# REPORT ON THE STATUS OF GRASSLANDS IN THE CHIHUAHUAN DESERT

*A management model*

*March 2019*

AMERICAN BIRD CONSERVANCY

pro natura noreste

# DEDICATION

*To Jonathan Franzen, with our deepest and most sincere gratitude for his valuable and selfless support to our mission. Without his generosity, we certainly would not have been able to achieve the progress we present today.*

*We reiterate our appreciation for his love of nature, his human quality, and his work toward building a better future.*

***Mauricio De la Maza-Benignos***
*General Director*

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# FOREWORD

We are losing the fight for the conservation of grasslands. Considering the current loss rate (~6% yearly), only due to agricultural expansion it is estimated that before 2025, natural grasslands will have disappeared in the state of Chihuahua. A paradigm change in our actions is required for the conservation of natural grasslands in Mexico. We consider water as a key aspect in any new strategies and efforts to conserve grasslands. In addition, landscapes should be the central axis to facilitate the rational management of such resources. The proposed management activities should take into account economic activities (livestock rearing, agriculture, tourism, among others), cultural aspects (traditions, values, and lifestyles), biodiversity factors (ecological corridors and environmental services), and climate change to achieve positive and sustainable results that foster balance between economic development and the conservation of natural resources in the regions.

**PRONATURA NORESTE A. C.**

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# EXECUTIVE SUMMARY

Grasslands are being severely affected by different interconnected factors, which result in the fragmentation of habitats and loss of biodiversity and environmental services. Land use change is considered a major cause of the decline and degradation of grasslands. Particularly, a shift from livestock rearing to crop cultivation has exacerbated grassland degradation through the overexploitation of surface and groundwater, inappropriate farming practices, climate change, increasing human populations, and the implementation of ineffective policies to regulate the above factors.

The present report arises from the need to reconsider the strategies that have been implemented to date in the conservation, restoration, and exploitation of grassland resources in the Chihuahuan Desert. The document analyses the general status of the ecosystem, along with the different anthropogenic activities that affect the distribution and composition of natural grassland landscapes. Lastly, it recommends a series of actions that could be undertaken to develop appropriate policies to facilitate the protection of grasslands, while sustainabaly leveraging their biodiversity, preserving such a natural heritage for future generations.

# INTRODUCTION

## 2.1 WHAT IS A GRASSLAND?

Grasslands are ecological communities formed by a herbaceous stratum of perennial grasses with a dominance greater than 70% (Granados-Sanchez et al., 2011).

There are two widely known types of grasslands including natural grasslands and human-induced grasslands. Natural grasslands result from climate and soil conditions, while human-induced grasslands result from removal of the original vegetation through anthropogenic activities such as in neglected crop fields (CONABIO, 2014).

Natural grasslands can be subdivided into different categories including the following:

### Grama grasslands

These are found on medium depth valleys, hillsides, and plateaus. Some of the major grass species found in grama grasslands include blue grama (*Bouteloua gracilis*), sideoats grama (*Bouteloua curtipendula*), black grama (*Bouteloua eriopoda*), and needlegrass (*Aristida spp.*) (Granados-Sanchez et al., 2011).

### Halophytic and gypsophilic grasslands

These grasslands are found in isolated interior drainage basins that contain high concentrations of salt and gypsum (Granados-Sanchez et al., 2011). Halophytic and gypsophylic grasslands are characterized by species such as *Bouteloua ramosa*, *Distichlis spicata*, *Pleuraphis mutica*, *Reederochloa eludens*, and *Sporobolus airoides* (Herrera Arrieta and Cortes Ortiz, 2009).

Natural grasslands are found in semi-arid areas, where the average annual temperatures fluctuate between 53 and 68°F, with average annual precipitations between 11.81 and 23.62 inches (CONABIO, 2014). They may be found in plains and mountainous areas, and are located at altitude of approximately 5,298.56 feet above sea level (fasl), with a gradient of distribution ranging from approximately 3280.84 to 9186.35 fasl (INEGI, 2004).

The grasslands referred to in the present report are found in the central plains in North America. They extend from South central Canada to central Mexico (Desmond 2004, cited in CONABIO, 2014).

In Mexico, these grasslands are located in the Chihuahuan Desert ecoregion. The Chihuahuan Desert is the largest desert in the American continent and is considered one of the arid regions with the greatest levels of biodiversity in the world. The Chihuahuan Desert is bordered by the Sierra Madre Oriental, the Trans-Mexican Volcanic Belt, the Sierra Madre Occidental (in Mexico), and the Rocky Mountains (in the United States). It covers an approximate area of 315,035 mi2, from New Mexico and Texas in the United States to Chihuahua, Coahuila, Durango, Guanajuato, Hidalgo, Nuevo Leon, Queretaro, San Luis Potosi, Tamaulipas and Zacatecas in Mexico (Morafka, 1977; Sutton, 2000; Hoyt, 2002, cited in Granados-Sanchez et al., 2011).

## 2.2 CURRENT STATUS OF GRASSLANDS

In the Americas, natural grasslands have undergone substantial transformations, to the point where only 1% of the tall grasslands and less than 30% of short and medium-sized grasslands remain (Gauthier, et al., 2003 cited in PACP-Ch,2011).

Currently, according to analyses carried out by the Pronatura Noreste team, using the National Institute of Statistics and Geography (INEGI) database series V, grasslands cover 12% of the Chihuahuan Desert within the Mexican territory (Figure 1). 63% of the grassland cover is located in the state of Chihuahua (Figure 2), where alarming losses of the ecosystem have been reported in recent years mainly due to human activity. In 1978, grasslands covered 24% of the area in the state of Chihuahua (Cotecoca, 1978, cited in PACP-Ch, 2011), while today their cover in the state of Chihuahua is only 13%.

It has been reported that in the Grasslands Priority Conservation Area (GPCA), which correspond to the Central Valleys (Figure 6), annual losses are reported to be 6% annual(only due to agricultural expansion), suggesting that grasslands in the region could completely disappear by 2025 (Pool et al., 2013). Such an eventuality would adversely affect the species that use these habitats, some of which are already endangered.

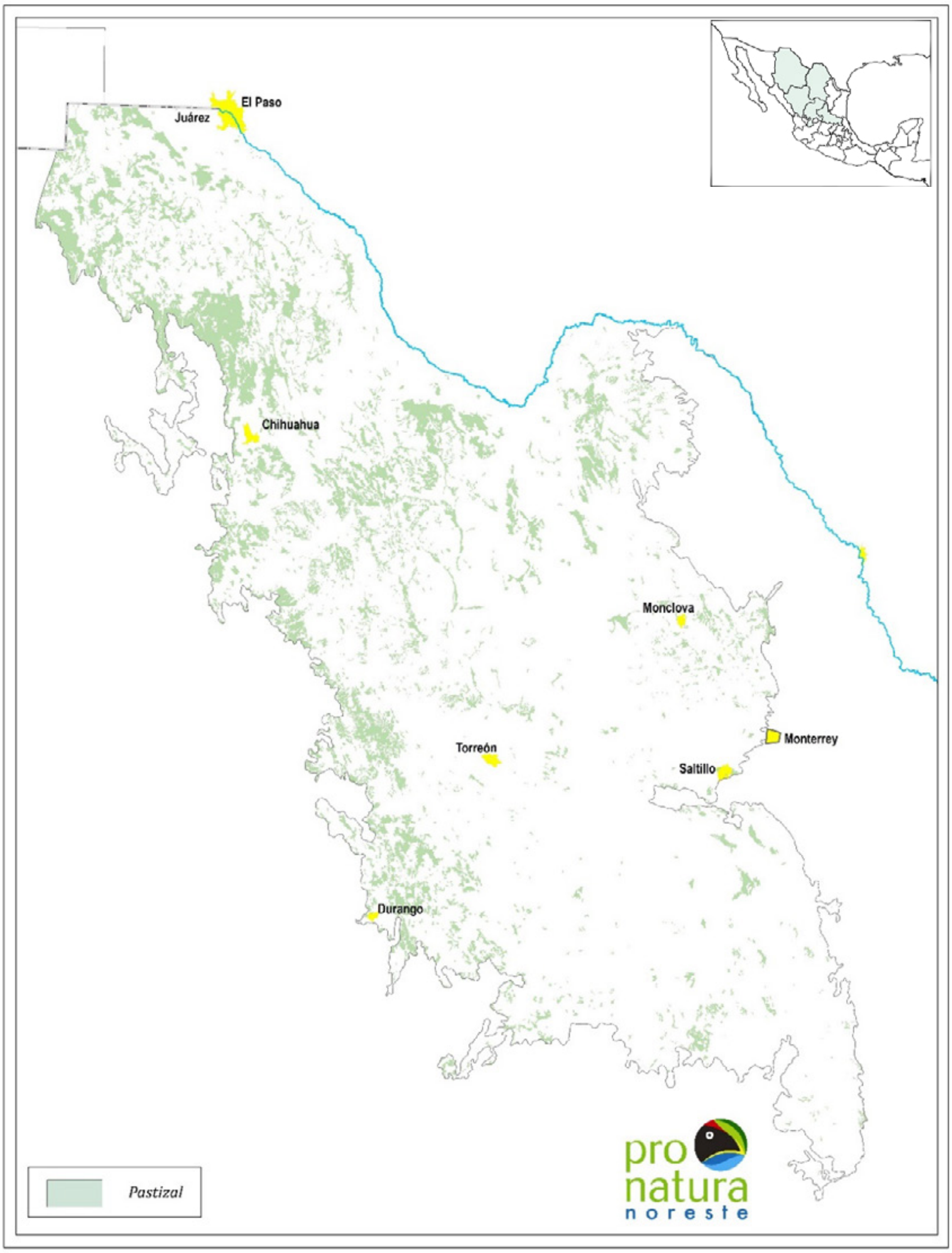


**Figure 1.** Mexican section of the Chihuahuan Desert and the distribution of grasslands.

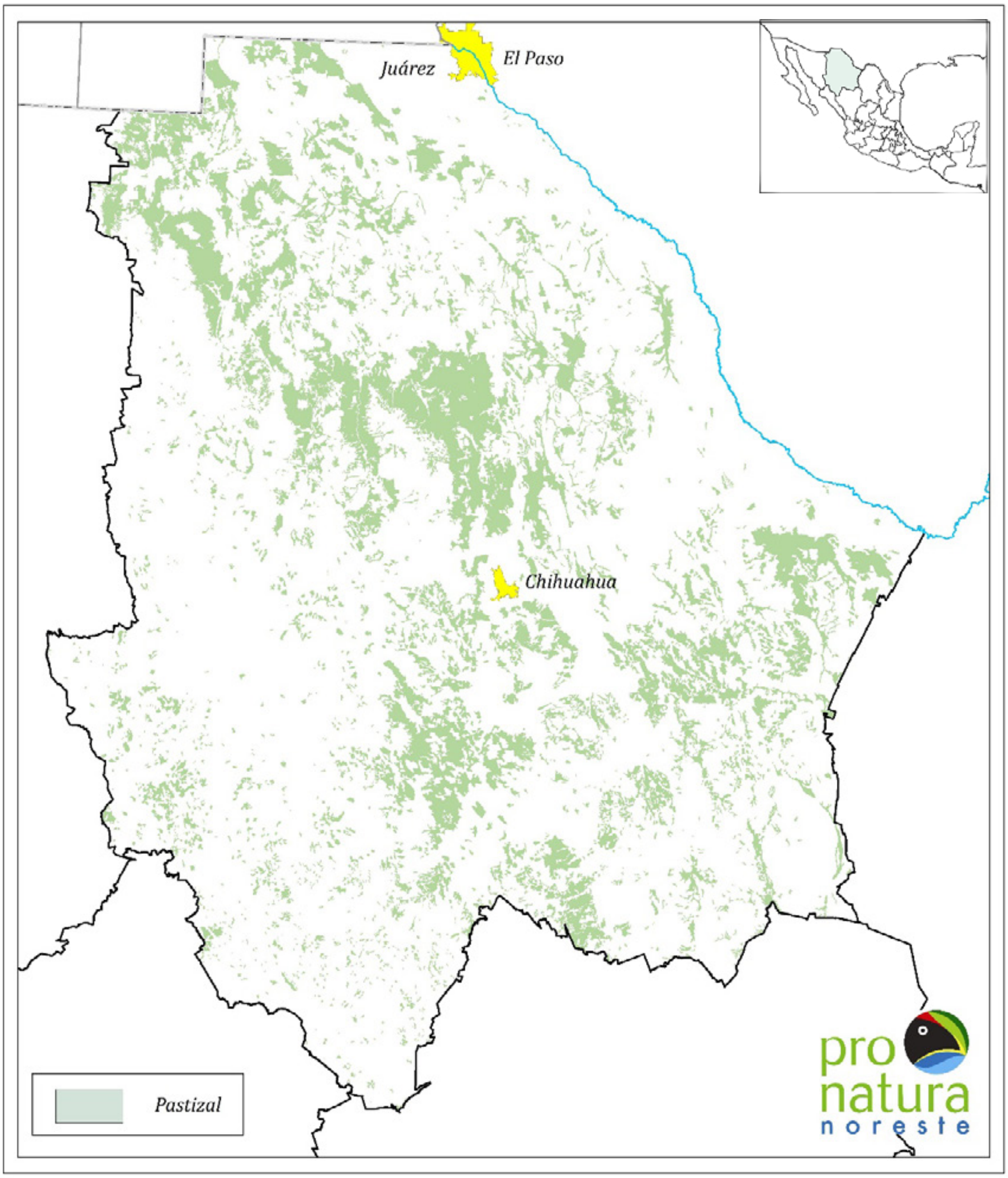


**Figure 2.** Grasslands in the state of Chihuahua.

## 2.3 ENVIRONMENTAL SERVICES

The following are some of the environmental services provided by grasslands, which maintain the proper functioning of the ecosystem and the quality of life of its inhabitants:

- They capture and sequester atmospheric carbon by transforming it into biomass.

