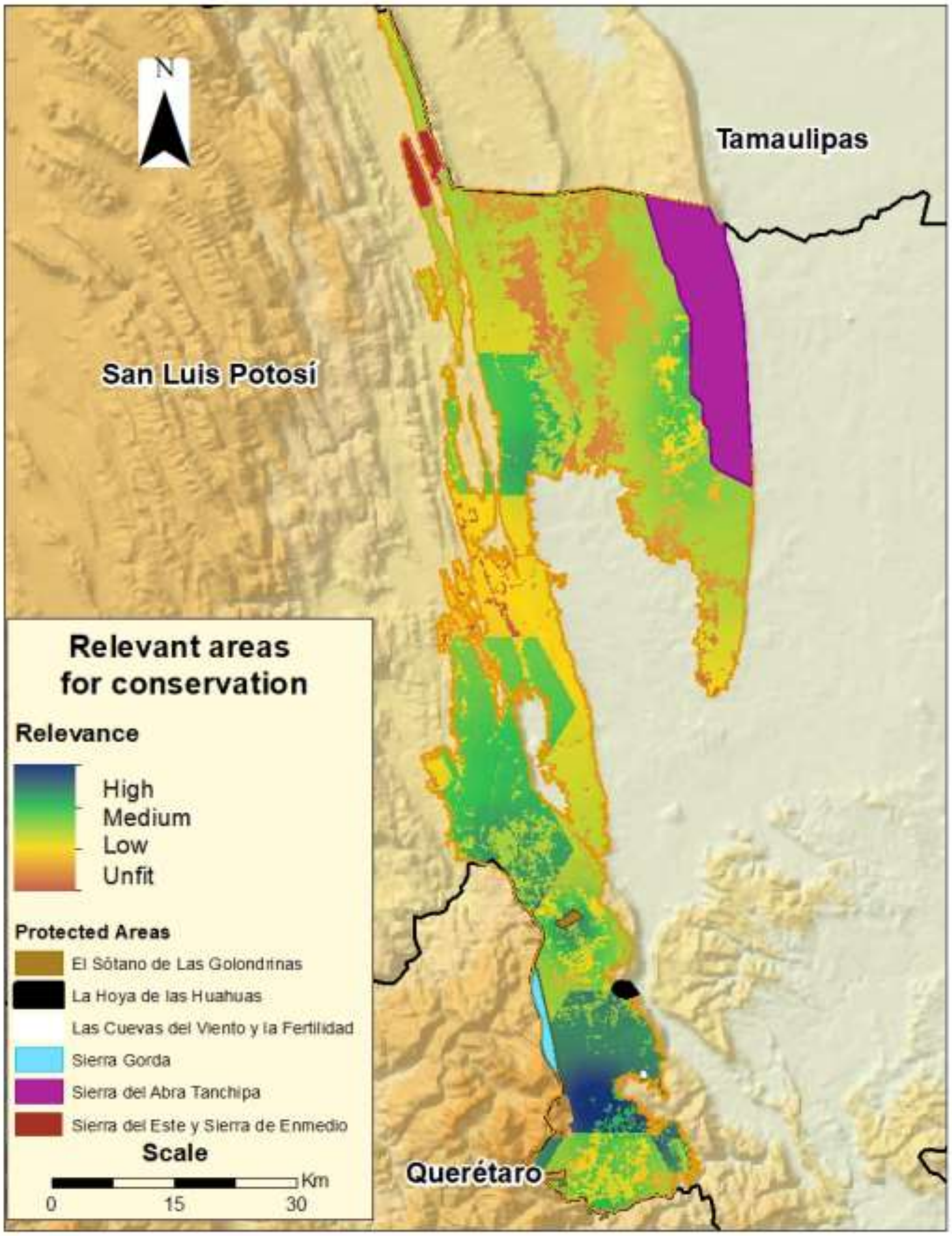
High suitability for conservation was observed mainly in the south of the area. Particulary near the Pas. Closest to the BRSAT, is evident the presence of an extensive agricultural matrix.

PHASE 2: CONNECTIVITY PATH LEAST COST PATH

The LCP tool used the map obtained in the phase one as a Resistance layer to find the LCPs from a point of origin (external point of the Abra Tanchipa perimeter to five different destinations (PA)

The "cheapest" path was obtained, oriented according to the resistance layer obtained with values of relevance for conservation; the path goes through the most conserved areas that are in the LCP from the BRSAT to the PA. (Map 23).The addition of the buffer allows visualizing the path.

The LCP pass through the remaining forest fragments and connect, in the first place Sierra de Enmedio y del Este, although is surrounded by medium suitability values is isolated by the morphology and the lack of vegetation to connect this PA. The detailed analysis of optimal sites for conservation was presented by the end of this section, with the incorporation of anthropogenic influences.

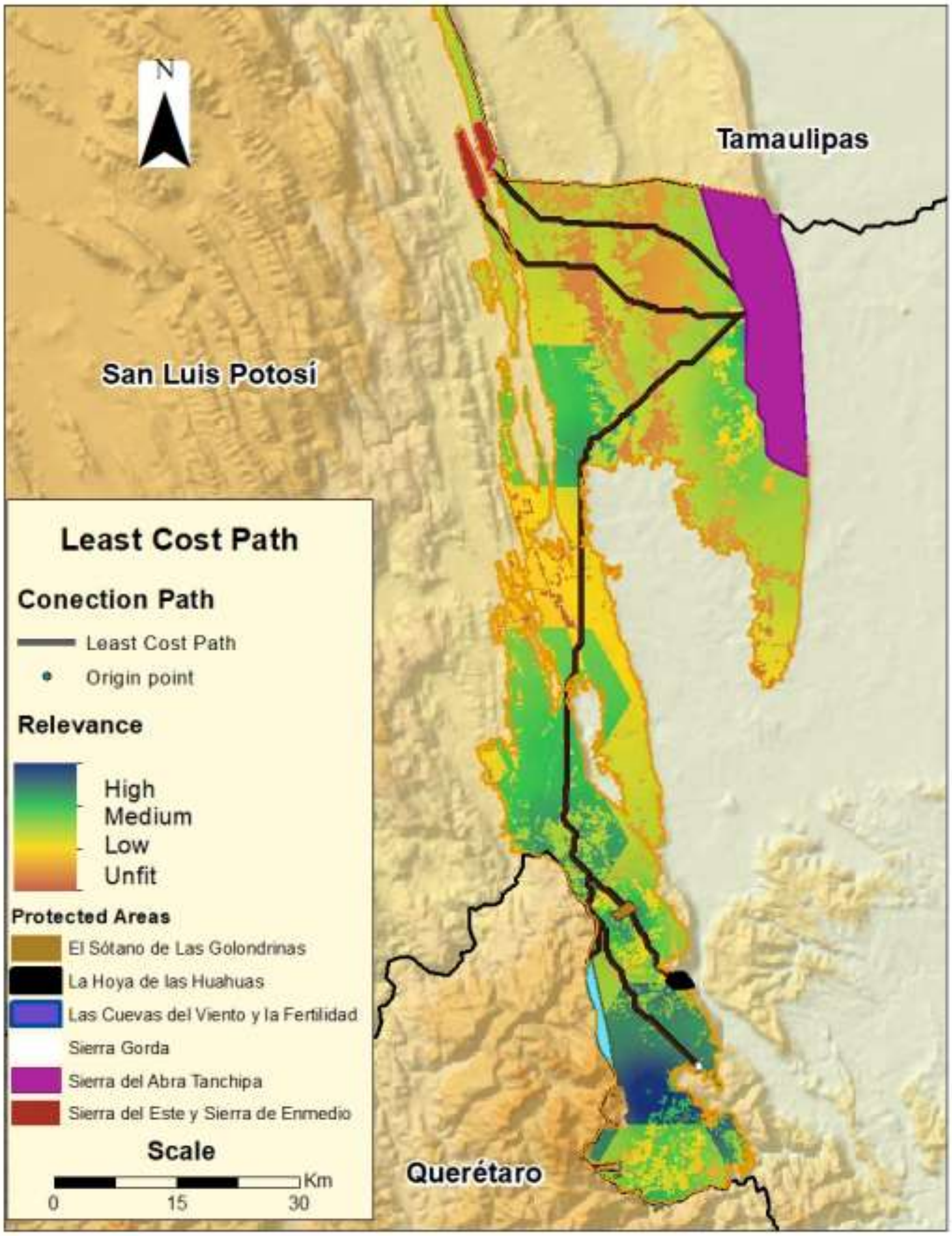


Map 22.Relevant areas for conservation. Own elaboration.

SUITABILITY MAPS FOR CONNECTIVITY CONSERVATION

PHASE 2: ASSIGMENT OF WEIGHTS

The obtained result of the experts consultancy was the weights assigned for each component according to the importance the criteria has for connectivity conservation (Table 11).



Map 23. Least Cost Path. Own elaboration

Table 11. Components Weighted assignment. Own elaboration.

Phisycal- ecological	
Forest degradation	19.8%
Soils suitability for agricultural production	16.3%
Priority sites for restoration	16.3%
Water bodies	37.3%
Slope	10.3%

Anthropogenic pressure	
Roads	25.4%
Highways	44.8%
Localities	29.8%

Subsidies and marginalization	
PES	44.43%
PROCAMPO - PROGAN	30.93%
Marginalization	24.64%

For the physical and ecological component, the expert determined the water bodies as the most important criterion, the highways of the anthropogenic pressures and the PES in the subsidies and marginalization component.

PHASE 3: SUITABILITY MAPS ELABORATION

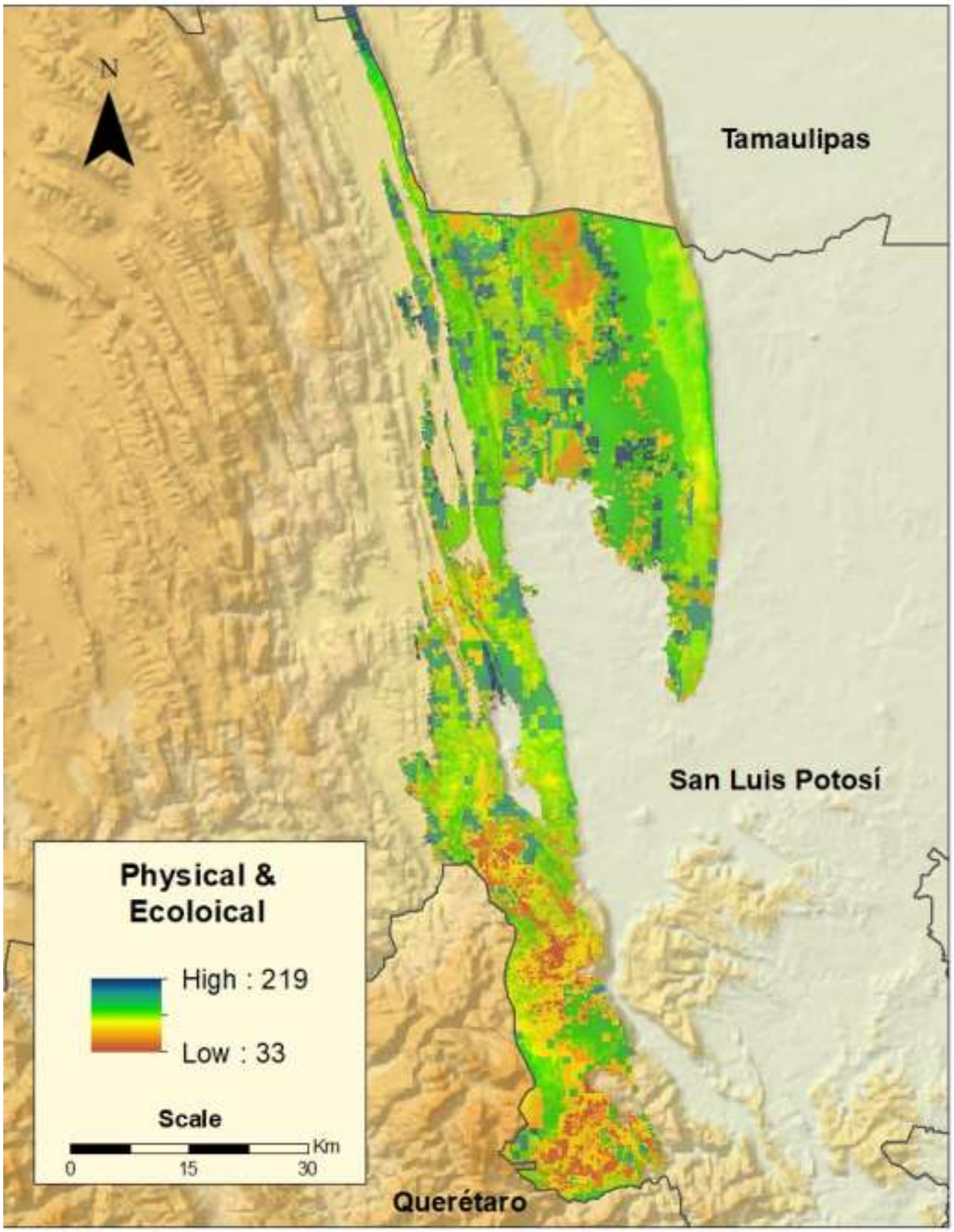
PHYSICAL AND ECOLOGICAL CRITERIA SUITABILITY MAP

An unexpected result was the high weighted given to water bodies. The majority of experts mentioned have faced consequences of water scarcity,-in a region where bodies of water are naturally abundant-. The second highest weight was assigned to forest degradation.

Experts consider conservation of degradations areas is a priority in the area. (Map 24). This layer shows a majority of high and medium values of suitability for conservation due to the exclusion of anthropogenic factors. Equal important the PSR, and Soil aptitude for agriculture, the less important attribute for conservation is the slope.

ANTHROPOGENIC PRESSURES CRITERIA SUITABILITY MAP

The layer of anthropogenic pressures shows an area with numerous restrictions for connectivity. According to experts, the presence of roads, highways and localities near areas for conservation has a different degree of pressure.



Map 24.Physical and ecological component. Own elaboration. Values = 0 minimum-255 maximum suitability for conservation

In the anthropogenic pressures component the opinions of the interviewed were diverse. Roads can facilitate the entry of firefighters (in case of a fire) to isolated places but it can also facilitate access for wildlife illegal traders. Similarly, highways are considered switches of biological connectivity, since they limit the movement of wildlife; but they also inhibit interaction with wildlife dealers.

The proximity to the human settlements (localities) represent a threat for conservation because it facilitates the access to natural resources (illegally in some cases). By the other hand in Ejidos Los Sabinos, communitarian brigades have promoted activities for conservation, like a communitarian forest fighters and a bird watchers (Map 25).Nevertheless, the main anthropogenic pressure mentioned by the experts is the highways, this element disrupt the connectivity, they explain that increases the access to protected lands, and isolate the fauna. In the area there are no wildlife crossing structures.

