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LAND USE CHANGE AND CATTLE RANCHING IN A MIXED-USE LANDSCAPE AND ITS RELATIONSHIP TO JAGUAR (*Panthera onca*) CONSERVATION: THE CASE OF THE RESERVA DE LA BIOSFERA SIERRA DEL ABRA TANCHIPA IN SAN LUIS POTOSÍ, MEXICO

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T E S I S

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La presente tesis, titulada: **Land use change and cattle ranching in a mixed-use landscape and its relationship to jaguar (*Panthera onca*) conservation: The case of the Reserva de la Biosfera Sierra Del Abra Tanchipa in San Luis Potosí, Mexico**, realizada por la alumna **Elizabeth Jean Painter**, bajo la dirección del Consejo Particular indicado, ha sido aprobada y aceptada por el mismo como requisito parcial para obtener el grado de:

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CAMBIO DE USO DE LA TIERRA Y GANADERÍA BOVINA EN UN PAISAJE DE USO MIXTO Y SU RELACIÓN CON LA CONSERVACIÓN DE JAGUAR (*Panthera onca*): EL CASO DE LA RESERVA DE LA BIOSFERA SIERRA DEL ABRA TANCHIPA EN SAN LUIS POTOSÍ, MÉXICO

Elizabeth Jean Painter MC
Colegio de Postgraduados, 2018

RESUMEN GENERAL

La tierra está experimentando un gran declive en la biodiversidad, y una estrategia que se ha implementado para desacelerar el proceso es el establecimiento de áreas protegidas. Sin embargo, la efectividad de las áreas protegidas en la preservación de la biodiversidad depende de cómo se maneje la tierra fuera de sus fronteras. Los objetivos de este estudio fueron describir la tasa de cambio de uso de la tierra, las prácticas ganaderas y la densidad de ganado en la zona, y cómo estos factores se relacionan con la conservación de jaguares (*Panthera onca*) dentro y fuera de la Reserva de la Biosfera Sierra del Abra Tanchipa (RBSAT) en San Luis Potosí, México. Para medir los cambios en el uso de la tierra, se analizaron los datos del uso de la tierra nacional (1985 a 2016) y las imágenes de satélite (1989 y 2016) en la RBSAT y 10 km del paisaje circundante. Se entrevistaron a 31 ganaderos para comprender las prácticas ganaderas; para entender cómo el manejo de la tierra fuera de la reserva contribuye a los esfuerzos de conservación del jaguar; se compararon los cambios en el uso de la tierra y las prácticas de manejo con los patrones de movimiento del jaguar dentro del área de estudio. Se conoció que la infraestructura y la agricultura tenían una tasa de aumento de + 4.5% y + 2.3% desde 1989 hasta 2016, respectivamente. En contraste, el bosque caducifolio tropical y la vegetación secundaria disminuyeron con una tasa de cambio de -0.4% y -0.3%. A nivel regional, se encuestó un total de 2,265.75 hectáreas, con 1,583 hectáreas dedicadas a la producción ganadera y 1,483 cabezas de ganado con una densidad de 0.66 cabezas por hectárea. Dentro del área de encuesta, se abarcaron

939 hectáreas, de las cuales 859 fueron dedicadas a la producción de ganado, incluidas 660 cabezas y una densidad de 0,70 cabezas por hectárea. El 69% de los ganaderos usaba sistemas de pastoreo rotacional y el 50% de los ganaderos usaba cercas eléctricas en alguna capacidad. Un promedio del 66% de los registros de dos jaguares machos equipados con collares GPS fueron identificados en vegetación secundaria y mostraron preferencia por la vegetación secundaria ($P < 0.001$, $\chi ^ 2 = 121.70$, df = 4), que tenía un área de 2.4% de pérdida de 1989 hasta 2016. También se documentó una disminución continua en la vegetación secundaria donde se encontraban más de la mitad de los registros de jaguares, y un aumento en las actividades antropogénicas que pueden conducir a más conflictos relacionados con el jaguar. La mayoría de los ranchos eran una combinación de pastizales y vegetación secundaria, incluidos algunos ranchos con cobertura total de árboles, lo que indica un mayor potencial de interacción entre los jaguares y el ganado. Los planes de gestión a nivel regional deberían incluir el desarrollo de políticas que incentiven las prácticas de manejo que impidan los conflictos entre el jaguar y el ganado y el mantenimiento de la vegetación secundaria y original.
Palabras clave*:* Reservas naturales, escala de paisaje, *Panthera onca*, dimensiones humanas, cambio en uso de suelo, ganadería.

LAND USE CHANGE AND CATTLE RANCHING IN A MIXED-USE LANDSCAPE AND ITS RELATIONSHIP TO JAGUAR (*Panthera onca*) CONSERVATION: THE CASE OF THE RESERVA DE LA BIOSFERA SIERRA DEL ABRA TANCHIPA IN SAN LUIS POTOSÍ, MEXICO

Elizabeth Jean Painter, MC

Colegio de Postgraduados, 2018

GENERAL ABSTRACT

The earth is experiencing a major decline in biodiversity, and a strategy that has been implemented to slow the process is the establishment of protected areas. However, the effectiveness of protected areas in preserving biodiversity depends on how land outside its borders is managed. The objectives of this study were to describe the rate of land use change, cattle ranching practices and cattle density in the area, and how these factors relate to the conservation of jaguars (*Panthera onca*) within and outside the Reserva de la Biosfera Sierra del Abra Tanchipa (RBSAT) in San Luis Potosí, Mexico. To measure land use changes, I analyzed national land use data (1985 to 2016) and satellite imagery (1989 and 2016) in the RBSAT and 10 km of the surrounding landscape; I interviewed 31 livestock producers to understand cattle ranching practices, and to understand how land management outside the reserve contributes to jaguar conservation efforts, I compared land use changes and management practices to jaguar movement patterns within the study area. I found infrastructure and agriculture had a +4.5% and +2.3% rate of increase from 1989 to 2016, respectively. In contrast, tropical deciduous forest and secondary vegetation decreased with a rate of change of -0.4% and -0.3%. Regionally, a total of 2,266 hectares were surveyed, with 1,583 hectares dedicated to cattle production and 1,483 heads of cattle with a density of 0.66 heads per hectare. Within the study area, 939 hectares were surveyed, with 859 dedicated to cattle production including 660 heads of cattle and a density of 0.70 heads per hectare. 69% of cattle ranchers used rotational grazing systems and 50% of ranchers used electric fences in some capacity. An average of 66% of the records from two male jaguars equipped with GPS collars were identified in and showed a preference for secondary vegetation (P<

0.001, X^2=121.70, df=4), which had a 2.4% area loss from 1989 to 2016. I found a continuous decrease in secondary vegetation where more than half of the records of jaguars were located, and an increase in anthropogenic activities that can lead to more jaguar-related conflicts. The majority of ranches were a combination of cleared pasture and secondary vegetation, including some ranches with full tree cover, indicating a higher potential for interaction between jaguars and cattle. Regional level management plans should include the development of policies that incentivize management practices that prevent jaguar-cattle conflicts and the maintenance of secondary and original vegetation.

Keywords: Natural reserves, landscape scale analysis, *Panthera onca*, human dimensions, land use change, cattle ranching.

DEDICATION

To the sound of the jungle in the dark, waiting for the response of a jaguar, a cry in the night, a million stars overhead. My heart, mind and imagination were captured by La Reserva, I am here because of her.

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To my advisors: Thank you for the encouragement to think big, develop my ideas and to follow my heart and my mind.

To my family: I appreciate the faith you showed in me by not worrying excessively and supporting me in every dream I’ve ever had.

A mi amor Pedro Antonio: Que camino hemos viajado. Has estado conmigo en cada paso, gracias. Al infinito y más allá.

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INTRODUCTION

The conservation and management of wildlife is a complex mechanism of rigorous scientific investigation, exploration of human dimensions, and the practicalities of implementation; when each element is involved throughout the process the field as a whole is better for it (Rosas-Rosas and Valdez, 2010). However, the implications of embracing wildlife management as a multiple-disciplinary field are wide reaching. The nexus of science, the public and the application of sound management practices is the future, and the conservation of jaguars (*Panthera onca*) provides an excellent case study.

As human developments expand and alter the boundaries of wild lands, they encroach on wildlife habitat, increasing the likelihood of human-wildlife conflicts. How land is managed surrounding a wild or legally protected area determines its success and its ability to maintain biodiversity in a form that also supports local communities (Brandon et al., 2005). Large predators are especially difficult to support using protected areas due to large home ranges and the negative attitudes they can evoke from communities (Cortina-Villar et al., 2012; Inskip and Zimmermann, 2009; Kellert et al., 1996). There are many locations around the world where these issues are timely and relevant, but a small natural reserve in an agriculturally dominated system in the Sierra Madre Oriental mountain range (SMO) has the ideal conditions to explore the dynamic between protected areas, rural communities and the conservation of endangered predators.

The Reserva de la Biosfera Sierra del Abra Tanchipa (RBSAT) was established in 1994 as a protected area in the state of San Luis Potosí, Mexico, to conserve the habitats of the unique flora and fauna including the jaguar (*Panthera onca*), listed as endangered in Mexico (Secretaría de Medio Ambiente y Recursos Naturales, 2010). It is one of the only reserves of tropical dry forest in the country (Arriaga et al., 2000; Hernández-SaintMartín et al., 2015; Mballa et al., 2011). Ortega-Huerta (2007) identified the RBSAT as having the highest biodiversity and lowest internal fragmentation rate for wildlife, compared to reserves in neighboring states. The caveat is, the RBSAT is also the smallest reserve in northeastern Mexico, and has one of the highest fragmentation rates outside of it. This inverse relationship threatens the functionality of the RBSAT, and the best way to preserve its utility is to incorporate the management objectives for the reserve with objectives identified by the community.

Land use change and changing human population densities are predicted to be the greatest drivers of modifications in the SMO, and Sahagún-Sánchez et al. (2011) pinpointed the conversion of contiguous habitat to farmland and grazing pastures as posing the greatest risk to the quality and value of the SMO as a conservation unit.

The conservation of the jaguar is not only vital to maintain an intact, healthy ecosystem through predation and competition, but is also an important cultural symbol to the Mexican people and throughout its range (Villordo-Galván et al., 2010). Throughout their range, jaguars prefer habitat with a high percentage of plant cover, sufficient prey, and a consistent water source (Seymour, 1989). Jaguars currently occupy only 46% of their historical range (Sanderson et al., 2002), but their preferences and utilization of a variety of habitat types are a testament to their ability to adapt to changing conditions. Jaguar habitat use in Mexico can be characterized by the quality of habitat in relation to vegetation type, proximity to reliable water sources, and elevation, ranging from tropical rainforests, to arid mountains, and desert grasslands (Ortega-Huerta and Medley, 1999; Villordo-Galván et al., 2010). Their prey preferences are just as varied and in Mexico the most common prey have been identified as collared peccary (*Pecari tajacu*), white-tailed deer (*Odocoileus virginianus*), white-lipped peccary (*Tayassu pecari*), white-nosed coati (*Nasua narica)*, and nine-banded armadillo (*Dasupus novemcinctus*) (Hernández-SaintMartín et al. 2015; Núñez et al., 2000; Rueda et al., 2013).

When prey species decline, jaguars are more likely to hunt domestic species. From 2010 to 2012, Hernández-SaintMartín et al. (2013) identified 13 jaguars within the RBSAT and outside its western borders. It is possible there has been a decrease in the rate of depredation events in the communities surrounding the RBSAT. Villordo-

Galván et al. (2010) recorded two depredation events with physical evidence and six depredations from reliable sources without evidence in the state of San Luis Potosí between 2006 and 2008. However, a scat analysis by Hernández-SaintMartín et al. (2015) found no evidence of livestock from samples collected from 2010 to 2012 within and outside the RBSAT.

The largest threats to jaguars in Mexico are habitat fragmentation and hunting in retaliation for depredation events (Quigley et al., 2015; Zarco-González et al., 2013). Habitat loss and fragmentation have a two-fold negative effect on jaguar populations; it decreases wild prey density and it increases the likelihood of human conflict and the depredation of livestock (Ferguson et al., 2013; Figel et al., 2011; Foster et al., 2010; Hoogesteijn and Hoogesteijn, 2008; Inskip and Zimmermann, 2009; Rosas-Rosas and Valdez, 2010). Conflicts and depredation events are the precursor for illegal hunting of jaguars and negative attitudes towards conservation (Zimmermann et al., 2005).

Shifting dynamics between humans and large carnivores highlight the pertinence of working with communities and quantifying the effects of land use change on populations of concern, because effective management plans cannot be developed lacking these components. The conservation of large predators will not have success unless it is practiced as if humans are an integral part of the ecosystem. The reserve's ecosystem is likely threatened by isolation, and land use surrounding the reserve has a major impact on its effectiveness in the conservation efforts of the SMO (Chapa-Vargas and Monzalvo-Santos, 2012; Dueñas-López et al., 2015). The valleys that border the reserve are of mixed use, including cattle ranching, cultivated crops like corn and sugar cane, small settlements and cities, and mining operations. An ongoing research project by Rosas-Rosas et al. (2016), is tracking jaguars within the RBSAT, preliminary data indicates that jaguars are using private and communal land outside the boundaries of the reserve which may increase the number of conflicts with local ranchers and increase the likelihood of predation events.

The conservation of the RBSAT is dependent upon a mutually beneficial relationship between the objectives of the reserve and the interests of the community. Both the reserve and the community should be thought of in terms of a fluid landscape and managed in a way that reflects the welfare of both entities. Concerning the management of wildlife populations, resource extraction, water resources and the conversion of forested land to grazing pasture, plans should be constructed with an expectation of shared use that is advantageous for both the community and the reserve. To achieve these objectives, it is necessary to understand local land use practices, the history of land use change in the area and its probable direction, and how these factors relate to jaguar habitat use. With this information we can model areas of shared use with a higher likelihood of encounters between jaguars and livestock, and potential actions to be taken to prevent conflicts, using the results to build a landscape scale suite of management options.

The objective of this study was to determine the effect of cattle ranching adjacent to the RBSAT, and how this relates to the conservation of jaguars that utilize the habitat within and outside its boundaries. With this study I investigated three components of conservation efforts to prevent conflict between cattle and jaguars: land use surrounding a natural reserve, ranching practices, and habitat preferences of jaguars sharing the landscape.

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GENERAL OBJECTIVE: To describe land use change and cattle ranching near a protected area and its relationship to the conservation of jaguars (*Panthera onca*).

Specific Objectives

1. Estimate the rate of land use change adjacent to the RBSAT.
2. Describe cattle ranching activities and estimate the density of cattle adjacent to the RBSAT.
3. Analyze jaguar habitat use and how this relates to land use change and cattle ranching practices.

CHAPTER 1. RATES OF LAND USE CHANGE SURROUNDING A PROTECTED AREA AND ITS RELATIONSHIP TO JAGUAR (*Panthera onca*) MOVEMENTS IN NORTHEASTERN MEXICO

1.1. ABSTRACT

The earth is experiencing a major decline in biodiversity across all species, and a strategy that has been implemented to slow the process is the establishment of protected areas. However, the effectiveness of protected areas in preserving biodiversity depends on how land outside its borders is managed. The objective of this study was to estimate the rate of land use change within and outside a natural reserve in San Luis Potosí, Mexico, and how this change relates to the conservation of jaguars (*Panthera onca*). This study measured the rate of land use change from 1985 to 2016 within the Reserva de la Biosfera Sierra del Abra Tanchipa (RBSAT) and ten km of the surrounding landscape through satellite imagery and national land use data. To understand how land management outside the reserve contributes to jaguar conservation efforts, land use changes were then compared to jaguar movement patterns within the study area. Infrastructure and agriculture had a 4.5% and 2.3% rate of increase from 1989 to 2016, respectively, and tropical deciduous forest and secondary vegetation decreased at a rate of -0.4% and -0.3%. An average of 66% of the records from both jaguars were identified in secondary vegetation, which had a 2.4% area loss from 1989 to 2016. This study found a continuous decrease in secondary vegetation where more than half of the records of jaguars were located, and an increase in anthropogenic activities that can lead to more jaguar-related conflicts. Shrinking habitat and human conflicts are the main threats to jaguar populations throughout its range. In the RBSAT, these threats are omnipresent. Regional level management plans should include the development of policies that incentivize management practices that prevent jaguar-cattle conflicts and the maintenance of secondary and original vegetation.

Keywords: land use classification, natural reserve, landscape-scale, secondary vegetation

1.2. INTRODUCTION

According to Polasky et al. (2007), the earth is experiencing a major decline in biodiversity across all species, and a strategy that has been implemented to slow the process is the establishment of protected areas. However, the effectiveness of protected areas in preserving biodiversity and supporting local economies depends on how land outside its borders is managed (Brandon et al., 2005; du Toit et al., 2017).

As a component of biodiversity, large predators are especially difficult to maintain through protected areas due to large home ranges and the negative attitudes they evoke from some communities (Brandon et al., 2005; Cortina-Villar et al., 2012; Inskip and Zimmermann, 2009; Kellert et al., 1996). There are many locations around the world where these issues are timely and relevant. An example of this, in the state of San Luis Potosí, in northeastern Mexico, is a biosphere reserve, named the Reserva de la Biosfera Sierra del Abra Tanchipa (RBSAT), located in a landscape dominated by agricultural and livestock production. It has the ideal conditions to explore the dynamics between protected areas, rural communities, and the conservation efforts for endangered predators.