- Pastures constitute one of the most productive pastoral resources that sustain livestock, which in turn provide food for humans.

- Habitats that provide feeding, reproduction, or resting grounds for diverse species.

- They facilitate the infiltration of water that replenishes aquifers.

- They minimize the effects of climate change by preventing land degradation.

- They facilitate the genetic flow of biodiversity due to their extension and connectivity with other types of vegetation.

The loss of grasslands can be detected by quantifying reductions in associated landscape features and ecological services. For livestock keepers, losing grasslands translates into losing competitiveness. Other consumers that exploit resources such as native flora or fauna experience a decline in populations or amounts of their resources of interest. Researchers who have monitored natural resources in the Chihuahuan Desert have reported biodiversity losses, declines in water infiltration, and a loss of soil (Banda, 2015).

## 2.4 PRIORITY SPECIES

The priority species for conservation can be selected based on their abundance, status of endemism, their dependence on given habitat for their life cycle (Figure 3) and their ecological importance in the ecosystem (Sanchez Herrera, 2012). In addition, efforts to conserve such species extend beyond the Mexican territory, since different institutions are involved in the conservation of migratory wildlife in Canada and the United States.

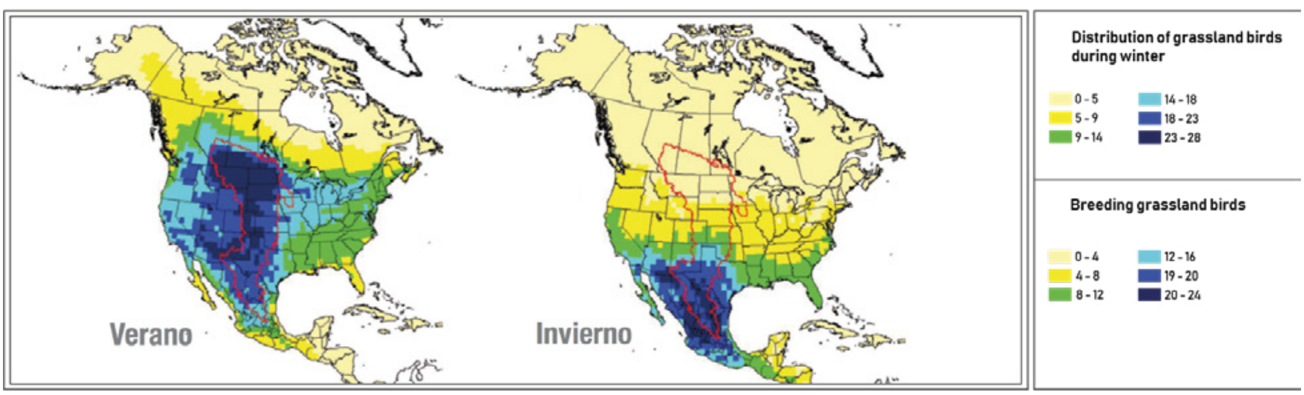


**Figure 3.** Distribution of obligate grassland birds of North America during summer (left) and winter (right). The red line indicates the limits of the grasslands (Blancher, 2003). Taken and modified from the PACP-Ch, 2011.

Figure 4 illustrates some priority faunal species in the Chihuahuan Desert grassland ecosystem and their conservation status according to the International Union for Conservation of Nature (IUCN) and the Official Mexican Standard NOM-059-SEMARNAT-2010, which aims to identify endangered floral and faunal species or populations in México through the integration of lists, as well as establishing criteria for assessing risks of extinction for species and populations in Mexico.

It is important to note that NOM-059 represents the status of the species in the Mexican territory while the IUCN status represents the global status.

| Common name in Spanish | Common name in English | Scientific name | Group | Status in NOM-059 | IUCN status |
|---|---|---|---|---|---|
| Águila real | Golden Eagle | *Aquila chrysaetos* | Birds | A | LC |
| Halcón aplomado | Aplomado falcon | *Falco femoralis* | Birds | A | LC |
| Gorrión chapulín | Grasshoper Sparrow | *Ammodramu savannarum* | Birds | | LC |
| Gorrión de Worthen | Worthen's Sparrow | *Spizella wortheni* | Birds | P | LC |
| Gorrión sabanero | Savannah Sparrow | *Passerculus sandwichensis* | Birds | A | EN |
| Zarapito pico largo | Long-billed Curlew | *Numenius americanus* | Birds | | LC |
| Bisbita llanera | Sprague's Pipit | *Anthus spragueii* | Birds | | VU |
| Escribano de collar castaño | Chestnut-collared Longspur | *Calcarius ornatus* | Birds | | NT |
| Gorrión de ala blanca | Lark Bunting | *Calamospiza melanocorys* | Birds | | LC |
| Chorlito llanero | Mountain Plover | *Charadrius montanus* | Birds | A | NT |
| Serpiente de cascabel de pradera | Prairie Rattlesnake | *Crotalus viridis* | Reptiles | Pr | LC |
| Tortuga del Desierto Chihuahuense | Mexican GiantTortoise | *Gopherus flavomarginatus* | Reptiles | P | VU |
| Perrito llanero | Arizona Black-tailed Prairie Dog | *Cynomys ludovicianus* | Mammals | A | LC |
| Perrito llanero mexicano | Mexican Prairie Dog | *Cynomys mexicanus* | Mammals | P | EN |
| Bisonte americano | American Bison | *Bos bison* | Mammals | P | NT |
| Berrendo | American Pronghorn | *Antilocarpa americana* | Mammals | P | LC |

**Figure 4.** Some conservation status of species in Chihuahuan Desert. NOM-059 status: Threatened (A), Endangered (P), Under special protection (Pr). IUCN status: Least Concern (LC), Vulnerable (VU), Near Threatened (NT), Endangered (EN).

## 2.5 RECOGNITIONS AND NOMINATIONS

The conservation of the natural resources in the Chihuahuan Desert could be achieved through the application of different environmental policy tools (Figure 5., 6., and 7.), such as Protected Natural Areas (Areas Naturales Protegidas, ANPF), Priority Conservation Areas (Regiones Prioritarias para su Conservacion, RPC), List of Wetlands of International Importance (Ramsar), Wildlife Conservation Units (Unidades Manejo para la Conservacion de la Vida Silvestre, UMA), Important Areas for Bird Conservation in Mexico (Areas de Importancia para la Conservación de las Aves en Mexico, AICA), and Grassland Priority Conservation Areas (GPCA). In addition, private conservation schemes and civic initiatives promoted and implemented by communities, national and international conservation NGOs, and private institutions could be considered (De la Maza-Benignos et al 2014). Such areas are delimited according to the value of their landscape, species value, the existence of unique elements in the ecosystem, and the presence of priority species, in addition to the environmental services provided at a biological, cultural, social, and economic levels.

Based on the different selection criteria for such areas, sometimes territories overlap or are assigned to more than one category, which reinforces information while providing integrated insights for addressing challenges. Nonetheless, the designation of areas as protected has been so far insufficient to maintain a good conservation status of the Chihuahuan Desert Grasslands.

| AICA | AICA location | ANPF | ANPF location | GPCA | GPCA location |
|---|---|---|---|---|---|
| Janos-Nuevo Casas Grandes | Chihuahua | Janos Biosphere Reserve (Reserva de la Biosfera Janos) | Chihuahua | Janos | Chihuahua y Sonora |
| Wetland Complex of Northwest Chihuahua (Complejo de Humedales del Noroeste de Chihuahua) | Chihuahua | Medanos de Samayaluca Flora and Fauna Protection Area (Area de Proteccion a la Flora y la Fauna Medanos de Samayaluca) | Chihuahua | Región de los Valles Centrales | Chihuahua |
| Sierra del Nido | Chihuahua, Coahuila y Durango | Mapimi Biosphere Reserve (Reserva de la Biosfera Mapimi) | Chihuahua | Mapimí | Chihuahua, Coahuila y Durango |
| El Tokio Prairies (Praderas del Tokio) | Zacatecas, San Luis Potosí, Coahuila y Nuevo León | | | El Tokio | Zacatecas, San Luis Potosí, Coahuila y Nuevo León |
| | | | | East Lakes (Lagunas del Este) | Chihuahua |
| | | | | Alto Conchos | Chihuahua |
| | | | | Zarca Ridges (Cuchillas de la Zarca) | Chihuahua y Durango |
| | | | | Poppy Plain (Llano de las Amapolas) | Chihuahua |

**Figure 5.** Some Protected Natural Federal Areas (ANPF), Important Areas for Bird Conservation in Mexico (AICA), and Grassland Priority Conservation Areas (GPCA) in the Chihuahuan Desert.

A clear example is the Janos grassland complex (Figure 6.), which was declared in December 2009 as a Protected Natural Area by the National Committee of Protected Natural Areas (Comisión Nacional de Areas Naturales Protegidas [CONANP]).

The Protected Natural Area hosts a rich diversity of bird species (227) and stands out among the rest of GPCAs in North America. Some of the migratory grassland bird species of interest for conservation in the area include the Sprague's Pipit (*Anthus spragueii*), the Chest-nut-collared Longspur (*Calcarius ornatus*), and the Lark Bunting (*Calamospiza melanocorys*), which have experienced significant decreases in their populations since 1966, at 55%, 84%, and 89.5%, respectively. In addition, the Janos-Nuevo Casas Grandes complex is home to the last colonies of Black-tailed Prairie Dogs (*Cynomys ludovicianus*) in Mexico (Panjabi et al. 2010; Manzano-Fischer 2006 cited in Banda, 2015). The decrease in species numbers is due to a dramatic reduction in habitats by up to 73% since 1988, leaving a small proportion of what was once the largest grassland reserve in the world (135,907.96 ac) (Ceballos et al. 2010, cited in Banda, 2015).

Another example is El Tokio (Figure 7.), which, had already lost 79% of its original grasslands by 2006. This place covers the South east of Coahuila, Southwest of Nuevo Leon, North of San Luis Potosí, and the South east of Zacatecas. It is home to the last Mexican prairie dog towns in the wild (*Cynomys mexicanus*), and other grassland obligate species. An urgent improvement in conservation strategies for the conservation and recovery of the species' habitat is needed to ensure their survival (Pronatura Noreste, 2017).

