Conservation of Crop Wild Relative Species in Bolivia

An Outline to Identify Favorable and Unfavorable Factors

to Support a Conservation Program

by

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ABSTRACT

Since the Convention on Biological Diversity was established in 1992, more importance has been given to the conservation of genetic resources in the international community. In 2001, the International Treaty on Plant Genetic Resources for Food and Agriculture (PGRFA) focused on conserving plant genetic resources, including crop wild relatives (CWR). Some of these genetic resources hold desirable traits—such as transfer of plant disease resistance, improvement of nutritional content, or increased resistance to climate change--that can improve commercial crops. For many years, ex situ conservation was the prevalent form of protecting plant genetic resources. However, after PGRFA was published in 1998, in situ techniques have increasingly been applied to conserve wild relatives and enhance domesticated crops. In situ techniques are preferred when possible, since they allow for continued evolution of traits through natural selection, and viability of seed stock through continuous germination and regeneration. In my research, I identified regions in Bolivia and rated them according to their potential for successful programs of in situ conservation of wild crop relatives. In particular, I analyzed areas according to the following criteria: a) The prevalence of CWRs. b) The impacts of climate change, land use change, population growth, and economic development on the continued viability of CWRs in an area. c) The socio-political and economic conditions that might impede or facilitate successful conservation programs and outcomes. This work focuses on

three genera of particular importance in Bolivia: Peanut (Arachis spp.), Potato (Solanum spp.) and Quinoa (Chenopodium spp.). I analyzed the above factors for each municipality in Bolivia (the smallest scale for which appropriate data were available). The results indicate which municipalities are most likely to successfully engage in CWR conservation projects. Finally, I present guidelines for the creation of conservation projects that pinpoint some of the potential risks and difficulties with in situ conservation programs in Bolivia and more generally.

DEDICATION

To God, my strength and peace in the most difficult times. My joy and light. Estoy lista para seguirte!!

To the people in Bolivia and the need we have to wisely use our resources for the benefit of all.

“…science without conscience is but the ruin of the soul.”
François Rabelais

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION

For thousands of years farmers have used a wide variety of plants to obtain food. From season to season they would save seeds for future planting. This process produced several hundred crop plants that were domesticated from wild relatives (Damania, 2008). After significant domestication of wild crop relatives, the continued viability of the wild progenitors was neglected. Uncontrolled grazing and periodic slash and burn activities produced severe genetic erosion and destruction of some CWR habitat (though some CWR’s are found on the borders of cultivated fields (Damania, 1994)). During the 1960s and 1970s the goal of increasing crop production in developing countries led to the Green Revolution. The introduction of identical crop germplasms over very large geographic areas led to a reduction of diversity of the local land races produced by hundreds of years of development and selection. Today, we use mainly three crops (rice, wheat, and corn) and very few strains of each relative to the earlier diversity of landraces. This has reduced the diversity of crop species and strains we grow and consume, creating a loss of agricultural biodiversity (FAO, 1999).

Crop Wild Relatives (CWR)

Crop wild relatives include crop ancestors and other closely related species. CWRs can confer beneficial genetic traits in commercial crops through interbreeding or gene transfer—such beneficial traits include resistance to pest and disease, drought tolerance and improvement in the nutritional value of crops, (Maxted et al, 2008; Meilleur and Hodgkin, 2004; Stolton et al, 2006). In the long term, this improvement could enhance food security programs in many countries around the world. These crop wild relatives provide useful genes through natural or artificial introgression. This process is the origin of many of the land races or crop varieties that are used today (Cromwell et al, 2003).

The use of CWR can be vital for poor communities in terms of improving their crops with each new season to fight common threats like pests diseases and climate variability. For example, in South Africa, people in rural villages keep home gardens with a variety of CWR. They personally use up to a 70% of this production and sell the rest. These gardens are the places where regular crops can obtain new gene material from CWR through pollination or human mediation and adapt to local conditions. Several different countries have reported the use of CWR as a source of food during periods of famine and seasonal farming (Azzu & Collette, 2008). This is a low-cost, sustainable strategy for small farmers to increase food security. Small farmers around the world do not need to buy improved seeds or pay royalties for their crops (Mouillé, et al, 2010).

The contribution of CWR to food security programs extends beyond use by the community of small farmers. Biotechnology has been used to speed the transfer of useful genes coding for resistance to pests and disease, or higher tolerance in saline soils, temperature, or humidity (Prance, 1997; Hajjar & Hodkin, 2007; Hodkin & Hajjar, 2008). The introduction of genes in crop plants has been easier and more effective when genes come from close relatives of the crop. Single-gene-controlled traits introduced from CWR to crops through biotechnology methods have provided virus resistance in rice, blight resistance in potato, powdery mildew resistance in wheat, and nematode resistance in tomato (Maxted et al, 2008). Hajjar and Hodgkin (2007) review the presence of CWR genes in released cultivars of 13 crops of international importance (wheat, cassava, millet, rice, maize, sunflower, lettuce, banana, potato, groundnut, tomato, barley and chickpea).