This reserve was established in 1994 as a national protected area for the myriad of unique flora and fauna found in this environmental link among the mounts of the Sierra Madre Oriental (SMO). There are 14 species of birds and three species of mammals considered endangered, threatened or with restricted distributions (Ortega-Huerta 2007). Wildlife species include the jaguar (*Panthera onca*) and the ocelot (*Leopardus pardalis*), both listed as federally endangered in Mexico (Hernández-SaintMartín et al., 2015; Martínez-Hernández et al., 2015; Secretaría de Medio Ambiente y Recursos Naturales, 2010). The RBSAT is situated in the middle of two counties, Ciudad Valles and Tamuín, which have growing populations and robust local economies. Ciudad Valles to the west of the RBSAT, had a 35% increase in population from 1990 to 2015 (Instituto Nacional de Estadística y Geografía, 2015a), and is the number one producer of sugar cane in the state, with a production valued at $49 million USD in 2016 (Calculated using the average exchange rate of 2016,

$19.435 Mexican pesos to $1 USD; Internal Revenue Service, 2018; Servicio de Información Agroalimentaria y Pesquera, 2017). Tamuín has a population that increased by 13% from 1990 to 2015, and leads the state in beef production, valued at $269 million in 2016 (Instituto Nacional de Estadística y Geografía, 2015a; Servicio de Información Agroalimentaria y Pesquera, 2018). The number of heads of cattle harvested has decreased in Ciudad Valles from 2,634 in 2008 to 2,245 in 2016, and has more than doubled in Tamuín from 107,752 to 290,300 in the same time period, but mainly under feedlot production (Servicio de Información Agroalimentaria y Pesquera, 2018).

Since 2010, research on and near the RBSAT has focused on its role in supporting prey species, jaguar and puma (*Puma concolor*) diet and activity patterns (Hernández-SaintMartín et al., 2015, 2013), the status of ocelot populations (Martínez-Hernández et al., 2015), the value in connecting jaguar populations (Dueñas-López et al., 2015), and recently, tracking jaguars in the region to study dietary and spatial requirements (Rosas-Rosas et al., 2016). Other activities have included community outreach, building local RBSAT law enforcement, the implementation of on-site education programs, and workshops, resources and financial support for ranchers (Comisión Nacional de Áreas Naturales Protegidas, 2014). However, land use change and the effects of cattle ranching and agricultural expansion, the main economic activities, remain unquantified.

Due to the fact that the highly productive valleys that border the reserve are of mixed use, including cattle ranching, cultivated crops, urban and rural developments, and mining operations (Dueñas-López et al., 2015), the RBSAT's ecosystem is likely threatened by isolation, and land use surrounding the reserve has a major impact on its effectiveness in the conservation efforts of the SMO (Chapa-Vargas and Monzalvo-Santos, 2012; Ortega-Huerta, 2007). Likewise, preliminary data indicates that jaguars are moving outside the boundaries of the RBSAT, which may increase conflicts with local ranchers and increase the likelihood of depredation events. Thus, by understanding the historical and current patterns of land use, we will strengthen strategies for future development and conservation efforts to promote coexistence.

An analysis of land use change over the last 31 years provides a historical backdrop to the current habitat use and potential interactions, conflicts, and confluence of jaguar activity and cattle and agricultural production. Therefore, the objective of this study was to estimate the rate of land use change within the RBSAT and ten km of its surrounding landscape, and assess how land use changes might influence efforts to conserve jaguars. The purpose is to contribute to the conservation of the jaguar, its role in maintaining an intact, healthy ecosystem through predation and competition, and preserving its importance as a cultural symbol to Mexican people and other cultures throughout its range (Villordo-Galván et al., 2010).

1.3. MATERIALS AND METHODS

1.3.1. Study Area

The study area includes the RBSAT and ten km of the surrounding landscape in San Luis Potosí, representing 1,080 km^2 of tropical deciduous forest, secondary vegetation, agricultural and livestock production, rural towns, and gravel mines (Figure 1.1). The RBSAT straddles the counties of Ciudad Valles and Tamuín, and shares its northern border with the state of Tamaulipas. It is located between 498742 - 511835 E and 2441379 – 2476980 N (UTM) and contains 214.64 km^2 of contiguous dry, tropical deciduous forest, with an altitude ranging from 500 to 800 meters (Arriaga et al., 2000). The climate is classified as sub-humid with summer rains from June to September, an average annual rainfall of 965 mm, and an annual average temperature of 25.7°C (Comisión Nacional de Áreas Naturales Protegidas, 2014). This reserve provides habitat for more than 231 species of plants and 161 species of vertebrates (Arriaga et al., 2000). Felid species include the jaguar, ocelot and puma, and other species include white-tailed deer (*Odocoileus virginianus)*, collared peccary (*Pecari tajacu*), and white-nosed coati (*Nasua narica)* (Hernández-SaintMartín et al., 2015).

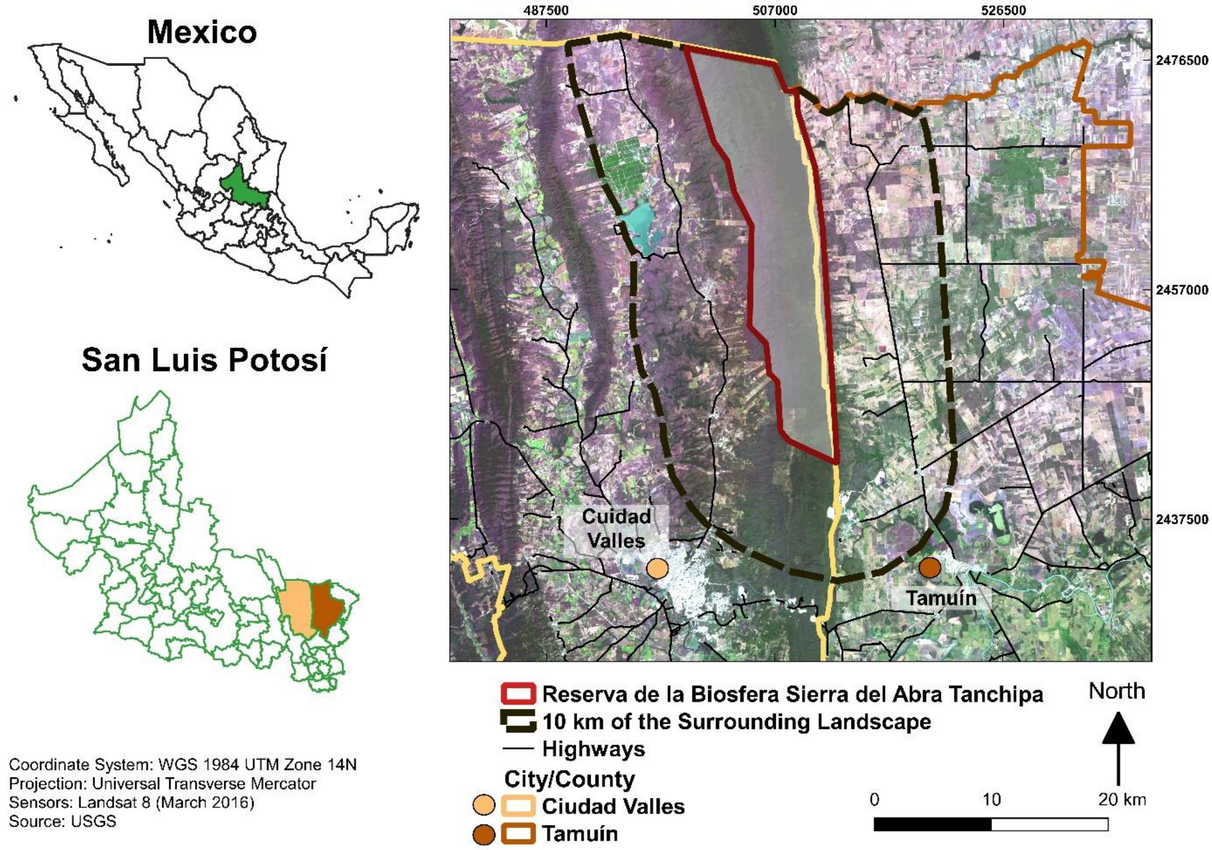


Figure 1.1. The study area, including the Reserva de la Biosfera Sierra del Abra Tanchipa and ten km of its surrounding landscape, and the complex matrix of land use from a satellite image captured on March 25, 2016.

1.3.2. Methods

1.3.2.1. Rate of land use change using vector data from 1985 to 2016.

To identify the rate of change of land use, I analyzed maps of land utilization types (LUT) from El Instituto Nacional de Estadística, Geografía e Informática (INEGI; Instituto Nacional de Estadística y Geografía, 2018) “Uso del Suelo y Vegetación escala 1:250,000” composed of six series: Series I (1985), II (1993), III (2002), IV (2007), V (2011), and VI (2016). They grouped land uses into three main categories: natural vegetation, agricultural uses (livestock, crop production and forestry), and complementary uses, which include urban zones, bodies of water, and erosion.

More detailed cartographic maps (1:50,000) are available in print from INEGI, and maps of this scale have been used by previous authors as verification material to assess the accuracy of classification methods (Chapa-Bezanilla et al., 2008; WoldeYohannes et al., 2018). For the two counties of interest, Ciudad Valles and Tamuín, maps were not available at this scale (Instituto Nacional de Estadística y Geografía, 2018).

I reviewed the LUTs for each series that were located within the boundaries of the study area. The earlier series had fewer LUTs and more specific LUTs in Series VI, likely due to repeated years of sampling and the continuous evolution of available technologies and methodologies, and others. For series I through VI there were 15 LUTs within the study area (Table 1.1).

To analyze the six series and to ensure continuity, I combined the LUTs into six classes of land use. I grouped the agricultural LUTs together based on the definitions from the data sets (Instituto Nacional de Estadística y Geografía, 2017, 2015b, 2009, 2005). For the class of infrastructure, I combined human settlements and urban zones as both being land use types dominated by buildings, infrastructure and highways. I excluded the category of lacking vegetation because it was designated as only a primary category in Series V and VI and represented 0.3% of surface area, and it was included in the other series as a scalable variable within the other vegetation classes to describe states of degradation (Instituto Nacional de Estadística y Geografía, 2015b).

Table 1.1. Original land utilization types (LUTs) from INEGI land use and vegetation maps Series I to VI and the six established classes used in this analysis.

Class/Included LUTs	**Series**					
	I	**II**	**III**	**IV**	**V**	**VI**
Agriculture						
Semi-permanent irrigated agriculture				X	X	X
Seasonal agriculture		X		X	X	X
Annual and semi-permanent seasonal agriculture		X	X	X	X	X
Semi-permanent seasonal agriculture		X	X	X	X	X
Seasonal agriculture	X					
Infrastructure						
Human settlements					X	
Urban zone		X	X	X	X	X
Water						
Bodies of water	X	X	X	X	X	X
Pasture						
Permanent cultivated pasture	X	X	X	X	X	X
Managed pasture (native species)	X	X	X	X	X	X
Tropical Deciduous Forest						
Tropical deciduous forest	X	X	X	X	X	X
Secondary Vegetation						
Marsh						X
Tropical deciduous forest – secondary arboreal vegetation	X	X	X	X	X	X
Tropical deciduous forest – secondary shrub vegetation	X	X	X	X	X	X
Excluded						
Lacking vegetation					X	X

To process the established classes and calculate the surface area, I followed the procedure established by Mas et al. (2009; Figure 1.2) and the program QGIS (QGIS Development Team, 2018). To specify the study area, I clipped all series to a total of 109,148 hectares.

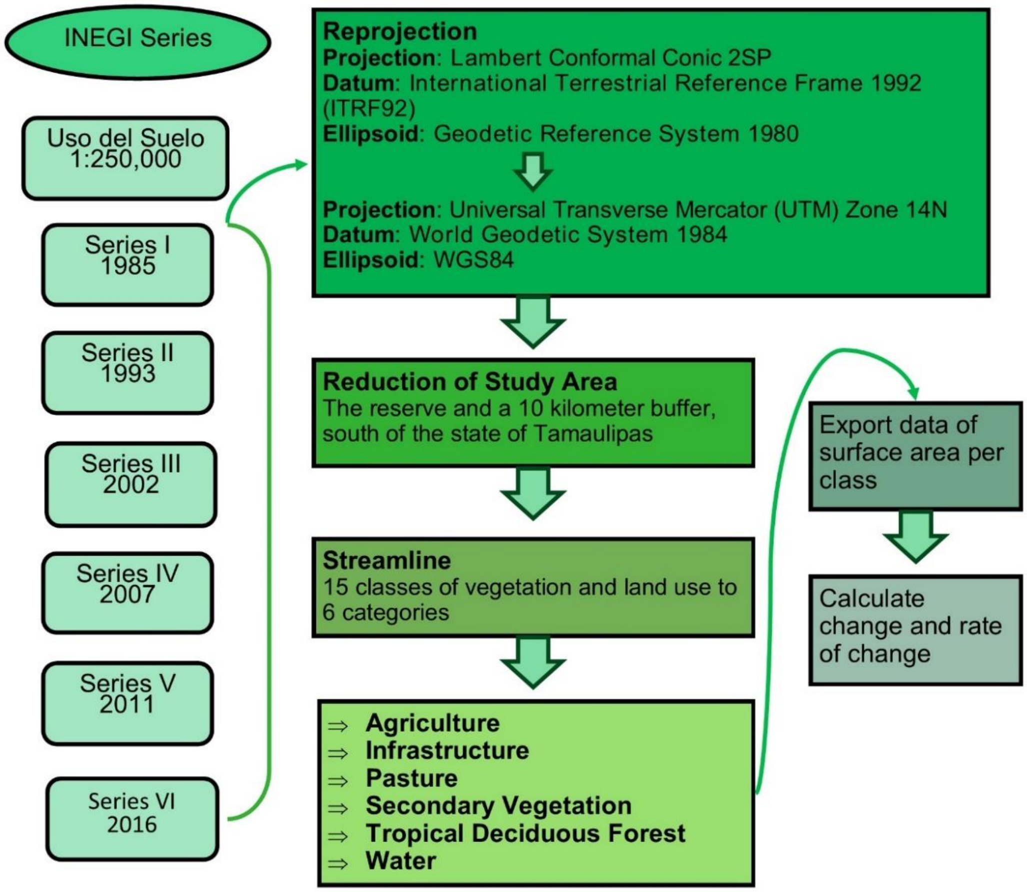


Figure 1.2. Work flow of the analysis of land use change using INEGI series data from 1985 to 2016.

To calculate rate of change in the study area, I used an equation from Miranda-Aragón et al. (2013) and Sahagún-Sánchez et al. (2011), used to calculate deforestation rates in the state of San Luis Potosí and in the SMO, respectively (Eq. 1). The formula was as follows:

[1] $RC = \left\{ \left(\frac{A2}{A1} \right)^{\frac{1}{n}} - 1 \right\} \times 100$

Where:

RC = The rate of change (%)

A_1 = Area in the first year (ha)

A_2 = Area in the final year (ha)

n = Number of years in the analysis period

Positive percentages represent increases in area and negative percentages represent losses in area, and the larger the number, the more intense the change.

1.3.2.2 Rate of land use change using satellite data from 1989 to 2016.

The vector data produced by INEGI provided an adequate general description of land use, however due to its small scale (1:250000), it was limited in its ability to provide fine details. Because the study area includes 109,148 ha, using satellite images permitted a more precise classification detailing the land uses and changes adjacent to the RBSAT.

Data Selection

I selected satellite images based on strict criteria in accordance with the temporal availability of the images during the dry season, and the percentage of cloud coverage (below 10%). These criteria highlighted the contrast between agriculture, dense forest, secondary vegetation, and pastures, notably sugar cane, which is a crop that stays green throughout the year, facilitating the differentiation between land uses (Fichera et al., 2012; Mei et al., 2016).

I analyzed two satellite images of medium spatial resolution (pixels of 30 meters), downloaded from the online platform EarthExplorer (US Geological Survey, 2018). The most appropriate images that were available at the end of the dry season, with no cloud coverage were two images, one from Landsat 4 Thematic Mapper (TM) from March 7th, 1989 and the other from Landsat 8 Operational Land Imager (OLI) from March 25th, 2016 (Table 1.2; Annex A).

Table 1.2. Description of satellite imagery selected for the analysis.

Month/Day/Year	Global Land Survey Sensor	LandSat	Number of Bands	Spatial Resolution	LandSat Scene ID
3/7/1989	TM	4	7	30 m	LT40260451989066XXX01
3/25/2016	OLI	8	11	30 m	LC80260452016085LGN01

I followed the procedures for preprocessing of the satellite images, supervised classification and accuracy assessment methodologies of previous research in land use change (Fernández-Landa et al., 2016; Horvat, 2013; Mei et al., 2016; Reyes-Hernández et al., 2006; Sahagún-Sánchez et al., 2011), using two software programs, QGIS and SAGA GIS (Conrad et al., 2015; Figure 1.3).