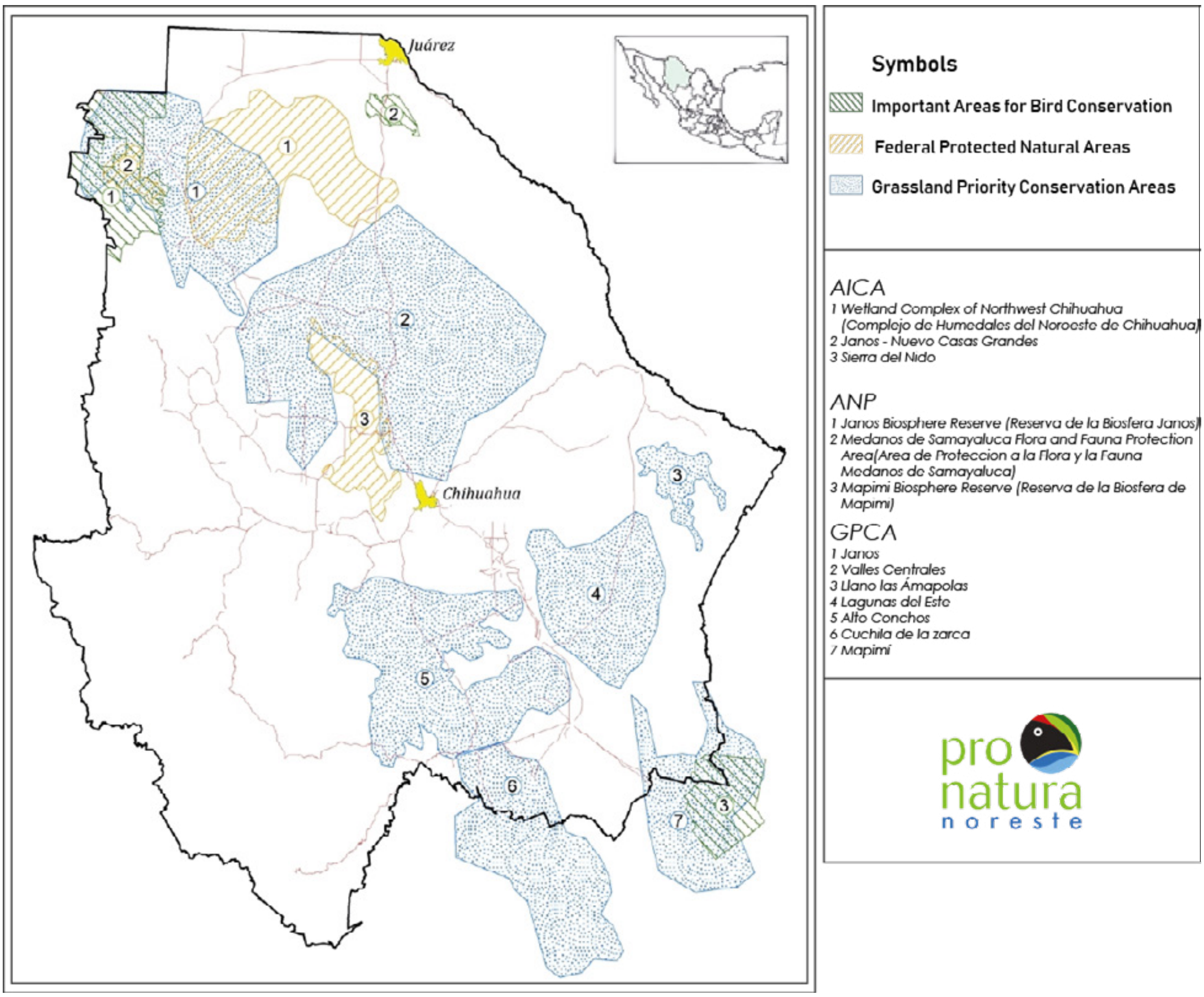


**Figure 6.** Protected Natural Areas (Areas Naturales Protegidas, ANPF), Important Areas for Bird Conservation in Mexico (Areas de Importancia para la Conservacion de las Aves en Mexico, AICA), Grassland Priority Conservation Areas (GPCA) mentioned in Table 2.

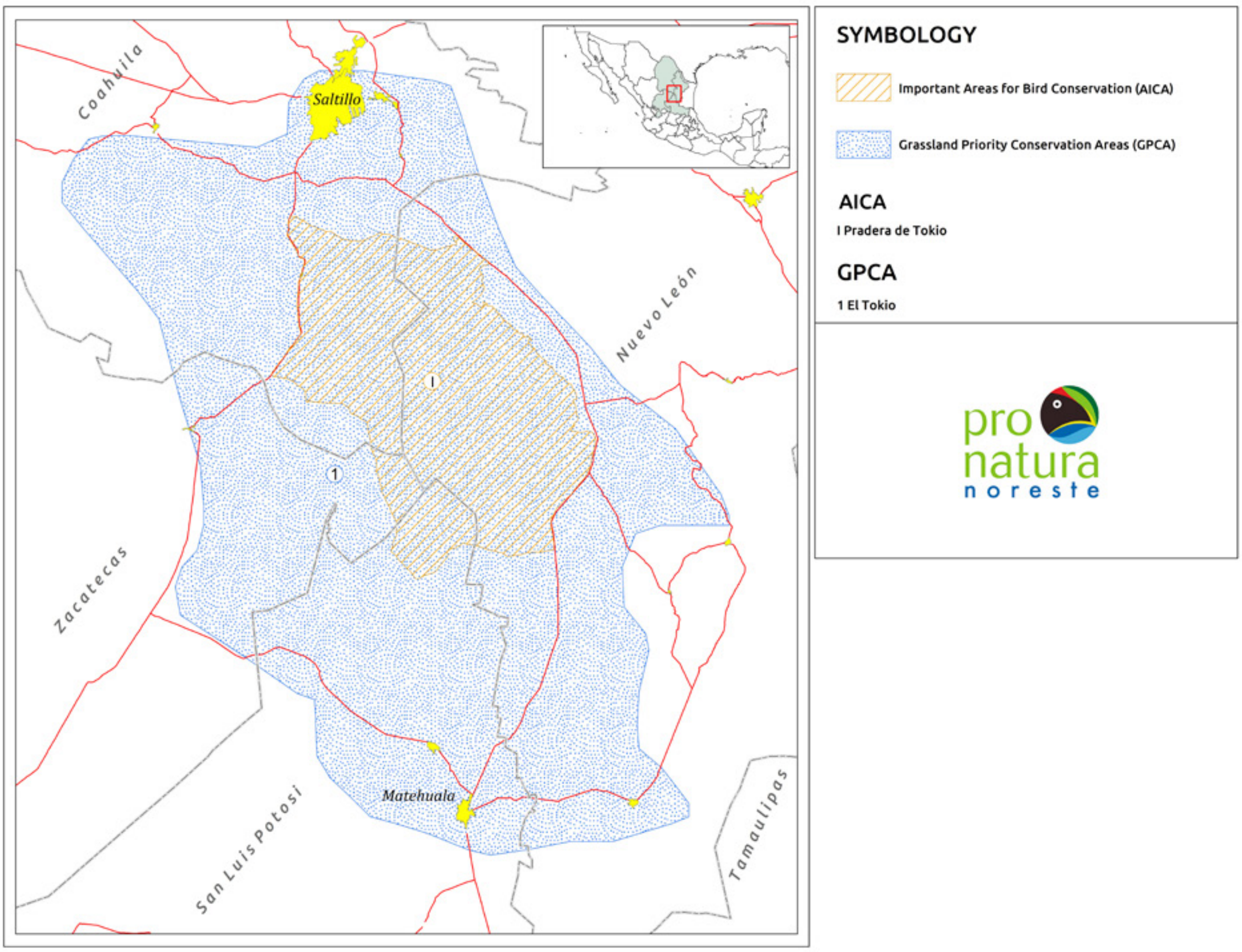


**Figure 7.** Important Areas for Bird Conservation in Mexico (AICA) and Grassland Priority Conservation Areas (GPCA) El Tokio. The symbols belong to Figure 6.

# THREATS

The major threats against the biological integrity of all the above protected areas are:

- Changes in land use.
- Exploitation of aquifers.
- Expansion of agricultural activities.
- Inappropriate livestock practices.
- Invasion by desert scrub and woody plant species.
- Fragmentation of habitats.
- Climate change effects.

The above threats are interrelated and are largely driven by water, since precipitation, water availability, and water exploitation influence the economic activities carried out in the areas, in addition to their expansion and intensity (Guzman-Aranda, 2011; WWF, 2018).

## 3.1 LAND USE CHANGE

Land use is defined by SEMARNAT (2012) as "the repairs, activities, and other contributions made by people on a determined type of surface, which can be of natural or anthropogenic origin." Land use change; therefore, refers to changes in the use or management of land by human beings, which can result in changes in ground surface characteristics (IPCC, 2012, cited in SEMARNAT, 2012).

In the Chihuahuan Desert region, land use change poses the greatest threat to ecosystems. Repurposing land that has native vegetation for human activities, mainly agriculture, causes the greatest challenges on an ecological level.

Today, there is no mechanism that takes into account the "land's natural purpose" when establishing and authorizing changes in land use, or considers the potential scale of degradation of native vegetation when granting licenses for the exploitation of parcels of land. This contributes to the continuous decline in grasslands and makes their conservation a lot more challenging.

## 3.2 EXPLOITATION OF AQUIFERS

Water extraction in the Chihuahuan Desert is a complex problem associated with the decline in grasslands, since aquifers with hydrological resources have facilitated the spread of agricultural and livestock activities, which leads to the restructuring of lands and the degradation of natural grassland vegetation. In addition, the widespread rearing of livestock has resulted in overgrazing and overstocking causing land erosion and degradation of natural vegetation.

In the Janos area (Figure 9), the areas with the highest water use intensities overlap with the most degraded grassland vegetation distribution. In Janos, water use levels are generally high since agriculture is the largest water user (Figure 8.), and it requires high amounts of water (Figure 10).

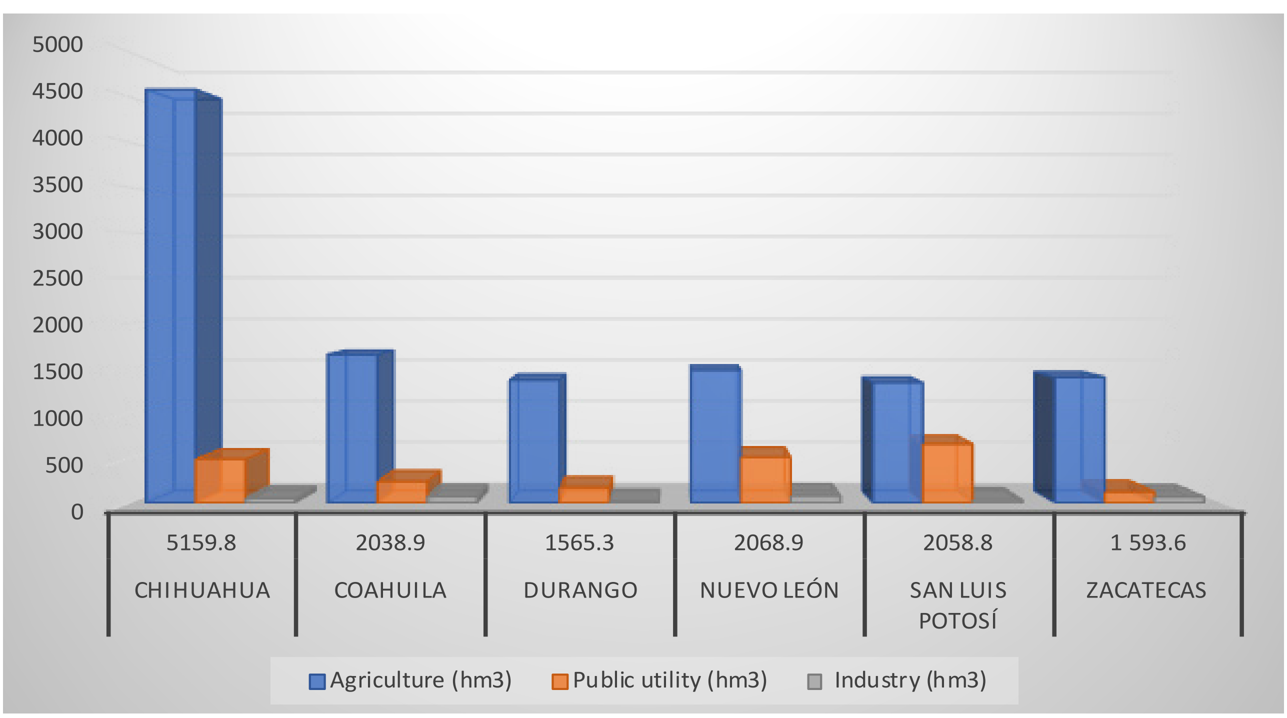


**Figure 8.** Concessional volumes and their use by federal entities. Includes surface and underground water. CONAGUA, 2016.