Threats to CWR

Given that it is difficult to quantify genetic erosion, it is important to identify the threats that could increase genetic loss in CWRs (Maxted et al, 2008). As part of biodiversity more generally, CWR are under increasing threat from factors such as: deforestation, mining, habitat fragmentation, urban expansion, introduction of exotic species, land clearing, changing agricultural systems, overgrazing, over-exploitation by humans, climate change, and inappropriate legislation and policy (FAO, 2010).

The threat of climate change to CWR is highlighted in a study focusing on three important crop genera: *Arachis* (peanut), *Solanum* (e.g., tomatoes and potatoes) and *Vigna* (e.g., beans) (Jarvis et al, 2008). The study predicts that 16–22% of species in these genera will become extinct before 2055 due to climate change. While some species are affected by habitat fragmentation, others (like potato) find disturbed environments suitable for migration. In the same way, some species adapt more easily to climate change than others. *Arachis* (peanut) is an example of genera that is highly vulnerable to climate change impacts.

The first State of the World Report on Plant Genetic Resources (FAO, 1998), estimated that since the beginning of the 1900s, about 75% of the genetic diversity of agricultural crops has been lost. One reason that the report highlighted is the widespread abandonment of genetically diverse traditional crops in exchange for genetically uniform modern crop varieties.

This change in practices is creating widespread loss of genetic diversity. In addition, when there are natural disasters, war, or civil strife, local seed availability may be severely diminished; seeds and other propagating materials may be lost or eaten; supply systems may be disrupted; and seed production systems may be destroyed (FAO, 2010). Not only are the world's plant genetic resources (PGRs) unevenly distributed but so is the capacity to use them. Most developing countries lack the infrastructure and breeders to improve crops with biotechnology (Kowalsky, 2002).

International framework for CWR conservation

The importance of the conservation and sustainable use of CWR is recognized in a number of international agreements and fora. The United Nation's Food and Agriculture Organization (FAO), through both its Commission on Genetic Resources for Food and Agriculture and its Global System for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture, is the international organization that is involved in the international policy context of CWR (FAO, 2006). The main objectives of the Commission are to ensure the conservation and sustainable utilization of genetic resources for food and agriculture, as well as the fair and equitable sharing of benefits derived from their use, for present and future generations. The Global System's objectives are to “ensure the safe conservation, and promote the availability and sustainable use of, plant genetic resources by providing a flexible framework for sharing the benefits and burdens” (FAO, 2006a).

In 1991, the FAO Conference encouraged the production of a first Report on the State of the World’s Plant Genetic Resources for Food and Agriculture. One of the main conclusions of this report was the need for an integrated approach to the conservation and utilization of the Plant Genetic Resources for Food and Agriculture program (PGRFA) (FAO, 1998).

A new report, published in 2010, shows an increase in concern and awareness for WCR conservation (FAO, 2010). There also has been an increase in the *ex situ* conservation approach, with more accessions to gene banks and exchange among them. The *in situ* conservation approach now has more surveys and inventories of species since the first report was published. This kind of conservation still occurs mainly in protected areas, and less attention has been given to conservation in places outside these areas. There is therefore a need to encourage farmers and local communities to sustainably use their agricultural biodiversity (better and more clear policies, legislation, regulations for *in situ* and on-farm management) (FAO, 2010).

The Convention on Biological Diversity (CBD) defines agricultural biodiversity as all components of biological diversity of relevance to food and agriculture and that constitute agroecosystems: the variety and variability of animals, plants and microorganisms at the genetic, species and ecosystem levels, which are necessary to sustain key functions of the agroecosystem, and its structure and processes (decision V/5 of the CBD, 1992). One dimension of agricultural biodiversity identified by the CBD that is of relevance to CWR refers to genetic resources for food and agriculture; these constitute the main units of production in agriculture, including cultivated species, domesticated species, and managed wild plants, as well as wild relatives of cultivated and domesticated species.

In its new 2020 targets, the CBD seeks to stop the loss of genetic diversity of cultivated plants and wild relatives (CBD, 2010). At the same time, strategies have to be created and implemented to “preserve the genetic diversity of other priority socio-economically valuable species as well as selected wild species of plants and animals”. In addition, both *ex situ* and *in situ* conservation of wild relatives of crop plants and other socio-economically valuable species should be improved inside and outside of protected areas (CBD, 2010).