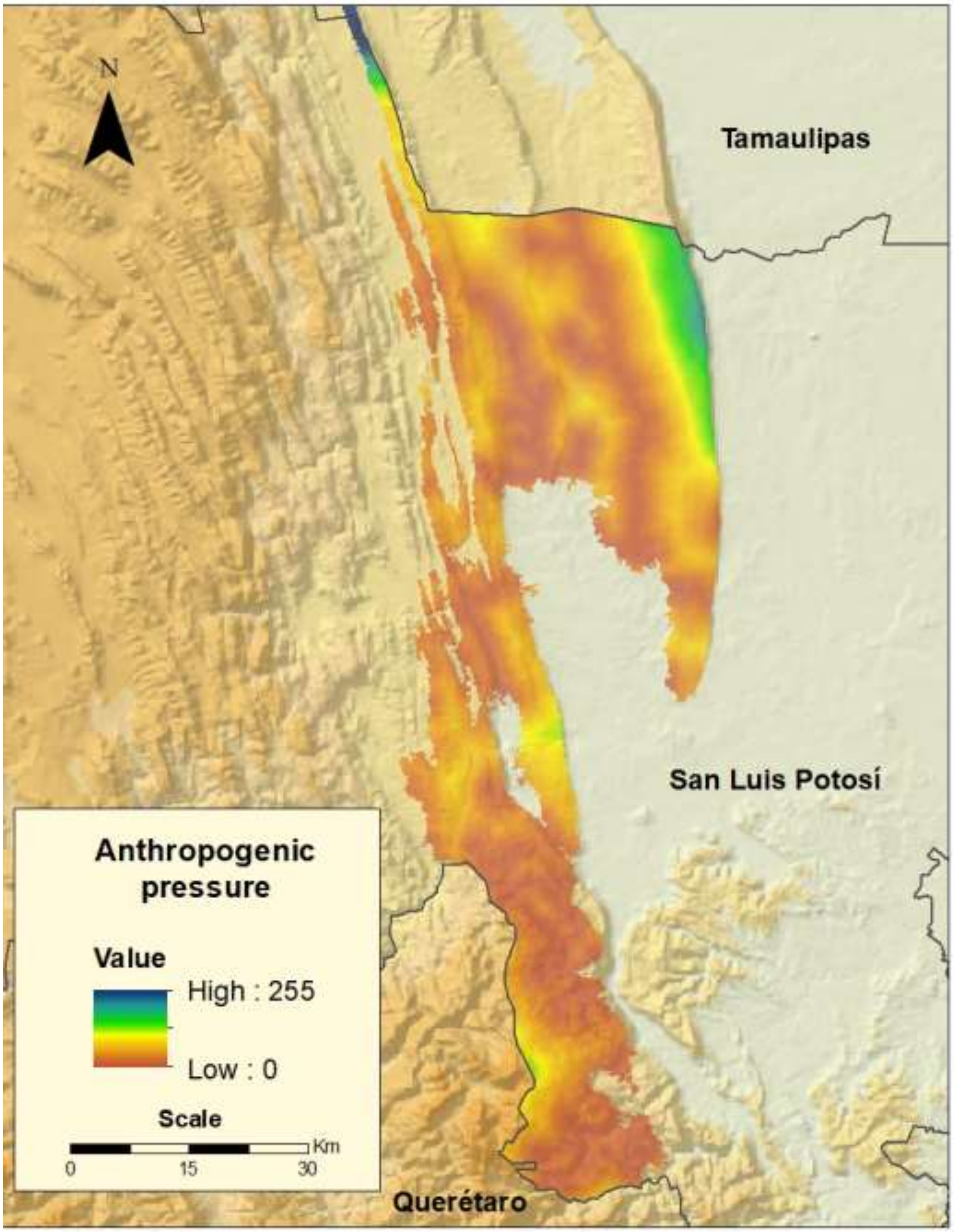
Under these criteria, it is observed that the area is mostly categorized as not suitable. Although, selected range of suitability (0 to 255) still permits to identify areas with lesser anthropogenic pressure (Map 25).

SUBSIDIES AND MARGINALIZATION (SOCIO ECONOMIC) COMPONENT

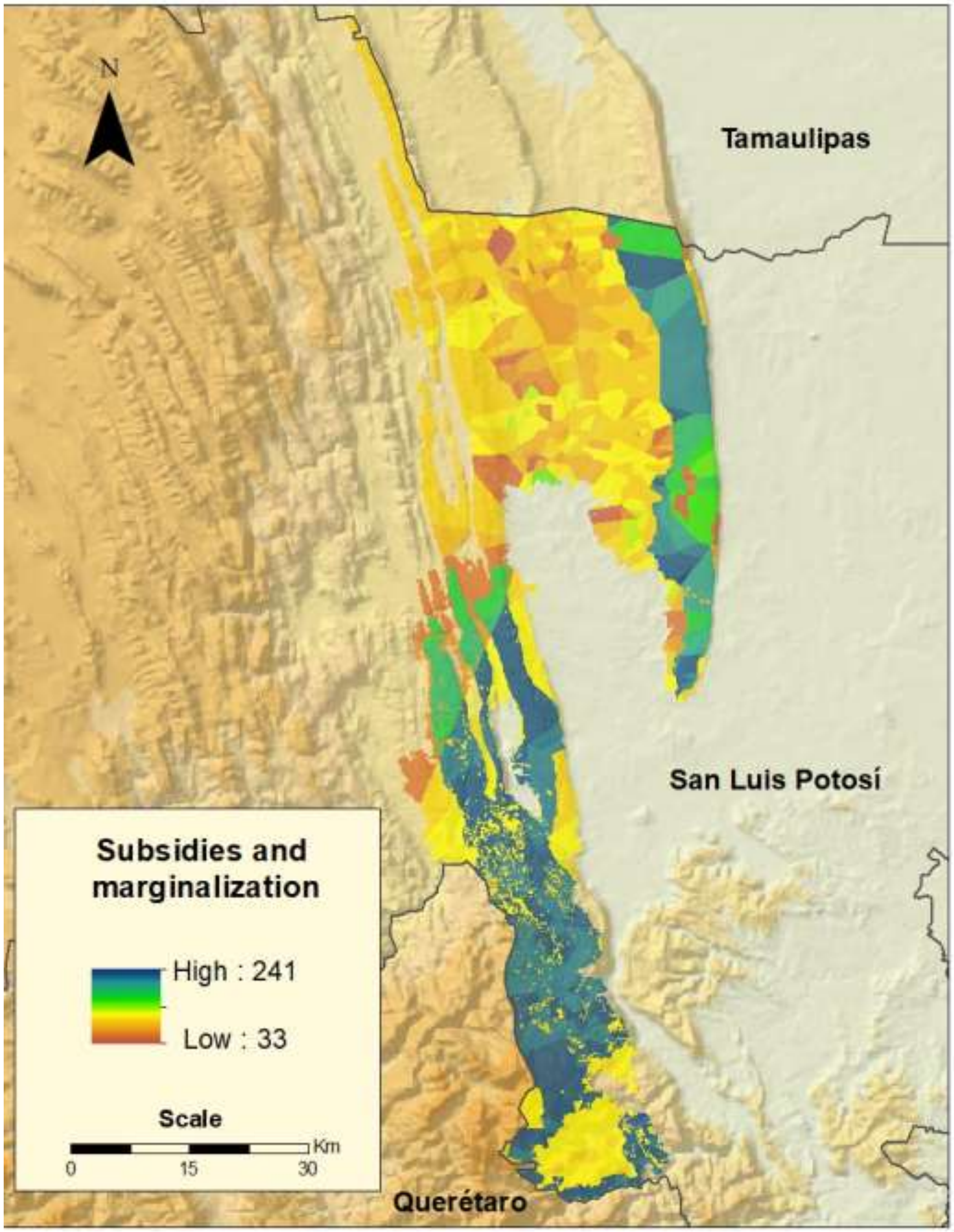
Economic support, experts acknowledged, is a key factor for conservation. The lack of alignment of public policies around territorial planning on the one hand favors livestock and agriculture, on the other, conservation. The subsidies analyzed are the most important of each institution. The National Forestry Commission (CONANP) and the Ministry of Agriculture in Mexico (SAGARPA) have worked uncoordinated for many years.

The experts recognized PES as the most important economic incentive for the conservation of this area. Practically the entire perimeter of “elective” areas for PES has the highest suitability valued. PROCAMPO-PROGAN subsidies denote areas with medium, low and unfit values. Even the above, the experts gave an important weight to this criteria. Experts considered having subsidies for agricultural activities in large areas is a restriction for conservation objectives. Therefore, there is a lower suitability on the map (Map 26) for greater surface area subsidized by PROCAMPO-PROGAN.

The marginalization is high and very high in the area. The southern part of the study area has a critical degree of marginalization (very high). The final layer shows the importance of the areas considered for payments of ecosystem services, which coincide with areas of high marginalization, therefore, the subsidy could represent an important element to encourage the interest of landowners in conservation, since which in turn are areas with few hectares dedicated to agricultural activities with PROCAMPO-PROGAN subsidies.



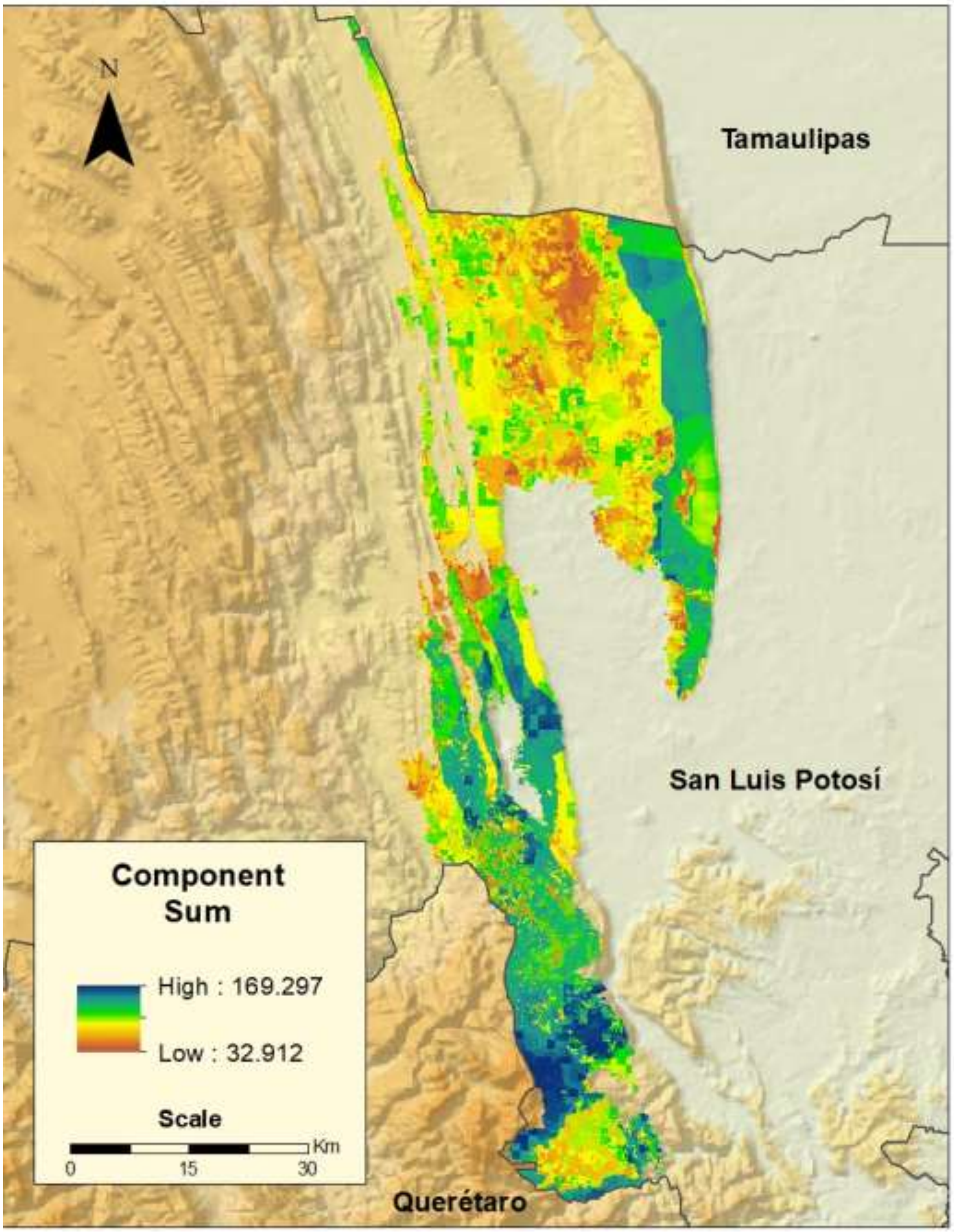
Map 25. Anthropogenic pressure component. Own elaboration.Values = 0 minimum-255 maximum suitability for conservation



Map 26. Subsidies and marginalization () Socio-economic component Own elaboration
Values = 0 minimum-255 maximum suitability for conservation

COMPONENT SUM SUITABILITY MAP

The result was obtained by combining the three components according to the weights assigned to each (Map 27). The following map highlights the most optimal areas for conservation considering the environmental, economic and social component of the landscape, although the area is dominated by anthropic factors, this result highlight there still areas of high value of suitability that worth preserve them and can be used to connect BRSAT.



Map 27. Component Sum (Physical-ecological, Anthropogenic pressure, and Socioeconomic components) Own elaboration Values = 0 minimum-255 maximum suitability for conservation

The highest weight was assigned to the environmental component, with almost 50% consensus. The importance of natural ecosystems in the area is recognized, mainly for the strong presence of the BRSAT experts. Secondly, subsidies and the degree of marginalization are key elements to consider when choosing an area and allocate it for conservation. Finally, anthropogenic pressures are less important in the choice of areas for conservation, due to experts consider *"we can do anything about infrastructure"* referring to the area has been disturbed since many years ago.

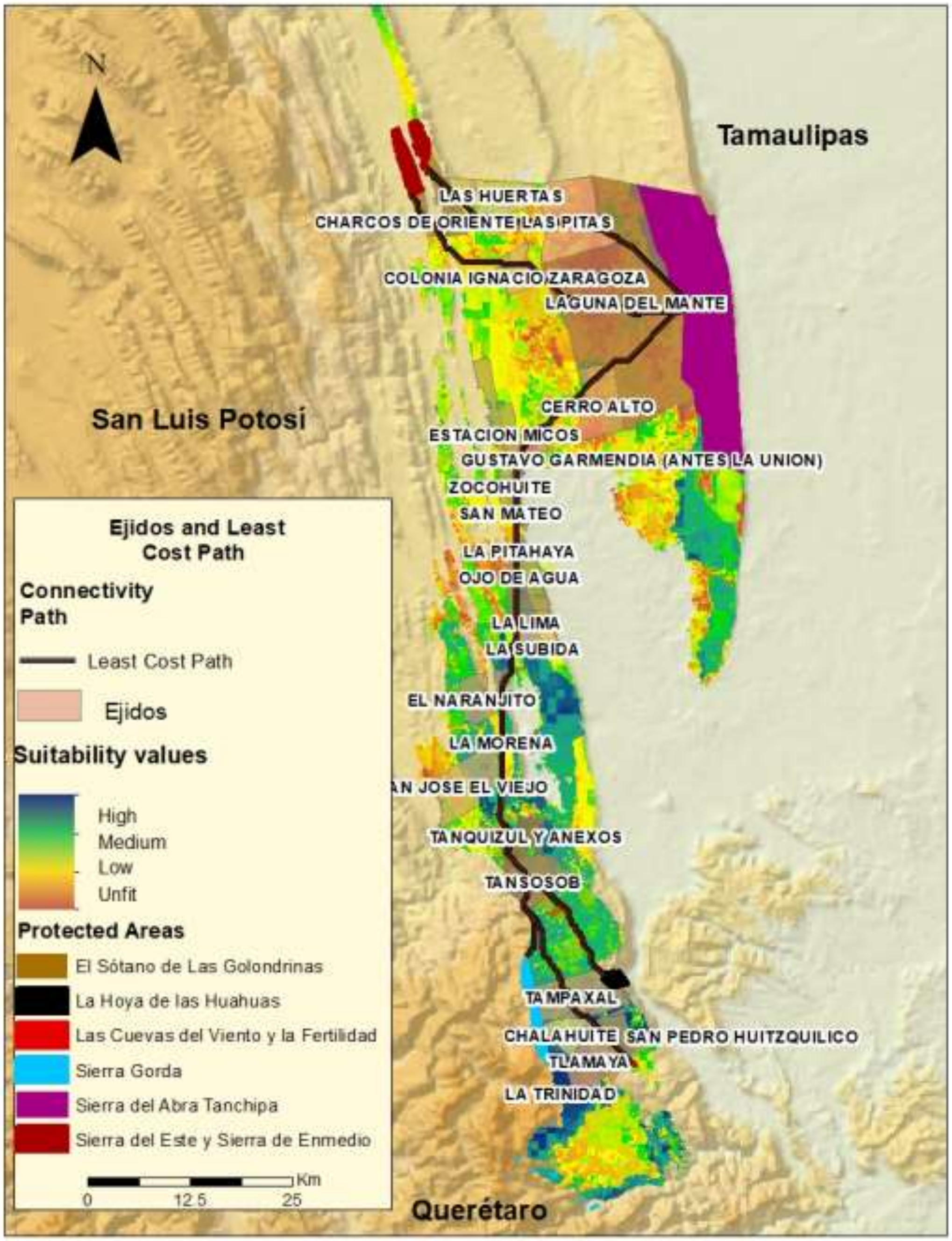
Nevertheless, the relevant areas for conservation in which LCP goes through, now area areas with various restrictions for conservation. The landscape is shaped by anthropogenic influences that must be taken into account to establish areas for conservation. In addition to the suitability values, the landscape is also a mixture of land tenures.