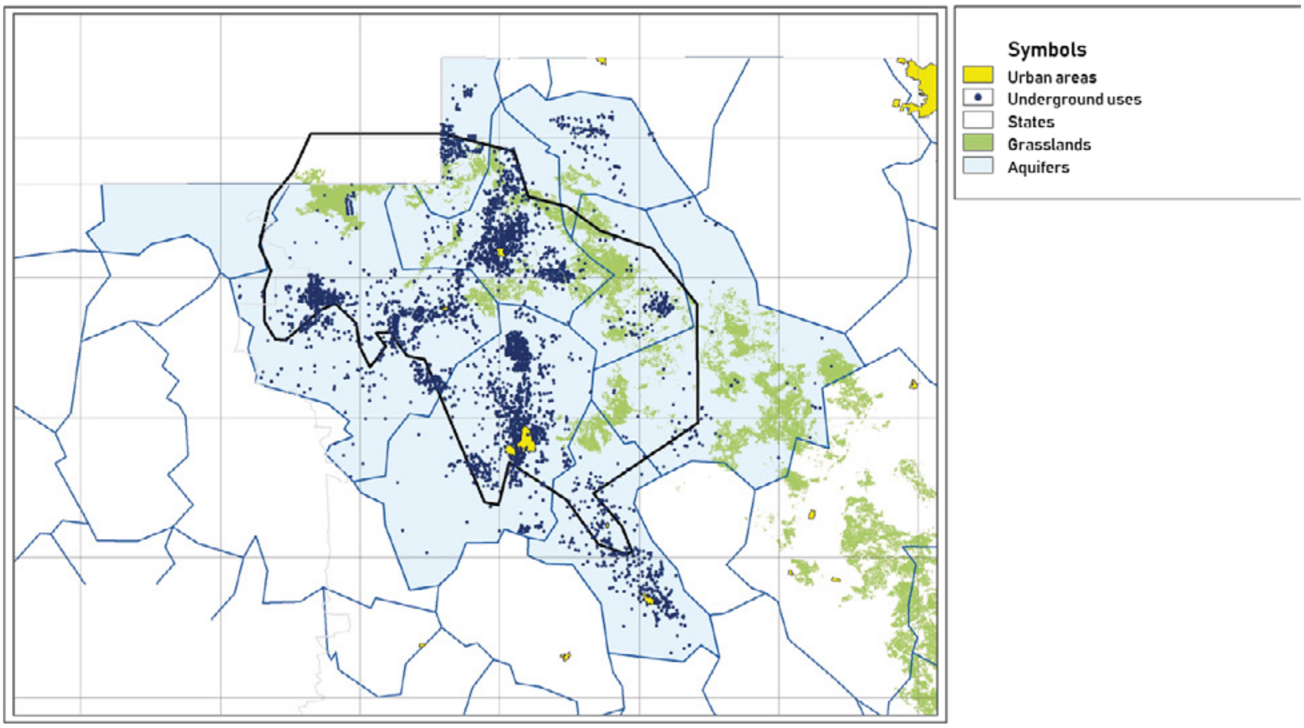


**Figure 9.** Distribution of grasslands and underground water exploitation in Janos. Taken and modified from GEOTEK, 2016.

| Use | Title deeds | Total volume (ft³) | Uses in Grasslands UACJ (ft³) | Uses in Grasslands INEGI (ft³) |
|---|---|---|---|---|
| Agricultural | 2,861 | 20,416,151,442.63 | 1,721,321,628.86 | 453,373,523.01 |
| Urban public | 210 | 1,236,907,732.15 | 15,271,121.30 | 648,907 |
| Livestock | 218 | 56,334,069.36 | 8,059,064.74 | 1,201,581.54 |
| Domestic | 402 | 21,862,388.45 | 942,566.11 | 317,832 |
| Other | 2 | 9,153,561.61 | | |
| Industrial | 8 | 6,202,103.02 | | |
| Multiple uses | 47 | 5,223,604.24 | 1,609,783.77 | |
| Services | 2 | 2,277,796 | | |
| Agricultural industry | 1 | 95,349.60 | | |
| Total | 3,751 | 21,754,208,043.56 | 1,747,204,164.81 | 455,541,843.54 |

**Figure 10.** Data on water volumes and utilization in Janos, collected by the Autonomous University of Ciudad Juarez (Universidad Autonoma de Ciudad Juarez, UACJ) and the National Institute of Statistics and Geography (Instituto Nacional de Estadistica y Geografia, INEGI). Taken and modified from GEOTEK, 2016.

The exploitation of hydrological resources is regulated through concessions granted by the National Water Commission (Comisión Nacional del Agua, CONAGUA), which are issued in accordance with the availability of basins and aquifers. However, due to an increase in the demand following population growth, and the development of productive sectors, a large proportion of the region is already experiencing overexploitation (Pronatura Noreste, 2016), which deems it necessary to assess prevailing status for facilitate sustainable use of water resources (closed seasons, regulations, or reserves). In addition, the issuance of title deeds does not consider the impact that water usage has in such ecosystems, which has resulted in the degradation of grasslands. Moreover, due to poor enforcement regulations by the water authorities, there are numerous uses that go against the current legal framework.

Arid climatic conditions, which are characterized by little to no rain, and high temperatures, are experienced in more than 50% of the national territory. In such places, access to surface water is limited and the only permanent sources of water are underground. Such conditions hamper the replenishment of aquifers, in addition to the extraction of large volumes of water, which leads to destructive and hardly reversible overexploitation (CONAGUA, 2013).

Overexploitation of aquifers refers to the extraction of water in volumes that are higher than their rates of replenishment. The most immediate effect of aquifer overexploitation is the continuous drop in aquifer levels, which could lead to depletion in extreme cases. The problem worsens in arid areas where ground water is extracted for intensive irrigation of crops and areas with high population growth.

A clear example of improper water management are the aquifers in Chihuahua, where 17 are considered to be in a shortage status following their overexploitation over the recent years and are operating with a shortage of almost −196% today (Figure 11). Notably, in 2016, the Cuauhtémoc aquifer was the most over-exploited in Mexico (JMAS, 2016, cited in Pronatura Noreste, 2016).

| Aquifers | Replenishment/ Extraction ft³/Year (2007) | Replenishment/ Extraction ft³/Year (2007) | Hydrological Basin | Shortage (%) in 2005 |
|---|---|---|---|---|
| Chihuahua-Sacra-mento | 2.32371e−6/4.2378e−6 | 1.9776e−6/2.37315e−6 | Conchos River (Rio Conchos) | -45.4 |
| El Saúz-Encinillas | 2.2601e−6/5.6503e−7 | 2.20364e−6/4.492026e−6 | Closed Basin (Cuenca Cerrada) | -27.5 |
| Tabalaopa-Aldama | 1.94584e−6/2.3343e−6 | 2.70157e−6/2.65213e−6 | Conchos River (Rio Conchos) | 0.0 |
| Laguna de Hormigas | 2.2601e−6/5.6503e−7 | 9.00524e−7/4.30839e−7 | Closed Basin (Cuenca Cerrada) | 0.0 |
| Laguna el Diablo | 1.5185e−7/7.0629e−9 | 2.8252e−8/7.0629e−9 | Closed Basin (Cuenca Cerrada) | 0.0 |
| Aldama- San Diego | 1.24308e−6/7.45139e−7 | 2.20717e−6/2.24601e-−6 | Conchos River (Rio Conchos) | 0.0 |
| Cuauhtémoc | 4.06825e−6/6.7804e−6 | 4.06825e−6/6.469647e−6 | Closed Basin (Cuenca Cerrada) | -196.0 |
| Meoqui-Delicias | 7.458458e−6/1.179157e−5 | 7.458458e−6/1.162559e−5 | Conchos River (Rio Conchos) | -172.2 |

**Figure 11.** Status of some overexploited aquifers in Chihuahua based on their extraction and replenishment. DOF, 2015.

## 3.3 AGRICULTURE

Over the last decade, various groups of agricultural producers have spread their activities into arid states of North Mexico, where they have taken over expansive territories and hundreds of wells with the purpose of extracting high amounts of ground water (CONAGUA, 2014). In such places, the major plant communities and crops are grasses and meadows, forage oats, green alfalfa, cotton, beans, and corn (SAGARPA, 2016). Such agricultural activities greatly contribute to the desertification of areas within the Chihuahuan Desert, due to the erosion of abandoned croplands that become unproductive after their intense exploitation.

Despite the crops being largely seasonal, according to SAGARPA (Figure 12.), their watering requirements presents the greatest challenge for grassland ecosystems, since higher productivity is achieved through irrigation compared to what productivity under natural conditions. Irrigation also facilitates the expansion of croplands into otherwise unsuitable areas.

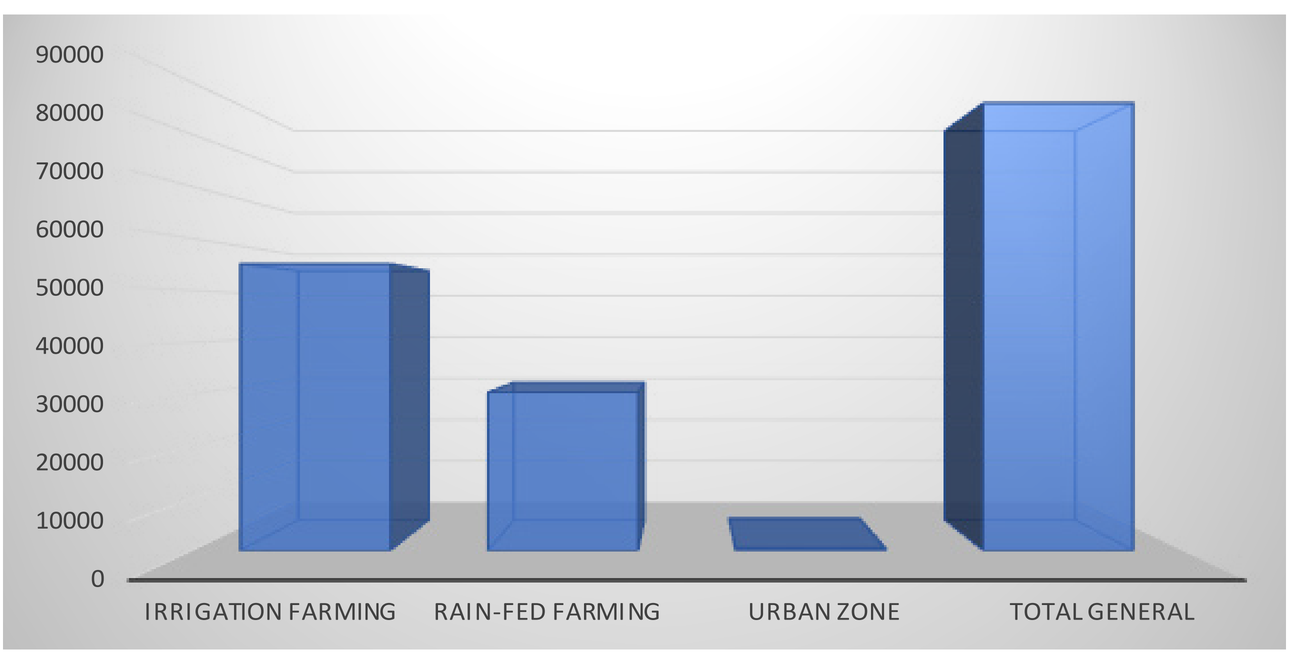


**Figure 12.** Chihuahuan Desert's areas under agriculture, per state. SAGARPA, 2016.

In the Valles Centrales region, a 6.04% annual rate of expansion in farming lands was reported from 2006 to 2011 (Figure 13), which has led to loss 69.240 hectares of grasslands and shrub lands in the valley. The development of irrigation farming was the factor driving the grasslands. At the current rate of development of irrigation, farming lands could degrade the grasslands remaining in the in low altitude regions of Valles Centrales by 2025 (Pool et al., 2013).

The expansion in farming activities in the Chihuahuan Desert is driven by water usage. Therefore, it is thought that areas with higher rates of water utilization will lose grasslands at more rapid rates.