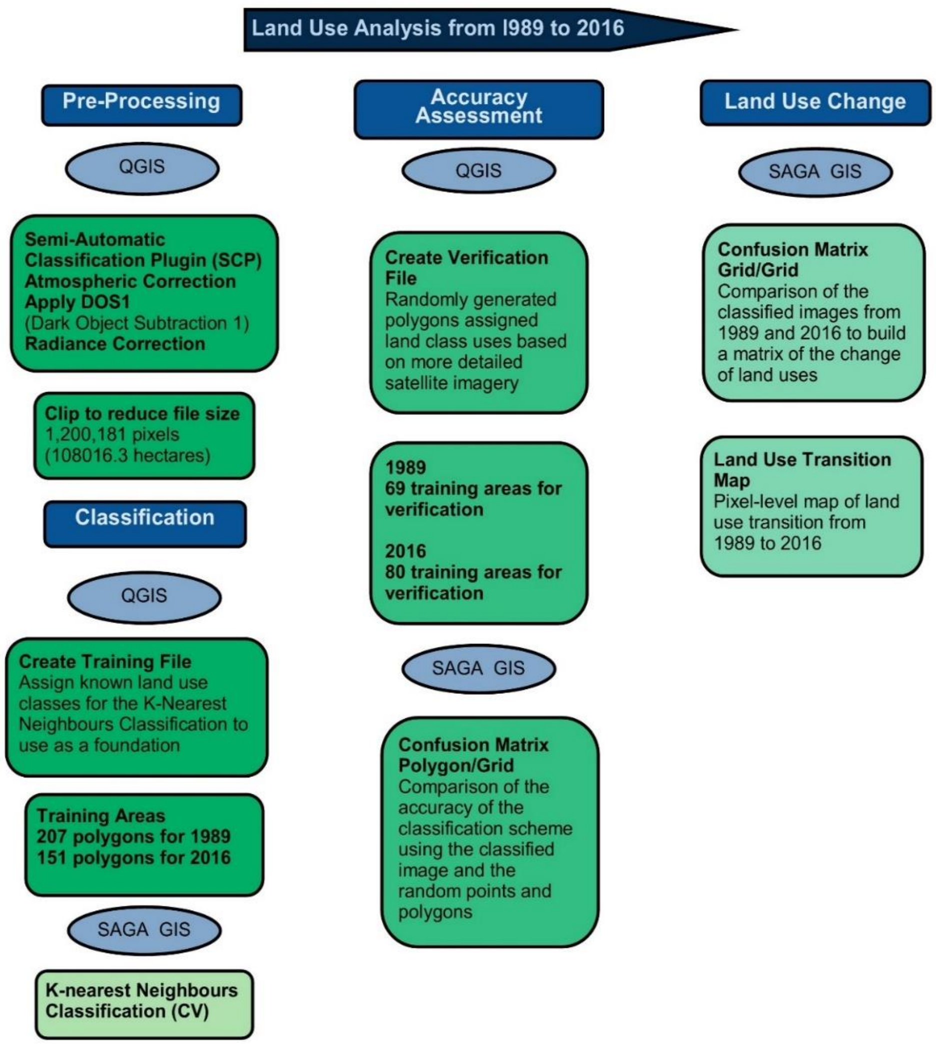


Figure 1.3. Work flow of the pre-processing, classification, and assessment of the treatment of satellite images.

Preprocessing

There are three components of preprocessing corrections for satellite images most commonly applied before the classification (Horvat, 2013). The first corrections were geographic, but were not necessary to perform because the Landsat images I used had already been processed and geo-referenced by the US Geological Survey (2015) to the Universal Transverse Mercator (UTM) projection, using the WGS84 datum and the WGS84 spheroid. The second set of corrections were for radiance and were performed using the Semi-Automatic Classification Plugin for QGIS (SCP; Congedo, 2016). The final corrections were atmosphere and were applied using the option within the SCP plugin to apply a Dark Object Subtraction (DOS1) correction (Hadjimitsis et al., 2010). I clipped the corrected images to the study area with a size 1,200,239 pixels (108,021 hectares).

Supervised Classification

The supervised classification included six classes: Agriculture, infrastructure, pasture, secondary vegetation, tropical deciduous forest, and water, based on two cartographic maps from the INEGI Series I from 1985 and Series VI from 2016 (Table 1.1). There were 13 original land use types (LUTs) within the study area from Series I and VI.

With the established land use classes, I developed a training file using three data inputs (Foody, 2002; Grinand et al., 2013; Reyes-Hernández et al., 2006). The first level of inputs were maps based on land use and vegetation from INEGI Series I and VI. The second inputs provided a higher level of detail, which were the satellite images projected in natural color (Landsat 8, bands 7-5-3; Landsat 4, bands 3-2-1) and false color composite images that highlight vegetation (Landsat 8, bands 6-5-4 and 4-3-2; Landsat 4, bands 5-4-3 and 4-3-2). I selected multiple polygons for each class using the SCP, and I assigned the polygons a land use class. For the image from 1989 I assigned classes to 207 polygons, and 151 polygons to the image from 2016 (Table 1.3).

Table 1.3. The number of training areas per class and the total number of pixels for 1989 and 2016 used to inform the algorithm that generated the classification based on satellite imagery.

	1989		2016	
	Polygons	**Pixels**	**Polygons**	**Pixels**
Water	21	17,293	14	9,312
Infrastructure	40	3,018	51	6,004
Tropical Deciduous Forest	53	39,631	24	17,836
Secondary Vegetation	48	66,610	21	33,587
Agriculture	13	6,450	29	24,291
Pasture	32	37,158	12	14,917
Total	**207**	**170,160**	**151**	**105,948**

The training file served as the basis for the classification algorithm K-nearest Neighbors Classification (Conrad, 2016) in SAGA GIS (Escamos et al., 2015; Qian et al., 2014). I ran 15 iterations of the classification, and after every iteration, I reviewed the classification results, and strengthened the training files in misclassified areas.

Accuracy Assessment

The accuracy assessment was conducted using the final classifications from 1989 and 2016 and two verification files. The SCP randomly selected polygons for each image without taking the land use classes into consideration (Table 1.4). I assigned land use classes to areas with a high level of certainty to serve as controls using different inputs including high-resolution satellite imagery from March 2016 (pixels of 1 m; Planet Team, 2017), the INEGI maps from Series I and VI, and field work. The generation of polygons for the image from 2016 did not include examples of water, the class with the least surface area, so I manually added polygons that should have corresponded to water.

I ran the Confusion Matrix (Grid/Polygon) module (Conrad, 2010) in SAGA GIS for each image, which compared the classification and the verification files to assess their level of agreement. This module generated the overall accuracy and the kappa index value.

Table 1.4. The number of training areas per verification file and the total pixels for 1989 and 2016 that were used to assess the accuracy of the classification system.

	1989		2016	
	Polygons	**Pixels**	**Polygons**	**Pixels**
Water	1	1,621	5	8,263
Infrastructure	6	29	5	17
Tropical Deciduous Forest	18	7,460	35	3,041
Secondary Vegetation	23	988	14	911
Agriculture	4	49	4	216
Pasture	17	579	17	250
Total	**69**	**10,726**	**80**	**12,698**

Land Use Change

To calculate the land use change from 1989 to 2016, I ran the Confusion Matrix (Grid/Grid) module in SAGA GIS (Conrad, 2015) with the two classified images, which produced a change matrix and a transition change map. I also applied the rate of change equation (Eq. 1).

1.3.2.3 Relationship of the occurrence of jaguars to land use change

To analyze the relationship between land use change and occurrence of jaguars, I was provided with jaguar movements from an ongoing project in the SMO that is monitoring jaguar populations and their use of the RBSAT as an ecological corridor. The data was collected from two male jaguars (JM01 and JM02) from 2016 to 2017 fitted with GPS collars (VECTRONIC Aerospace GmbH; Rosas-Rosas et al., 2016). One hundred GPS records were randomly selected from each jaguar and loaded into SAGA GIS. Based on the map of land use from 2016, each record was assigned a land use class using the plugin Add Grid Values to Points (Conrad, 2003), and I calculated the percentage of records within each class. While the classification of land use from 2016 provides information of interest on current jaguar movements, an important theme is the potential effects of land use change. To address these issues, I compared the location points with the transition change map that describes how each pixel shifted in its land use from 1989 to 2016.

1.4. RESULTS

1.4.1. Rate of land use change using vector data from 1985 to 2016.

Over the 31-year analysis period, tropical deciduous forest and secondary vegetation declined as the western border of the RBSAT became more fragmented (Figure 1.4). In the first series from 1985, the dominant classes were tropical deciduous forest (45.4%), pastures (32.3%), and secondary vegetation (21.0%) (Table 1.5; Figure 1.5). In 1993 there was an increase in pasture (+16.2%), and a decrease in tropical deciduous forest (-7.0%) and secondary vegetation (-2.8%). The percentage of pasture, tropical deciduous forest and secondary vegetation remained relatively unchanged from 1993 to 2002, however in 2007 there was a 3.5% decrease in pasture and a 0.6% decrease in secondary vegetation. The area of agriculture almost doubled from 3.8% in 2002 to 7.1% in 2007. There was a marked increase in infrastructure, from 0.1% in 2007 to 0.7% in 2011, with a moderate increase in agriculture (+0.6%), and a slight decrease in pasture and secondary vegetation (-1.2% and -0.1%) in 2011. In 2016, the areas remained relatively stable, with a slight decrease in tropical deciduous forest (-2.1%) and pasture (-0.6%) and an increase in secondary vegetation (+2.4%) and infrastructure (+0.2%).

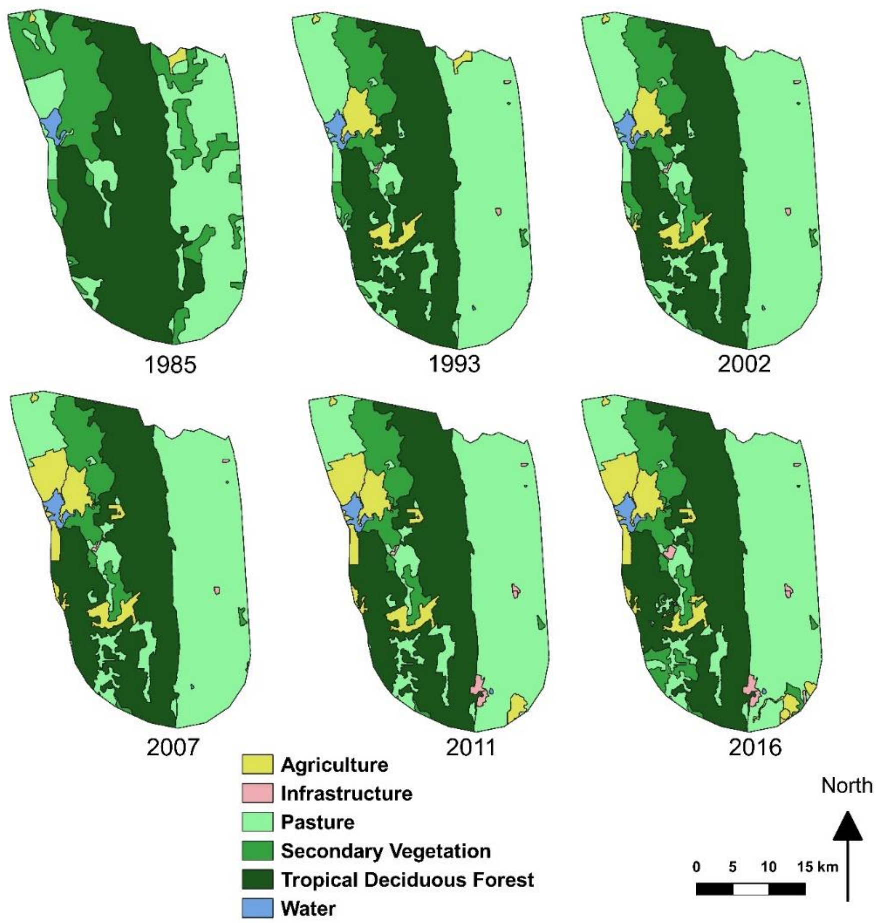


Figure 1.4. Maps of land use classes generated from vector data from 1985 to 2016.

Table 1.5. Land use classes in area and percent from 1985 to 2016 derived from vector data.

Class	Series I		Series II		Series III		Series IV		Series V		Series VI	
	1985		1993		2002		2007		2011		2016	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Agriculture	573.4	0.5	4217.0	3.9	4127.5	3.8	7702.1	7.1	8358.5	7.7	8457.3	7.8
Infrastructure	*NR*	*NR*	163.7	0.2	163.7	0.2	163.7	0.2	762.8	0.7	968.4	0.9
Pasture	35300.9	32.3	52986.0	48.5	53269.1	48.8	49449.6	45.3	48177.3	44.1	47550.8	43.6
Secondary Vegetation	22912.2	21.0	8900.2	8.1	10147.9	9.3	9479.8	8.7	9403.5	8.6	11983.9	11.0
Tropical Deciduous Forest	49534.2	45.4	41916.0	38.4	40474.8	37.1	41387.6	37.9	41467.0	38.0	39208.7	35.9
Water	827.7	0.8	964.9	0.9	964.8	0.9	964.8	0.9	978.6	0.9	978.6	0.9
Total Hectares	**109148.4**											

NR = Data not Reported

The total change from 1985 to 2016 showed a move towards agriculture and infrastructure development (Figure 1.6). The most notable changes from 1985 to 2016 were increases in agriculture from 0.5% to 7.7%, in infrastructure from 0.0% to 0.9%, and in pasture from 32.3% to 43.6%. Secondary vegetation and tropical deciduous forest correspondingly decreased from 21.0% to 11.0% and from 45.4% to 35.9%, respectively. The surface area of water remained relatively stable, with a 0.1% increase.

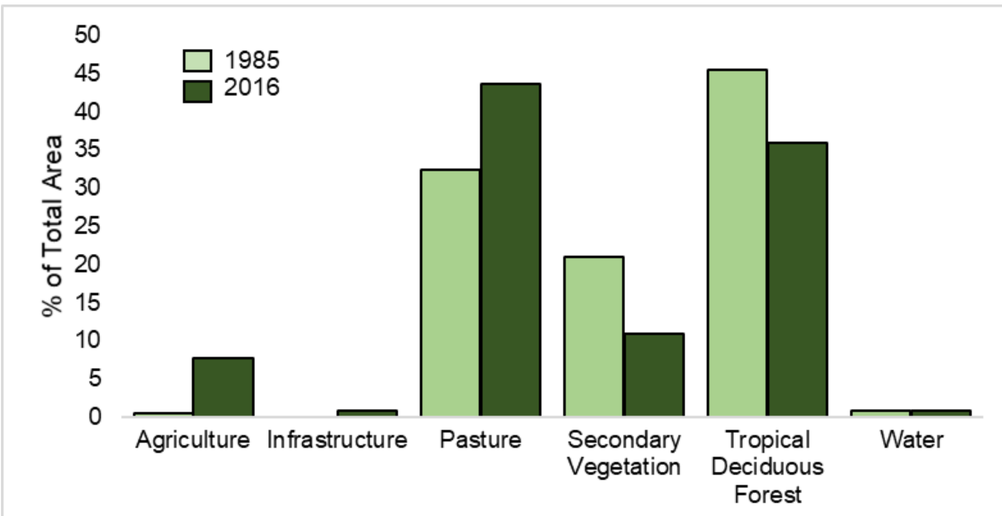


Figure 1.5. Land use categories in percentage of total area in 1985 and 2016 derived from vector data.

From 1985 to 1993, agriculture and infrastructure had dramatic increases, and secondary vegetation had a marked decrease in area (Table 1.6). Looking at the change from 1985 to 2016, agriculture had a rate of change of +9.1% and infrastructure had a rate of change of +24.8% (Fig.1.7). The growth of these two classes of land use coincide with the decrease in secondary vegetation (-2.1%) and tropical deciduous forest. While pasture shows a positive rate of change, it is not a strong trend, suggesting a stronger shift towards the pursuit of agriculture.

Table 1.6. Rate of change per class derived from vector data from 1985 to 2016.

Rate of Land Use Change (%)						
	1985-1993	**1993-2002**	**2002-2007**	**2007-2011**	**2011-2016**	**1985- 2016**
Agriculture	28.3	-0.2	13.3	2.1	0.2	9.1
Infrastructure	89.1	0	0	46.9	4.9	24.8
Pasture	5.2	0.1	-1.5	-0.7	-0.3	1.0
Secondary Vegetation	-11.2	1.5	-1.4	-0.2	5	-2.1
Tropical Deciduous Forest	-2.1	-0.4	0.5	0.1	-1.1	-0.8
Water	1.9	0	0	0.4	0	0.5

Note: Positive percentages represent increases and negative percentages represent losses of area.

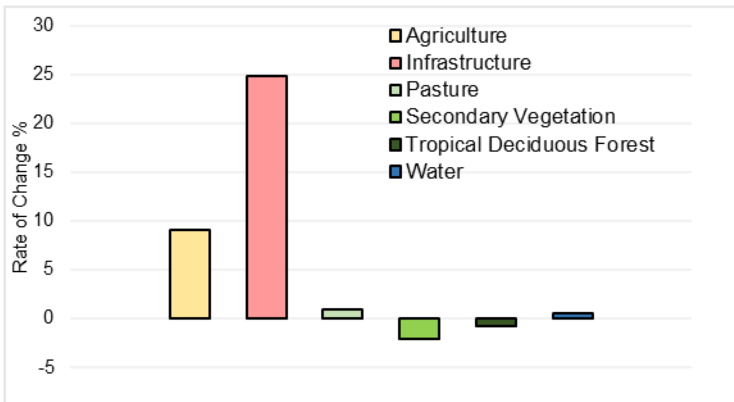


Figure 1.6. Rate of change per land use class derived from vector data from 1985 to 2016.