To identify clearly, the above mentioned, information of land tenure was incorporated. The Ejidos that are located in the LCP was added to the map (Map 28). The majority of the path is in Ejidal properties.

LCP obtained goes through 27 different Ejidos. In the north (from east to west), most of the properties are Ejidos. In the east and in the south, fragments of high suitability for conservation are identified, and some of them correspond to another type of property.

Near the BRSAT there are fragments whose conservation is critical to establish connectivity in the through the agricultural matrix; This Ejidos are Laguna del Mante, Las Pitas, Colonia Ignacio Zaragoza, Cerro Alto, Las Huertas, Charcos de Oriente, Estación Micos, La Loma, San Mateo, Zocohuite.

There are other Ejidos, mainly in the west and in the south of the study área, that has high values of suitability for conservation, desirable sites for conservation; Las flores y anexos, la Loma, La Cañada, Chalahuite, San Pedro Huitzquilico, Tlamaya. Somo others presents fragmented areas and highly conserved areas too. This is the case of Ejidos; Ojo de Agua, Tanquizul Y Anexos, Tansosob, Tampaxal, San José El Viejo, La Morena y el Naranjito, La Lima, La Subida, La Pitahaya, San Antonio Huichimal.



*Map 28. Ejidos and Least Cost Path. Own elaboration.*the name ofthe Ejidos are shown in the map*

INCORPORATION OF THE VDAC SCHEME

PHASE 1: INTERVIEWS ABOUT THE VDAC CONSERVATION SCHEME

Establishing the path, as a strategy to connect the BRSAT will be impossible if relevant areas for conservation are not protected. Results of the interviews are described, focusing on the opinion of the as the interview as group (Institutional, Landowners, and Academia).

KNOWLEDGE

Seventy six percent of interviewed of the three groups knew the VDAC conservation scheme; however, 23% who did not know it, were only landowners group (Figure 6).

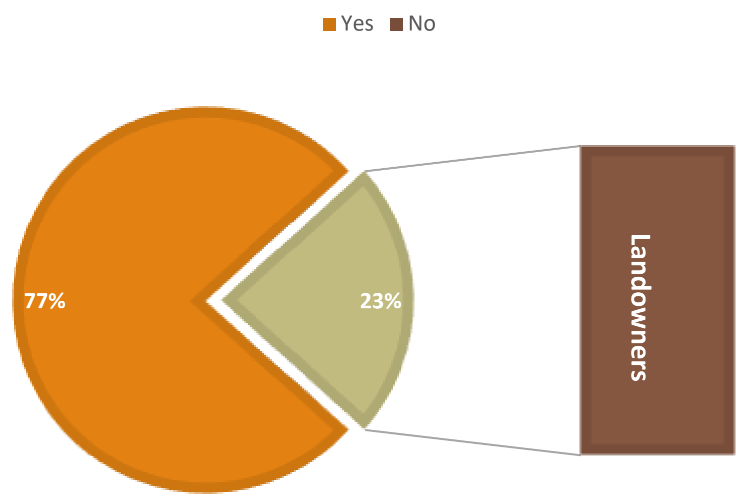


Figure 6.Knowledge about VDAC. Own elaboration

In this case, the stakeholders were briefly informed about VDAC definition, benefits, and procedures on how to register a property, all according to the official information of the National Commission of Natural Protected Areas web page, consulted on May 2019(CONANP, 2019).

POTENTIAL FOR CREATION OF VDCA

According to obtained data, 70% of the stakeholders recognize a VDCA registration could allow activities that generates economic incomes. When the interviewees, answer that they do not consider VDCA will bring economic benefits, in this context, was also positive. From the 30 % remaining, landowners (10%) and one expert from CONANP mention the importance of the authentic willingness of voluntary conservation with no economic incentives. Sixteen percent consider VDAC will not allow activities that generates economic income.

The main activities mentioned are listed above (Figure 7). Landowners mentioned tourism as main economic benefit of a certification while institutional experts concur in the access to subsidies, and academic group presume the major benefit could be the added value to products or services.

Potential

50%	Tourism
23%	Extraction of natural resources
10%	Willignes of conservation (per se)
10%	Access to subsidies
7%	None

Figure 7. Potential for economic benefits with a VDAC Own elaboration.

Data shown the interviewed consider there is potential for the creation of the VDAC in the region. Most stakeholders believe VDAC could lead to the increase of surfaces with sustainable forest management and may help to develop connectivity strategies for the Sierra del Abra Tanchipa reserve.

It should be noted that the VDAC as a voluntary conservation scheme, seeks people find in conservation an opportunity to benefit from their natural resources., 93% of respondents agree that this model can help to solve socio-environmental problems. The remaining almost 7% mention that they would not make any difference; these people are from the group of producers, particularly ejidatarios who live on what their land produces. Three answers were grouped in the next Figure 8).

96% of the all the stakeholders groups, agree that with the certification of a property could promote the development of sustainable management strategies in forest areas, help to solve socio-environmental problems of the BRSAT region and that could be as a strategy to create structural connectivity of the BRSAT with other NPs

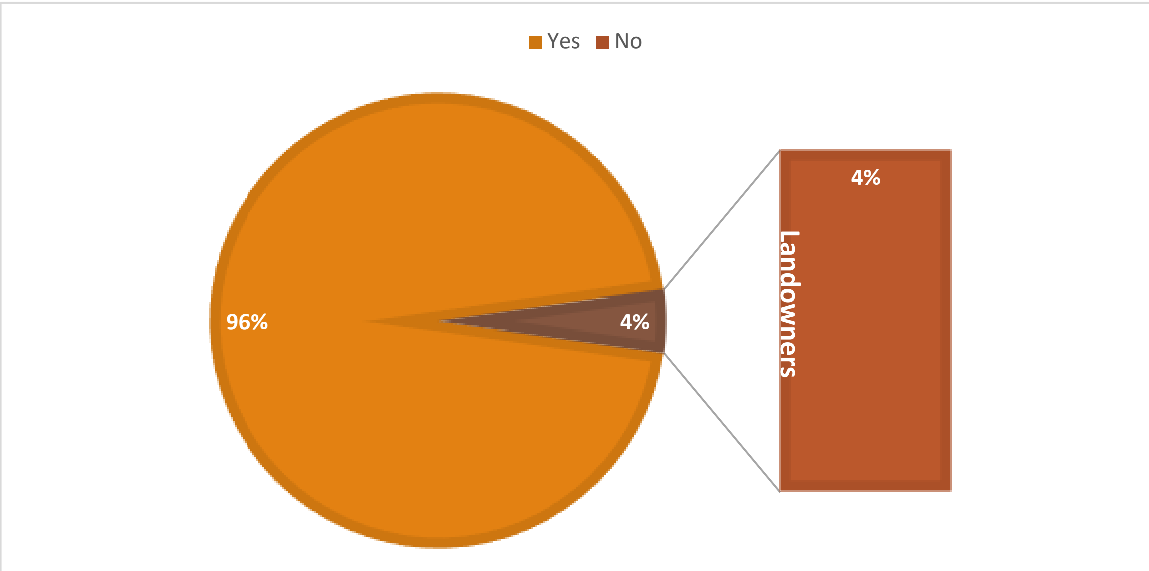


Figure 8. Potential for the creation of VDACs Own elaboration.

MOTIVATIONS FOR THE CREATION OF VDCAS

Main motivation to create a VDAC is the possibility to have an economic incentive. Nevertheless, in landowners group (6 out of 15 interviewees) mentioned environmental conservation is their main motivation, comparing to those (7 out of 15) who consider economic incentives the major motivation. Although institutional and academic groups affirmed that landowners had no interest in conservation, just in economic benefits and consider this, is the owners motivation.

The third motivation for the three groups is the “Shielding”. With a VDAC certificate, owners can “shield” their lands from land use changes (Figure 9).

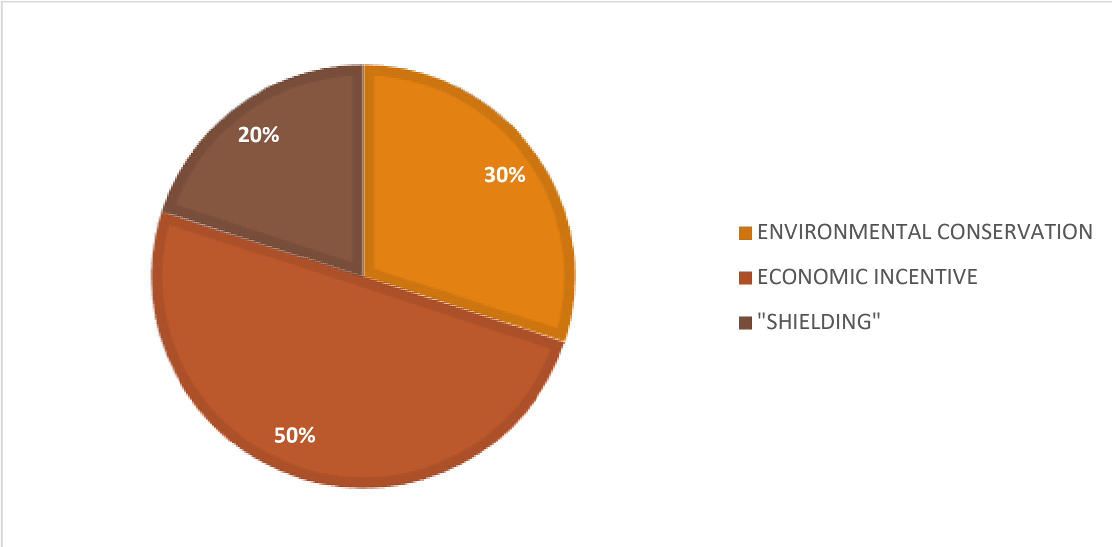


Figure 9.Motivations for the certification of VDAC. Own elaboration.

LIMITATIONS FOR THE CREATION OF VDCA

The answers were grouped in six categories. As can be seen, there was no majority preference. The answers are distributed in the categories uniformly. Each stakeholder group presented the challenges from their perspective. For the institutional group, the main challenge is to comply with the responsibilities acquired after certification. Landowners mentioned the main obstacle is the lack of information about VDAC, the same for the academy group (Figure 10)

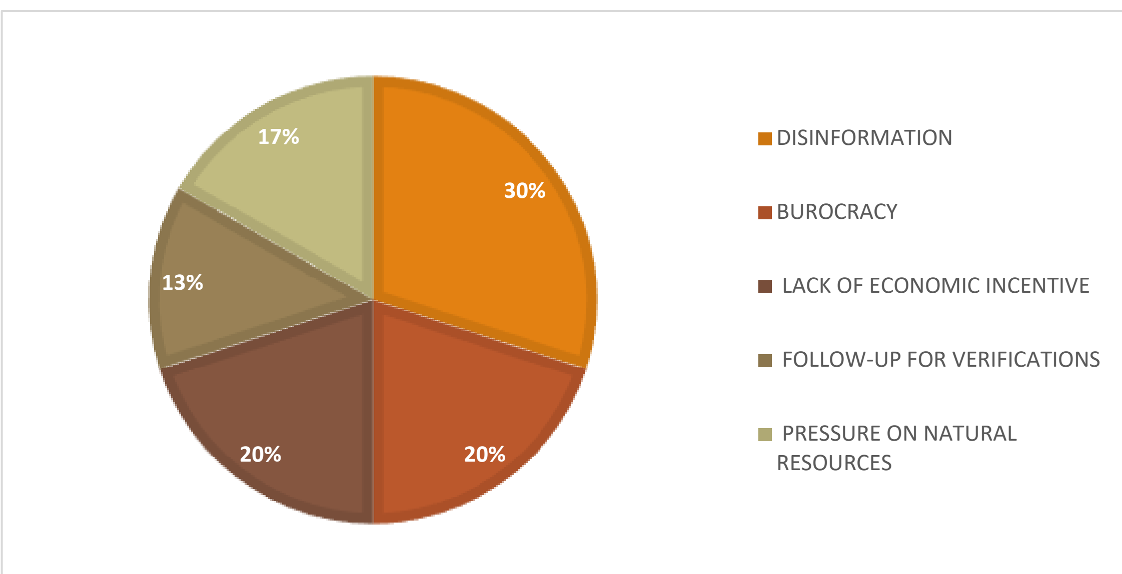


Figure 10. Main constraints for the certification of VDAC. Own elaboration.

According to the information obtained, there are advantages in the VDAC certification. Half of the stakeholders consider certify lands will help to increase PA regional surface, access to federal subsidies (20%) and in less proportion (10%) willingness of conservation (without any mandate or incentive), shielding and sustainable use of natural resources. For all the groups, the main advantage is in the environmental aspect.

In contrast, disadvantages lack of economic compensation for the maintenance of the land, more than half of the landowners confirm it, followed by the anthropogenic pressures that are exerted on natural resources. For the government sector, the main disadvantage is that the VDACs do not have direct supervision by CONANP, and for the academy sector, in addition to the lack of financial compensation, the aforementioned disadvantage is the non-fulfillment of the responsibilities entailed by the certification. Both are enlisted in Figure 11

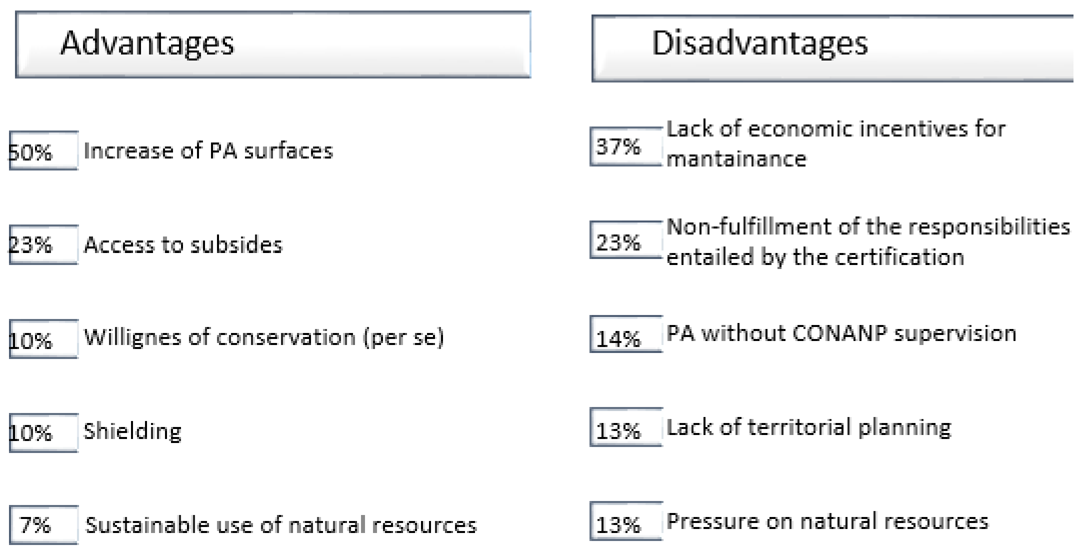


Figure 11. Advantages and disadvantages in the VDAC certification. Own elaboration.

PHASE 2. INCORPORATION OF POTENTIAL VDAC TO THE CONNECTIVITY PATH.

The voluntarily destined conservation areas, according to the interviewees, would be a useful tool to create connectivity. Once VDAC could be established.