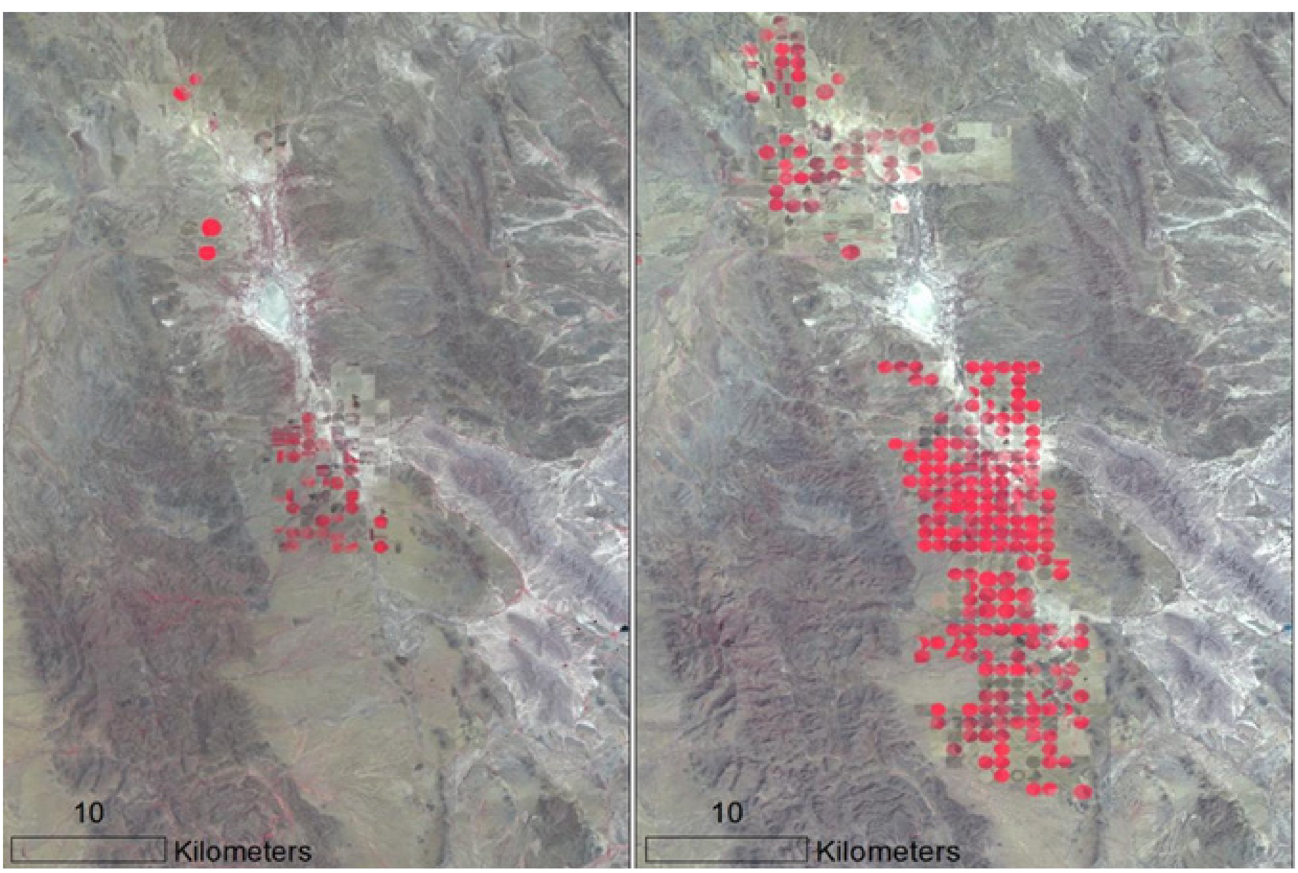


**Figure 13.** Satellite image of a Chihuahuan grassland area where a considerable expansion of farmland has occurred. Left: Red dots represent the farmlands in 2006. Right: Farmland expansion by 2011. Taken from Bird Conservancy of the Rockies, for the Rio Grande Joint Venture Management Board, McAllen, 2011.

## 3.4 RANCHING

The Chihuahuan Desert has a rich variety of physiography, climatic, and edaphic conditions, which make it particularly suitable for livestock keeping. Although the activity has been practiced for many generations, over the past few decades, there has been constant decline in fodder productivity, which has had a direct negative impact on agricultural and livestock production in different areas of the Chihuahuan Desert. Several factors that have led to the decline in production levels include lack of effective coordination between the farming and government agencies, and the lack of technical consultancy (PACP-ch, 2011).

In order to document such changes, the Council for the Agricultural and Livestock Development in Northern Mexico (Consejo de Fomento Agropecuario del Norte de México, CFAN) carried out one of the most extensive studies on livestock health and natural resources and their interactions (Escobar, 2008 cited in Guzman-Aranda et al., 2011), assessing approximately 600 livestock farms. The study found that over 80% of the farms had overgrazing and erosion challenges. In addition, over 50% of the farms had bush invasions. Overall, it is estimated that in the course of the last five decades, the Chihuahuan Desert has lost 70% of its fodder capacity, and in the last two decades, Chihuahua's livestock production has decreased by 50% (INIFAP, 2008, cited in Guzman-Aranda et al., 2011).

The negative effects of livestock on terrestrial ecosystems are attributed to overgrazing, inappropriate grazing and resting periods producing heterogeneous damage across territories. These practices are rooted in the lack of investment in infrastructure and training, and the poor capacity to plan ahead and respond to changing climatic conditions, among other factors (Guzman-Aranda, 2011).

In the Chihuahuan Desert, there are three major livestock keeping activities. They include the following:

## Traditional Husbandry

### *Management*

This one is the most common practice. It is characterized by the following:

- Low investment in infrastructure and equipment systems.

- Reactive supplementation.

- Minimal or lack of implementation of the rotational or holistic grazing systems.

- The surface-area-to-volume ratio of animals is not taken into account to ensure better grazing methods.

- Basic health management. Vaccination according to the law.

- (Internal/external) de-worming at regular intervals

### *Effects*

- The health of the grassland ecosystem goes from deteriorated to extremely deteriorated.

- On a scale of 1 to 5, the livestock condition status ranges from 1 to 3, with 1 representing an extremely thin and malnourished animal and 5 representing a healthy animal.

## Basic Rotational Husbandry (Intensive)

### *Management*

This term refers to a grazing system where there is an interest in keeping a balance between the grassland ecosystem and livestock production for breeding and exportation. It is defined by the following characteristics:

- Extensive implementation of rotational or holistic grazing system.

- Accurate farm management registries and bookkeeping.

- High investment in technology to develop a more appropriate grazing system.

- Lower rates of supplementation. Adequate grazing increases biomass production.

- Annual vaccination by law, as well as supplementation of vitamins, deworming, and general veterinary care based on the needs of the herd.

- The carrying capacity is estimated to avoid overgrazing.

- The productive parameters are precise. A reproductive control is carried out with a synchronization and insemination schedule.

- Genetic improvement of the herd is ensured.

### *Effects*

- On a scale from 1 to 5, livestock health status ranges from 2 to 3, with "1" representing an extremely thin and malnourished animal and "5" representing an overweight animal.

- When implemented appropriately, there is an observable decrease in bush infestation and soil erosion.

## Ultra-intensive farming

### *Management*

The grazing system is quite similar to the intensive system with regard to its management. There are only a few differences between them as follows:

- Animal density is considerably higher (animals per surface unit or animals per hectare), and total hectares of land are not considered when determining density, but the hectares to be divided.

- Dietary supplements are given to the livestock.

- Genetic improvement is sought, and is qualitatively registered.

- Rotational grazing is carried out hourly.

### *Effects*

- On a scale of 1 to 5, livestock health status ranges from 2 to 4, with "1" representing an extremely thin and malnourished animal, and "5" representing an overweight animal.

- When implemented properly there is an observable decrease in bush infestation and soil erosion.

## 3.5 INVASIVE SPECIES

An invasive plant species is a plant that is not native to a specific location and is able to spread exponentially in the said region, endangering the survival of native species, damaging the environment and negatively affecting the economic activities in the surrounding areas. All invasive species share a common characteristic. They are resistant to adverse environmental conditions (mainly water scarcity), which give them an advantage over native species in competition for natural resources such as territory, light, and nutrients (Pinedo et al., 2013).

Today, the grasslands of the Chihuahuan Desert have been invaded by African grasses that have modified the ecosystem composition and dynamics (Melgoza et al. 1998 cited in Pinedo et al., 2013). Nevertheless, the situation is partly due to the premeditated introduction of the species with the aim of restoring soil and the areas with damaged vegetation, as well as, providing additional food resources for livestock.

Three examples are the Natal grass (*Melinis repens*), the Lehmann lovegrass (*Eragrostis lehmanniana*), and the buffel-grass (*Pennisetum ciliare*). The species have a high level of tolerance against soil depletion, which, for the livestock industry represents a way of keeping their farms functioning during extreme droughts and overgrazing conditions in spite of endangering native species (Pinedo et al., 2013).

### Natal grass

Natal grass can be found on roadsides within farming lands and in natural vegetation areas because wind, cattle, and people easily disperse its seeds.

Even though it minimizes soil erosion, it is highly invasive and easily takes up the space occupied by native species because it is highly tolerant to adverse climate conditions.

The results of 129 occurrence records in Chihuahua indicate that Natal grass is responsible for the reduction in the quantity and diversity of native species. Native species of grass are the most affected (Pinedo et al., 2013).

## Lehmann lovegrass

In 1959, Lehmann lovegrass was introduced in Arizona, Unites States, as it was considered as the appropriate species of grass to restore soil and pasture that had been affected by overgrazing and droughts.

During the 1960s, it was introduced to "La Campana," a research facility of the National Institute of Agricultural and Forestry Research (INIFAP), located at Valles Centrales, Chihuahua, Mexico. Since then, the Lehmann lovegrass has progressively invaded the surrounding grasslands found between 1.86 and 2.79 m from their point of origin, and with an altitude level between 3280 and 5249 fasl, with 5 in to 8.6 in of rain (Melgoza col. 1986 cited in Pinedo et al., 2013). The biodiversity of the area has decreased from 15 native species in 1985 to 6 native species in 2005 (Pinedo et al., 2013).

## Buffel-grass

The robust bush grass is native to tropical Africa, India, and Madagascar. Buffel-grass was introduced to Sonora, Mexico, in 1950, to be used as fodder. The species was assessed and approved by several American institutions, such as the Rancho Santa Ana Botanic Garden in Mississippi (1889), the University of Texas at Austin Herbarium, and the Coastal Plain Experiment Station in McMeill, between 1907 and 1922 (Devender et al., 2009).

Today, buffel-grass has spread widely, to the point of replacing native species and it has created meadows similar to those in the African savannas. It can be found on roadsides and along highways (Devender et al., 2009).

Other invaders of the grasslands are shrubs, which are increasingly denser in degraded areas.

## 3.6 CLIMATE CHANGE

The United Nations Framework Convention on Climate Change defines climate change as "a change of climate attributed directly or indirectly to human activity that alters the composition of the global atmosphere, and which, in addition to natural climate variability, is observed over comparable time periods." Climate change is caused by an increase in the concentrations of greenhouse gases in the atmosphere, which maintain the heat from the sun's rays in the earth's atmosphere, which in turn increase the temperature on the earth's surface through a feedback mechanism. The concentrations of these gases are increased by human activity and emissions from the livestock industry, the burning of fossil fuels, and changes in soil practices.

According to the Millennium Ecosystem Assessment from 2017, in the future, climate change will be the primary factor influencing biodiversity loss. An increasing rate of climate change results in changes in floral and faunal distribution increased rates of the extinction, changes in reproductive cycles, migration patterns of birds, and growth patterns of plants, among others, since species are unable to adapt as rapidly to the changing environments.

This is even more alarming in case of the Chihuahuan Desert, since it is on the most vulnerable regions to climate change globally (Townsend et al., 2002 cited in PACP-Ch, 2011).

The impacts of climate change are not only linked to a higher occurrence and severity of droughts and erosion (particularly in areas with little vegetative cover) but also to the spread and a higher distribution of scrublands that benefit from higher amounts of carbon in the atmosphere (USGCRP, 2009 cited in PACP-Ch, 2011).