During the past decade, the parties to the CBD agreed that the priority at this time lies in facilitating the implementation of the Ecosystem

Approach (EA) for all biodiversity conservation actions. The EA defines 12 principles related to the holistic management of land, water and living resources, and provides five points of operational guidance (CBD, 2002). As Azzu and Collette (2008) recognize, “it is important to conserve CWR within the context of the ecosystem as a whole, given their important contribution not only to ecosystem health and resilience, but in the provision of essential ecosystem services.”

First conservation actions

Until the mid 1990s, the main method of agricultural biodiversity conservation was the collection and storage of seeds in national and international gene banks as part of an *ex situ* strategy. This strategy today is recognized as limited but complementary to *in situ* conservation; it can serve as a useful counterpart *to in situ* conservation as long as samples can be protected from genetic contamination (Mulvany and Berger, 2003).

There are two main advantages of preserving a CWR ecosystem rather than just an individual species *ex situ.* The first is that *in situ* conservation allows the process of evolution by natural selection to continue, and thus the species adapts to its current environment, even as that environment is changing. Prance (1997) suggests that a second advantage is the avoidance of the complicated technology used in the large and sophisticated facilities devoted to *ex situ* conservation. In addition, seed banks are most effective for seeds from temperate regions, where a period of dormancy is natural. In the case of tropical seeds, some plants have recalcitrant seeds and others do not even qualify as orthodox or recalcitrant (Baskin and Baskin, 2001). Orthodox seeds can survive drying and/or freezing when kept on *ex situ* facilities. On the other hand, various CWR are native to rainforest ecosystems where most of the seeds are recalcitrant (they do not survive drying and freezing during *ex-situ* conservation).

The concept of *in situ* conservation of PGRs has been expanded to include the maintenance of varieties and cultivars of crop plants in agroecosystems (Azzu and Collette, 2008). Agroecosystems can maintain their stability and ecological equilibrium with the help of human communities that exchange seeds from local crops with CWR seeds and let natural cross-pollination take place. In some countries, this practice is part of tradition and cultural practice; the variety, production, storage and exchange are components of a dynamic agro-ecosystem. This system becomes an important source of seeds for food crops for small farmers in developing countries (Damania, 2008; Louette, 2000; Almekinders et al 1994).

Global Environment Facility (GEF) Project on CWR. In 2004 the Global Environment Facility (GEF) decided to implement a project focused on the *in situ* conservation of CWR in five countries. The three main factors they considered when choosing the countries were: whether the country had high levels of native biodiversity; whether the country had more than five CWR species of world importance; and whether the country had a high poverty level. Armenia, Bolivia, Madagascar, Sri Lanka and Uzbekistán were the countries chosen (VBRFMA, 2009). The main objective of this project was to build a database on the *in situ* distribution of CWR in these five countries.

After six years, the project outcomes include an international information system that supports the conservation of CWR in different countries. An increased awareness of the need for safe and effective conservation of CWR and their availability for crop improvement in these five countries is the other outcome of this project (UNEP-GEF, 2008).

In Bolivia, the participating institutions synthesized information from different sources and did fieldwork. Using the information included in gene banks for the selected species, botanists in Bolivia made new collections in the areas registered in the accessions notes from the gene bank. They also added, whenever possible, new distribution points for species. They identified 195 species of CWR from 17 genera (*Anacardium, Ananas,* *Annona, Arachis, Bactris, Capsicum, Chenopodium, Cyphomandra, Euterpe, Ipomoea, Manihot, Phaseolus, Pseudananas, Rubus, Solanum, Theobroma y Vasconcellea*). Among the final products of this project was the Red Book of CWR in Bolivia (Mora et al., 2009), and geo-referenced maps containing the locations where species were collected.

Given this background, my overarching question is: What are the opportunities for, and barriers to, conservation of CWRs in Bolivia, particularly with respect to potato, peanut and quinoa?

Objectives

My first objective for this project was to identify regions in Bolivia and rated them according to their potential for successful programs of in situ conservation of wild crop relatives. In particular, I analyzed areas according to the following criteria:

a) The prevalence of CWRs.

b) The impacts of climate change, land use change, population growth, and economic development on the continued viability of CWRs in an area.

c) The socio-political and economic conditions that might impede or facilitate successful conservation programs and outcomes.

My second objective was to use this information to elaborate a set of recommendations that can promote the implementation of future conservation projects for WCR's in Bolivia.

The study took into account the distribution area of 3 species in each of 3 genera, for a total of 9 species. To identify the opportunities, I used the municipality division as my area of analysis since the data is available in this scale. This also made it easier to identify if certain municipalities would have potential interest in CWR conservation projects. The analysis used primarily geographical information system tools to identify the relationships between different factors analyzed in this study.

In order to understand why I chose my area of analysis and variables, it is important to review some information about the Plurinational State of Bolivia. In the next part I will describe some socio economic factors and ecological features of the country.