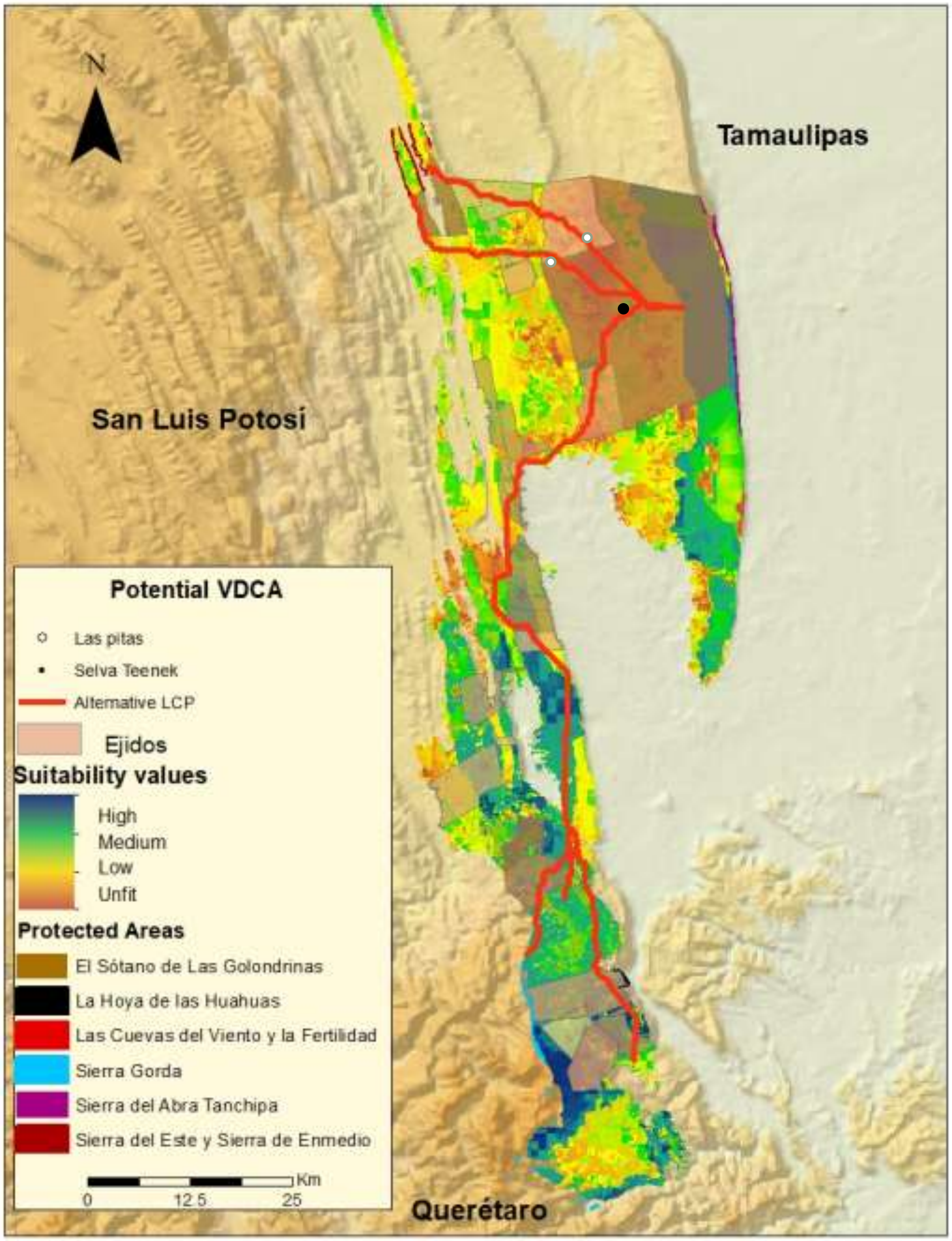
Therefore, the identified areas whose owners showed interest to certify them as VDAC were incorporated to the path Map 29. Five landowners (3 private owners and 2 Ejidatarios) show interest, although only two could specify the areas they would like to incorporate to VDAC scheme. The properties Selva Teenek and Ejido Las Pitas were added as destinations.

The path was modified to include these two VDAC proposals and to alter the connectivity path with the incorporation of this areas. Both areas are found in critical areas for connectivity conservation.

The suitability values in these areas are medium and low, and are part of the fragmented matrix between Abra Tanchipa and Sierra del Este and Sierra de Enmedio. The path shows that Ejido las Pitas is a key area for connectivity. This Ejido has one of the highest values in the suitability map (in this fragmented critical area), and a high relevance for conservation. Particulary, Ejido las Pitas has similar vegetation to Abra Tanchipa, increasing the potential to act as an optimal ecological corridor.

The property known as Selva Teenek is a small property located 28 km in a straight line to Las Pitas. Both areas are located in agricultural matrix but also near to forest remnants (IMAGEN). Their locations, relevance for conservation and the willingness of the landowners to establish VDAC

Therefore, connectivity is not limited to the main path, or to the suitable sites founded. VDAC can be used to create ecological corridors mainly if; The areas presents the same ecosystems that BRSAT, exist willingness of the owners in conservation, helps to prevent the growth of the agricultural matrix, or bring some economic benefit for the landowners and the population itself. This is what ILM approach suggests, to conciliate the needs of the economic and social sector in the natural landscape in order to achieve biodiversity



Map 29.Potential VDAC. Own elaboration

6 DISSCUSION

The UNDP) in its sustainable development goals (SDG), goal 15, mentions that must be achieved

"Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss" and that urgent actions must be taken to reduce the loss of natural habitats and biodiversity which are part of our common heritage and support global food and water security, climate change mitigation and adaptation, and peace and security." (UNDP, 2015)

Since 1993, has been proven the importance of biodiversity and the requirement to establish an ecological corridor between Del Cielo Biosphere Reserve (Tamaulipas) and Sierra de Abra Tanchipa This would protect the habitat of resident species, migratory species, and ecosystem transition.

The RBSAT Management Program mentions the creation of an ecological corridor with Sierra Madre Oriental should be supported to ensure connectivity between Reserves (SEMARNAT, 2014; SEMARNAT & CONANP, 2014)

This study found through the incorporation of 11 criterion and multicriteria analysis the suitability for conservation that BRSAT surroundings has. LCP and can be proposed as ecological corridor to connect it with other PA through heterogeneous matrix of suitability values; which could be established by promoting the VDCA scheme and by motivation of landowners to obtain benefits with the certification of their lands. On the findings and contrasts of this study with others, the following was found: Identification of relevant areas for conservation

DELIMITATION OF THE STUDY AREA

The delimitation of the study area, was the result of a preliminary analysis of connectivity through the vegetation index NDVI, used commonly to establish corridors(Muratet et al., 2013), and with the TPI to obtain landforms classification to identify manually topographic "linking" of the area (De Reu et al., 2013). Once the layers were combined, the delimitation of the polygon should be made manually. This process is complex and could lead to errors and subjectivity establishing the limits of the area.

This delimitation was realized for two main reason: to verify the structural connectivity of the area outside the limits of SLP (to ensure that the Paths founded for this study could be part of a larger corridor in the future); and to delimit the polygon to the administrative limits of SLP. This, to respond the need of BRSAT management program of creating connectivity for the RBSAT in an operative area. There had been previous failures working with connectivity projects that exceeds BRSAT management jurisdiction (CESMO).

Despite of that, connectivity studies in the future must be carried out considering a larger area to enhance connectivity through the biosphere reserves in Tamaulipas and Queretaro, with a systematic approach of linking first surroundings of BRSAT, and then expand those connectivity Paths.

RELEVANT AREAS FOR CONSERVATION

DATA GATHERING RESISTANCE/COST LAYER ELABORATION

For this first step, the aim was to found relevant areas for conservation based in four ecological criteria (Forest, fauna, PA, PTSBC). For this phase, human pressure criteria was not included, in order find in the fragmented matrix the relevant areas for conservation even though, they were exposed to anthropogenic pressures. The anthropogenic pressures were added in the suitability map.

To achieve this, only ecological criteria that gives information relevant for conservation were used and a suitability values assigned were ranging from zero to 255. Thus, less optimal sites are not excluded but added to a low category of relevance to conservation. This in order to have the largest area available for the Least Cost Path tool can create a path, despite the fragmentation of the area. In contrast other studies where suitability is limited to narrow ranges (e.g zero-3)and potential areas are disqualified by operate in limited option range (Guzmán Wolfhard & Raedig, 2019).

To determine relevant sites for conservation it is essential to verify through fieldwork the accuracy of geospatial analysis. Although this was not done in this study, field work is required at the beginning and end of the study to reduce errors and uncertainties of the geospatial analysis (Bennett, 2003; Garcia-Alaniz et al., 2017).

ArcGIS 10.5 was used to reclassify and standardize the four layers of information mainly from a vectorial format to a raster that could be compared and summed with others. This was done using, Euclidean Distance, and Kernel Density tools. The use of two different tools is relevant to analysis data more precisely. For e.g, density of fauna records is not would not present the distances to PA.

This was used also in multicriteria analysis and suitability maps that incorporates information in different formats. With the same purpose, adding a buffer is a very common tool (Delattre, Baudry, & Burel, 2018; Guzmán Wolfhard & Raedig, 2019; Shirabe, 2018) , although this could limit the potential spatial information that could be obtained from the original format

The geospatial information of the four used criteria was limited by some factor; Recent information about land use and vegetation on the most precise scale (1:50,000) was published in 2015, but contain information since 2009, under these circumstances is difficult ensure the ecosystems permanence. Although there are supervised classifications images with higher resolutions, there is not one that covers the entire study area,

For the fauna records, worth mention that taxonomic information for each group was reclassified according the IUCN red list categories, including the category “data deficient”. This is relevant information about species occurrences, only that a direct or indirect assessment of risk of extinction is not possible because data on abundance or distribution are lacking.

Even though the fauna occurrences records used in this study are numerous and comprises four different taxa, it cannot be assured that the species are currently in those areas. Data bases used has record from at least 30 years to nowadays. Other method should be incorporate to precise fauna distribution.

For many years potential distribution models has been used, like the cases for mammals (Botello,et al., 2015), birds (Jacinto-Flores, et al., 2017) and plants (Torres Acosta et al., 2019). For further approaches to connectivity and fauna distribution, is recommended the use of this tool should be when information about populations and habitat requirements of relevant species is available. A species distribution modeling was not possible due to the different focus frame of this research.

Notwithstanding, the use of fauna records for this study, it is a proposal to work with sighting densities as space distribution and thus considerate four different taxonomic groups, adding them different suitability values whether species are in some risk category..

The information from CONABIO (2007) of Terrestrial Priority Sites for Biodiversity Conservation was included for being a robust source of information that identifies areas that are biological relevant for biodiversity conservation and that are threaten(Ernesto Suárez-Mota & Luis Villaseñor, 2018; Terán-Valdez, 2013). However, the layer is not updated, the land use changes in the area has rapidly increased since its elaboration (2007). It would be more accurately use more recent data of biodiversity loss, although this information has not being updated.

For further studies, more variables should be consider, that include detailed scales and recent information to obtain a more accurately outlook of the relevance for conservation.

Finally, to obtain the resistance layer, all the standardized layers of the criteria were summed. The weighted given in this case was not given for experts; this factor should be considerate if more criteria will be included. In this case, each criteria had the same weight for each layer considering the main objective was to create a resistance layer to find maximum available surface no with specific characteristics for a particular specie, so there was no discriminatory attribute to weight the layers differently.

The results shows relevant areas for conservation without any restriction on their size, although previous studies that used this method, usually link major protected areas (Beier et al, 2008)

Linking small patches has been used in the recent years to link of vegetation to create a paths through the fragmented matrix (Fahrig et al., 2019; Guzmán Wolfhard & Raedig, 2019)

In contrast to reported by (Salazar et al., 2017) that corridors must not take into consideration minimum surfaces to promote connectivity, in where the plants and mainly animals populations can remain viable. Although, the most recent studies of international fragmentation experts highlight there is no empirical evidence supporting the widespread assumption that a group of small habitat patches generally has lower ecological value than large patches of the same total area (Fahrig et al., 2019) Successful connections between various small fragments should be analyzed.

Image 1. Biosphere Reserve Sierra del Abra Tanchioa (BRSAT)

In the same way, relevant areas to conservation of this study contrast with the vision that protected areas should preserve places with habitat attributes of umbrella species and then connect them. As in Mexico, where the Jaguar (*Panthera onca*) habitat requirement has been used to establish places to ecological corridors (Errejón Gómez et al., 2018; Rodríguez-Soto, Monroy-Vilchis, & Zarco-González, 2013)(Errejón Gómez et al., 2018; Rodríguez-Soto et al., 2013)

In this case, a wide variety of species occurrences from different groups was used for two main reasons, there area has high levels of biodiversity that is in some category of threats (SEMARNAT, 2014); and species need linkages to maintain their populations processes . Umbrella species, like large carnivores have generalists habitats and they can marginal move through degraded habitats, and a corridor designed for them does not serve most habitat specialists with limited mobility(Beier et al., 2008) . The resistant layer obtained aims to fulfill different habitat requirement combining to this target, different land cover.

Furthermore, this result, the reported by Ersoy (2019), that a "mix of land covers (particularly, woodlands, mixed vegetation and unimproved grassland) have a high potential to provide corridors for the maximum number of species (Ersoy et al., 2019) So adding this criterion paths would be evaluate by requirements of various species to be functional and not only structural. This shown in the different values commented in the result section.

As mentioned before the RBSAT is surrounded by a fragmented agricultural landscape. This creates the need to consider as much surface as possible among the surrounding of that can be used to be connected.

However, their connection was considered as crucial since these private areas could be strategically used for the connectivity conservation management

LEAST COST PATH

There are other methods to obtain paths for landscape connectivity, such as random walk modeling network analysis or gravity models(Lee et al., 2014). Although, least cost path is widely recognized for being optimal, efficient , cheap and flexible for structural or functional connectivity(Adriaensen et al., 2003; Lee et al., 2014; Raney, 2009; Rodríguez-Soto,et al., 2013).

A buffer was added to the path. Although it has been debated is whether is necessary add protection buffers to the least cost paths(Delattre et al., 2018), for this study it was consider that are barriers or filter strip that helps to separate land used mainly for agriculture land as done by Gene (2019). In addition, it was added to be more visible on the cartography.

Finally, the source and destinations for the path were PA. This should be complemented with the new relevant sites for conservation founded; even they do not have a category of protection, enlarging the study area to different orientation (West East) to obtain more paths to connect more relevant areas to increase the opportunities to generate connectivity for BRSAT. On only path might not be favorable for species distribution and movement, more than one path should be identified(Guzmán Wolfhard & Raedig, 2019), linking as many fragments of relevance of conservation as possible.

The Path obtained incorporated fauna criteria, so it can be consider that has a mixed approach (structural and functional connectivity). This path have being used before to increase the

Although establish a connectivity paths for functional connectivity will require more accurate information of habitat distribution(Pascual-Hortal & Saura, 2008) and needs for specific taxas (A. Bennett, 2003; Taylor et al., 2010), and also to validate this information through some potential distribution model for e.g., based on mechanisms from dispersal ecology(Delattre et al., 2018).

We observed that the highest connectivity (% of individuals having moved from A to B) was obtained when both the matrix and the corridor

The obtained path crosses the study area from origin to destination through an area classified with high, medium and low relevance for conservation values. Although, the least cost path will follow the "cheapest path" this will have the highest values of relevance for conservation in the area. The path obtained was created in a heterogeneous matrix. According to recent studies in connectivity (Delattre et al., 2018; Ersoy et al., 2019) a path that go across different coverage types, consequently with different qualities generates great potential to connectivity. We could expect according to recent studies that the path could represent a high connectivity for species moving from one point to another, because the corridor area will have slightly better quality (relevance for conservation) than the matrix.

This areas of relevance presented by the path, also can be used to locate optimal surface to other conservation schemes, as the Payment for environmental Services(PES), like was propose by Zhang et al.,(2019).

Ramirez-Reyes (2018) analyzed the PES benefices in Mexico during 12 year (2000-2012). He reported, "PES program reduced both forest cover loss and forest fragmentation (…) Low-PES areas increased twice as much of the number of forest patches, forest edge, forest islets, and largest area of forest lost compared to high-PES areas". According to this, PES could help to reduce fragmentation in Mexico; under these circumstances, the least cost path would help targeting areas with major importance to conservation.