According to the IPCC's RCP 8.5 scenario, based on a projected temperature rise from 34.5°F to 35.6°F over the 2045–2069 period, grasslands will migrate to higher altitude zones with better conditions of vertical dissection, resulting in a 37% decrease in their distribution. Even under favorable conditions in the territories, grasslands in flat and hilly plains would completely disappear in future (Figures 14 and 15) if they are unable to adapt to the changing conditions (Pronatura, 2017)

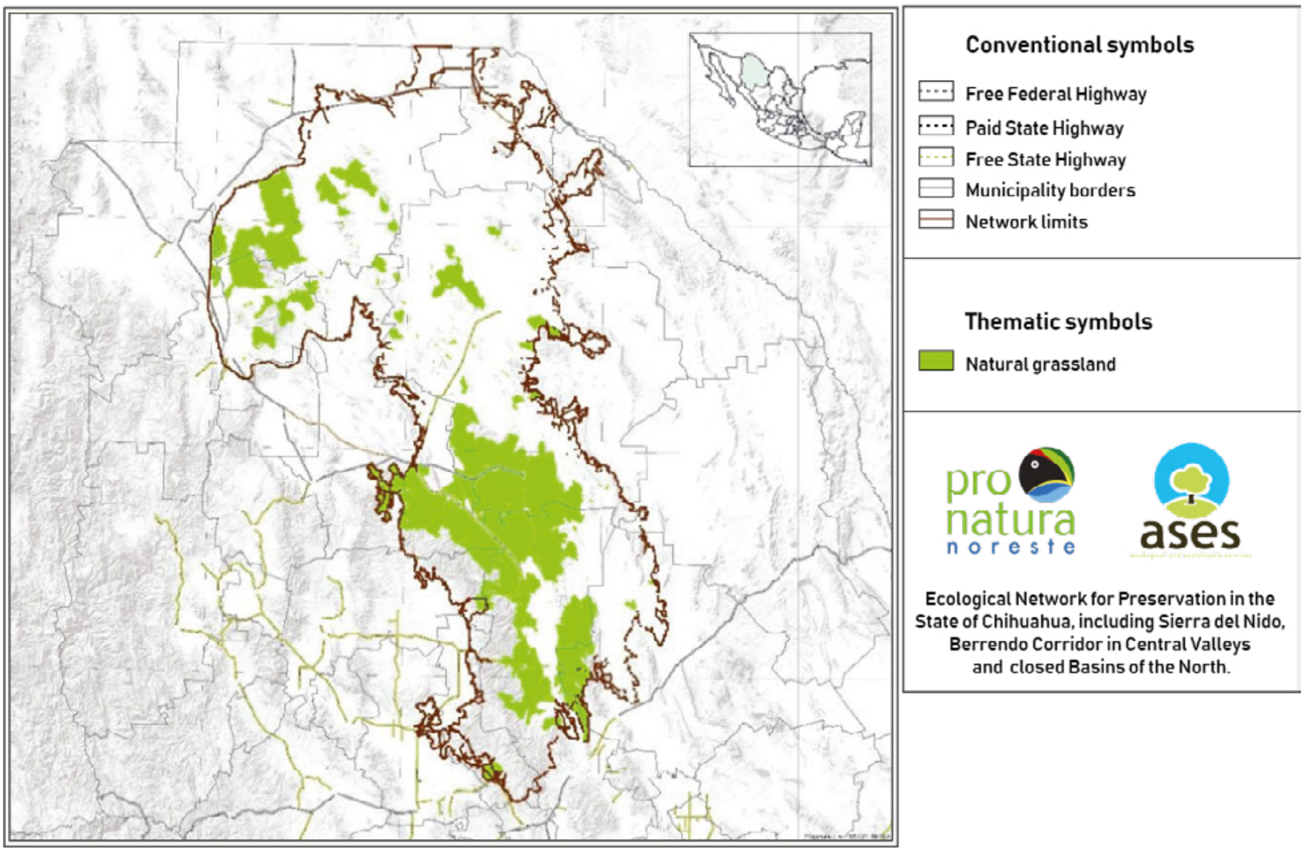


**Figure 14.** Projection of grassland distribution based on the percentage of favorable ecological conditions created by climate change. Modified map, ASES, 2016.

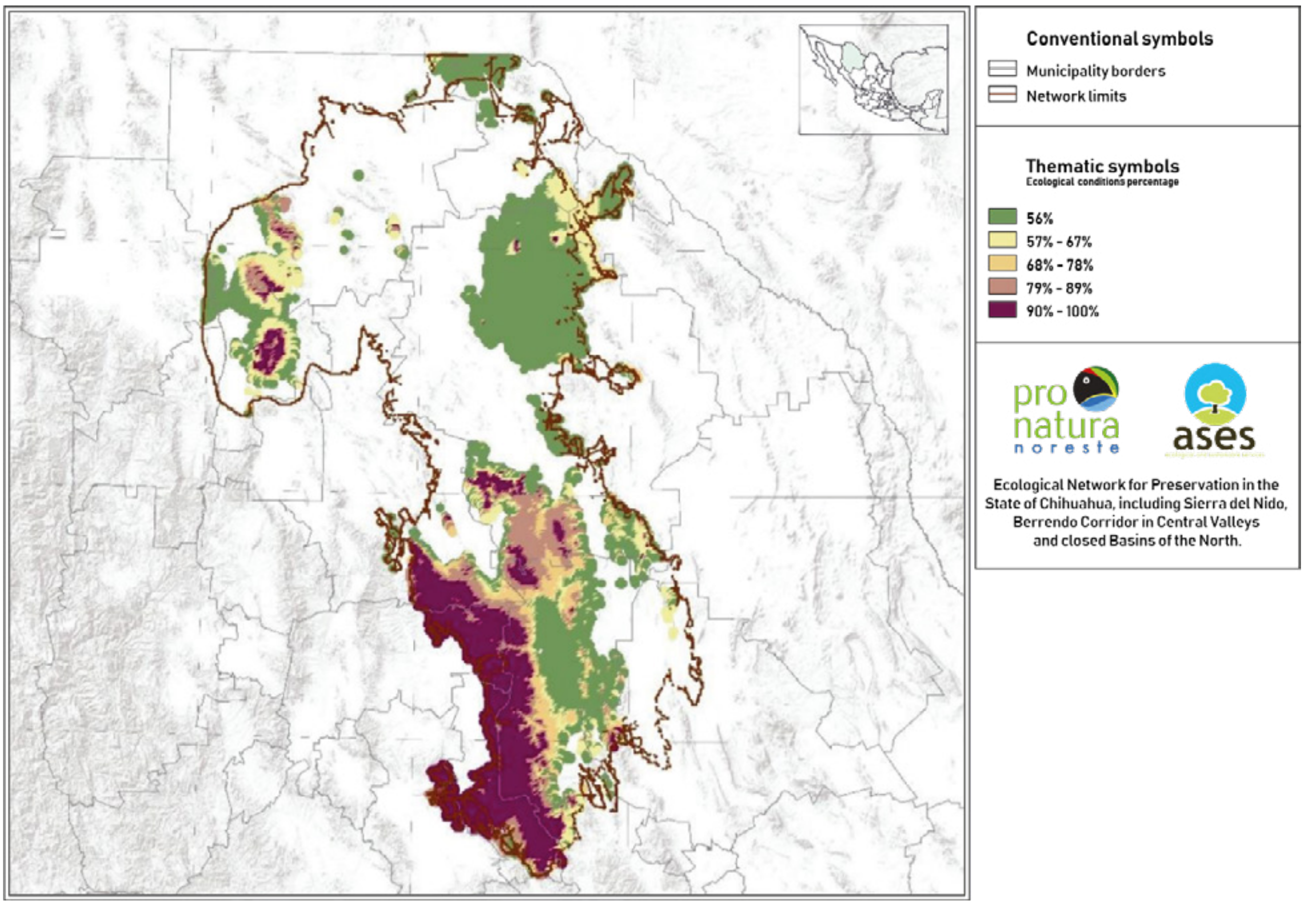


**Figure 15.** Current distribution ranges of Chihuahua grasslands. Modified map, ASES, 2016.

## 3.7 HABITAT FRAGMENTATION

Habitat fragmentation is the continued division of a natural area into sections, causing the reduction or loss of habitats by interrupting the genetic and adaptive flow of different species. It is the result of interaction between the negative impacts of both anthropogenic activities and climate change.

In Chihuahuan Desert grasslands, the fragmentation is mainly due to changes in land use that affect soil, such as adoption of irrigation agriculture and the expansion of human infrastructure, in addition to other ecological threats. Therefore, fragmentation of grasslands results in the loss of vegetation, soil erosion, and invasion by bush species that form secondary bush vegetation (ASES, 2016).

The following charts (Figures 16 and 17) illustrate the proportion of the soil surface in hectares in Chihuahuan Desert (a portion of Sierra del Nido, the Central Valleys and the Wetland Complex of the Northwest of Chihuahua) that has been modified by the above-mentioned factors.

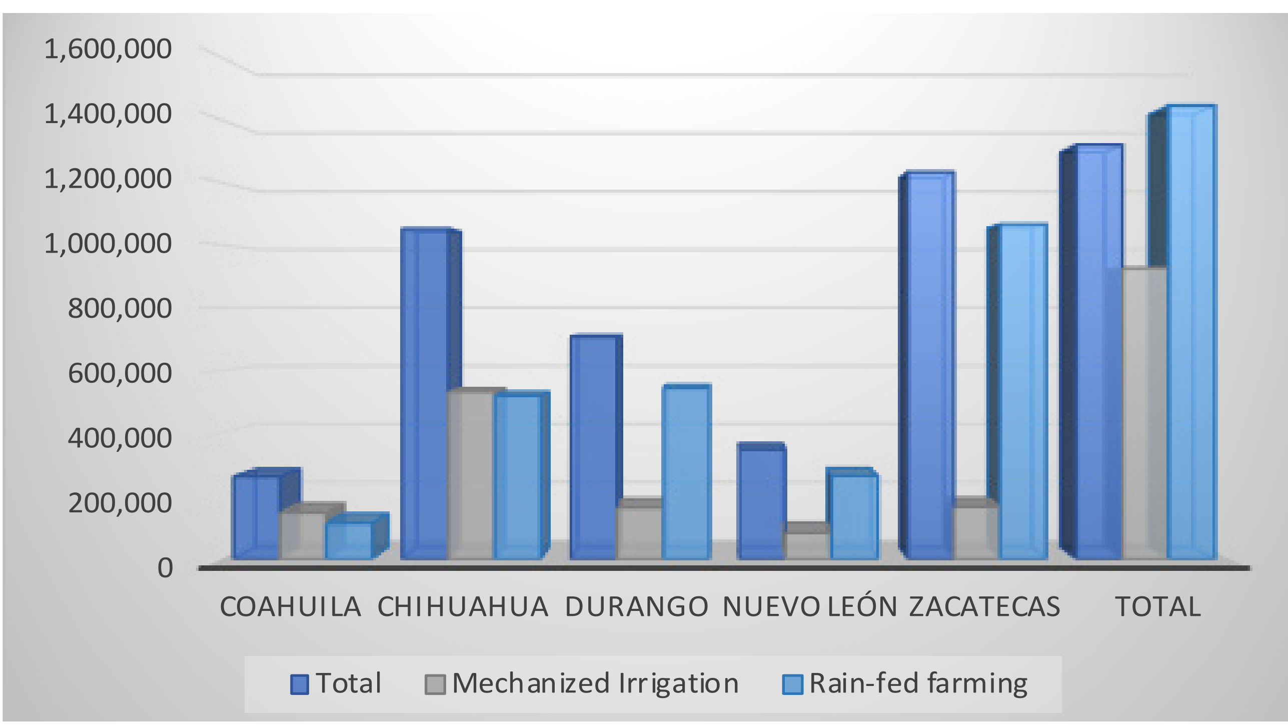


**Figure 16.** Fragmented grassland area by land use. North of Chihuahua, Villa Ahumada, Buenaventura and Nuevo Casas Grandes. ASES, 2016.

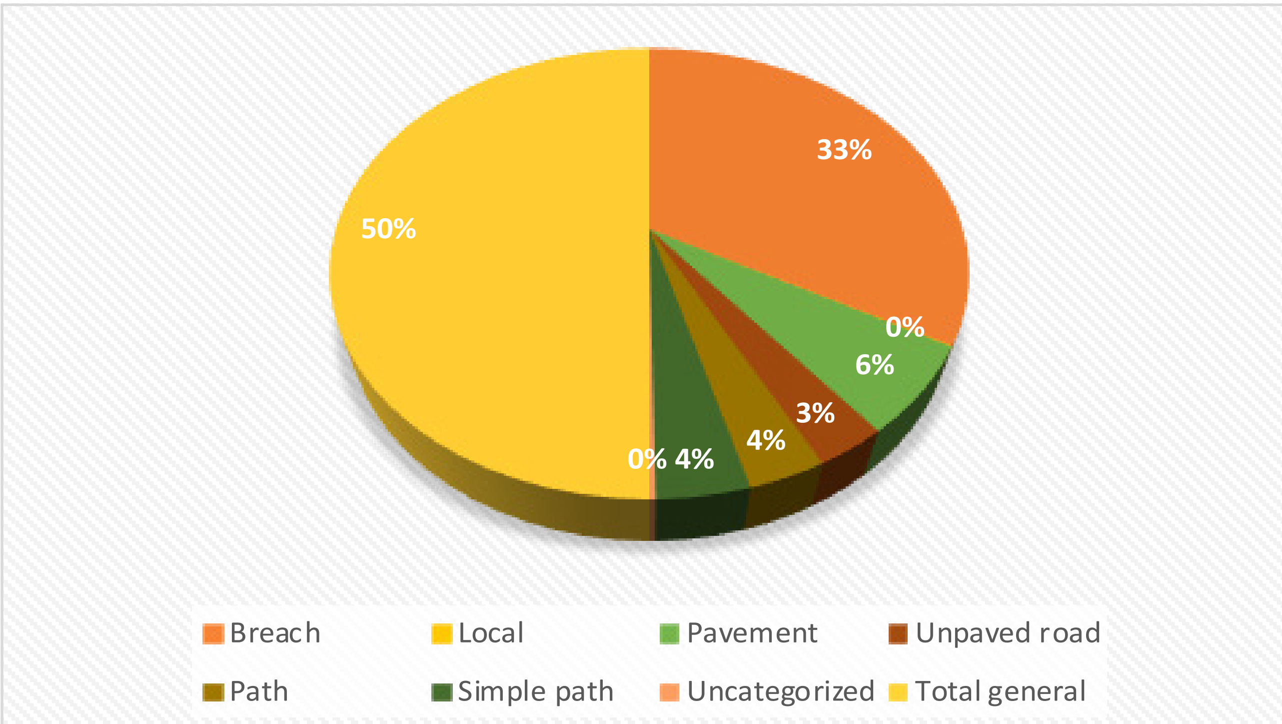


**Figure 17.** Fragmented grasslands area based on transport infrastructure. North of Chihuahua, Villa Ahumada, Buenaventura and Nuevo Casas Grandes. ASES, 2016.