1.4.2. Rate of land use change using satellite imagery from 1989 to 2016.

Similar to the maps resulting from the land use change analysis of vector data, the changes of land use in the 27-year time period are visually remarkable, from a more contiguous landscape to more heterogeneity (Figure 1.7). The results differed from the INEGI vector data in the area of each land use class. One of the most notable differences is in secondary vegetation. In the INEGI data of 1985 and 2016 the secondary vegetation accounts 21.0% and 11.0% respectively, and the satellite classification estimated that it represented 34.8% in 1989 and 32.1% in 2016.

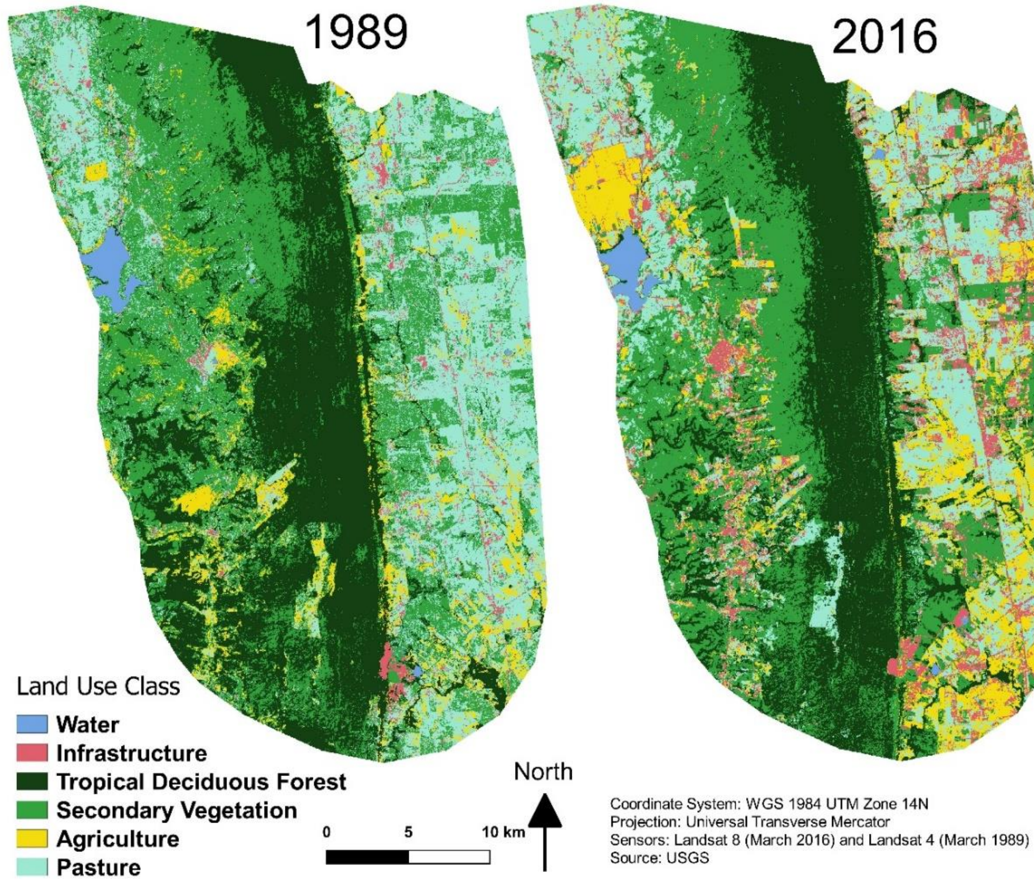


Figure 1.7. Land use classes of the RBSAT and ten km of the surrounding landscape from 1989 and 2016 analyzed using satellite imagery.

The largest gains from 1989 to 2016 were in infrastructure (+6.0%) and agriculture (+5.5%; Figure 1.8). The largest losses were pasture, tropical deciduous forest and secondary vegetation, -5.7%, -3.0% and -2.7%, respectively (Table 1.7). The largest directional changes were in infrastructure and agriculture with a rate of change of +4.5% and +2.3%, respectively. The most intense loss was pasture, with a rate of change of -0.9%.

Table 1.7. Totals and change in area in hectares (ha) and percent (%) measured by the classification of satellite imagery from 1989 and 2016.

	1989		2016		Change 1989 to 2016		
	(ha)	**%**	**(ha)**	**%**	**(ha)**	**%**	**Rate of Change %**
Water	1180.2	1.09	1214.9	1.12	34.7	0.0	0.1
Infrastructure	2858	2.6	9329.5	8.6	6471.5	6.0	4.5
Tropical Deciduous Forest	31930.6	29.6	28640.3	26.5	-3290.3	-3.0	-0.4
Secondary Vegetation	37599.3	34.8	34630.9	32.1	-2968.4	-2.7	-0.3
Agriculture	6843.4	6.3	12778.4	11.8	5935	5.5	2.3
Pasture	27610	25.6	21427.6	19.8	-6182.5	-5.7	-0.9

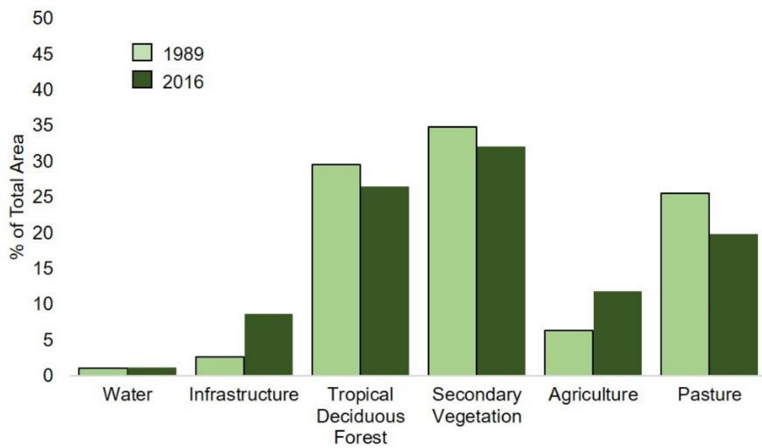


Figure 1.8. Area of land use categories in percentage of total area in 1989 and 2016 from the classification of satellite images.

The greatest contributor to the change matrix was 20,463 ha (19.14%) of tropical deciduous forest that remained unchanged, the majority of which was located in the RBSAT, a benefit of the protected 21,464 ha (Table 1.8). Similarly, 17,364 ha of secondary vegetation were preserved (16.24%). Pasture from 1989 was converted to 5,661 ha of agriculture, 5,692 ha of secondary vegetation, and 4,208 ha of infrastructure. Water and infrastructure both increased, however some conversions were illogical but fell within the range of error of the classification. For example, infrastructure, tropical deciduous forest, secondary vegetation, and pasture all transitioned to water, but only accounted for 0.21% of the total area.

Table 1.8. Confusion matrix of land use changes in area (ha and %) from 1989 to 2016 as determined by the classification of satellite images.

Land use classes from 1989 imagery	Land use classes from 2016 imagery	A	B	C	D	E	F	Total for 1989
	A. Water	962.46	40.41	22.23	70.11	35.19	49.59	1,179.99
		0.90%	0.04%	0.02%	0.07%	0.03%	0.05%	1.10%
	B. Infrastructure	14.31	885.6	92.52	345.96	508.68	1,007.1	2,854.17
		0.01%	0.83%	0.09%	0.32%	0.48%	0.94%	2.67%
	C. Tropical Deciduous Forest	49.68	461.16	20,463.39	8,884.71	893.52	836.82	31,589.28
		0.05%	0.43%	19.14%	8.31%	0.84%	0.78%	29.54%
	D. Secondary Vegetation	96.66	2999.79	5567.13	17,363.52	3,793.14	7,312.95	37133.19
		0.09%	2.81%	5.21%	16.24%	3.55%	6.84%	34.73%
	E. Agriculture	18.36	695.43	1,005.12	1,818.18	1,810.53	1,479.06	6,826.68
		0.02%	0.65%	0.94%	1.70%	1.69%	1.38%	6.38%
	F. Pasture	73.08	4,208.85	1,206.36	5,692.32	5,661.45	10,504.71	27,346.77
		0.07%	3.94%	1.13%	5.32%	5.29%	9.82%	25.57%
	Total for 2016	1214.55	9291.24	28356.75	34174.8	12702.51	21190.23	106930.08
		1.14%	8.69%	26.52%	31.96%	11.88%	19.82%	

1.4.3. Relationship between jaguars and land use change

The two jaguars, JM01 and JM02, were predominately recorded in secondary vegetation, 69% and 63% respectively, with fewer records in infrastructure, agriculture and pasture (Figure 1.9 and Figure 1.10). Tropical deciduous forest only accounted 24% of the records from JM01 and 27% from JM02. The jaguar JM02 was recorded more frequently in agriculture, however the fragmentation, agricultural and livestock production east of the RBSAT is higher than the western side where JM01 was active. Only 23% of the records of both jaguars fell within the boundaries of the RBSAT.

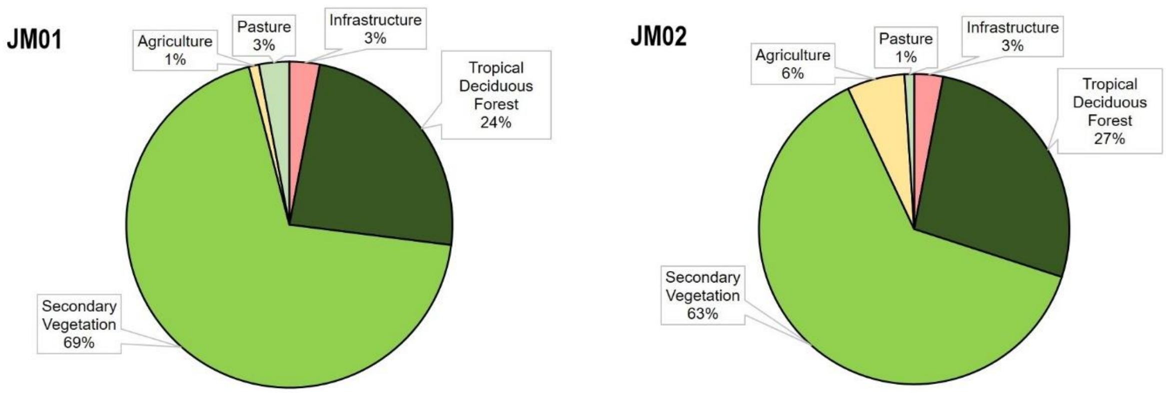


Figure 1.9. Jaguar records and their corresponding land use based on the 2016 classification of satellite imagery.

The movements of both jaguars were both restricted, JM01 to the west of the RBSAT and JM02 to the east. The majority of tropical deciduous forest between the jaguars' ranges was maintained from 1989 to 2016. Both jaguars were recorded in stable secondary vegetation the majority of the time (38% and 22%; Figure 1.11). However, the transition change map showed that 25% of the records of JM01 were in secondary vegetation that had previously been tropical deciduous forest in 1989, and JM02 was located 38% of the time in secondary vegetation that had been pasture in 1989.

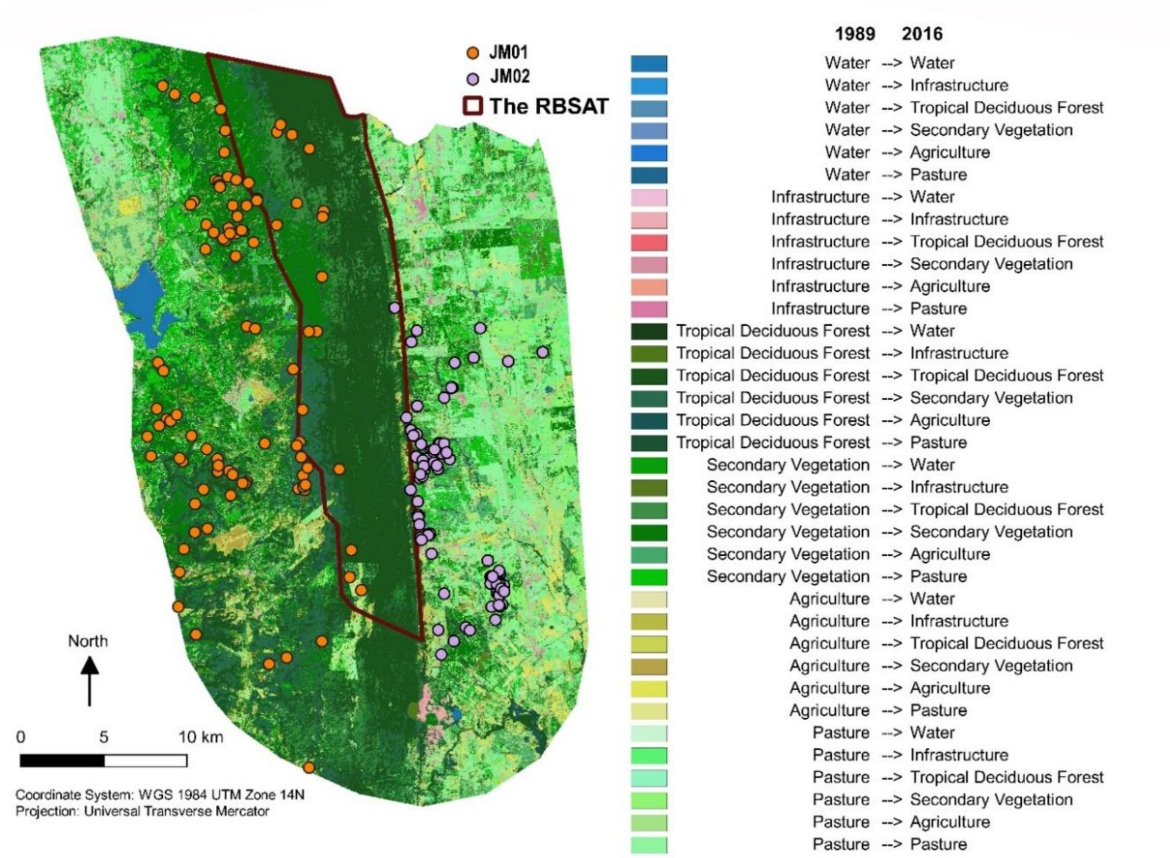
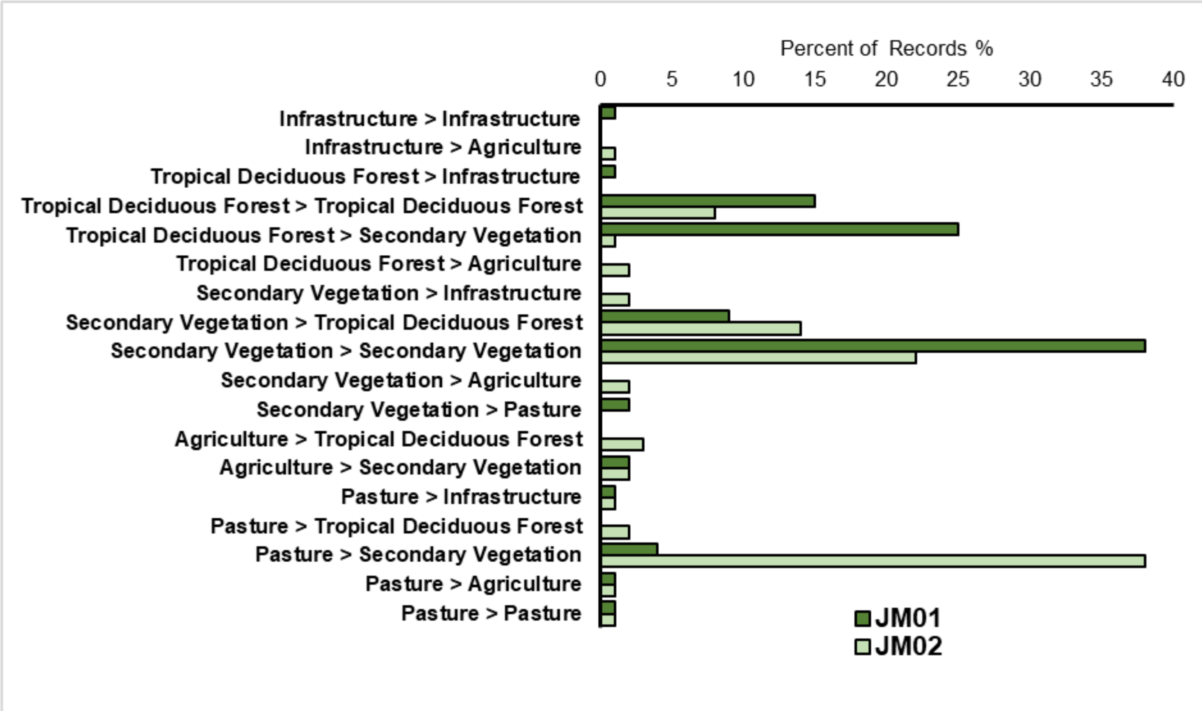


Figure 1.10. Jaguar movement records collected from February 2016 to March 2017 (JM01) and from October 2016 to August 2017 (JM02) and a land use transition change map based on a satellite imagery from 1989 and 2016.



Note: The symbol > indicates a transition between land use classes from 1989 to 2016.

Figure 1.11. The percent of records and their locations from two jaguars within the study area as described by a land use change map that dictates the transition of land use by pixel from 1989 to 2016.

1.5. DISCUSSION

The use of two methods to analyze land use change and the rate of change in and near the RBSAT provided different results. However, this is to be expected due to the difference in scale of the initial data sets. The satellite imagery classification, while prone to more user error (Escamos et al., 2015; Qian et al., 2014), was based on an image of much greater detail, which lends more weight to inferences based on this data.