Through the resistant layer of relevant areas for conservation and the least cost path obtained, the isolation of Abra Tanchipa from other Pa is evident, mainly to the east and west. Sierra de Enmedio and Sierra del Este are isolated too. Lack of connectivity among these areas is a threat to the populations of different taxa that inhabit in these areas and between them. Errejón (2018) reported similar result; BRSAT is at risk of becoming a simple forest patch. This and isolation can cause severe problems to biodiversity, even generate local extinctions.

Is necessary promote connectivity for the BRSAT with other reserves to avoid becoming "islands "of biodiversity This also was mentioned by (Errejón Gómez et al., 2018), although in contrast, this research created connectivity paths to the south of BRSAT, particularly with the biosphere reserve el Cielo, In contrast with previous studies that only have promoted connectivity to the the North of BRSAT with the biosphere reserve El Cielo.

Despite the results, there is still the debate whether biological corridors promote connectivity or not. Some authors mention(García Quiroga & Abad Soria, 2014; Geldmann et al., 2015; Wood et al., 2017) that it is not proven that these paths will create connectivity and that the species will move through the paths, specially the ecological corridors elaborated through GIS tools(Gene et al., 2019).

According to the ONU around 1.6 billion people depend on forests for their livelihoods (UNDP, n.d.), An ecological corridor should help to resolver in integral form social, economic and environmental problems and to secure the access to natural resources"(Sloan et al., 2019). Considering these points, this proposal aims to establish a biological corridor integrating the human component was realized.

It has been proposed that agricultural matrix should be included in connectivity studies, to connect fragments(Petracca et al., 2014) or avoid establishing paths near agricultural matrices (Wood et al., 2017)

SUITABILITY MAPS FOR CONNECTIVITY CONSERVATION

CHOICE OF COMPONENTS AND CRITERIA

To find connectivity paths, data compatible with GIS have been used, limiting this information to cartographic data, that rarely includes specific information on the requirements of habitat species.

According to Beier (2008)"Habitat for any species is defined based on life requirements, such as food, cover, nesting sites, safety against hazards and relationships with competing or facilitating species". So this information has to be inferred, for e.g, soil cover is related to food and cover and humans and this are a major danger to many species(Beier et al., 2008). Layers of human interventions are relevant components to consider in the movement of organisms. Beier (2008) suggest that linking studies should include factors related to human disturbances.

The variables chosen for the analysis were grouped into three components: environmental, anthropogenic pressure and socio economic (subsidies and marginalization) and were based on the studies of(Moffett & Sarkar, 2006; Terán-Valdez, 2013; Torres Acosta et al., 2019)

More criteria should be incorporated to each component to have a complete overview of the socio-environmental and economic situation of the area. As a suggestion, incorporating the economic activities of the population and the dynamics of land use change accordingly would be an important in the establishment of corridors. In addition, ecological component could be strengthened with criteria of habitat requirements of different taxa or even the available paths of displacement of birds or jaguars that already exists in the area.

DATH GATHERING CRITERIA RECLASIFICATION AND STANDARIZATION

Adriaensen (2003) highlights importance of use of the best quality images, information and layers for the elaboration of suitability maps. Frequent errors occurs when different scales, projections, sources information, periodicity and sampling methods are combined. For the 11 different layers, used to create the suitability maps, the most recent and precise information available was used, although in some cases it was desirable to have more accurate data. Mainly with the land use cover, and edaphodology layer that for the State of San Luis Potosí are outdated.

The same that in the first objective, the layers used different process to standardize and reclassify the information. Criteria reclassification was done according the information contained in each layer (e.g marginalization categories where already establish as high, medium, low).If it did not contain information to classified it, was done according to the research needs and field observation, although this should be avoided, the mismanagement of the information could altered the results of the source layers.

The above mentioned, occurred for e.g with the PROCAMPO-PROGAN information. Thiessen polygons were used to standardize the layer, although there are other methods and tools that could help to present the information more accurately, e.g, spatial references of the subsidies, the number of beneficiaries or monetary compensation. Another case occurs with the soils and the slope that both were reclassified with the highest values of suitability to plane sites and to high slope respectively. Even though this seems contradictive, planes surfaces are land use changes and high slope mainly in mountains are often important sites for biodiversity conservation(Chaverri-Polini, 1998). In further studies, this “pre” assignment could be consulted with experts.

WEIGHTS ASSIGNMENT

In the region, weighted opinions from experts have been used and granted certainty to find conservation areas in the fragmented territory of the Sierra Abra de Tanchipa, although with different objectives (Torres Acosta et al., 2019)

As was presented by Comino (2016) is indispensable key representatives experts are identified and consulted face-to-face to obtain objective evaluations of the variables in the AHP methodology. This method has been criticized due to interdependence between criteria and alternatives that can lead to divergences between judgment and the ranking criteria. By the other hand this method is widely used and recognized because is easy to use and to adapt to different needs that allows to reduce subjectivity and inconsistencies in the opinion of the experts(Hester & Velasquez, 2013)

The experts for this case were selected from the stakeholders of the Advisory Council, for being entities that have influence in the BRSAT management. Nevertheless, the results of the AHP may not be a broad consensus, because in somehow these experts are related and concern to the biosphere reserve protection. Further approaches must consider do a stakeholder analysis integrating different visions and interest in the uses of the BRSAT area.

SUITABILITY MAPS ELABORATION

Suitability maps obtained (physical-ecological component, anthropogenic pressure component, socio-economic component and the sum of it) are the result of combining the AHP with the Multicriteria analysis. This latter, has been commonly used for connectivity and conservation planning (Chávez González et al., 2015; Comino et al., 2016; Malczewski, 1999; Penrod et al., 2006; Rega, 2014) Although there still cons on its utilization mainly because, subjective factors in a decision making process, could not be completely avoided. In this case, this subjectivity was reduced through the AHP method.

The suitability map shows the physical-biological, socioeconomic, anthropogenic pressure combined in the area, and it can be measured in the degree of suitability for connectivity conservation purposes.

There are no similar studies that combines the criteria used in this analysis at the same scale. Nevertheless, at a larger scale, this study can be compared with those realized in the SMO region by Andrea Terán (2013). The suitability in the ecological map is similar; is evident there exists a high suitability for conservation in the study area. Despite this, the economic and social maps (as are named in this study) do not correspond with the suitability founded in this study (High-medium/low respectively).

This could be caused by many reasons: the layers used were not all the same, experts did not make the assignment mong other reason. However, it can be inferred that one of the main difference could be in the scale. To enhance connectivity in large areas could be optimal, use the most detailed information. Working at larger map scales lead to generalize information by not having specific details of the areas, the scale used for e.g, land use cover layer in Terán (2013) studies , was of 1:250 000, in this study was 1: 50 000. When this focus is applied, the suitability of the map changes. Although this inference needs to be further studied

This information in a smaller scale (detailed) could be useful to establish corridors for large species with wide ranges of movement, but for establishing corridors in a fragmented matrix , with small patches, with different land tenures, and numerous landowners, it will be useful be able to target specific areas. More information should be analyze.

In addition, from the relevant areas for conservation that were identified in the first objective, (broad areas) through the suitability map and the least cost path, the most optimal areas to connectivity conservation can be elected. This could facilitate the decision making process, to focus efforts for conservation, instead of protecting large areas without knowing the socio economic factors that occur in the area that can lead to the failure of conservation strategies.

From the resultant analysis of the suitability maps and multi criteria analysis through the experts, some information can be discussed.

For this study the incorporation of subsidies to agricultural activities, allowed to visualize its spatial distribution in the study area, but also to identify the number if of hectares subsidized. According to experts, the government subsidies "

Image 2. Sugar Cane crops subsidied

PROCAMPO-PROGAM" can favor conservation. Some owners who have large agricultural livelihoods can allocate fractions for conservation; also, private owners interested in conservation mention not relying on their lands, and therefore could designate them to conservation and there is a third group that believes that small-scale agriculture would be more easily incorporated into sustainable techniques and also be used for conservation.

This is relevant a relevant finding, since the growth of the agricultural matrix is the main cause of land use change in the area. As mentioned by owners during the interviews, the willingness to incorporate new areas for conservation can come from people who have lots of land and can use some for conservation or whose owners have minimal areas that can be used with conservation-friendly techniques (such as small-scale organic farming or agroforestry).

These possibilities should be analyzed in subsequent studies since this study yielded results on people with agricultural vocation who are interested in designate part of their land, or switching to small-scale sowing schemes, which are conservation friendly, both considering certify your properties as VDCA

It worth highlight experts and owners mentioned being worried about water scarcity. For e.g two private owner mention during the interview, that the water scarcity is generating conflicts mainly between the sugar cane agricultures, that uses a lot of water from the natural sources, like rivers, and the tourist sector that is affected by the lack of water in the rivers to navigate through them.

The experts mention also that the incorporation of surfaces to the PES could be a good incentive to establish VDCA that promotes connectivity.

The PES was accepted in the area, some owners were interested in conserving their land if there was a greater possibility of accessing government support. Likewise, experts recognize the functionality of this conservation scheme; although they also mention that PES subsides in Mexico need to be improved, designating federal budget to this program, so more landowners have the opportunity to access to subsidize their lands in favor of conservation.

According to the experts interviewed from the institutional field, from CONAFOR and CONANP mention that VDCAs could lead to access to the PES and vice versa, so both could focus on generating strategies to sum surfaces to establish a corridor, this should be considered in future research.(PA).

In the anthropogenic pressures component in this study could helped to show were restrictions for the connectivity path. The areas with unfit values in the anthropogenic suitability map, were dismiss from the final map

INCORPORATION OF POTENTIAL VDAC TO THE CONNECTIVITY PATH

As an additional result of this analysis, it was found that ecological corridors in Mexico do not have a protection category itself. Therefore, studies of connectivity in Mexico should propose alternatives for their protection. In this case, VDCA scheme is explored.

Few scientific literatures exists about VDCA. CONANP provides information about how many areas are, where are located; number of certified hectares, among others, nevertheless there is a lack of information on the knowledge, motivations, advantages and disadvantages of the owners of VDCA and a lack of methodologies to analyze this recent scheme of conservation in Mexico. This study presents a small glimpse into the opinion of experts and landowners about the VDCA that allows identifying the opinion of the experts and landowners. Although to understand the willingness or the perception of landowners in this conservation scheme, a larger sample of interviewees is needed as well as a broader questioner. Although the above mention, relevant information obtained is discussed:

Peña Azcona (2015) studied the perceptions of VDCA in the Oaxaca Isthmus, where VDCA has been stablish, in some cases for than 5 years. Her results founded that the main interested in certifying VDCA were government institutions representatives and private initiatives like NGOs. This interest of private initiatives has accelerated the process of certifying lands in favor biodiversity conservation. In this study, although there is also interest from CONANP, the main interested are the landowners as Ejidatarios and private owners.

The VDCA scheme, allows not only the landowners can certificate their lands, this also can bring forward by private initiatives. Although in this study were not identified, the development of conservation projects in privates' conservation areas has been proposed in other areas. Development agencies like GIZ have found relevant areas for conservation and designed projects for landowners and government agencies, so if the landowners agree they can be intermediaries for VDCA certification (GIZ & CONANP, 2016).

Image 3. Ejidatario from "Las Pitas"

Related to the motivation, limitations, constraints, advantages and disadvantages of VDCA scheme, similar approaches can be compared.

In the Oaxaca Isthmus, the motivations for certification came mostly from external interests that propose certification to landowners as a strategy to have benefits. Landowners recognized that the certification does not generate any benefit, although they recognize that vegetation cover increases in certificated land. There is still confusion from the owners about the mechanisms, commitments and implications of certificate a VDCA, and the author highlights that motivation for conservation prevails in the area although is independent from the certification process, this has to do with guaranteeing the use of resources, with water standing out.

This conclusions are similar to some findings of this study; the prevail of disinformation of the landowners about the certificate a VDCA, and in the interest of the landowner of protecting their natural resources independently of a certificate. The Peña Alcoza (2015) studies was carried out in an area that already has VDCA, this could mean people has identify the benefits for their own experiences. In this study, the motivation for the certification of VDAC was the possibility to obtain some economic benefit, the main advantages the increase of protected areas and the main disadvantage the lack of economic resources to help to the management of the land.

The main motivations coincide both studies, in the interest of taking care of the territories, conserving natural resources is not precisely obtained by a certificate; conservation is not determined by being certified or not (Peña Azcona, 2015)

At the same time, in this study private owners showed interest in environmental conservation, although their main interest were to be able to obtain some economic benefits with the certification; 2 of them said they were interested in PES subsidies (Hoya Verde and Las Pitas), one of them (Hoya verde) is also interest in certified sustainable tourism that could be achieved with a VDCA registration. The owner of the Selva Teenek said she wanted to certify to protect her land from changes in land use.

Although the Ejidatarios' livelihoods (from Laguna del Mante and Los Sabinos) depend on agriculture, they mention being motivated to conserve because they have recognized the importance of caring for the environment, one of them from Ejido Laguna del Mante, was interested in certify his land as VDCA, in order to obtain additional economic benefits from his product. .

As mentioned by owners during the interviews, the willingness to incorporate new areas for conservation can come from people who have lots of land and can use some for conservation or whose owners have minimal areas that can be used with conservation-friendly techniques (such as small-scale organic farming or agroforestry). These possibilities should be analyzed in depth in subsequent studies since this study yielded results on people with agricultural vocation who are interested in allocating part of their land, or switching to small-scale sowing schemes, which are conservation friendly, both considering certify your properties as VDCA

The experts mention also that the incorporation of surfaces to the PES could be a good incentive to establish VDCA that promotes connectivity. The PES was accepted in the area, some owners were interested in conserving their land if there was a greater possibility of accessing government support. Likewise, experts recognize the functionality of this conservation scheme; although they also mention that PES subsides in Mexico need to be improved, designating federal budget to this program, so more landowners have the opportunity to access to subsidize their lands in favor of conservation. According to the experts interviewed from the institutional field, from CONAFOR and CONANP mention that VDCAs could lead to access to the PES and vice versa, so both could focus on generating strategies to sum surfaces to establish a corridor, this should be considered in future research.(PA).

For the establishment of VDCA as a connectivity conservation strategy, experiences from other countries that have manage similar private conservation areas can be used. For e.g, in Brazil, exists free data access to information about "Conservation Units" called Natural Heritage Private Reserves (RPPNs) that are private domain with the objective to conserve biodiversity voluntarily in private areas; this could lead to have more systematic integration of private protected areas into the network of protected areas in Mexico(Guzmán Wolfhard, 2015).

In addition, the connectivity among this Conservation Units has been studied. Corridors, has no governmental category of protection as in Mexico Therefore, private conservation areas have been promoted as a strategy to connect fragmented areas, their results (Guzmán Wolfhard & Raedig, 2019)established connections between small fragments in order to connect them and in the future achieve connectivity on a larger scale.

In accordance with this study, the crucial role played by the will of the landowners to preserve their properties has been highlighted. Guzmán & Raedig (2019) mention that participatory monitoring strategies should be implemented, to motivate landowners on the relevance for biodiversity that came up with the conservation of their natural spaces. The authors mention by e.g. voluntary wildlife monitoring, where landowners can be involved in conservation by registering occurrences of different species of plants and animals.

Finally, as stated by Dominguez (2009) the will to conserve is linked to respect for natural resources, but also, as this studies show a consensus that will is linked to economic incentives. .

Due to the lack of literature and recent creation of the conservation scheme landowners should be better informed, and there is capacity building necessary, to consider this a viable option to promote connectivity and other conservation strategies.

These study present only two potential areas to be destined for conservation. The question is whether the connectivity path should be modified to pass through the protected sites or if the sites to be protected should be on the path. Due to the lack of studies in the region for management measures, and the null certification of VDCA in the State of San Luis Potosí, both options could be useful in the connectivity of the area, and thus subsequently evaluate its effectiveness. This is a proposal to have a systematic approach to prioritize efforts in promoting the VDCA in specific areas that are critical to connectivity.