# DISCUSSION AND RECOMMENDATIONS

## 4.1 TERRITORIAL PLANNING

Based on the Environmental and Natural Resources Secretariat (SEMARNAT) definition, ecological territorial planning is an instrument within the national environmental policy for managing the exploitation of lands within the territory based on up to date assessments of natural resources, the social condition of its inhabitants, and the capacity of the assessed area. Such assessments take into account proprietary and market factors to determine the exploitation capacity of territories with low risks of degradation.

Territorial planning according to SEMARNAT incorporates the concept of "natural purpose of the soil," which means that if an area's natural purpose is a grassland the exploitation activities of the soil resources in the grassland should be compatible, so that the human and economic activities undertaken do not compromise the continuity of the ecosystem, such as sustainable livestock rearing. In contrast, urban infrastructure or intensive farming activities would be incompatible with the environment. Therefore, based on the guidelines, setting up such infrastructure in a grassland would be inappropriate (PACP-ch, 2011).

It is recommended to determine areas where the soil resources could be exploited based on the degree of the natural vegetation disturbance expected, areas that could potentially recover with little degradation, and the need to preserve untouched sections.

## 4.2 PLANNING AND SUSTAINABLE WATER MANAGEMENT

Mauricio De la Maza-Benignos

The scenario in Chihuahuan Desert grasslands highlights the need for planning and water management under a water security plan.

Water security is defined as the capacity of a population to safeguard sustainable access to adequate quantities and acceptable quality of water to sustain livelihoods, human well-being, and socio-economic development, while ensuring protection against water-borne pollution, water-related disasters, and preserving ecosystems under a climate of peace and political stability (UNO, 2013).

In order to achieve such a vision of water planning, a doctrinal plan is proposed for integrated aquifer and hydrological basin management, where the following principles are taken into account: environmental governance, environmental services, rule of law consolidation, and environmental ethics. The purpose of the four components is to make up for the current discrepancy in various water programs, where biodiversity is secondary to water management.

### Environmental Governance

The purpose of this kind of governance is to ensure lasting economic, social, and institutional development that facilitates balance between the state, civil society, and the market.

Environmental governance involves processes that address the utilization and distribution of natural resources by making decisions and dealing with their consequences to ensure the sustainability of environmental goods and services.

Governance processes are inherently political and are often carried out in contexts where the participants are unequal, and occasionally, less empowered parties are excluded, whether due to unintended omission or discrimination. Consequently, it is necessary to encourage the participation of the different sectors and cultures that form a society and include them through forums and public policies that consider the desires and needs of citizens, besides the corresponding environmental measures. In addition, transparency and accountability in government and public institutions are necessary to ensure access to information and its assessment by citizens, as well as the basic capacity to apply the law at every level.

## Environmental Services

There is a major discrepancy between the current water programs and the sustainable exploitation of the resource, with implications for biodiversity.

The environmental services provided by the ecosystems influence the quality of life of residents, and the growth and development of other organisms that are part of the ecosystems. Consequently, the water security program by Pronatura Noreste considers biodiversity and habitats as key elements of their strategies. Specifically, the programs intend to fight for the inclusion of environmental services into land usage and water management legal frameworks.

## Consolidation of the rule of law

To guarantee the fulfillment of current water needs, and to assign legal status to the specific resources, it is critical to ensure the consolidation of the rule of law. In addition, to avoid scarcity due to the excessive exploitation of water resources, we must implement the necessary legal instruments to ensure the resources are exploited sustainably in a manner that facilitates replenishment. Consequently, Pronatura Noreste developed a legal concept for water concessions, which suggests water preservation to maintain habitats from a water security perspective. The major purpose is to increase the conversion of concessions for ecological applications.

## Environmental Ethics

"Environmental ethics extends community limits to include the land, water, plants, and animals, or collectively, the earth". (Leopold, A., 1949). Environmental ethics is a branch of philosophy that extends social constructs to include all livings beings and their habitats. It was first addressed in the 1970s by thinkers, such as Aldo Leopold, Garrett Hardin, and Lynn White Jr. Lynn White Jr contended that the root of our ecological crisis was philosophical.

The regular concept of water security is inconsistent with the ethical concept that one of our fundamental rights is to grow in a healthy environment, implying that it takes into account each of its components, including all species that inhabit the specific ecosystem. Based on a comprehensive perspective, a moral and ethical approach could be considered, as well as a constitutional model for our right to live in a clean and safe environment.

It is necessary to include such ethical concepts as basic elements of communication campaigns to various audiences.

## Management

There is always competition for water usage. This makes us perceive water management and its relationship with grasslands from an economic and political perspective.

The current distribution and assignment of water is based on power. To ensure a fair distribution of resources, it is fundamental to apply a governance model where every party is equally represented in efforts and discussions to determine and assign appropriate water resource exploitation activities.

Similar to the environmental governance model, the implementation of water security program in the Chihuahuan Desert region that takes into account both fundamental doctrines and biodiversity is needed.

## 4.3 SUSTAINABLE RANCHING

During the last decade, Pronatura Noreste has promoted a paradigm shift: livestock rearing can be an ally of conservation.

In the previous conservation strategies livestock did not have access to major natural areas to prevent overgrazing and loss of biodiversity. However, sustainability, which is a concept, acknowledged by other similar institutions globally, recognizes economic development as one of its essential components, which is why we propose an alternative approach to the problem.

In 2012, sustainable livestock keeping schemes, proposed by Pronatura Noreste, began to be based on the restoration and conservation of pasture, using livestock as a tool in the recovery of natural processes in the ecosystems, such as the carbon, nitrogen, and water cycles, which result in soil formation and forage production. Such schemes operate under the premise that the deliberate management of livestock, which imitates the function that bison once had in pastures, results in reduction of costs and increase in income from livestock activity, while simultaneously creating and maintaining habitat structure for pastoral species.

This is possible because programmed livestock activity in the field facilitates the aeration of the soil, the incorporation of organic matter, and the stimulation of the regrowth of pasture. An increase in pasture production due to such processes implies a decrease in operational costs for farms, in addition to an increase in profits.

Considering such schemes, Pronatura Noreste designed an adaptive management model for livestock practices (Figure 18.) in its Sustainable Ranching Program, where legal agreements are signed with livestock producers to establish guidelines for long-term productive projects managed from a conservation perspective.

According to the agreements, an integral diagnosis and analysis of the natural resources and the current livestock operations in a property are initiated with the aim of optimizing on a case-by-case basis. Technical improvements required for this purpose may include:

• Animal surface-area-to-volume ratio adjustment
• Application of a rational grazing plan.

• Soil restoration work.

• Pre-thinning operations of bush species.

• Redistribution of troughs.

• Genetic enrichment of the herd.

• Fire management.

Such operations are carried out during the implementation of the management plan because of a coordinated effort between Pronatura Noreste and the owners of the properties.

In addition, Pronatura Noreste facilitates, as much as possible, the financing of the restoration activities and the purchase of management infrastructure.

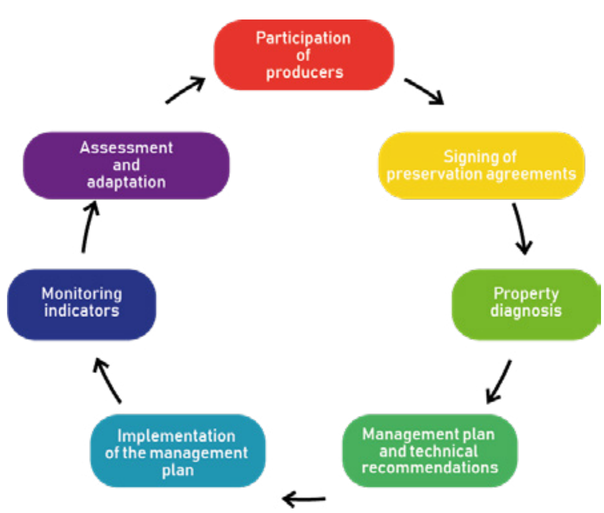


**Figure 18.** Operation model of the Pronatura Noreste Program for Sustainable Ranching.

An example of the model was implemented in El Tokio, where overgrazing was significantly reduced by investing in basic infrastructure that would allow a fencing system to control flow and animal surface-area-to-volume ratio on the land (Pronatura Northeast, 2017).

The development of the projects is accompanied, in addition, by the continuous monitoring of indicators, such as increase in the basal coverage, the supply of forage, and the density and diversity of birds, as well as the technical training of the producers.

The monitoring of the vital signs in the sites that implement the Sustainable Ranching Model, after 5 years of implementation, reveals that to date, more than 200,000 hectares have adopted sustainable livestock management practices, 5,730 hectares have been subjected to soil restoration works, more than 900 people have participated in workshops, seminars or conferences and, there has been a 30% increase in bird richness in the lands.

The purpose of the Conservation and Vision 2025 Plan of Pronatura Noreste is to leverage efforts through three strategies and enhance the positive impact of the model:

### Profitability of Livestock Farms

It involves promoting economic incentives, through certifications or awards, for breeders who raise animals in an environmentally friendly manner. For example, through access to preferential prices in the sale of animals and the purchase of inputs and materials.

### Strategic Extension

It aims to improve the capacities of natural resource managers and field technicians.

### Communication and Disclosure

It seeks to promote livestock culture, the value of the countryside, love for the land, traditions, and regional history.

In the future, a key factor of interest that could be integrated into sustainable livestock management is a balance between the greenhouse gas emissions and the capture of atmospheric carbon by grasslands in suitable condition, so that it is linked to the other aspects aimed at improving livestock practices in such an ecosystem.

As an appendix, a financial analysis is presented that explains the premises of the sustainability schemes under which Pronatura Noreste works, as well as the results in terms of profitability.

## 4.4 ECOLOGICAL CONSERVATION NETWORK

In response to the problem of habitat fragmentation resulting from human activities and the effects of climate change, it is necessary to establish a strategy that facilitates the conservation of both the unique elements in the environment and the sets of ecological processes that operate in the environment, in addition to essential environmental goods and services (Múgica. et al., 2002, ASES, 2016.), which is how the concept of Ecological Networks and Greenways emerged.

The ecological conservation network is a biogeographic concept that, from a landscape ecology and sustainable development perspective, is the sum of the ecological corridors connected with natural habitats (sites of reproduction, feeding, rest, protection, among others) and reservoirs of biological richness, alluding to a network of natural infrastructure that provides the necessary conditions for biodiversity through galleries of displacement and migration of flora and fauna, in a landscape mosaic where man also operates (Jongman et al., 2004, cited by ASES, 2016.).

Therefore, the word corridor refers to any functional structure that connects two ecosystems, different habitats, or their components, which allows the dispersion of ecological flows (organisms, matter, energy, and genetic information) that are vital for the survival and evolution of the species.

The application of ecological networks as a conservation strategy addresses the maintenance of biological diversity, while operating as a basic element in ecosystem conservation and land use planning (Hinojos-Mendoza, 2014, ASES, 2016.).

An example of an ecological network program (Figure 19.) is the one proposed by Pronatura Noreste in Chihuahua, where an analysis was made for the establishment of an ecological conservation network, which includes the Sierra del Nido, Central Valleys, and the Closed Basins of the North. The proposal presents the basis and principles of emerging environmental governance concepts, which consider the integration of the human and natural factors into a single policy for land use planning. In such a case, the composition of the landscape, the habitats of migratory birds (Birdscapes), the waterway corridors, the vegetation dispersal corridors, and the pronghorn wildlife corridor were taken into account (ASES, 2016.).

The analysis of fragmentation effects of the habitats revealed that to achieve an ecological network that connects Sierra del Nido, the Closed Basins of the North and Central Valleys, the major fragmented areas that require restoration are located north of the municipality of Chihuahua, Villa Ahumada, Buenaventura, and Nuevo Casas Grandes.