The results from the analysis of nationally collected geospatial vector data from 1985 to 2016 displayed increases in agriculture and pasture and a decrease in tropical deciduous forest and secondary vegetation. The conflicting category between the two analyses was the changing state of pasture. The vector data described an increase and the satellite image analysis described a decrease.

The accuracies of the classifications based on satellite imagery were within the expected ranges of the overall accuracy (91% for 1989 and 2016) and kappa values (83% for 1989 and 84% for 2016); kappa values of 81%-100% indicate an almost perfect level of agreement (Landis and Koch, 1977; Annex B). These values of accuracy are similar to previous classifications at the state level. In San Luis Potosí, Chapa-Vargas and Monzalvo-Santos (2012) obtained a 72% overall accuracy and 68.9% Kappa. In Campeche, Porter-Bolland et al. (2007) obtained an 87% overall accuracy, and in Chihuahua, Currit (2005) obtained an 86% overall accuracy and 85.29% Kappa. At the national level Velázquez et al. (2010) obtained a 71% overall accuracy of a classification of Mexico.

The highest rates of change in infrastructure and agriculture and the decreases in pasture are an indication of a regional trend shifting away from cattle ranching towards the production of sugar cane and citrus. The increase in infrastructure corresponds to agricultural production and the loss of secondary vegetation following a pattern of commercial and residential development in response to the population growth in Ciudad Valles (35.2%) and Tamuín (13.5%) from 1990 to 2015 (Instituto Nacional de Estadística y Geografía, 2015), and the rise in the production of sugar cane (Servicio de Información Agroalimentaria y Pesquera, 2017).

It also follows a national and state-level trend of a loss of contiguous habitat due to anthropogenic modifications (Mas et al., 2009; Velázquez et al., 2010). Miranda-Aragón et al. (2013) identified one of the highest rates of change in San Luis Potosí to be a shift towards seasonal agriculture (+1.1%) and irrigated agriculture (+4.8%) in the years 1993 to 2007, compared to the findings of our study, in which the rate of change of agriculture as a combined category was +2.3% from 1989 to 2016.

A loss of tropical deciduous forest and secondary vegetation and the increase in population and anthropogenic activities showed developments and land use changes that increase the likelihood of interaction between jaguars that are using the reserve and the areas outside the reserve (Hernández-SaintMartín et al., 2015; Rosas-Rosas and Bender, 2012). The pasture lands had a negative rate of change; however, in economic terms, there is a continued high level of cattle production and associated activities, especially in Tamuín.

The relationship between the 1989-2016 transition change map and the 200 location points from jaguars recorded in the counties of Ciudad Valles and Tamuín, showed a tendency for a high volume of records in secondary vegetation. Within the study area, secondary vegetation accounted for 32.1% of the surface area in 2016, and was used more than twice as often by both jaguars than tropical deciduous forest. Secondary vegetation is highly variable partially due to its role in a variety of land use successions. It can be the result of abandoned pastures or agriculture, it can be due to thinning and altering tropical deciduous forest, or the result of changing infrastructure (Wandelli and Fearnside, 2015). This was reinforced by the number of records that were located in secondary vegetation that had transition from pasture (JM02) and tropical deciduous forest (JM01). Only 23% of the records from the jaguars fell within the boundary of the RBSAT, which suggests the necessity to include stakeholders outside of the RBSAT in conservation efforts.

A potential driver of preference for secondary vegetation could be the presence of prey. While research has shown a healthy prey base in the RBSAT for the jaguar (Hernández-SaintMartín et al., 2015, 2013), it is possible the expansion of agricultural and livestock production has attracted prey species to transitional land uses. In the county of Tamasopo, south of Ciudad Valles, Ávila-Nájera et al. (2011) found evidence of two important prey species for jaguars in the RBSAT, collared peccary and white-nosed coati, using tropical deciduous forest, agriculture and roads. In Campeche, Escamilla et al. (2000) recorded collared peccary, white-tailed deer, jaguars and pumas in a complex mosaic of agriculture, livestock production and tropical forest. In this study, the jaguars' preference for secondary vegetation is not necessarily indicative of a selection of traditionally optimal habitat, but may be a result of a mixed-use landscape.

In addition, the RBSAT does not have any permanent water sources (Hernández-SaintMartín et al., 2013), creating a dynamic during the dry season in which wildlife seek water outside of the boundaries of the reserve, including jaguars and their prey.

Villordo-Galván et al. (2010) mentioned that in the state of San Luis Potosí, between 2006 and 2008, there were six depredation events reported, and Hernández-SaintMartín et al. (2015) found no evidence of livestock in a scat analysis from samples collected from 2010 to 2012 within and outside the RBSAT.

The rates of change identified by the classification of satellite images indicate that the rapid increase in infrastructure and agriculture is a trend that will dramatically change the landscape. As managers, researchers, and stakeholders we need to seek approaches that manage for the response of resident jaguars, mitigating conflicts, supporting jaguar populations, and protecting the economic success of the communities adjacent to the reserve.

The development of jaguar management strategies depends on available research and cooperation. Adaptive management requires structured monitoring and a willingness to change methods and alter tactics depending on the feedback and results (Williams, 2011). Variables that have been identified as important factors in pinpointing the likelihood of conflicts between cattle and jaguars include the distance from a protected area, the presence of riparian vegetation, and seasonal availability of water (Alfaro et al., 2016; Peña-Mondragón and Castillo, 2013; Rosas-Rosas et al., 2010); however, these are variables that cannot be altered with policy changes. This is why working with members of the community and site-specific prevention methods is so vital. Approaches on an individual level include secure fencing (Quigley et al., 2015), guard animals, limiting grazing to open areas and the management of pregnant cows and young calves (Rosas-Rosas et al., 2015). The limitations to these methods include costs, labor, and the willingness of property owners. Regional level management plans include insurance programs (Dickman et al., 2011), the development of supplemental income that incentivizes management practices that are beneficial for secondary vegetation and stewardship of the land (Rosas-Rosas and Valdez, 2010), the protection of wild prey species (Amador-Alcalá et al., 2013), and education outreach.

Mexico is the first Latin American country to institute insurance for depredation; it is a component of the National Confederation of Livestock Organizations (CNOG). In

2016, 46,869,392 heads of livestock were insured, and from 2009 to 2014, 2,075 depredations were compensated, 435 of which were positively identified as jaguar depredations (Fondo de Aseguramiento, CNOG, 2014).

With small groups of ranchers near the RBSAT, Rosas-Rosas et al. (2015) have successfully tested and implemented management strategies described above in addition to improving livestock nutrition, and the use of silos to prolong the availability of high-quality feed. They also published a compilation of information and techniques for the ranching communities of the SMO, which includes the conservation of jaguars and their relationship with cattle in Latin America, the general characteristics of the region, depredation patterns, the keys to identifying the perpetrators of depredation attacks, and effective and easily implemented management techniques. This technical handbook is an excellent example of the impactful application of research in a format designed for a public audience. Combined with the strength of the national insurance program, Mexico is preventing depredations from multiple angles.

1.6 CONCLUSIONS AND SUGGESTIONS

The rate of change of land use near the RBSAT is high and moving in a direction away from natural vegetation towards agricultural and infrastructure development. The combination of a decrease in preferable jaguar habitat (secondary vegetation and tropical deciduous forest), and the increase in agriculture and infrastructure, will alter the landscape to become less hospitable for jaguars that may lead to conflicts between ranchers and jaguars.

Conservation in the RBSAT is dependent upon a mutually beneficial relationship between the objectives of the reserve and the interests of the community, and managed in a way that reflects the interests of both parties. Concerning the management of wildlife populations, resource extraction, water resources and the conversion of forested land to grazing pasture and agricultural production, plans should be constructed with an expectation of shared use that is advantageous for both the community and the reserve. Shrinking habitat and human conflicts are the main threats to jaguar populations throughout its range, and in the RBSAT these threats are omnipresent.

To expand the applicability of the results of this study and to aid in understanding the direction and force of land use changes along the border of the RBSAT, a larger study area, including the entire counties of Ciudad Valles and Tamuín would be ideal to provide a larger, landscape scale analysis of the region and the SMO. By classifying satellite images of higher resolution, for example from the SPOT collections of images (2.5 m to 20 m; Centre National d'études Spatiales, 2018), would provide more detail, and make boundaries of secondary vegetation, tropical deciduous forest, and agriculture clearer, in combination with field verification to improve the input to the classification models. In addition, a full census of the land parcels that share a boundary with the reserve would serve to generate more specific information on land use activities with a high potential to influence the RBSAT and its objectives to preserve biodiversity.

The findings of this study support and emphasize the value of practices encouraged by Rosas-Rosas et al. (2015). Understanding land use change, ranching practices near the RBSAT, and supporting agricultural and livestock practices that minimize the impact of land use change and shift practices to promote coexistence in a wildlife-friendly matrix.

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CHAPTER 2. CATTLE RANCHING IN A MIXED USE LANDSCAPE AND ITS RELATIONSHIP TO JAGUAR (*Panthera onca*) CONSERVATION: THE CASE OF THE RESERVA DE LA BIOSFERA SIERRA DEL ABRA TANCHIPA IN SAN LUIS POTOSÍ, MEXICO

2.1. ABSTRACT

In 2016, cattle ranching was a $113 billion-dollar business in Mexico, which has more than doubled in the last decade. As the ranching industry grows, more encounters will occur between humans, livestock and large predators which will mean an even greater conversion pressure on wild lands. The objective of this study was to describe ranching activities near a small natural reserve in San Luis Potosí, Mexico, to estimate the density of cattle by interviewing cattle ranchers near the Reserva de la Biosfera Sierra del Abra Tanchipa (RBSAT), and compare these results with jaguar records. A total of 2,266 hectares were surveyed, with 1,583 hectares dedicated to livestock production, including a livestock population of 1,483 heads of cattle (0.66 heads per hectare), 120 goats, 54 sheep and 73 pigs. Within the study area, including the core of the RBSAT and a 10 km of the surrounding landscape, 939 hectares were surveyed, with 858.5 dedicated to cattle production, and a density of 0.70 heads per hectare. Concerning grazing systems, 69% of cattle ranchers used rotational designs, and 50% of ranchers used electric fences in some capacity. An average of 66% of the records from two male jaguars equipped with GPS collars were identified and showed a preference for secondary vegetation ($P < 0.001$, $\chi^2 = 121.70$, df=4).The majority of ranches were a combination of cleared pasture and secondary vegetation and shrubs, including some ranches with full tree cover, indicating a higher potential for interaction between jaguars and cattle. Because large tracts of tropical forest are difficult to protect, small patches of secondary vegetation may act as stepping stones and refuges that provide sufficient resources for jaguars. As jaguars and producers share the landscape, it is vital to collaborate with communities to ensure the success of both.

Keywords: Ranching management, human dimensions, wildlife conflict prevention, conservation

2.2. INTRODUCTION

Trends show that agricultural production and cattle ranching operations are growing their land holdings and investing in business expansion in Mexico and Central America (Food and Agriculture Organization, 2018, 2009; Robinson et al., 2014). In 2016, cattle ranching was a $6.3 billion USD business in Mexico (Calculated using the average exchange rate of 2016, $19.435 Mexican pesos to $1 USD; Internal Revenue Service, 2018;), and from 2006 to 2016 the value of cattle ranching more than doubled (Servicio de Información Agroalimentaria y Pesquera, 2018).

As the ranching industry grows, more encounters will occur between humans, livestock and large predators (Brandon et al., 2005; Inskip and Zimmermann, 2009), which will mean an even greater pressure on wild lands (Davis and Lopez-Carr, 2014; Olsoy et al., 2016). In efforts to conserve wild cats, a human dimensions' approach to policy development and the integration of community input and desires are vital to success (Amador-Alcalá et al., 2013; Rosas-Rosas and Valdez, 2010; Zarco-González et al., 2013). With the aim to integrate conservation efforts with working landscapes it is essential to collaborate with rural communities and agricultural and livestock producers to develop management plans that are beneficial to both parties by financial and ecological measures.

There are many locations around the world where these issues are timely and relevant and in the state of San Luis Potosí in northeastern Mexico, there is a small reserve that is threatened by isolation and land use change, specifically the unquantified effects of cattle ranching. In one of the two counties adjacent to the reserve, cattle production was worth $269 million in 2016 (Servicio de Información Agroalimentaria y Pesquera, 2018). The Reserva de la Biosfera Sierra del Abra Tanchipa (RBSAT) is situated in a matrix of high agricultural and livestock production in the Sierra Madre Oriental mountain range (SMO) and is an important refuge for resident jaguars (*Panthera onca*) (Dueñas-López et al., 2015). It has the ideal conditions to explore the dynamics between the production of cattle, protected areas and the conservation of endangered predators.

The jaguar is the largest felid in the Americas and is classified as endangered in Mexico (Secretaría de Medio Ambiente y Recursos Naturales, 2010), due to habitat fragmentation and illegal hunting. Sanderson et al. (2002) identified Mexico as a country with a large amount of suitable habitat that may serve the species in the long term and there have been concerted efforts to fill knowledge gaps in the country (Rodríguez-Soto et al., 2011). Conservation efforts of other large predators have been successful by utilizing a combination of legislation and community outreach to develop relationships and cooperatives that support programs that ensure lasting change; jaguar conservation programs and research in Mexico are already applying this framework (Inskip and Zimmermann, 2009). While conservation efforts are gathering steam, the ranching industry and agricultural production are increasing at a rapid rate, and understanding how jaguars are using changing landscapes will inform management objectives and efforts to guide land use and land use change to maximize the landscape for all stakeholders.

The production of cattle for meat and other products is an important component of the Mexican economy. In 2016 Mexico had 33.9 million heads of cattle (Food and Agriculture Organization, 2018), and 48.1 million hectares of land dedicated to cattle production (Table 2.1; Instituto Nacional de Estadística y Geografía, 2016). Mexico had 49,951,552 hectares of agricultural land in production, San Luis Potosí had 1,483,816 hectares, the counties of Ciudad Valles and Tamuín had 92,182 and 32,312 hectares (Instituto Nacional de Estadística y Geografía, 2016). In addition, in 2016 there were an estimated 25.9 million people that live in rural communities, approximately 20% of the country’s population (Food and Agriculture Organization, 2018). Rural communities are more dependent on natural resources than urban populations, and this inherently leads to more encounters, extractions, and competition with wildlife (Polasky et al., 2007).

Table 2.1. Land in agricultural, livestock and cattle livestock production at the country, state and county levels in 2016 (Instituto Nacional de Estadística y Geografía, 2016).

	Agriculture	Livestock	Cattle
		Hectares	
Mexico	49,951,552	64,106,426	48,067,426
San Luis Potosí	1,483,816	1,056,309	827,134
Ciudad Valles	92,182	51,165	41,320
Tamuín	32,312	121,320	108,259

Ciudad Valles leads the state in the production of sugar cane and Tamuín leads the state in the production of beef (Servicio de Información Agroalimentaria y Pesquera, 2018, 2017). The importance of the agricultural and ranching industries in San Luis Potosí are vital to the success of the state, however the role of the RBSAT is key in this context as a refuge of biodiversity amidst a mixed-use landscape.

A key to preventing conflict between producers and jaguars is understanding how cattle and jaguars might potentially interact in the landscape and how current and potential management practices might influence those interactions (Rosas-Rosas et al., 2015). In a landscape of high agricultural and livestock production, rich biodiversity, and a contentious large predator, it is essential to develop landscape-scale management plans based on sound landscape-scale research. Understanding ranchers, their concerns, challenges, and financial drivers will be key to providing the resources and methods to manage for conservation and co-existence in the region (Brenner, 2011). The success of these management plants will depend on involving local communities with the goal of a shared-use landscape. The objective of this study was to describe ranching activities near a small natural reserve in San Luis Potosí, Mexico, to estimate the density of cattle by interviewing cattle ranchers near the Reserva de la Biosfera Sierra del Abra Tanchipa (RBSAT), and compare these results with jaguar records in the study area.

2.3. MATERIALS AND METHODS

2.3.1. Study Area

The study area includes the RBSAT and ten km of the surrounding landscape in San Luis Potosí, representing 1,080 km^2 of tropical deciduous forest, secondary vegetation, agricultural and livestock production, rural towns, and gravel mines (Figure 2.1). The RBSAT straddles the counties of Ciudad Valles and Tamuín, and shares its northern border with the state of Tamaulipas. It is located between 498742 - 511835 E and 2441379 – 2476980 N (UTM) and contains 214.64 km^2 of contiguous dry, tropical deciduous forest, with an altitude ranging from 500 to 800 meters (Arriaga et al., 2000). The climate is classified as sub-humid with summer rains from June to September, an average annual rainfall of 965 mm, and an annual average temperature of 25.7°C (Comisión Nacional de Áreas Naturales Protegidas, 2014). This reserve provides habitat for more than 231 species of plants and 161 species of vertebrates (Arriaga et al., 2000). Felid species include the jaguar, ocelot and puma, and species with high abundances include white-tailed deer (*Odocoileus virginianus)*, collared peccary (*Pecari tajacu*), and white-nosed coati (*Nasua narica)* (Hernández-SaintMartín et al., 2015).