Finally, Dominguez (2009) that environmental problems are severe when poverty levels are high, as in the study area marginalization rates are high and very high, this is the importance of incorporate robust socio-economic variables (Domínguez, 2009), and requires add criteria's as perceptions of landowners about connectivity, use of resources and voluntary conservation to complete cartographic variables

The effects on biodiversity conservation of VDCA are virtually unknown, although there are records of having served as a positive strategy to preserve floristic diversity in Oaxaca (Silva Aparicio et al., 2018), Further studies should be carried out to recognize the environmental, social, economic and conservation potential for VDCA connectivity.

7 CONCLUSIONS

This suggested connectivity path should be consider to establish measures for conservation and connectivity. The suitability map eminently show the isolation of BRSAT in the agricultural matrix. Relevant areas for conservation can act as connectivity nodes, especially in the BRSAT surrounding (north of the study area) where the human activities still modify the landscape, and forest remnants continue to be lost.

Suitability maps could facilitate the decision making process, to focus efforts for conservation, instead of protecting areas without including the anthropogenic influence that occurs in the area.This can lead to the failure of conservation strategies. Large areas can hardly be conserved, however, as recently found, small and connected fragments have the power to continue to shelter for wildlife and to promote their dispersion. Connectivity studies in the area have been conducted previously, and no changes in practice have been made. Therefore, this study proposes to work at detailed scales (small scales)

By not having a category of protection, is recommended to find synergies for establishing possible areas for conservation and connectivity corridors for biodiversity. The ILM approach, connectivity conservation strategies and PA ansd VDCA, are nowadays strategies supported by the Mexican environmental agencies, combining strategies and budgets and aligning policies could lead to the creation of synergies between public and private and sectors to achieve solutions for the lack of connectivity and its consecuences

In addition water scarcity factor should be incorporated to the conservations efforts. There is notably concern about this phenomenon because is having an evident negative impact in economic activities of the region; sugarcane crops, and tourism. The interviewed seemed more concern about water scarcity, than biodiversity conservation per se. This concern could be used to increases the interest of landowners on conservation approaches for their properties. PES, which focus on water protection, could be introduced to promote connectivity between forest fragments, and thus in the end, the ecosystem service of water retention Further, protection of hydrological resources is the main criteria to access to PES. These subsidies were also mentioned as an incentive to establish VDCA. This last, could be further analyzed to create robust strategies for the promotion of the creation of VDCAs.

Connectivity studies should be continued, expanding the origins and destinations and exploring new paths. However it is recommended to work at detailed scales in order to find also a way to establish the corridor in the practice.

Although the sample and distribution of the interviews were limited, as a first approach shows the relevant role that CONANP has in the promotion and certification of areas, as has happened in other parts of the country. There is a positive perception about VDCA although misinformation about the procedures, obligations and benefits prevails. This is new approach and there are not certified areas yet in state. More research could be done to corroborate if there are benefits certifying VDCAs.

The Ejidos added to the connectivity path, it worth mention that The Ejido Las Pitas is a key area for the connectivity of BRSAT. This property combines high suitability values, is an “oasis” in the agricultural matrix. This area could serve as a corridor for the fauna of BRSAT, due to both share similar ecological characteristics. Even one owner expressed that *"there are many animals here; I have even seen the jaguar."* Therefore, although the owner of this property showed interest in the certification to date, the procedure has not been finalized. The results also show that the main motivations for certification were the proposal by the CONANP, whose role for the certification of the first VDCAs in the region will be crucial.

Finally, it is recommended to explore the connectivity of the Biosphere Reserve Sierra Gorda with the same effort that ecological corridors with the RB el Cielo has been studied. Since structural connectivity seeks conserved spaces that can serve as a refuge for various taxas in a fragmented matrix and to increase studies on connectivity due to the urgency of prevent that BRSAT becomes and isolated forest patch.

8 REFERENCES

Adriaensen, F., Chardon, J. P., De Blust, G., Swinnen, E., Villalba, S., Gulinck, H., & Matthysen, E. (2003). The application of “least-cost” modelling as a functional landscape model. *Landscape and Urban Planning*, *64*, 233–247. https://doi.org/10.1016/S0169-2046(02)00242-6

Aguayo, P. M. (2013). *Apuntes de Teledetección: Índices de vegetación*. Chile.

Aguilar, A., & Tabarelli, M. (2010). Edge Effects and Seedling Bank Depletion: The Role Played by the Early Successional Palm Attalea oleifera (Arecaceae) in the Atlantic Forest. *Biotropica*, *42*(2), 158–166.

Alvarez, R. A. Z., Recagno, E. M. P., Manent, M. B., & Santana, J. R. H. (2013). Áreas Prioritarias de Geo-conservación de la biodiversidad en la Península de Baja California, México. *Journal of Latin American Geography*, *12*(3), 7–31. https://doi.org/10.1353/lag.2013.0036

Andam, K. S., Ferraro, P. J., Pfaff, A., Sanchez-Azofeifa, G. A., & Robalino, J. A. (2008). Measuring the effectiveness of protected area networks in reducing deforestation. *Proceedings of the National Academy of Sciences of the United States of America*, *105*(42), 16089–16094. https://doi.org/10.1073/pnas.0800437105

Beier, P., Majka, D. R., & Spencer, W. D. (2008). Forks in the road: Choices in procedures for designing wildland linkages. *Conservation Biology*, *22*(4), 836–851. https://doi.org/10.1111/j.1523-1739.2008.00942.x

Bennett, A. (2003). Linkages in the Landscape: The Role of Corridors and Connectivity in wildlife Conservation. In *Pacific Conservation Biology* (Vol. 5). https://doi.org/10.1071/pc990158

Bennett, A. F. (1999). *Linkages in the landscape : the role of corridors and connectivity in wildlife conservation*. Australia: IUCN.

Bernard, H. R., & Ryan, G. W. (2010). *Analyzing qualitative data : systematic approaches*. SAGE publications, Inc.

Bezaury-Creel, J. E. (2009). *El valor de los bienes y servicios que las áreas naturales protegidas proveen a los mexicanos*. Mexico: The Nature Conservancy.

Bommarco, R., Vico, G., & Hallin, S. (2018). Exploiting ecosystem services in agriculture for increased food security. *Global Food Security*, *17*, 57–63. https://doi.org/10.1016/J.GFS.2018.04.001

Botello, F., Sánchez-Cordero, V., & Ortega-Huerta, M. A. (2015). Disponibilidad de hábitats adecuados para especies de mamíferos a escalas regional (estado de Guerrero) y nacional (México). *Revista Mexicana de Biodiversidad*, *86*(1), 226–237. https://doi.org/10.7550/RMB.43353

Boyle, S., & Smith, ,. (2010). Can landscape and species characteristics predict primate presence in forest fragments in the Brazilian Amazon? *Biological Conservation*, *143*, 1134–1143. https://doi.org/10.1016/j.biocon.2010.02.008

Butchart, S. H. M., Walpole, M., Collen, B., van Strien, A., Scharlemann, J. P. W., Almond, R. E. A., … Watson, R. (2010). Global Biodiversity: Indicators of Recent Declines. *Science*, *328*(5982), 1164 LP – 1168. https://doi.org/10.1126/science.1187512

Castillo, Y. R. M. del. (2017). La conectividad del paisaje y su importancia para la biodiversidad. *Saber Más*, (November).

Castro-Navarro, J., Sahagún Sánchez, F. J., & Reyes-Hernández, H. (2017). Dinámica de fragmentación en la Sierra Madre Oriental y su impacto sobre la distribución potencial de la avifauna. *Madera y Bosques*, *23*(2), 99. https://doi.org/10.21829/myb.2017.2321429

CDB. (2018). Convention Text. Retrieved May 8, 2018, from https://www.cbd.int/convention/articles/default.shtml?a=cbd-02

CEP. (2018). *PERFIL SOCIODEMOGRÁFICO DE LA POBLACIÓN INDÍGENA EN EL ESTADO DE SAN LUIS POTOSÍ*. San Luis Potosí .

Chaverri-Polini, A. (1998). Las montañas, la diversidad biológica y su conservación. *Unasylva*, *49*(195).

Chávez González, H., González Guillén, M. de J., & Hernández de la R, P. (2015). Metodologías para identificar áreas prioritarias para conservación de ecosistemas naturales. *Revista Mexicana de Ciencias Forestales*, *6*(27), 8–23.

Comino, E., Bottero, M., Pomarico, S., & Rosso, M. (2016). The combined use of Spatial Multicriteria Evaluation and stakeholders analysis for supporting the ecological planning of a river basin. *Land Use Policy*, *58*, 183–195. https://doi.org/10.1016/J.LANDUSEPOL.2016.07.026

CONABIO. (2008). *Capital natural de México Volumen, vol.I : Conocimiento actual de la biodiversidad* (Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Ed.). México.

CONABIO. (2012). Corredor Biológico Mesoamericano México (CBMM). Retrieved August 4, 2019, from https://www.biodiversidad.gob.mx/corredor/cbmm/cbmm.html

CONABIO. (2015). Límites y regionalización de los Corredores Biológicos del sureste de México. Retrieved from Portal de Geoinformación website: http://www.conabio.gob.mx/informacion/gis/?vns=gis_root/region/biotic/anpe09gw

CONABIO. (2019a). PORTAL DE GEOINFORMACIÓN. Retrieved from SISTEMA NACIONAL DE INFORMACIÓN SOBRE BIODIVERSIDAD website: http://www.conabio.gob.mx/informacion/gis/

CONABIO. (2019b). Sistema Nacional de Información sobre Biodiversidad. Registros de ejemplares de anfibios.

CONABIO. (2019c). Sistema Nacional de Información sobre Biodiversidad. Registros de ejemplares de aves. Retrieved from Catálogo de metadatos geográficos website: http://geoportal.conabio.gob.mx/metadatos/doc/html/aves.html

CONABIO. (2019d). Sistema Nacional de Información sobre Biodiversidad. Registros de ejemplares de mamíferos. Retrieved from Catálogo de metadatos geográficos website: http://geoportal.conabio.gob.mx/acceso/mamiferos/2019/04/02

CONABIO. (2019e). Sistema Nacional de Información sobre Biodiversidad. Registros de ejemplares de reptiles.

CONABIO. (2019f). Sitios Prioritarios para la Restauración. Retrieved from Catálogo de metadatos geográficos website: http://www.conabio.gob.mx/informacion/gis/layouts/spr_gw.png

CONABIO, CONANP, & TNC. (2008). Sitios Prioritarios para la conservacion terrestre. Retrieved from Catálogo de metadatos geográficos. website: http://www.conabio.gob.mx/informacion/metadata/gis/spt1mgw.xml?_xsl=/db/metadata/xsl/fgdc_html.xsl&_indent=no

CONABIO, & INIFAP. (1995). Edafología. Retrieved from Catálogo de metadatos geográficos website: http://www.conabio.gob.mx/informacion/metadata/gis/eda251mgw.xml?_httpcache=yes&_xsl=/db/metadata/xsl/fgdc_html.xsl&_indent=no

CONAFOR. (2012). *Inventario Nacional Forestal y de Suelos. Informe 2004-2009*. Jalisco.México: CONAFOR.

CONAFOR. (2019). Áreas Elegibles PSA 2019. Retrieved from Programa Apoyos para el Desarrollo Forestal Sustentable website: https://www.conafor.gob.mx/apoyos/index.php/inicio/app_apoyos#/detalle/2019/79

CONANP. (2014). *Guía para la certificación y manejo de áreas destinadas voluntariamente a la conservación*. 54.

CONANP. (2018a). *Áreas Naturales Protegidas Federales de México*. México.

CONANP. (2018b). *La participacion ciudadana en las áreas naturales protegidas*. mexico.

CONANP. (2019). Áreas Destinadas Voluntariamente a la Conservación. Retrieved August 21, 2019, from https://advc.conanp.gob.mx/

CONAPO. (2002). POBLACIÓN TOTAL, POBLACIÓN INDÍGENA Y SUS CARACTERÍSTICAS. Retrieved July 15, 2019, from INDICADORES SOCIOECONÓMICOS DE LOS PUEBLOS INDÍGENAS DE MÉXICO website: http://www.cdi.gob.mx/indicadores/em_cuadro01_slp.pdf

CONAPO. (2011). *Indice de Marginación por Entidad y Municipio 2010*. México.

Crooks, K. R., Burdett, C. L., Theobald, D. M., King, S. R. B., Di Marco, M., Rondinini, C., & Boitani, L. (2017). Quantification of habitat fragmentation reveals extinction risk in terrestrial mammals. *Proceedings of the National Academy of Sciences of the United States of America*, *114*(29), 7635–7640. https://doi.org/10.1073/pnas.1705769114

Crooks, K. R., & Sanjayan, M. (2006). Connectivity conservation: maintaining connections for nature. *Connectivity Conservation*, 1–20. https://doi.org/10.1017/CBO9780511754821.001

Cubides Isaacs, P. J. (2011). *MODELO DE CONECTIVIDAD ESPACIAL EMPLEANDO SISTEMAS DE INFORMACIÓN GEOGRÁFICA, CALIDAD DE HÁBITAT Y DISTRIBUCIÓN CASO TAPIR DE MONTAÑA (TAPIRUS PINCHAQUE) EN EL EJE CAFETERO COLOMBIANO.* Universidad Nacional de Colombia.

Dayer, A. A., Rodewald, A. D., Stedman, R. C., Cosbar, E. A., & Wood, E. M. (2016). Wildlife Conservation and Private Protected Areas: The Discrepancy Between Land Trust Mission Statements and Their Perceptions. *Environmental Management*, *58*(2), 359–364. https://doi.org/10.1007/s00267-016-0713-3

De Reu, J., Bourgeois, J., Bats, M., Zwertvaegher, A., Gelorini, V., De Smedt, P., … Crombé, P. (2013). Application of the topographic position index to heterogeneous landscapes. *Geomorphology*, *186*, 39–49. https://doi.org/10.1016/j.geomorph.2012.12.015

Delattre, T., Baudry, J., & Burel, F. (2018). An onion-like movement corridor? Possible guidelines emerging from small-scale movement rules. *Ecological Informatics*, *45*, 48–58. https://doi.org/10.1016/J.ECOINF.2018.03.006

Dobson, A.; Ralls, K.; Foster, M.; Soule, M. E.; Simberloff, D.; Doak, D.; Estes, J. A.; Mills, L. S.; Mattson, D.; Dirzo, R.; Arita, H.; Ryan, S.; Norse, E. A.; Noss, R. F.; Noss, R. F.; Johns, D. (1999). Connectivity: maintaining flows in fragmented landscapes. In *Continental Conservation*. Island Press.

Domínguez, E. (2009). *Conectividad biológica y social Zonas de infuencia de las áreas naturales protegidas*. CONABIO.

Driscoll, D. A. (2004). Extinction and Outbreaks Accompany Fragmentation of a Reptile Community. *Ecological Applications*, *14*(1), 220–240.

Dudley, N. (2008). *Directrices para la aplicación de las categorías de gestión de áreas protegidas*. Gland, Suiza: UICN.

Eastman, R. (2012). *IDRISI Selva. Guia SIG y procesamiento de imágenes* (Clark Univ). Worcester, MA USA.

Ernesto Suárez-Mota, M., & Luis Villaseñor, J. (2018). México Priority sites for the conservation of floristic richness and endemism of the Northern Sierra of Oaxaca, Mexico. *Acta Botánica Mexicana*, *124*. https://doi.org/10.21829/abm124.2018.1296

Errejón Gómez, J. C., Vila Subirós, J., Flores Flores, J. L., Reyes Hernández, H., & Muñoz-Robles, C. A. (2018). Conectividad de los ecosistemas entre las reservas de la biosfera “El Cielo” y

“Sierra del Abra Tanchipa” en México. *Investigaciones Geográficas*, (70). https://doi.org/10.14198/INGEO2018.70.09

Ersoy, E., Jorgensen, A., & Warren, P. H. (2019). Identifying multispecies connectivity corridors and the spatial pattern of the landscape. *Urban Forestry and Urban Greening*, *40*(August 2018), 308–322. https://doi.org/10.1016/j.ufug.2018.08.001

Espinosa-Organista, D. Ocegueda-Cruz, S. (2008). El conocimiento biogeográfico de las especies y su regionalización natural. In *Capital natural de México, Conocimiento actual de la biodiversidad* (pp. 33–65). México: CONABIO.