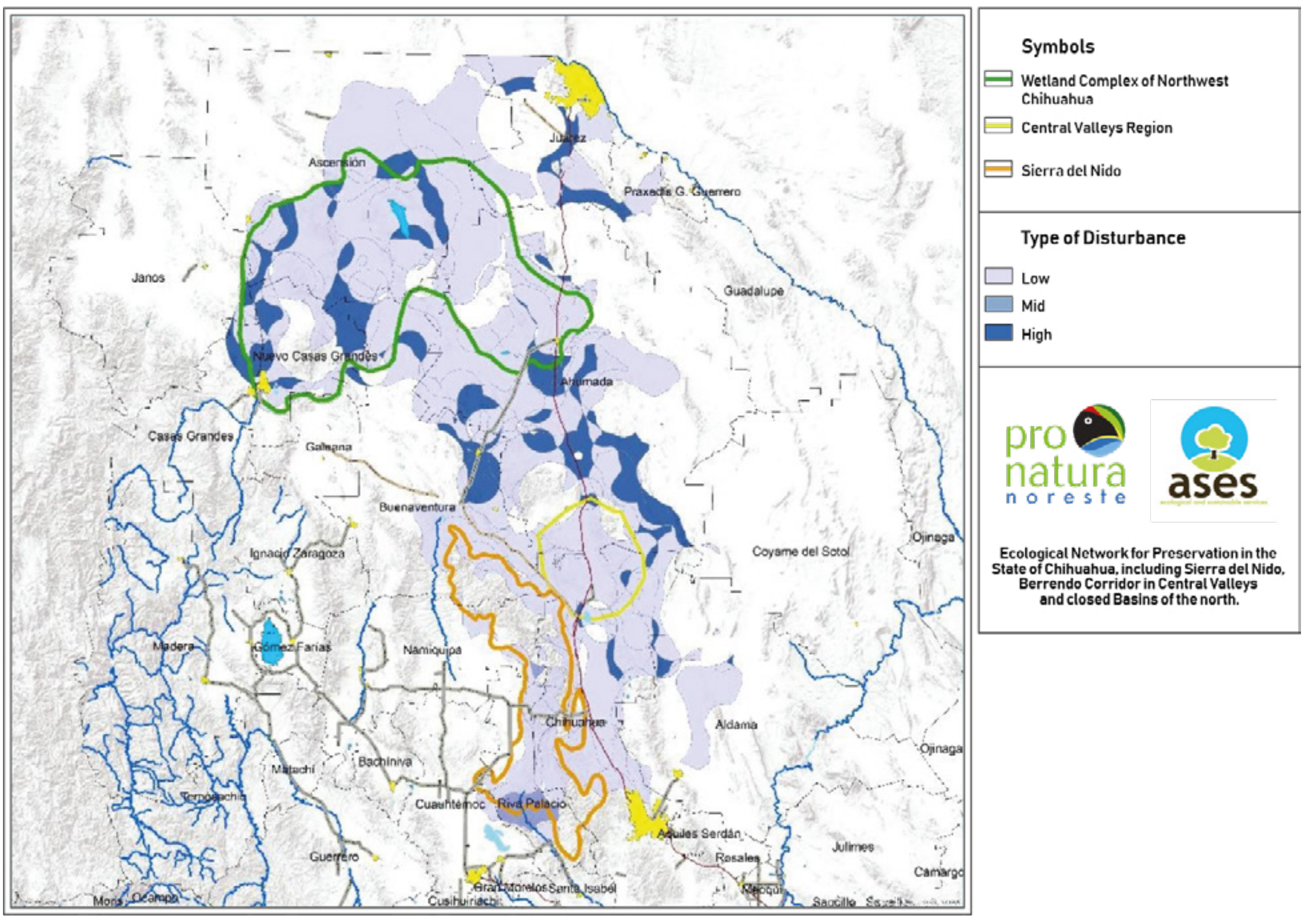


**Figure 19.** The area for the ecological network proposed for the grasslands of Chihuahua is denoted by a purple shade, as well as its degree of disturbance. Modified map, ASES, 2016.

## 4.5 VITAL SIGNS

Currently, organizations such as Pronatura Noreste have monitored the diverse conditions of the ecosystems through a program called "Vital Signs," which corresponds to a strategy of registering the physical, biological, and social conditions of a given site, obtaining solid data (provided by the natural and social sciences) that are used to identify, prioritize, and guide conservation programs, as well as to obtain indicators of their effects.

The monitoring of the Vital Signs of grasslands in the Chihuahuan Desert focuses on:

- The presence, distribution, and abundance of priority species.
- The availability and status of surface and underground water bodies.
- The status of natural vegetation and soil.
- Climatic conditions.
- Anthropogenic activities.
- Policies and the institutional arrangements operating the sites.
- The willingness of the residents to participate in and implement programs to be developed.

Data from the areas are obtained before, during, and after the implementation of the proposed strategies, while aspiring improvement in indicators representing effects on the natural and social environment.

A recommendation for this program consists in carrying out a constant review of the chosen variables and their role in the results of the projects carried out, so that, if necessary, they can be reconsidered or adjusted.

# CONCLUSION

There has been a critical loss of grasslands in the Chihuahuan Desert over the last 50 years. It is estimated that, based on the current loss rate in the Central Valleys of Chihuahua (6% per year), natural pastures will disappear entirely by 2025.

The reduction is mainly attributed to the impacts of human activities that involve the use of water, since this predisposes natural pasture areas to changes in land use that aim to expand human infrastructure, livestock ranching, and crop agriculture, the latter being the activity that poses the greatest threat.

Added to this scenario are the challenges in adapting to climate change that, altogether, lead to the loss of environmental services, which maintain the structure of the landscape and sustain economic activities, and the fragmentation of the habitats that function as shelters and feeding and reproduction grounds for species.

In turn, such impacts are harmful to the species that inhabit the ecosystems, by leading to loss of territories and changes in natural conditions necessary for their survival, such as the availability of water, food, climatic conditions, adaptive displacement and genetic flow, and those leading to increasingly critical status.

To address the complex challenges of the sites and to recommend appropriate strategies to reverse the trends, coordinated actions are required to mitigate and reverse the environmental damages as much as possible:

1. The territorial ordering in terms of ecology, using legal instruments facilitate the consideration of the natural properties and capacity of the soil, and paying special attention to sites in which land use change would occur based on the degree of disturbance of the original natural vegetation.

2. The water ordering with a vision of water safety, which considers reserving of volumes supporting ecological systems and balancing needs with other uses in critical grassland areas (GPCAs, ANPFs, AICAs, etc.).

**3.** Coordination with institutions and landowners to:

**a)** Implement and improve livestock practices that prevent the deterioration of the vegetation, and that have economic benefits for the producers implementing them.

**b)** Increase the efficiency of irrigation activities in agricultural areas.

**4.** Through the strategies above, maintain the integrity of the important pasture areas, as well as rehabilitate deteriorated sections, to the extent possible, while seeking connectivity among them through ecological conservation networks.

**5.** Continuous monitoring of ecosystem health, priority species, the human context, and economic production to facilitate sustainable exploitation of resources.

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# APPENDIX 1 - FINANCIAL ANALYSIS OF LIVESTOCK COMPARISON BETWEEN THREE PRODUCTION MODELS

A financial analysis was carried out using the methodology of evaluation of investment projects with the purpose of comparing the level of profitability of three livestock production models used in the grassland region in the state of Chihuahua, including the traditional model, the basic rotational model, and the ultra-intensive model. The models are explained in detail in pages 16, 17, and 18 of the present report.

To evaluate the projects, three cash flow statements were developed, which were projected over a period of 10 years in each of the modalities for three fictitious farms. The financial items and production parameters are based on information obtained through third-party sources: interviews with farmers through open and direct questions related to general countable data, equipment, food, medicines, the market, jobs, and salaries, among others, as well as the expense and cost structures. The validation of the financial models was made in direct consultation with farmers, as well as with the technical and administrative staff of Pronatura Noreste, who have more than 10 years' experience in the execution of sustainable livestock projects in the region. Once generated, the information was validated by our livestock partners.

## Methodology

Based on the productive and financial information collected from farmers in the region, 10-year cash flow projections were made for each of the production models evaluated. For the analysis, the traditional indicators used to value an investment project, the net present value (NPV), the internal rate of return (IRR), and the recovery time of the investment (PR) were estimated.

The exercise was carried out based on the following assumptions:

The livestock production system corresponds to the widespread cow-calf operation.

Virtual area of the farms evaluated: **4,200 ha**

The coefficient range for each evaluated production model was adjusted to the target load, based on the information obtained from the interviews with the producers. It is assumed that the target carrying capacity is already available from year 0 of the exercise. In other words, the exercise assumes that it is not passing from one model to another:

**Traditional:** 60 ha/UA/year
**Basic rotational:** 20ha/UA/year
**Ultra-intensive:** 10ha/UA/year

The rotation times for the basic rotational and ultra-intensive models are adequate to prevent the effects of overgrazing.

The initial investment in inventories is made up of pre-existing livestock at commercial value (auction) reflecting the opportunity cost.

The basic minimum infrastructure is available (e.g., driving yards, workers' houses, perimeter fence, etc.). It´s value is assigned to real estate and not to the production system. Therefore, the total cost of the land is excluded from the exercise.

The non-livestock investment is based on additional infrastructure needs per production model. This represents a real cash outflow (capital contribution).

The projections are 10 years. At the end of the 10 years, the value of the inventories is recovered (virtually) at commercial value (auction price).

The inflationary increase in the course of the years is not considered.
Risk variables are not considered.

## Results

| Conceptos | Tradicional | Rotacional básico | Intensivo |
|---|---|---|---|
| Investment | | | |
| Infrastructure | $0 | $900.000 | $6.000.000 |
| Livestock | $1.045.220 | $4.010.020 | $7.330.080 |
| | | | |
| Fixed costs | $203.574 | $410.027 | $419.771 |
| Costos Variables | $33.832 | $132.092 | $212.512 |
| Total | $237.406 | $542.119 | $632.283 |
| | | | |
| Sales revenue | $512.693 | $1.653.992 | $2.912.844 |
| Annual gross income | $275.287 | $1.111.873 | $2.280.561 |
| Administrative expenses | $275.000 | $275.000 | $275.000 |
| Operation profit | $287 | $836.873 | $2.005.561 |
| Operation margin | 0% | 51% | 69% |
| | | | |
| Ecosystem recovery time (years) | | 4 | 4 |
| ROI time (years) | | 5 | 6 |
| | | | |
| IRR | 0,00% | 17,00% | 15,00% |
| NPV (15%) | -$682.970 | $438,030.90 | $26,398.10 |

## Discussion

Based on the information obtained from the interviews with the farmers, as well as the experience of Pronatura Noreste's technical staff, the basic and ultra-intensive rotational livestock models, once established, increase productivity by improving the carrying capacity of the properties, with the potential to improve from 70 AU per total area to 210 AU and 420 AU, respectively. In addition, recovery of the degraded ecosystem was possible when moving from a traditional model to the basic rotational or the ultra-intensive model, approximately from the fourth year of initiation. This is because in the traditional model, the farmer's control over the foraging of the livestock is very limited, which leads to deterioration and decapitalization in natural terms, which is reflected in the continuous degradation of the land. In contrast, the basic rotational model and the ultra-intensive model establish subdivisions of the total area, where forage times according to the carrying capacity are determined for each one, which allows the programmed recovery of the vegetation.

It was verified through the financial analysis that the traditional model, based on the NPV (−$682,970), IRR (0.0%), and PR (0 years) values, is not a profitable option, because such a scheme tends to operate at the breaking point. Similarly, in increase in profitability in the basic and ultra-intensive rotational models was evaluated in comparison with the traditional model, and the values for the basic rotational model and the ultra-intensive model, respectively were as follows: NPV ($438,030.90); IRR (17.0%), and PR (5 years), and NPV ($26,398.10); IRR (15.0%), and PR (6 years).

When comparing the results between the basic rotational and the ultra-intensive models, internal rate of return and the net present value were higher in the basic rotational. The situation potentially reflects a phenomenon of diminishing returns to scale.

According to the data obtained, the basic rotational and the ultra-intensive models, compared to the traditional model, facilitate minimization of environmental impacts in terms of vegetation loss and soil erosion, while being profitable. Therefore, to raise the quality of life of the residents of the region, and to maintain the natural grasslands of the Chihuahuan Desert in a good state of conservation, we recommend the implementation of programs and public policies that seek to modifying traditional livestock models to direct them toward the basic rotational or the ultra-intensive model.