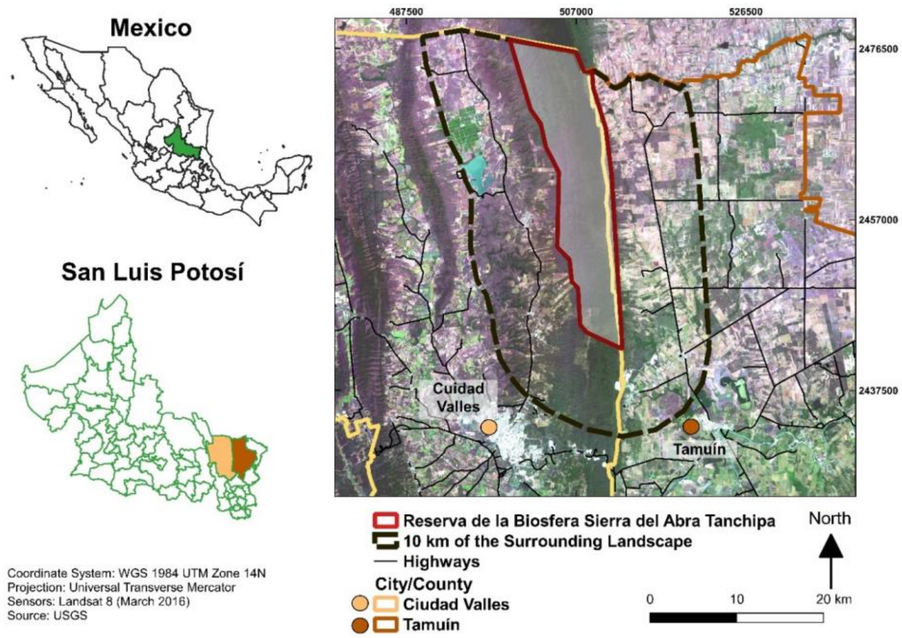

Figure 2.1. The study area, including the Reserva de la Biosfera Sierra del Abra Tanchipa and ten km of its surrounding landscape, and the complex matrix of land use from a satellite image captured on March 25, 2016.

In comparison to the robust biodiversity within the RBSAT, it is surrounded by a mixed-use landscape that includes cattle ranching, agricultural activities at a small and commerical scales, and gravel extraction. The level of production of sugar cane ranks Ciudad Valles as the leading county in the state, producing more than $49 million in 2016, Tamuin and Ciudad Valles combined represented 57% of the production in the state (Servicio de Información Agroalimentaria y Pesquera, 2017; Table 2.2). Ciudad Valles and Tamuin accounted for 81% of the state's beef production in 2016 (Servicio de Información Agroalimentaria y Pesquera, 2018). In the same year, the county of Tamuín produced 140,264 tons of beef, valued at $269,894,211 USD.

Table 2.2. Production and value of sugar cane and beef at the state and municipal level in 2016.

	San Luis Potosí	Ciudad Valles	Tamuín
Sugar Cane (USD)	$122,170,132	$49,078,066	$21,147,200
Sugar Cane (Metric Ton)	4,543,485	1,911,380	703,435
Beef Production (USD)	$335,802,264	$2,204,528	$269,894,211
Beef Production (Metric Ton)	176,407	1,021	140,264

2.3.2. Methods

The approach to this study was twofold. The first component was interviews with livestock producers to better understand the local communities, details of ranching practices, and to estimate the density of cattle near the RBSAT (Annex C and D). The majority of ranchers did not have property that was directly adjacent to the RBSAT, however this provided a wider, landscape-level analysis. The second component of this study was to know how jaguar conservation relates to ranching practices and the potential for encounters.

2.3.2.1. Interviews

I conducted 27 non-random, semi-structured interviews of livestock ranchers within and near the study area, and a representative of the Cattle Ranching Society of Tamuín. Of the 27 respondents, 26 individuals were interviewed regarding current ranching practices on 30 different ranches (Annex E), and one individual was interviewed as a representative of the Cattle Ranching Society of Tamuín. Of all 26 respondents, 16 ranches were located within the study area, and to increase the number of participants, 14 ranches outside of the study area were included in the analysis, which provided insight into ranching practices on a larger scale.

All interviews were conducted on-site in the form of interviews and field visits. The combination of semi-structured interviews and field visits helped to provide a full picture of the empirical information, the state of cattle management in reality, and the vegetation status on the property (Knapp and Fernandez-Gimenez, 2009). The questions were prepared in a manner that allowed for elaboration if the ranchers demonstrated interest (Zimmermann et al., 2005). The level of interest, willingness to respond and the likelihood of truthful responses varied widely, however the majority of respondents reacted favorably and were interested in the research questions of historical land use and contemporary land use practices within the context of jaguar conservation.

One of the principal messages I began the interviews with was my non-bias interests. I was not associated with any government entities interested in administering fines for disregarding laws such as having un-registered animals, illegal water-sources, or selling cattle through non-legal channels. I also clarified that I was seeking the stories of the respondents, negative or positive especially regarding their views and experiences with depredation and wildlife in general (Amador-Alcalá et al., 2013). With these baselines established, many individuals provided me with insight that they might have been hesitant in sharing.

2.3.2.2 Jaguar Records

To analyze the relationship between cattle ranching practices and the land use of jaguars, data were collected from two male jaguars in and near the RBSAT (JM01 and JM02; Rosas-Rosas et al., 2016). One hundred unique GPS records were selected from each individual and loaded into SAGA GIS. Using the plug in “Add Grid Values to Points” (Conrad, 2003), each record was assigned one of six land use classes derived from a land use classification map based on a Landsat 8 satellite image from 2016 (Figure 1.7). The classification included six land use types: Water, infrastructure, tropical deciduous forest, secondary vegetation, agriculture, and pasture derived from INEGI Cartographic Series I and VI (Instituto Nacional de Estadística y Geografía, 2017, 2005). The data from these points was then exported and I calculated the percentage of records within each class of land use.

To assess whether the jaguar records were random or if they were actively selecting land use types, I employed the Chi-square goodness of fit test and Bonferroni simultaneous confidence intervals (Byers et al., 1984; Neu et al., 1974).

The Chi-square goodness of fit test is a measure of whether there was a significant difference between the expected number of records in a land use category and the number of locations that were observed (Byers et al., 1984; Neu et al., 1974; Eq. 1). The number of records expected in each class is related to the proportion of the total area represented by the class and the total number of records (200). Water was excluded from the analysis as a potential land use type due to its small percentage of surface area and the likelihood of observed records.

[1] $\chi^2 = \Sigma(O_i - E_i)^2/E_i$

Where: O_i = Observed number of records and E_i =Expected number of records.

To determine whether the difference between expected use and actual use was statistically significant within each land use class, I used Bonferroni simultaneous confidence intervals (Eq. 2) These intervals use a Z statistic based on the number of categories (k=5) and the confidence level (α=0.05). With the resulting confidence intervals, I used the expected proportion of records (P_{io}), and if it fell outside the intervals, it was considered a significantly different use than the observed proportions. If the P_{io} values were smaller than the intervals it was considered a selected (preferred) land use class, and if the values were larger than the intervals it was considered an avoided land use class (Byers et al., 1984; Neu et al., 1974).

[2] $\bar{p}_i - Z_{\frac{\alpha}{2k}}\sqrt{\frac{\bar{p}_i(1-\bar{p}_i)}{n}} \leq p_i \leq \bar{p}_i + Z_{\frac{\alpha}{2k}}\sqrt{\frac{\bar{p}_i(1-\bar{p}_i)}{n}}$

Where: P_i = Proportion of records observed, α=0.05, k= the number of land use classes, and n = the number of observations.

2.4. RESULTS

2.4.1. Interviews

Of the 26 interviews with ranchers regarding 30 ranches, eight ranches were located in Tamuín, 20 were located in Ciudad Valles, and two ranchers lived in the county of San Vicente Tancuayalab to the south (Figure 2.2). The 26 practicing ranchers, accounted for a total of 2,266 hectares, with 1,583 hectares dedicated to livestock production. The two largest land parcels consisted of 300 hectares each and both represented mixed used parcels of cattle and sugar cane production with secondary vegetation and tropical deciduous forest, located in the county of Ciudad Valles. The average number of permanent employees was two and the maximum was four, with a range of two to ten seasonal employees (Table 2.3).

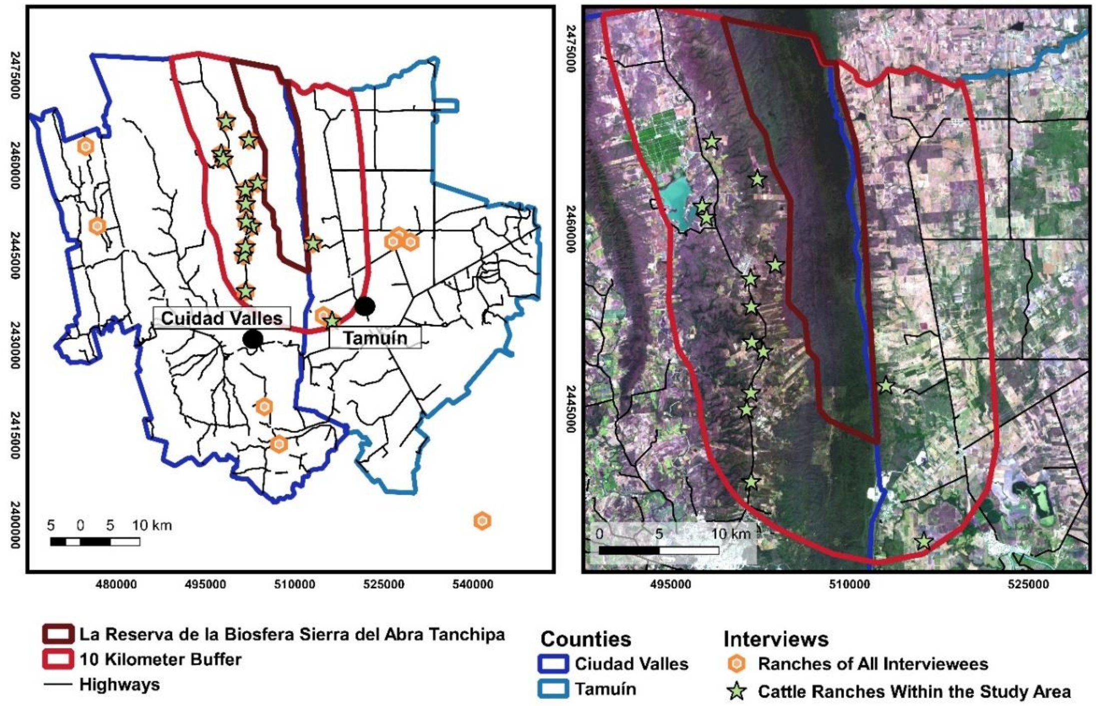

Figure 2.2. All ranch locations of currently practicing interviewees and locations of cattle ranchers interviewed within the RBSAT and 10 km of the surrounding landscape that were analyzed in this study.

Table 2.3. General characteristics of the 26 cattle ranchers, representing 30 ranches within and near the study area.

Summary of Interviews of Practicing Cattle Ranchers (Averages)	
Age	57
Number of years as the owner of the property	22
Extension average (ha)	80
Surface area dedicated to livestock production (ha)	58
Permanent employees	2
Seasonal employees	2
Surface area dedicated to grazing (ha)	50
Surface area dedicated to agriculture (ha)	14
Heads of cattle	55
Bulls	2
Cows	35
Calves per year	19
Average weight at time of sale (kg)	208
Age in months at the time of sale	8

The livestock production from the 30 ranches included 1,483 heads of cattle, 120 goats, 54 sheep and 73 pigs in total. Every rancher raised cattle with the objective to sell male calves when they reached the ideal weight. The average weight at the time of sale was 208 kg, and the majority of ranchers described a decrease in value for calves above 230 kg. Ranchers reported the average price per kg was $44.37 ($2.47 USD), for a total average profit of $9,219.20 per calf ($512.18 USD). With respect to livestock feeding, 77.8% of ranchers used supplemental feed, which included forage from corn, sugar cane, alfalfa, and other grasses, and only 33.3% produced their own supplemental forage. The rest purchased feed from feed stores, the cattle ranching societies, or relatives. All respondents had watering tanks, or natural and semi-natural watering holes, some also purchased water and 22% had wells (Table 2.4). The estimated cattle density was 0.655 heads of cattle per hectare, including parcels used for cattle production and agriculture.

Table 2.4. Summary of water sources used by 26 ranchers through the counties of Ciudad Valles and Tamuín.

Water Sources	
Watering tank	55.6%
Watering tank and puchased water	22.2%
Watering tank and well water	22.2%

Of all cattle ranchers interviewed, 16 ranches were located within the study area within the 10 km surrounding the RBSAT, with two ranches in Tamuín and 14 ranches in Ciudad Valles. The ranches accounted for a total of 939 hectares (58.69 hectares on average), with 859 dedicated to cattle production (53.66 hectares on average; Table 2.5). The average number of permanent employees was two with an average of two seasonal employees. The average number of heads of cattle were 41. Of the ranchers interviewed, 60% had rotational grazing systems in place, with an average number of 11 divisions of 10 hectares that were grazed for an average of 24 days. All respondents had barbed wired fences along the perimeter, 50% had barbed wire fences for interior divisions, 38% used electric fences for the interior and 12% had a combination. Only 18.75% were concerned about depredation of their cattle by jaguars, puma and coyote (*Canis latrans*). The estimated cattle density was 0.703 heads of cattle per hectare.

Table 2.5. (a) General characteristics the 16 cattle ranchers within the study area, (b) rotational systems in use, and (c) the use of fences.

(a) **Summary of Interviews of Practicing Cattle Ranchers (Average)**	
Age	58
Number of years as the owner of the property	23
Extension average (ha)	59
Surface area dedicated to livestock production (ha)	54
Permanent employees	2
Seasonal employees	2
Surface area dedicated to grazing (ha)	47
Surface area dedicated to agriculture (ha)	5
Heads of cattle	41
Bulls	1
Cows	28
Calves per year	12
Average weight at time of sale (kg)	195
Age in months at the time of sale	6

(b) **Rotation System**	
Yes (%)	69
No (%)	31
Average number of parcels	11
Average size (ha)	10
Average number of days between rotations	24

(c) **Fences**	
Barbed Wire Perimeter Fence (%)	100
Interior Divisions	
Barbed Wire (%)	50
Electric (%)	38
Barbed Wire and Electric (%)	12

2.4.2. Jaguar Records

The two jaguars, JM01 and JM02, were predominately recorded in secondary vegetation, 69% and 63% respectively, with fewer records in infrastructure, agriculture and pasture (Figure 2.3 and Figure 2.4). The movements of both jaguars were both restricted, JM01 to the west of the RBSAT and JM02 to the east. Tropical deciduous forest only accounted 24% of the records from JM01 and 27% from JM02. The jaguar JM02, was recorded more frequently in agriculture, however the fragmentation, agricultural and livestock production east of the RBSAT is higher than the western side where JM01 was active. Only 23% of the records of both jaguars fell within the boundaries of the RBSAT.

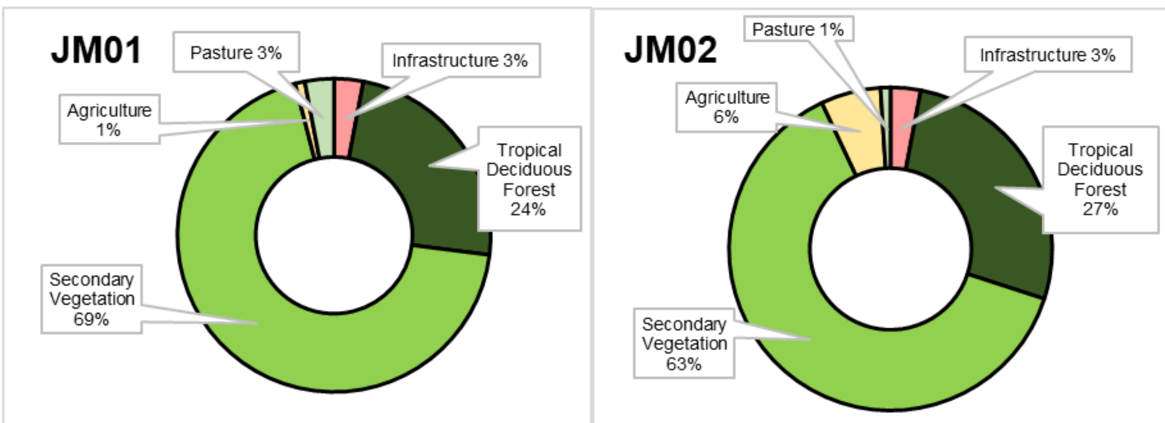

Figure 2.3. Jaguar records and their corresponding land use based on the 2016 classification of satellite imagery.

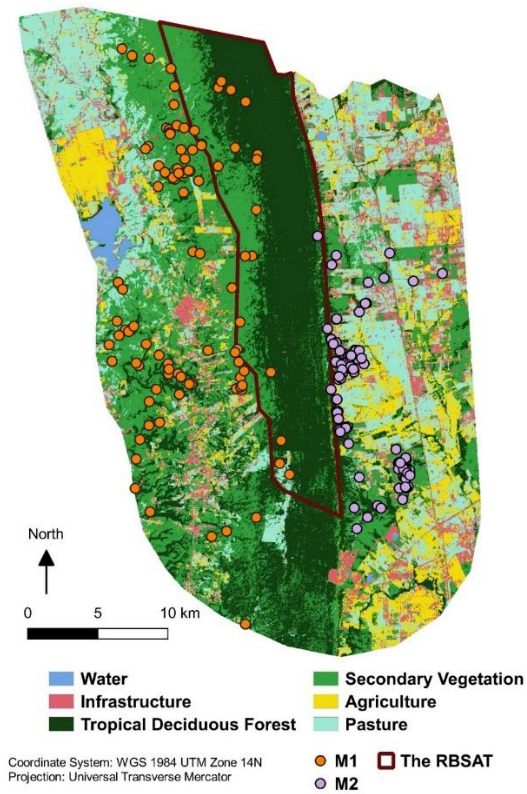

Figure 2.4. 200 randomly selected location readings from two jaguars (JM01 and JM02) with GPS and a land use classification based on satellite imagery from 2016.