Fagan, W. F., & Calabrese, J. M. (2007). Quantifying connectivity: balancing metric performance with data requirements. *Connectivity Conservation*, 297–317. https://doi.org/http://dx.doi.org/10.1017/CBO9780511754821.014

Fahrig, L. (2003). EFFECTS OF HABITAT FRAGMENTATION ON BIODIVERSITY. *Annu. Rev. Ecol. Evol. Syst*, *34*, 487–515. https://doi.org/10.1146/annurev.ecolsys.34.011802.132419

Fahrig, L. (2017). Ecological Responses to Habitat Fragmentation Per Se. *Annual Review of Ecology, Evolution, and Systematics*, *48*(1), 1–23. https://doi.org/10.1146/annurev-ecolsys-110316-022612

Fahrig, L., Bennett, J. R., Cazetta, E., Watling, J. I., Metzger, J. P., Tischendorf, L., … Morrison, P. (2019). Is habitat fragmentation bad for biodiversity? *Biological Conservation*, *230*(September 2018), 179–186. https://doi.org/10.1016/j.biocon.2018.12.026

FAO. (2015a). *Evaluación de los recursos forestales mundiales 2015 ¿Cómo están cambiando los bosques del mundo? Segunda edición*. Roma: ORGANIZACIÓN DE LAS NACIONES UNIDAS PARA LA ALIMENTACIÓN Y LA AGRICULTURA.

FAO. (2015b). *Evaluación de los recursos forestales mundiales 2015 Compendio de datos*. Roma.

FAO. (2017). *Landscapes for Life approaches to landscape management for sustainable food and agriculture*. ROMA: FAO.

Ferraz, G., Nichols, J. D., Hines, J. E., Stouffer, P. C., Bierregaard, R. O., & Lovejoy, T. E. (2007). A large-scale deforestation experiment: Effects of patch area and isolation on Amazon birds. *Science*, *315*(5809), 238–241. https://doi.org/10.1126/science.1133097

Fischer, J., & Lindenmayer, D. B. (2007). Landscape modification and habitat fragmentation: a synthesis. *Global Ecology and Biogeography*, *16*(3), 265–280. https://doi.org/10.1111/j.1466-8238.2007.00287.x

Forman, R. T. T., & Godron, M. (1981). Patches and Structural Components for a Landscape Ecology. *BioScience*, *31*(10), 733–740. https://doi.org/10.2307/1308780

Frost, P., Campbell, B., Medina, G., & Usongo, L. (2006). Landscape-scale Approaches for Integrated Natural Resource Management in Tropical Forest Synthesis, part of a Special Feature on Do we need new management paradigms to achieve sustainability in tropical forests? Landscape-scale Approaches for Integrated N. *Source: Ecology and Society*, *11*(2).

Garcia-Alaniz, N., Equihua, M., Pé rez-Maqueo, O., Equihua Benítez, J., Maeda, P., Pardo Urrutia, F., … Solecki, W. (2017). *The Mexican National Biodiversity and Ecosystem Degradation Monitoring System*. https://doi.org/10.1016/j.cosust.2017.01.001

García Quiroga, F., & Abad Soria, J. (2014). Los corredores ecológicos y su importancia ambiental: propuestas de actuación para fomentar la permeabilidad y conectividad aplicadas al entorno del río Cardeña (Ávila y Segovia). *Observatorio Medioambiental*, *17*(0), 253–298. https://doi.org/10.5209/rev_obmd.2014.v17.47194

Garrido-Garduño, T., & Vázquez-Domínguez, E. (2013). Métodos de análisis genéticos, espaciales y de conectividad en genética del paisaje. *Revista Mexicana de Biodiversidad*, *84*(3), 1031–1054. https://doi.org/10.7550/RMB.32500

Geldmann, J., Coad, L., Barnes, M., Ian D.Craigie, Hockings, M., Neil D. Burgess, … Leverington, F. (2015). Changes in protected area management effectiveness over time: A global analysis. *Biological Conservation*, *191*, 692–699. https://doi.org/10.1016/J.BIOCON.2015.08.029

Gene, S. M., Hoekstra, P. F., Hannam, C., White, M., Truman, C., Hanson, M. L., & Prosser, R. S. (2019). The role of vegetated buffers in agriculture and their regulation across Canada and the United States. *Journal of Environmental Management*, *243*, 12–21. https://doi.org/10.1016/J.JENVMAN.2019.05.003

GITTA. (2013). Suitability analysis with the help of suitability maps. Retrieved August 21, 2019, from http://www.gitta.info/Suitability/en/html/MCMOAnalysis_learningObject1.html

GIZ. (2012). Integrated landscape management for biodiversity conservation in the Sierra Madre Oriental (ProMIP). Retrieved May 20, 2018, from https://www.giz.de/en/downloads/GIZ2018-en-promip-Mexico.pdf

GIZ, & CONANP. (2016). *Cooperación público-privada pautas para el sector privado méxico en áreas naturales protegidas*.

Gutiérrez-Carbonell, D., & Bezaury-Creel, J. (2009). Áreas naturales protegidas y desarrollo social en México. In *Capital natural de México, vol.II : Estado de conservación y tendencias de cambio* (pp. 385–431). México: CONABIO.

Guzmán Wolfhard, L. V. (2015). *Connectivity Conservation Management: Linking Natural Heritage Private Reserves (RPPNs) in the Northwestern and Serrana Region of Rio de Janeiro State, Brazil*. Cologne university of applied sciences.

Guzmán Wolfhard, L. V., & Raedig, C. (2019). *Connectivity Conservation Management: Linking Private Protected Areas*. 155–171. https://doi.org/10.1007/978-3-319-89644-1_11

GWS. (2018). UNESCO’s Man and the Biosphere Program. Retrieved May 19, 2018, from http://www.georgewright.org/mab

Habel, J., Augenstein, B., Meyer, M., Nève, G., Rödder, D., & Assmann, T. (2010). Population

Genetics and Ecological Niche Modelling Reveal High Fragmentation and Potential Future Extinction of the Endangered Relict Butterfly Lycaena helle. In J. C. Habel & T. Assmann (Eds.), *Relict Species* (pp. 417–439). Berlin, Heidelberg: Springer Berlin Heidelberg.

Haddad, N. M., Brudvig, L. A., Clobert, J., Davies, K. F., Gonzalez, A., Holt, R. D., … Townshend, J. R. (2015). Habitat fragmentation and its lasting impact on Earth's ecosystems. *Science Advances*, *1*(2), e1500052. https://doi.org/10.1126/sciadv.1500052

Haddad, N. M., & Tewksbury, J. J. (2006). Impacts of corridors on populations and communities. *Connectivity Conservation*, 390–415. https://doi.org/10.1007/BF01189749

Hernández-Cerda, M. E., & Carrasco-Anaya, G. (2004). Climatología. In Las prensas de Ciencias (Ed.), *Biodiversidad de la Sierra Madre Oriental* (p. 527). Ciudad de México: Facultad de Ciencias.

Hester, P. T., & Velasquez, M. (2013). An analysis of multi-criteria decision making methods. In *International Journal of Operations Research* (Vol. 10).

Ibáñez, I., Katz, D. S. W., Peltier, D., Wolf, S. M., & Connor Barrie, B. T. (2014). Assessing the integrated effects of landscape fragmentation on plants and plant communities: The challenge of multiprocess-multiresponse dynamics. *Journal of Ecology*, *102*(4), 882–895. https://doi.org/10.1111/1365-2745.12223

INEGI. (2010). *Censo Nacional de Población y Vivienda 2010*. México.

INEGI. (2017). *Modelo Digital de Elevación de San Luis Potosi*.

INEGI. (2018). *Conjunto de datos vectoriales de información topográfica escala 1:50 000 serie III.*

IUCN, & WCPA. (2010). *50 Years of Working for Protected Areas A brief history of IUCN World Commission on Protected Areas IUCN World Commission on Protected Areas*.

Jacinto-Flores, N. E., Sánchez-González, L. A., & Almazán-Núñez, R. C. (2017). Patrones de distribución y zonas prioritarias para la conservación de la avifauna de la costa del Pacífico de Guerrero, México. *Revista Mexicana de Biodiversidad*, *88*(4), 960–977. https://doi.org/10.1016/J.RMB.2017.10.038

Jiménez Sierra, C. L., Sosa Ramírez, J., Cortés-Calva, P., Breceda Solís, C. A., Íñiguez Dávalos, L. I., & Ortega-Rubio, A. (2014). México país megadiverso y la relevancia de las áreas naturales protegidas. *Investigación y Ciencia*, *22*(60), 16–22.

Laurance, W. F., Camargo, J. L. C., Luizão, R. C. C., Laurance, S. G., Pimm, S. L., Bruna, E. M., … Lovejoy, T. E. (2011). The fate of Amazonian forest fragments: A 32-year investigation. *Biological Conservation*, *144*(1), 56–67. https://doi.org/10.1016/J.BIOCON.2010.09.021

Lee, J. A., Chon, J., & Ahn, C. (2014). Planning landscape corridors in ecological infrastructure using least-cost path methods based on the value of ecosystem services. *Sustainability (Switzerland)*, *6*(11), 7564–7585. https://doi.org/10.3390/su6117564

LGEEPA. *Ley General Del Equilibrio Ecológico Y La Protección Al Ambiente*. , (2012).

López-Barrera, F., Martínez-Garza, C., & Ceccon, E. (2017). Ecología de la restauración en México: estado actual y perspectivas. *Revista Mexicana de Biodiversidad*, *88*, 97–112. https://doi.org/10.1016/J.RMB.2017.10.001

López Báez, W., & Santos Reynoso, R. (2016). Manejo integral del paisaje para la adaptación al cambio climático en la Sierra Madre de Chiapas, México. *Revista Mexicana de Ciencias Agrícolas*, *7*(8).

López Yela, F. N. (2017). *ANALISIS DE CONECTIVIDAD ESPACIAL Y FRAGMENTACION DE LA ECORREGIÓN CIÉNAGA GRANDE DE SANTA MARTA*. Universidad Militar Nueva Granada.

Loyola, R., Devictor, V., Maas, B., Miller-Rushing, A. J., Pejchar, L., Corlett, R. T., … Primack, R. B. (2019). How does habitat fragmentation affect biodiversity? A controversial question at the core of conservation biology. *Biological Conservation*, *232*, 271–273. https://doi.org/10.1016/j.biocon.2018.12.029

Luna, I., Morrone, J. j, & Espinosa, D. (2004). Biodiversidad de la Sierra Madre Oriental. In *UNAM-CONABIO*. https://doi.org/10.1245/s10434-011-1656-9

Malczewski, J. (1999). *GIS and Multicriteria decision analysis* (D. of G. U. of W. Ontario, Ed.). New York, USA.: John Wiley and Sons Inc.

Manent-Bollo, M. (2017). *La Geografia del Paisaje y La Geoecologia. Teoría y Enfoques* (pp. 127–151). pp. 127–151.

Martínez Alandi, C., Múgica de la Guerra, M., Castell Puig, C., & de Lucio Fernández, J. V. (2009). *CONECTIVIDAD ECOLÓGICA Y ÁREAS PROTEGIDAS. HERRAMIENTAS Y CASOS PRÁCTICOS*. Madrid: EUROPARC.

McCune, J. L., Van Natto, A., & MacDougall, A. S. (2017). The efficacy of protected areas and private land for plant conservation in a fragmented landscape. *Landscape Ecology*, *32*(4), 871–882. https://doi.org/10.1007/s10980-017-0491-1

Melo, F., Salas, E. M., Benítez, J., & Ceballos, G. (2010). Forest fragmentation reduces recruitment of large-seeded tree species in a semi-deciduous tropical forest of southern Mexico. *Journal of Tropical Ecology*, *26*, 35–43. https://doi.org/10.1017/S0266467409990435

Moffett, A., & Sarkar, S. (2006). Incorporating multiple criteria into the design of conservation area networks: A minireview with recommendations. *Diversity and Distributions*, *12*, 125–137. https://doi.org/10.1111/j.1366-9516.2005.00202.x

Moilanen, A., & Nieminen, M. (2002). Simple Connectivity Measures in Spatial Ecology. *Ecology*, *83*, 1131–1145. https://doi.org/10.2307/3071919

Muratet, A., Lorrillière, R., Clergeau, P., & Fontaine, C. (2013). Evaluation of landscape connectivity at community level using satellite-derived NDVI. *Landscape Ecology*, *28*(1), 95–105. https://doi.org/10.1007/s10980-012-9817-1

Ortíz-Rodríguez, A. J., Muñoz-Robles, C., & Borselli, L. (2019). Changes in connectivity and hydrological efficiency following wildland fires in Sierra Madre Oriental, Mexico. *Science of the Total Environment*, *655*, 112–128. https://doi.org/10.1016/j.scitotenv.2018.11.236

Panagakos, G. (2016). *Green Corridors and Network Design*. https://doi.org/10.1007/978-3-319-17175-3_4

Pascual-Hortal, L., & Saura, S. (2008). Integrating landscape connectivity in broad-scale forest planning through a new graph-based habitat availability methodology: application to capercaillie (Tetrao urogallus) in Catalonia (NE Spain). *European Journal of Forest Research*, *127*(1), 23–31. https://doi.org/10.1007/s10342-006-0165-z

Peña Azcona, I. (2015). *Percepción socioambiental de las Áreas Destinadas Voluntariamente a la Conservación en el Istmo Oaxaqueño*. El Colegio de la Frontera Sur.

Penrod, K., Cabañero, C. R., Beier, P., Luke, C., Spencer, W., & Rubin, E. (2006). *South Coast Missing Linkages Project- A linkage Design for the Santa Mónca-Sierra Madre Connection*. Idyllwild, CA, USA,.

Perramond, E. P. (2008). The Rise, Fall, and Reconfiguration of the Mexican Ejido. *Geographical Review*, Vol. 98, pp. 356–371. https://doi.org/10.2307/40377336

Petracca, L. S., Hernández-Potosme, S., Obando-Sampson, L., Salom-Pérez, R., Quigley, H., & Robinson, H. S. (2014). Agricultural encroachment and lack of enforcement threaten connectivity of range-wide jaguar (Panthera onca) corridor. *Journal for Nature Conservation*, *22*(5), 436–444. https://doi.org/10.1016/J.JNC.2014.04.002

Pütz, S., Groeneveld, J., Alves, L. F., Metzger, J. P., & Huth, A. (2011). Fragmentation drives tropical forest fragments to early successional states: A modelling study for Brazilian Atlantic forests. *Ecological Modelling*, *222*(12), 1986–1997. https://doi.org/10.1016/J.ECOLMODEL.2011.03.038

Ramirez-Reyes, C., Sims, K. R. E., Potapov, P., & Radeloff, V. C. (2018). Payments for ecosystem services in Mexico reduce forest fragmentation. *Ecological Applications*, *28*(8), 1982–1997. https://doi.org/10.1002/eap.1753

Raney, M. (2009). *Using graph theory to compare least cost path and circuit theory connectivity analyses*. Montana, UE.

RANP. (2018). *Areas Naturales Protegidas Estatales de México*. México.

Redlands. (2014). *ArcGis 10.5*.

Reed, J., Van Vianen, J., Deakin, E. L., Barlow, J., & Sunderland, T. (2016). Integrated landscape approaches to managing social and environmental issues in the tropics: learning from the past to guide the future. *Global Change Biology*, *22*(7), 2540–2554. https://doi.org/10.1111/gcb.13284

Rega, C. (2014). *Landscape Planning and Rural Development Key Issues and Options Towards Integration*. SPRINGER BRIEFS IN GEOGRAPHY .

Reyes-Hernández, H., Olvera-Vargas, L., Sahagún-Sánchez, F. J. y Mass-Caussel, J. F. (2009). *Transformation of the forest cover and future scenarios in the Sierra Madre Oriental, Physiographic Region, San Luis Potosí, México.* Symposium on Remote Sensing of Environment, Sustaining the Millennium Development Goals. Stresa, Italia.

Reyes, H., de Nova, A., Galarza, E., Torres, D., & Vázquez, B. (2016). Programa de Conservación para el Desarrollo Sostenible PROCODES. In *Informe final Noviembre 2016*. https://doi.org/10.1016/S0306-9192(01)00014-8

Rodríguez-Soto, C., Monroy-Vilchis, O., & Zarco-González, M. M. (2013). Corridors for jaguar (Panthera onca) in Mexico: Conservation strategies. *Journal for Nature Conservation*, *21*(6), 438–443. https://doi.org/10.1016/J.JNC.2013.07.002

Rzedowsky, J. . (2006). *Vegetación de México*. México, D.F: LIMUSA.

Saaty, T. L. (2008). Decision making with the analytic hierarchy process. In *Int. J. Services Sciences* (Vol. 1).

Sahagún-Sánchez, F. J., Reyes-Hernández, H., Flores Flores, J. L., & Vargas, L. C. (2011). Modelización de escenarios de cambio potencial en la vegetación y el uso de suelo en la Sierra Madre Oriental de San Luis Potosí, México. *Journal of Latin American Geography*, *10*(2), 65–86. https://doi.org/10.1353/lag.2011.0029

Sahagún-sánchez, F., & Reyes-hernández, H. (2018). *Impactos por cambio de uso de suelo en las áreas naturales protegidas de la región central de la Sierra Madre Oriental , México Impact of land use cover change on protected natural areas in central region of Sierra Madre Oriental , Mexico*. *12*(2), 6–21.

Salazar, E., Mendoza, J., Ochoa-Gaona, S., Ku-Quej, V., & Hidalgo-Mihart, M. (2017). Evaluación de la conectividad del paisaje en la región Puuc-Chenes, México, con base en los requerimientos de hábitat del jaguar (Panthera onca). *Investigaciones Geográficas, Boletín Del Instituto de Geografía*, *2017*(92), 101–115. https://doi.org/10.14350/RIG.52210

Salgado Ugarte, I. H. (2002). *Métodos Estadísticos No Paramétricos de Suavización para Análisis de Datos Biológicos*. México.

Salido Pérez, G. A. (2015). Buenas prácticas para la definición de redes ecológicas en España. *Universidad de Alicante y WWF España*, 1–11.

Sarukhán, J., Koleff, P., Carabias, J., Soberón, J., Dirzo, R., Llorente-Bousquets, J., … Méndez, G. G. (2017). Síntesis (actualizada a 2017) de Capital natural de México. In *Capital natural de México. Síntesis: evaluación del conocimiento y tendencias de cambio, perspectivas de sustentabilidad, capacidades humanas e institucionales*. México.

Saura, S., Bastin, L., Bertzky, B., Battistella, L., Mandric, A., & Dubois, G. (2018). Protected area connectivity: Shortfalls in global targets and country-level priorities. *Biological*

Conservation, *219*, 53–67. https://doi.org/10.1016/J.BIOCON.2017.12.020

Sautu, R., Boniolo, P., Dalle, P., & Elbert, R. (2006). *Manual de Metodología. Construcción del Marco teórico, formulación de los objetivos y elección de la metodología*. Buenos Aires, Argentina: Consejo Latinoamericano de Ciencias Sociales CLACSO.

Schelhas, J. (2007). El valor de los fragmentos del bosque; enlaando el conocimieno social y ecológico. In O. Chassot & C. Morera (Eds.), *Corredores Biológicos. Acercamiento conceptal y experiencias en América Latina* (p. 128). San José, Costa Rica: Centro CientíficoTropical/ Universidad Nacional de San José Costa Rica.

Scherr, S. J., Shames, S., & Friedman, R. (2013). Defining Integrated Landscape Management for Policy Makers. *Ecoagriculture. Policy Focus*, (10).

SEGAM. (2016a). Área Natural Protegida Monumento Natural "El Sótano de las Golondrinas." Retrieved July 14, 2019, from http://www.segam.gob.mx/ANPsotano.html

SEGAM. (2016b). Área Natural Protegida Sitio Sagrado Natural "Las Cuevas Sagradas del Viento y de la Fertilidad." Retrieved July 15, 2019, from http://www.segam.gob.mx/ANPcuevas.html

SEGAM. (2018a). Área Natural Protegida Monumento Natural La Hoya de las Huahuas. Retrieved July 14, 2019, from http://www.segam.gob.mx/ANPhuahuas.html

SEGAM. (2018b). Área Natural Protegida Reserva Estatal "Sierra del Este y Sierra de Enmedio. Retrieved July 14, 2019, from http://beta.slp.gob.mx/SEGAM/Paginas/ANPS/ESTATALES/Sierras.aspx

Selinske, M. J., Howard, N., Fitzsimons, J. A., Hardy, M. J., Smillie, K., Forbes, J., … Knight, A. T. (2019). Monitoring and evaluating the social and psychological dimensions that contribute to privately protected area program effectiveness. *Biological Conservation*, *229*, 170–178. https://doi.org/10.1016/J.BIOCON.2018.11.026

SEMARNAT. (2014). *Programa de Manejo de la Reserva de la Biósfera Sierra del Abra Tanchipa*. México.

SEMARNAT. (2018). Corredor Biológico Chichinautzin. Retrieved August 20, 2019, from https://www.gob.mx/semarnat/articulos/corredor-biologico-chichinautzin

SEMARNAT, CONABIO, CONAFOR, & CONANP. (2017). *Visión Nacional de Manejo Integrado del Paisaje y Conectividad*. 58.

SEMARNAT, & CONANP. (2014). *Programa de Manejo: Reserva de la Biosfera Sierra del Abra de Tanchipa*. https://doi.org/10.5751/ES-04940-170415

SEMARNAT, & CONANP. (2018). *100 años de Conservación en México 1917-2017 Áreas Naturales Protegidas*. México: CONANP.

Shirabe, T. (2018). Buffered or bundled, least-cost paths are not least-cost corridors:

Computational experiments on path-based and wide-path-based models for conservation corridor design and effective distance estimation. *Ecological Informatics*, *44*, 109–116. https://doi.org/10.1016/J.ECOINF.2018.02.002

Silva Aparicio, M., Castro Ramírez, A. E., Castillo Campos, G., Silva Aparicio, M., Castro Ramírez, A., & Castillo-Campos, G. (2018). Estructura y composición de leñosas en dos bosques de las regiones Mixteca y Valles Centrales de Oaxaca, México. *Madera y Bosques*, *24*(1). https://doi.org/10.21829/myb.2018.2411445

Sloan, S., Campbell, M. J., Alamgir, M., Engert, J., Ishida, F. Y., Senn, N., … Laurance, W. F. (2019). Hidden challenges for conservation and development along the Trans-Papuan economic corridor. *Environmental Science & Policy*, *92*, 98–106. https://doi.org/10.1016/J.ENVSCI.2018.11.011

Suárez-Mota, M. E., Villaseñor, J. L., & López-Mata, L. (2017). Dominios climáticos de la Sierra Madre Oriental y su relación con la diversidad florística. *Revista Mexicana de Biodiversidad*, *88*(1), 224–233. https://doi.org/10.1016/j.rmb.2017.01.020

T.E Lovejoy, R.O.Bierregaard, Jr., A.B. Rylands, J.R Malcolm, C.E Quintela, L.H. Harper, K.S Brown, Jr., A.H Powell, G.V.N. Powell, H.O.R.Schubart, and M. . H. (1986). *Edge and other effects of isolation on Amazon forest fragments*. (January 1986).

Taylor, P. D., Fahrig, L., & With, K. A. (2010). Landscape connectivity: a return to the basics. *Connectivity Conservation*, 29–43. https://doi.org/10.1017/cbo9780511754821.003

Terán-Valdez, A. (2013). *A biological corridor for the Sierra Madre Oriental (San Luis Potosí, México): Socio-economic viability for enhancing connectivity. Master*.

Tischendorf, L., & Fahrig, L. (2000). On the usage and measurement of landscape connectivity What is landscape connectivity? *Oikos*, *90*, 7–19.

Torres Acosta, E. L., Hernández, H. R., Muñoz, C. A., & Lejia, E. G. (2019). Distribución y conservación de Quercus oleoides Schltdl. & Cham. en la Reserva de la Biosfera Sierra del Abra Tanchipa. *Revista Mexicana de Ciencias Forestales Vol.*, *10*(52).

Turner II, B., Cortina Villar, S., Foster, D., Geophegan, J., Keys, E., Klepeis, P., … Vance, C. (2001). Deforestation in the Southern Yucatán Peninsular region: An integrative Approach. *Forest Ecology and Management*, (154), 353–370.

Uezu, A., Metzger, J., & M.E. Vielliard, J. (2005). Effects of structural and functional connectivity and patch size on the abundance of seven Atlantic Forest bird species. *Biological Conservation*, *123*, 507–519. https://doi.org/10.1016/j.biocon.2005.01.001

UICN. (2008). *CATEGORÍAS Y CRITERIOS DE LA LISTA ROJA DE LA UICN*. Gland, Suiza.

UICN. (2018). ¿Qué es un área protegida? | UICN. Retrieved May 7, 2018, from https://www.iucn.org/es/regiones/américa-del-sur/nuestro-trabajo/áreas-protegidas/¿qué-es-un-área-protegida

UNDP. (2015). Goal 15: Life on land. Retrieved August 4, 2019, from SUSTAINABLE DEVELOPMENT GOALS website: https://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-15-life-on-land.html

UNEP. (2010). *Decisión adoptada por la conferencia de las partes en el convenio sobre la diversidad biológica en su décima reunión.el plan Estratégico para la Diversidad Biológica 2011-2020 y las Metas de Aichi para la Diversidad Biológica*. 18–20. Nagoya, Japón: UNEP.

UNEP, CBD, & SBSTTA. (2011). *REPORT ON HOW TO IMPROVE SUSTAINABLE USE OF BIODIVERSITY IN A LANDSCAPE PERSPECTIVE*. Motreal.

Williams, J. C., & Snyder, S. A. (2005). Restoring habitat corridors in fragmented landscapes using optimization and percolation models. *Environmental Modeling & Assessment*, *10*(3), 239–250. https://doi.org/10.1007/s10666-005-9003-9

Wood, M. A., Sheridan, R., Feagin, R. A., Castro, J. P., & Lacher, T. E. (2017). Comparison of land use change in payments for environmental services and National Biological Corridor Programs. *Land Use Policy*, *63*, 440–449. https://doi.org/10.1016/j.landusepol.2017.02.005

Worboys, G. L., Francis, W. L., & Lockwood, M. (2010). *Connectivity Conservation Management. A global Guide*. London: Earthscan.

Zhang, Z., Meerow, S., Newell, J. P., & Lindquist, M. (2019). Enhancing landscape connectivity through multifunctional green infrastructure corridor modeling and design. *Urban Forestry and Urban Greening*, *38*(October 2018), 305–317. https://doi.org/10.1016/j.ufug.2018.10.014

9 ANNEXES

Annex 1. Questioner applied during the fieldwork

Cuestionario general
Fecha Nombre del Entrevistado: Actor/Profesión: Sitio/Predio Conocimiento 1 ¿Conoce el esquema de Conservación de la CONANP *Áreas Destinadas Voluntariamente a la conservación ADVC*? SI NO 2 ¿Conoce los procedimientos y responsabilidades que conlleva la certificación de un predio como ADVC? SI NO Potencial 3 ¿Considera que con la certificación de un predio le permitiría realizar alguna actividad que genere ingresos económicos? SI NO 4 ¿Cuáles? 5 ¿Considera que, con la certificación de un predio, promovería el desarrollo de estrategias de manejo sustentables de las áreas forestales? (Zonificación del área-Acciones de protección, conservación y restauración de los recursos naturales-Lineamientos para el uso y aprovechamiento de los recursos naturales del predio) SI NO 6 ¿Considera que las ADVC serían benéficas para resolver problemáticas socio-ambientales del RBSAT y su Área de influencia? SI NO 7 ¿En qué medida? Excelente-Bueno-Regular-Perjudicial-Sin diferencia 8 ¿Considera las ADVC podrían utilizarse para crear conectividad estructural de la RBSAT con otras ANP? SI NO Motivación 9 ¿Cuál es considera es la principal motivación de los propietarios para crear un ADVC? Conservación ambiental-Incentivo económico-Blindaje- Otro 10 ¿Considera debería promoverse la creación de más ADVC? SI NO 11 ¿Cree existe interés de parte de los propietarios de la tierra? SI NO 12 ¿Considera se debería tener en algún otro criterio/incentivo para la certificación de un predio como AVDC? SI NO 13 ¿Cuál? Limitaciones 14 ¿Cuáles considera son los principales retos en la creación de las ADVC por parte de los propietarios de la tierra? 15 ¿Cuáles serían las ventajas de la creación de ADVC en las cercanías de la RBSAT? 16 ¿Cuáles serían las desventajas de la creación de ADVC en las cercanías de la RBSAT? 17 Uno de los objetivos del nuevo programa de manejo para la RBSAT es *lograr la integración del territorio y fomentar el desarrollo local mediante un esquema de gobernanza ambiental que promueva el uso sostenible de los recursos naturales y existe la meta de incorporar nuevas áreas de conservación para incrementar la conectividad de la RBSAT bajo la integración de intereses distintos de uso del territorio* ¿Considera las ADVC podrían contribuir a cumplir este fin? SI NO

Annex 2. Experts selected for AHP method consultancies

EXPERTS	INSTIUTIONS
GOVERNMENTAL INSTITUTIONS	1. CONANP BRSAT
	2. .CONANP BRSAT
	3. CONANP BRSAT
	4. CONAFOR BRSAT
	5. MUNICIPAL SECRETARY OF ECOLOGY OF CIUDAD VALLES
LANDOWNERS	6. EJIDATARIO LAGUNA DEL MANTE (SMALL FARMER)
	7. EJIDATARIO LOS SABINOS (SMALL FARMER)
	8. EJIDATARIO GUSTAVO GARMENDIA (CATTLE RANCHER)
	9. PROPIETARIO "HOYA VERDE" (PRIVATE SECTOR)
	10. PROPIETARIO "SELVA TEENEK" (ONG)
ACADEMIA	11. UASLP (CD. VALLES)
	12. UASLP
	13. UASLP
	14. UASLP
	15. UASLP

Annex 3. interviewees of VDCA scheme

EXPERTS	INSTIUTIONS
GOVERNMENTAL INSTITUTIONS	1. CONANP RBSAT
	2. CONANP RBSAT
	3. CONANP RBSAT
	4. CONANP RBSAT
	5. CONANP RBSAT
	6. CONAFOR CD. VALLES
	7. CONAFOR NATIONAL OFFICES
	8. MUNICIPAL SECRETARY OF ECOLOGY OF CIUDAD VALLES
LANDOWNERS	9. COMMISSARIAT EJIDO LOS SABINOS
	10. EJIDATARIO LOS SABINOS(FARMER)
	11. EJIDATARIO LOS SABINOS(FARMER)
	12. EJIDATARIO LOS SABINOS (FARMER)
	13. EJIDATARIO LOS SABINOS (PRIVATE SECTOR)
	14. COMMISSARIAT EJIDO LAGUNA DEL MANTE
	15. EJDATARIO LAGUNA DEL MANTE (FARMER)
	16. EJIDATARIO LAGUNA DEL MANTE(FARMER)
	17. EJIDATARIO LAGUNA DEL MANTE(FARMER)
	18. COMMISSARIAT (SUBSTITUTE) EJIDO GUSTAVO GARMENDIA
	19. EJIDATARIO GUSTAVO GARMENDIA (CATTLE RANCHER)
	20. EJIDATARIO GUSTAVO GARMENDIA (CATTLE RANCHER)
	21. PRIVATE OWNER “LAS PITAS” (PRIVATE SECTOR/FARMER)
	22. PRIVATE OWNER “HOYA VERDE” (PRIVATE SECTOR)
	23. ´PRIVATE OWNER “SELVA TEENEK” (PRIVATE SECTOR)
	24. ONG “SELVA TEENEK”
ACADEMIA	25. UASLP CD. VALLES
	26. UASLP
	27. UASLP
	28. UASLP
	29. UASLP
	30. UASLP