The difference between the expected habitat use based on spatial availability differed from the habitat selected by both jaguars according to the Chi-square goodness of fit test (P< 0.001, χ^2= 121.70, df=4). The Bonferroni intervals indicated that the jaguars selected secondary vegetation, avoided infrastructure, agriculture, and pasture, and both used tropical deciduous forest in according to its availability (α=.05; Table 2.6).

Table 2.6. Jaguar locations in the RBSAT and the 10 km of the surrounding landscape in relation to five classes of land use, the expected number of locations in relation to the habitat availability, and the Bonferroni confidence intervals that test the significance of the difference between land use selection and its spatial availability by jaguars in the study area.

Land Use Class	Area (ha)	Expected Number of Records	Observed Records	Proportion Expected in Area (P_{io})	Proportion Observed in Area (P_i)	Bonferroni Intervals for P_i			Significance (α=.05)
Infrastructure	9330	17	6	0.087	0.030	-0.014	$\leq P_2 \leq$	0.074	Avoided
Tropical Deciduous Forest	28640	54	51	0.268	0.255	0.130	$\leq P_3 \leq$	0.350	Used according to its availability
Secondary Vegetation	34631	65	132	0.324	0.660	0.571	$\leq P_4 \leq$	0.809	Selected
Agriculture	12778	24	7	0.120	0.035	-0.016	$\leq P_5 \leq$	0.036	Avoided
Pasture	21428	40	4	0.201	0.020	-0.014	$\leq P_6 \leq$	0.074	Avoided

2.5. DISCUSSION

General trends among cattle ranchers that were interviewed within and near the study area were very similar. The cattle density for the all ranchers interviewed was 0.655 heads of cattle per hectare, and 0.703 heads per hectare within the study area. The average number of permanent employees at both at a greater scale and within the study area was two, indicating the majority of ranching operations are small scale. The high percentage of producers who used supplemental feed (77.8%) indicated that the majority are not producing or maintaining sufficient pasture, either natural pastures or non-native grasses. Although all ranchers were aware of the presence of jaguars, the four most common topics of concern were robbery, drought, the price per kilogram of calves, and the freedom to move cattle across county lines for sales. In addition, the low number of individuals with rotational systems in place, especially within the study area (69%) indicated a lack of knowledge, interest or financial means in the potential benefits. Rotational systems are a key component to improving production and increasing the number of cattle that can be produced within a limited area (Jacobo et al., 2006).

The 200 records from jaguars demonstrated a preference for secondary vegetation. Within the study area, secondary vegetation accounted for 32.1% of the surface area in 2016 (Table 1.7), and was used more than twice as often by both jaguars. The Chi-squared value and the Bonferroni intervals proved preferential selection of secondary vegetation, compared to the other land use classes. Secondary vegetation is highly variable partially due to its role in a variety of land use successions. It can be the result of abandoned pastures or agriculture, it can be due to thinning and altering tropical deciduous forest, or the result of changing infrastructure (Wandelli and Fearnside, 2015). Additionally, the majority of ranches are a combination of cleared pasture and secondary vegetation and shrubs, including some ranches with dense tree cover, suggesting a higher potential for interaction between jaguars and cattle.

There are legal restrictions to clearing secondary vegetation and forest on land designated for agricultural and livestock production (Secretaría de Medio Ambiente y Recursos Naturales, 1994), that ranchers are conscious of, and some view as a limitation to increasing cattle production. It is also perceived as a risk by ranchers that could increase the likelihood of depredation. The jaguars preferred use of secondary vegetation, demonstrates level of validity to this concerns, that there are jaguars moving through the secondary vegetation on and bordering ranches and agriculture fields.

There is a movement towards “holistic” ranching in Latin America, which is considered a return to more traditional methods (Alfaro et al., 2016). The characteristics include a higher emphasis on the use of native pastures, maintaining higher tree coverage, using less herbicides and discouraging the use of fire (Nahed-Toral et al., 2013). These methods are seen as a long-term approach to cattle ranching that produces a higher return, is more tolerant to seasonal variability, and promotes less drastic land use changes. Three ranchers that were interviewed had received holistic ranching trainings, and had modified their practices to eliminate the use of fire, move towards rotational grazing, and maintaining ranches with a diversity of vegetation coverage. These ranchers were in the minority and had briefly formed their own association with particular emphasis on their ranching practices in relation to the RBSAT. However, these efforts dissolved due to indifference.

The rate of jaguar depredation on domestic species varies from region to region. Rosas-Rosas et al. (2015) named three potential reasons for depredation. First, a decrease in wild prey resources may translate to a denser and more visible domestic prey resource. Second, the health of the offending animal can be an impetus for depredation because a sick animal is more likely to take risky prey. Third, management practices of ranchers can facilitate or impede depredation by changing the energetic price of taking livestock. The entirety of the RBSAT has been characterized as a zone of high risk of depredation by jaguars because of the mixed land use around its borders (Rosas-Rosas et al., 2015).

Only 23% of the records of both jaguars were located within the boundaries of the RBSAT. This indicates that jaguars are highly integrated within the working landscape, and are a factor of consideration regarding cattle ranching practices. There has been very little depredation reported in the last few years, with a suspected reduction. Villordo-Galván et al. (2010) mentioned that in the state of San Luis Potosí, between 2006 and 2008, there were six depredation events reported, and Hernández-SaintMartín et al. (2015) found no evidence of livestock in a scat analysis from samples collected from 2010 to 2012 within and outside the RBSAT. However, as the rate of change of land use increases, it will increase the risk of depredation of livestock.

Practices that prevent and minimize conflict include adequate fencing (Quigley et al., 2015), guard animals, nutritional supplements, limiting grazing to open areas, and the management of pregnant cows and young calves (Rosas-Rosas et al., 2015). Ranchers included labor and financial constraints to implementing more secure fencing and reproduction schedules. In addition, only 31% of ranches within the study area had individuals living on the property providing vigilance at night. Managing secondary vegetation to minimize the risk to cattle and maximize its value as jaguar habitat should be a priority, however, these techniques for the reduction of risk should be carried out on a regional level, not just on individual land parcels. The objective of conservation efforts in the region is to protect habitat and potential habitat in a matrix with connectivity (Olsoy et al., 2016).

Understanding the current state of ranching practices of producers near the RBSAT will help us plan more directed management changes and strategies. Coupled with the habitat preference demonstrated by the two jaguars in both Ciudad Valles and Tamuín, the importance of maintaining secondary vegetation is evident. As fragmentation rates increase in the Sierra Madre Oriental (Ortega-Huerta, 2007), small vegetation patches, and areas of continuous secondary vegetation may be key in ensuring the survival of the species. Dueñas-López et al. (2015) identified the RBSAT as a fundamental patch of suitable habitat connecting jaguar populations throughout northern and central Mexico. Because large tracts of tropical forest are difficult to protect, small patches of secondary vegetation may act as stepping stones that provide sufficient resources for jaguars. As jaguars and producers share the landscape, it is vital to collaborate with communities to ensure the success of both.

2.6. CONCLUSIONS AND SUGGESTIONS

Although jaguars are clearly present in the study area and outside, the most common concerns of the ranchers interviewed included robbery, drought, and the freedom to seek the highest price, the concern of depredation was not among these. Not all cattle ranchers within the study area are utilizing techniques that minimize the risk of conflicts with jaguar; the majority of ranchers required supplemental feed (81%), not one rancher had perimeter electric fences, and only 50% had full or partial electric fences in interior divisions. The majority of ranches did not have someone, or guard animals on the property at night (69%). The density of cattle per ha was similar within (0.655) and outside the study area (0.705). The majority of ranches had secondary and original vegetation in addition to pasture, and the habitat preference of the two jaguars in this study was secondary vegetation. Combined with practices not geared towards conflict prevention, the majority of ranchers have a higher risk of depredation.

This study provides evidence of the presence of jaguars outside of the borders of a natural protected area, with a strong preference for secondary vegetation. The risk of depredation of livestock is high, especially concerning the highly productive landscape matrix outside the RBSAT. This was the first study of its kind to summarize cattle ranching practices in comparison with habitat preferences of an endangered large carnivore.

Working directly with ranchers is a valuable strategy, and the initial steps towards this aim were taken by this study: First to establish relationships and channels of communication; Second, to learn about current management practices; and third to provide information about jaguars and other carnivores in the area and ways to minimize depredation of livestock. Concurrently, the other step will be to establish more baseline information on the jaguar population. The goal is to develop more long term contact, at all levels, with the ranching community as problem solvers, and as members of the community invested in the economic success of the region and the ecological success of sound conservation practices. Examples of current programs included supporting hunting, eco-tourism and the sustainable extraction of resources that support jaguar prey species (Rosas-Rosas and Valdez, 2010), the establishment of local law enforcement dedicated to protected areas (Wildlife Conservation Society, 2018), already in progress in the RBSAT (Comisión Nacional de Áreas Naturales Protegidas, 2014), and wildlife monitoring programs designed for use in rural communities (SMART Conservation Software, 2018), and monitoring programs that provide a monetary incentive for the maintenance of jaguar prey on cattle ranches (Northern Jaguar Project, 2017). The two greatest threats to jaguars are habitat loss and fragmentation, and illegal hunting of jaguars and their prey; both are issues that involve the actions of humans at all levels, community, state, federal and international. Therefore, it is imperative to take a multiple disciplinary approach to management that includes all levels of society with emphasis on all stakeholders.

The increase the impact of this study, increasing the number of interview participants within the 10 km surrounding the RBSAT, with particular emphasis on those parcels that share the border. Additionally, more directed questions regarding burning, clearing, and species specific pasture details would provide insight into land use change and how the landscape might change in the future, and its potential influence on jaguars in the region.

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GENERAL CONCLUSIONS

Land use change at the global level is a threat to all biodiversity, especially vulnerable species, which includes those that require large home ranges and a stable prey base. These characteristics, in combination with an inherently conflicted relationship with humans, are what make the jaguar susceptible to the negative impacts of land use change. Understanding the complicated relationship between protected areas and the conservation of large carnivores is fundamental to developing regional policy that protects the rights of communities to make a living and protects the fauna that share the landscape. This study addressed the historical and current land use within and outside the RBSAT, and analyzed jaguar habitat preference within this context.

This study found a continuous decrease in secondary vegetation where more than half of the records of jaguars were located, and an increase in anthropogenic activities that can lead to more jaguar-related conflicts. The majority of ranches were a combination of cleared pasture and secondary vegetation and shrubs, including some ranches with full tree cover, indicating a higher potential for interaction between jaguars and cattle. Because large tracts of tropical forest are difficult to protect, small patches of secondary vegetation may act as stepping stones and refuges that provide sufficient resources for jaguars. As jaguars and producers share the landscape, it is vital to collaborate with communities to ensure the success of both.

This is the first application of a land use change analysis near a natural protected area applied within the context of jaguar conservation efforts. To expand the applicability of the results of this study and to aid in understanding the direction and force of land use changes along the border of the RBSAT, a larger study area, including the entire counties of Ciudad Valles and Tamuín would be ideal to provide a larger, landscape scale analysis of the region and the SMO. In addition, a full census of the land parcels that share a boundary with the reserve would serve to generate more specific information on land use activities with a high potential to influence the RBSAT and its intentions to preserve biodiversity.

Shrinking habitat and human conflicts are the main threats to jaguar populations throughout its range. In the RBSAT, these threats are omnipresent. Regional level management plans should include the development of policies that incentivize practices that prevent jaguar-cattle conflicts and the maintenance of secondary vegetation.

ANNEX

Annex A. Supplemental satellite information

Landsat Thematic Mapper (TM)

Data Collection	From 1982 to 2012
Pixel Size	TM Multispectral bands: 30 meters TM Panchromatic band: 15 meters TM Thermal Infrared bands: 100 meters resampled to 30 meters
Output Format	GeoTIFF
Map Projection	World Geodetic System (WGS) 84 datum Universal Transverse Mercator (UTM) map projection (Polar Stereographic for Antarctica)

Adapted from the United States Geological Survey long term archives, Landsat Thematic Mapper (TM) (accessed 30 May 2018). https://lta.cr.usgs.gov/TM

Landsat 8 Operational Land Imager (OLI)

Data Collection	From February 2013 - Present
Pixel Size	OLI Multispectral bands: 30 meters OLI panchromatic band: 15 meters TIRS Thermal bands: 100 meters (resampled to 30 meters to match multispectral bands)
Output Format	GeoTIFF
Map Projection	World Geodetic System (WGS) 84 datum Universal Transverse Mercator (UTM) map projection (Polar Stereographic for Antarctica)

Adapted from the United States Geological Survey long term archives, Landsat 8 Operational Land Imager (OLI) (accessed 30 May 2018). https://lta.cr.usgs.gov/L8

Landsat 4-5 Thematic Mapper (TM) Band Designations

Bands	Wavelength (micrometers)	Resolution (meters)
Band 1 – Blue	0.45 – 0.52	30
Band 2 – Green	0.52 – 0.60	30
Band 3 – Red	0.63 – 0.69	30
Band 4 – Near Infrared (NIR)	0.76 – 0.90	30
Band 5 – Shortwave Infrared (SWIR) 1	1.55 – 1.75	30
Band 6 – Thermal	10.40 – 12.50	120* (30)
Band 7 – Shortwave Infrared (SWIR) 2	2.08 – 2.35	30

https://landsat.usgs.gov/what-are-band-designations-landsat-satellites

Landsat 8 Operational Land Imager (OLI) And Thermal Infrared Sensor (TIRS) Band Designations

Bands	Wavelength (micrometers)	Resolution (meters)
Band 1 – Ultra Blue (coastal/aerosol)	0.435 – 0.451	30
Band 2 – Blue	0.452 – 0.512	30
Band 3 – Green	0.533 – 0.590	30
Band 4 – Red	0.636 – 0.673	30
Band 5 – Near Infrared (NIR)	0.851 – 0.879	30
Band 6 – Shortwave Infrared (SWIR) 1	1.566 – 1.651	30
Band 7 – Shortwave Infrared (SWIR) 2	2.107 – 2.294	30
Band 8 – Panchromatic	0.503 – 0.676	15
Band 9 – Cirrus	1.363 – 1.384	30
Band 10 – Thermal Infrared (TIRS) 1	10.60 – 11.19	100 * (30)
Band 11 – Thermal Infrared (TIRS) 2	11.50 – 12.51	100 * (30)

https://landsat.usgs.gov/what-are-band-designations-landsat-satellites

Annex B. Accuracy matrices of the classifications from 1989 and 2016

Error matrix of the accuracy of the classification of the 1989 satellite image measured in area (hectares).

		Classification						
		Water	Infrastructure	Tropical Deciduous Forest	Secondary Vegetation	Agriculture	Pasture	
Training Areas	Water	144.36	0	0	0	0	0	
	Infrastructure	0	0.18	5.58	0.09	0	1.08	
	Tropical Deciduous Forest	0	0	608.94	8.01	0.09	0.99	
	Secondary Vegetation	0	1.71	42.66	77.76	0	11.43	
	Agriculture	0	0.09	2.88	0.27	2.16	0.27	
	Pasture	0	0.63	4.41	1.89	2.07	37.8	
	Total	144.36	2.61	664.47	88.02	4.32	51.57	955.35

Error matrix of the accuracy of the classification of the 2016 satellite image measured in area (hectares).

		Classification						
		Water	Infrastructur	Tropical Deciduous Forest	Secondary Vegetation	Agriculture	Pasture	
Training Areas	Water	742.95	0	0	0	0	0	
	Infrastructure	0	0.27	0.09	0.36	0.36	1.08	
	Tropical Deciduous Forest	0	0	201.96	1.26	0	0	
	Secondary Vegetation	0.27	0	67.68	58.68	0	0	
	Agriculture	0.09	0.45	0.09	0.54	19.08	0.9	
	Pasture	0	0.81	3.78	21.15	0	20.52	
	Total	743.31	1.53	273.6	81.99	19.44	22.5	1142.37

Annex C. Landowner survey

COLEGIO DE POSTGRADUADOS
INSTITUCIÓN DE ENSEÑANZA E INVESTIGACIÓN EN CIENCIAS AGRÍCOLAS
CAMPUS SAN LUIS POTOSÍ

Nombre del informante: ______________________________

Comunidad: ______________________________

Municipio: ______________________________

Coordenadas de la entrevista: ______________________________

Fecha de encuesta: día ________ **mes** __________________ **año 2017**

1. Datos Generales

1.1 ¿Nombre?
____

1.2 ¿Edad?
____

1.3 ¿Cuántos años tiene de ser ganadero?
____

2. Datos del Predio

2.1 ¿Nombre del predio?
____

2.2 ¿Desde cuándo (años) ha tenido este predio?
____

2.3 ¿Cuántos años ha tenido su familia este predio?
____

2.4 ¿Cuántas hectáreas?
_______ Total

Tenencia	Ganadería
1. Privada	
2. Ejidal	
3. Privada rentada	
4. Ejidal rentada	

2.5 ¿Renta algunos terrenos o parcelas?
_______ **(1=Sí; 0=No)**

2.5.1 ¿Cuáles?
____

1, NÚMERO DE CUESTIONARIO └──┘

2.5.2 ¿A quién?
____

2.5.3 ¿Costo de la renta/hectárea?
_______ $

2.6 ¿Qué tan cerca está del área natural protegida?
_______ kilómetros

2.7 ¿Cuántos empleados permanentes?
____

2.8 ¿Cuántos empleados temporales?
____

2.9 ¿Cuánta superficie dedica al agostadero?
_______ ha

2.10 ¿Cuánta superficie dedica a la agricultura?
_______ha

3. Ganado

3.1 ¿Cuántos animales ha tenido en el último año?

Tipo de ganado	Cantidad
1.Bovino	
2.Caprino	
3.Ovino	
4.Porcino	
5.Equino	
6. Aves de corral (gallinas, guajolotes)	
7. Otro(especifique)	

3.2 ¿Cuántos de ganado bovino?

Etapa	Cantidad de Novillos/as
1. Vacas (Vientres)	
2. Toros	
3. Becerros/año	
CANTIDAD TOTAL	

3.3 ¿Cuál es la finalidad de su actividad ganadera?

Ganado	Uso 1. Alimento (Autoconsumo) 2. Venta 3. Trabajo en campo 4. Otro (especifique)
1.Bovino	
2.Caprino	
3.Ovino	
4.Porcino	
5.Equino	
6. Aves de corral	
7. Otro (especifique)	

3.4 ¿Qué es el objetivo de la actividad ganadera?

☐ 1. Crías
☐ 2. Engordar
☐ 3. Procesar
☐ 4. Todo

3.5 De lo que vende, ¿a quién se lo vende principalmente?

Ganado	¿A quién lo vende? 1. Al gobierno federal 2. Al gobierno estatal 3. Al gobierno municipal 4. A intermediarios 5. Se vende en la misma comunidad 6. Se vende en otra comunidad/ciudad 7. Otro	A Cuál Peso	Después cuantos meses
1.Bovino			
2.Caprino			
3.Ovino			
4.Porcino			
5.Equino			
6. Aves de corral			
7. Otro (especifique)			

3.6 ¿Hay una época específica para la reproducción de bovino?

_______ **(Sí o No)**

3.7 ¿Qué fuentes de agua tiene para su ganado?

Fuentes	Sí
1. Presa	
2. Agua Potable	
3. Presa y Agua Potable	
6.Otros (especifique)	

3.8 ¿Qué come su ganado?

Tipo de ganado	**Dónde come/pastorea el ganado** 1. Pastoreo libre 2. Produce el alimento 3. Compro el alimento y suplemento 4. Libre y produce 5. Libre y compra 6. Libre, produce, y compra 7. En las tierras de uso común
1. Bovino	
2. Caprino	
3. Ovino	
4. Porcino	
5. Equino	
6. Aves de corral	
7. Otro (especifique)	

3.9 ¿Da alimentación suplementaria (alimento comercial)?
_______ **(Sí o No)**

3.9.1 ¿Cuántos kilos da por día/individual?
_______ kg

3.9.2 ¿Lo da sólo en épocas?
____

3.9.2.1 ¿En qué épocas?
____

3.10 ¿En caso de comprar el alimento, ¿Dónde lo compra?
☐ 1. Al gobierno federal
☐ 2. Al gobierno estatal
☐ 3. Al gobierno municipal
☐ 4. A intermediarios
☐ 5. La misma comunidad
☐ 6. Otra comunidad/ciudad _______________________________
☐ 7. Otro___________________________

3.10.1 ¿Hace ensilados?
_______ **(Sí o No)**

3.10.2 ¿Tiene silos permanentes?
_______ **(Sí o No)**

3.10.3 ¿Qué ensila?
____

3.10.4 ¿En qué época lo da?
____

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4, NÚMERO DE CUESTIONARIO └┘

3.11 ¿Da sales?
_______ **(Sí o No)**

3.11.1
☐ 1. Mineral
☐ 2. Común
☐ 3. Los dos

3.11.2 ¿Por qué no da sal mineral?
____

3.12 ¿Tiene praderas?
_______ **(Sí o No)**

3.12.1 ¿Superficie?
____

3.12.2 ¿Qué tipo de pasto?
____

3.12.3 ¿Cuál es la altura?
_______ m

3.13 ¿Tiene agostadero/Potreros?
_______ **(Sí o No)**

3.13.1 ¿Superficie?
_______ ha

3.13.2 ¿Cuál fue la altura?
_______ m

3.14 ¿Las praderas/Los agostaderos tienen cercos?
_______ **(Sí o No)**

3.14.1 ¿De qué tipo?
____

3.14.2 ¿Cuántos hilos y qué tan separados están los postes?
_______ hilos
_______ separación

3.14.3 ¿En qué condición están los cercos (ver el deterioro o el arreglo para que estén funcionales)?
☐ 1. Bien
☐ 2. Más o Menos
☐ 3. Falta

3.15 ¿Dónde se duerme el ganado?
☐1. Libres en la parcela

☐2. Encerado
☐3. Otro _____

3.15.1 ¿Tiene vigilancia?
_______ **(Sí o No)**

3.15.2 ¿Tiene sitios protegidos o acondicionados para que duerman?
_______ **(Sí o No)**

3.15.3 Ubicación del corral (encierro)
☐ 1. En la casa
☐ 2. Cerca de la casa
☐ 3. En las tierras de uso común
☐ 4. En la casa o tierras de algún familiar (prestado)
☐ 5. En mi potrero
☐ 6. Otro (especifique)

3.15.4 Tipo de corral (encierro)
☐ 1. Para pastorear
☐ 2. Para hembras preñadas
☐ 3. Para todo todos los animales
☐ 4. Para becerros
☐ 5. Para encerrar a los animales en la noche

3.16 ¿Tiene un sistema de rotación?
_______ **(Sí o No)**

3.16.1 Numero de parcelas
____

3.16.2 Días por rotación
____

4. Cultivos

4.1 ¿Qué siembra/cultiva en sus tierras? **(X=Sí)**

Cultivos	Riego	Humedad	Temporal
1.No siembra			
2.Maíz			
3.Caña de azúcar			
4.Frijol			
5.Hortalizas			
6. Frutales			
7. Otros (especifique)			

4.2 ¿Qué es el destino de la producción que obtiene?

Cultivos	Destino 1. Autoconsumo 2. Lo vendemos 3.Parte se vende y parte para el autoconsumo 4. Alimento para Ganado 5.Se queda en la parcela o terreno 6.Otro (especifique)____
1. Maíz	
2. Caña de azúcar	
3. Frijol	
4. Hortalizas	
5. Frutales	
6. Otros (especifique)	

4.3 De lo que vende, ¿Dónde lo vende principalmente?

Cultivos	¿Dónde lo vende? 1. Al gobierno federal 2. Al gobierno estatal 3. Al gobierno municipal 4. A intermediarios 5. Se vendió en la misma comunidad 6. Se vendió en otra comunidad/ciudad _________________________________
1. Maíz	
2. Caña de azúcar	
3. Frijol	
4. Hortalizas	
5. Frutales	
6. Otros (especifique)	

4.4 ¿Qué fuentes de agua tiene para la actividad agrícola?

Fuentes	X=Sí
1.Temporal	
2.Permanente	
3. Aguajes	
4. Manantial	
5. Pozo	
6.Otros (especifique)	

4.5 ¿Usa fertilizantes usa para los cultivos?
____ **(Sí o No)**

4.5.1 ¿Cuales?
____

4.6 ¿Quema las tierras para prepararlas?
_______ **(Sí o No)**

4.6.1 ¿Con qué frecuencia?
_______ Meses

4.6.2 ¿Qué superficie recibe este tratamiento?
_______ Ha

4.6.3 ¿El tratamiento es específico para algún cultivo?
_______ **(Sí o No)**

4.7 ¿Ha desmontado?
_______ **(Sí o No)**

4.7.1 ¿Cuántas hectáreas?
____

5. Pérdidas

5.1 ¿Muertes sufre por año?
____

5.2 ¿Qué tipo ganado bovino se le muere más?
☐ 1. Vacas (Vientres)
☐ 2. Toros
☐ 3. Becerros
☐ 4. Vacas y Becerros

5.3 ¿De qué?

Tipo de ganado	Causas de pérdida de ganado 1.Sequía 2.Robo 3.Muerte en parto 4.Accidentes 5.Extravío 6.Depredación **(continúe)** 7.Inundación 8.Enfermedades 9.Envenenamiento 10.Otra (especifique)
1.Bovino	
2.Caprino	
3.Ovino	
4.Porcino	
5.Equino	
6.Aves de corral	
7.Otro (especifique)	

5.4 ¿Cómo supo cuál fue la causa? (Huellas, cámaras, excremento, visto)
____

5.5 ¿Sitios de mortalidad?
____

5.6 ¿Cuánto vale cada ganado?

Tipo de ganado	$ Pesos
1.Bovino	
2.Caprino	
3.Ovino	
4.Porcino	
5.Equino	
6.Aves de corral	
7.Otro	

5.7 ¿Cómo calcula el monto?
____

5.8 ¿Cambió sus métodos de manejo después?
_______ **(Sí o No)**

5.9 ¿Le preocupó que la fauna silvestre le mate su ganado? (o lo siguió depredando)
_______ **(Sí o No)**

5.10 ¿Qué prácticas utiliza para minimizar las pérdidas? (para evitar que se le mueran más animales)

Prácticas	X=Sí
Corrales	
Animales del protector	
Ninguna	

5.10.1 Con corrales, ¿qué diseño usa y para cuales animales?

Tipo de ganado	Tipo de corral (encierro) 1. Para todos los animales 2. Para hembras preñadas 3. Para encerrar a los animales en la noche 4. Para pastorear	Ubicación del corral (encierro) 1. En la casa 2. Cerca de la casa 3. En las tierras de uso común 4. En la casa o tierras de algún familiar (prestado) 5. En mi potrero 6. Otro (especifique)
1.Bovino		
2.Caprino		
3.Ovino		
4.Porcino		
5.Equino		
6.Aves de corral		
7.Otro (especifique)		

5.11 ¿Ha visto depredadores en o cerca de sus tierras? ¿Sí no los ha visto, los ha escuchado?

Depredadores	X=Sí
1.Tigrillo	
2.Ocelote	
3.Jaguarundi/onza	
4.Puma	
5.Jaguar **(continúe)**	
6.Coyotes	
7.Serpientes	
8.Aves	
9.Zorra	
10. Otro (especifique)	

6. Apoyo

6.1 ¿Ha tenido apoyos del gobierno u otras instituciones en su actividad agrícola o ganadera?
_______ (1=Sí; 0=No)

6.1.1 ¿Cuáles son las instituciones que lo ha apoyado?

☐1. SAGARPA Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca, y Alimentación
☐2. SEDARH Secretario de Desarrollo Agropecuario y Recursos Hidráulicos (SLP)
☐3. CNOG Confederación Nacional de Organizaciones Ganaderas
☐4. CONANP Comisión Nacional de Áreas Naturales Protegidas
☐5. AGLCV Asociación Ganadera Local Cd Valles
☐6. AGLT Asociación Ganadera Local de Tamuín
☐ 7. Otro
____
____

6.1.2 ¿Qué tipo de apoyos ha recibido?

☐1. Fondo de Aseguramiento (CNOG)
☐2. Sistema de Facturación Electrónica (CNOG)
☐3. ONCESEGA El Organismo Nacional de Certificación de Servicios Ganaderos (CNOG)
☐4. SINGA Sistema Nacional de Identificación Individual de Ganado (CNOG)
☐ 5. Otro
____
____

6.2 ¿Ha recibido algún tipo de asesoría o capacitación para la conservación de recursos naturales o mejoramiento del hábitat?
_______ **(Sí o No)**

6.2.1 ¿Quién impartió esa asesoría y cuándo?

____ organización
_______ año

10, NÚMERO DE CUESTIONARIO └─┘

7. El Futuro

7.1 ¿Tiene preocupaciones del futuro del rancho?

_______ **(Sí o No)**

7.1.1 ¿Qué le preocupa?

____
____
____

7.2 ¿Le interesa programas gubernamentales o de organizaciones no gubernamentales que le apoyan en mejorar sus técnicas/prácticas de manejo de ganado y/o cultivos?

_______ **(Sí o No)**

7.2.1 ¿Para qué aspectos de manejo?

____

¿Tiene preguntas para mí?

Annex D. Cattle ranching association survey

COLEGIO DE POSTGRADUADOS
INSTITUCIÓN DE ENSEÑANZA E INVESTIGACIÓN EN CIENCIAS AGRÍCOLAS
CAMPUS SAN LUIS POTOSÍ

Colegio de Postgraduados

Nombre del informante: ____

Comunidad: ____

Fecha de encuesta: día ________ **mes** __________________ **año 2017**

1. Datos Generales

1.1 ¿Nombre?

____

1.2 ¿Edad?

____

1.3 ¿Cuántos años tiene de ser ganadero?

____

1.4 ¿Nombre de la organización?

____

1.5 ¿Cuántos años tiene en la organización?

____

1.6 ¿Cuál es su cargo?

____

1.7 ¿Cuántos años tiene en esta posición?

____

1.8 ¿Cuál es el objetivo de esta asociación?

____
____
____

1.9 ¿Cuáles son los beneficios a ganaderos?

____
____
____

1.10 ¿Tiene relaciones con otras asociaciones?

_______ **(Sí o No)**

1, NÚMERO DE CUESTIONARIO

1.10.1 ¿Cuales?

____
____

1.10.2 ¿Qué es el objetivo de las relaciones?

____
____
____

2. Miembros

2.1 ¿Cuántos individuos forman parte de la asociación?

____

2.2 ¿Cuánto es el costo para ser miembro?

____

2.3 ¿Hay un mínimo de cabezas?

_______ **(Sí o No)**

2.3.1 ¿Cuántas?

____

2.3.2 ¿Necesitan ser residentes del municipio?

_______ **(Sí o No)**

2.3.2.1 ¿Residentes o sus ranchos?

____

2.3.3 ¿Necesitan tener ganado registrado?

____

2.4 ¿Qué es el rango del tamaño de productores?

____

2.4.1 Cabezas

____

2.4.2 Ganancia

____

2.5 ¿Producen reportes anuales del estado de los negocios?

_______ **(Sí o No)**

2.5.1 ¿De los ingresos?

_______ **(Sí o No)**

2.6 ¿Hace reportes anuales de pérdidas y sus causas?

_______ **(Sí o No)**

2.7 ¿Tiene un registro de eventos de depredación?

_______ **(Sí o No)**

2.8 ¿Se da seguro a los ganaderos?

_______ **(Sí o No)**

2.8.1 ¿Qué cubre?

____
____

2.8.2 ¿Está incluido en el costo de miembros?
_______ **(Sí o No)**

2.8.3 ¿Cómo determina el precio de compensación financiera?

____
____

2.9 ¿Cuáles son las preocupaciones más grandes de sus miembros?

____
____
____

2.10 ¿Qué problemas es la asociación trabajando para resolver ahora?

____
____
____

3. Captaciones

3.1 ¿Da talleres?

_______ **(Sí o No)**

3.2 ¿Quién los da?

____

3.3 ¿Cuántos los da por ano?

____

3.4 ¿De qué temas?

____
____
____

3.5 ¿Cuántos miembros participan?

____

3.6 ¿Hay un costo?

_______ **(Sí o No)**

3.7 ¿Hay una demanda de más talleres?

_______ **(Sí o No)**

3.8 ¿Qué podemos hacer las instituciones educativas para construir una mejor relación con los ganaderos?

____
____
____

Annex E. Photographs of ranch visits

View of the RBSAT from Laguna del Mante, Ciudad Valles, January 2016.

Communal farmland in the RBSAT, Laguna del Mante, Ciudad Valles, January 2016.

Palm Forest, county of Ciudad Valles, February 2016.

View of the south eastern border of the RBSAT from a private ranch, county of Tamuín, January 2016.

Example of a system of divisions for a 50-day rest cycle, Rancho Roble, Luis Enrique Martínez Hernández, Ejido Gustavo Gramendia, Ciudad Valles. November 18, 2017.

Pasture for the day, Rancho Roble, Luis Enrique Martínez Hernández, Ejido Gustavo Gramendia, Ciudad Valles. November 18, 2017.

Example of diversification, egg production. Rancho Roble, Luis Enrique Martínez Hernández, Ejido Gustavo Gramendia, Ciudad Valles. November 18, 2017.

Rancho Viejo, Martin Cervante Ramos, Ejido El Coco, Tamuín. February 20, 2018.

a. 

b. 

Rancho Viejo, Martin Cervante Ramos, Ejido El Coco, Tamuín. February 20, 2018.

a. 

b. 

Site of depredation (most likely coyote). José Luis Mentado, Ejido Milenio 2000, Tamuín. February 13, 2018.

Site of depredation (most likely coyote). José Luis Mentado, Ejido Milenio 2000, Tamuín. February 13, 2018.

Asociación Ganadera, where sales are processed, Tamuín. February 4, 2018.

“Presa” or watering hole for 60 heads of cattle, Daniel Echavarría, Ejido La Hencada, January 12, 2018.

CEMEX gravel extraction site on the southern border of the RBSAT, December 7, 2017.