Plurinational State of Bolivia – General Framework

The Plurinational State of Bolivia (Bolivia) is the fourth poorest country in South America with a gross domestic product per capita of $14, 715 (USD). There is a population of approximately 10,227, 299 habitants and a low density of 21.8 habitants per square mile (INE, 2007).

The main exportation products are: natural gas, zinc, gold, silver, soybean and sugar (WB, 2011). The country is divided politically into (in order of decreasing size) departments, provinces, municipalities and cantons.

Bolivia is also classified as a megadiverse country. Located between the Andes and the Amazon, it has 22 different eco-regions. The Chiquitano Dry Forest is the only endemic eco-region of Bolivia (Ibish & Mérida, 2004). The 22 eco-regions are grouped into 3 main regions: The high Andean region and *altiplano*, the eastern Andean slopes and inter-Andean valleys, and the lowlands (Ibish & Mérida, 2004).

- The Andean region covers 28% of Bolivia. It is characterized by high montane tropical vegetation. Elevation varies from 3,200 to 7,000 m. Monthly temperatures range from < 0 to 10°C.
- The Eastern Andean slopes and Inter-Andean valleys cover 13% of Bolivia and are mainly composed of valleys and Yungas (the Andean per-humid forests on the northeastern slopes of the Andes). The average altitude is 2,500 m. Monthly temperatures range from 15 to 25°C. This area is characterized by its agricultural activity.
- Lowlands cover 59% of Bolivia. The altitudes range from 100 to 1,000 m, and extend from the humid Amazonian forest of Pando to the dry Chaco forests in the southeast of the Santa Cruz and Tarija departments. Monthly temperatures range from 23 to 28°C.

Fig 1. Bolivia - Political division and ecosystems.

Political situation. As a result of the colonial regime, indigenous people were marginalized for many decades until 1952, when the first Agrarian Revolution took place. Since then, indigenous groups have increasingly participated in the political life of the country and demanded recognition of their rights to land and natural resources management. However, many of the political parties that first promised to listen to these demands later neglected them (Do Alto, 2007).

The 1990's brought a new set of regulations, with the introduction of the Neoliberal model for all policies and environmental rules. The government signed many international treaties, and welcomed the cooperation of international agencies like Conservation International (CI) or World Wide Fund for Nature (WWF). The first Department on Environmental Issues in South America was established together with the environmental legislation; in addition, the Natural Protected Areas System emerged as a priority in Bolivia's national policy.

For the past decade, Bolivia has experienced a set of changes in its political organizations and social movements. The transition was from a model where the central government had total control of all management in the country, to a more decentralized model, where smaller scale governments (municipalities) have new responsibilities and duties. These changes are the product of regulations from international agencies like the World Bank (WB) and the International Monetary Fund (IMF), but also from different social movements that emerged out of the class struggle.

The most recent change of political parties in the central government brought some additional changes to the environmental field. The new Constitution recognizes that all natural resources are the property of the nation and that any economic activity related to them should benefit Bolivians and their social development. Indigenous groups are legally recognized and moreover, their ownership of the natural resources they use is recognized. The second Agrarian Revolution started in 2008 and intends to distribute land to all indigenous groups in Bolivia.

In this political environmental context, implementing conservation projects for WCR is an alternative way for rural communities in Bolivia to act as stewards of their resources and potentially be economically compensated.

Municipalities as analytical unit

Bolivia is divided into nine departments and each one is further divided into provinces. Each province is divided into municipalities and these are also divided into cantons. In total, Bolivia has 332 municipalities. The decentralization process empowered municipalities over provinces, giving them the chance to administrate and execute their projects with state funds or international aid.

Murphree (2005) mentions five principles for policy-making in the CAMPFIRE project executed in Zimbabwe. One of these principles remarks on the importance of considering a smaller scale where more efficiency can be achieved through communal resource management, where members can have meetings face to face and enforce conformity through peer pressure. Hence, I considered the municipality as the appropriate scale of analysis in my project; it is small enough to allow focused and context-sensitive resource management, and has the political legitimacy to do so. In addition, many of the data required for my analysis are available at the level of the municipality.

Aside from the improvement of their crops and land races to resist disease outbreaks and climate change, there are other benefits that the municipality can obtain from promoting the conservation of WCR's. There may be certain intellectual property rights they can claim, or they may be able to market certain genetic properties that could confer benefits on more distant crop complexes. Aguilar (2001) describes how some indigenous communities in Peru and Ecuador have received legal assistance from US universities, who are paying royalties to use their knowledge and the variety of crops they domesticated and registered under international intellectual property rights treaties.

Bolivia and the CWRs

The use of CWR in Bolivia is diverse. Mostly these wild relatives are used to enhance the quality of traditional crops, by making them pest or disease resistant, or by giving them additional nutritional properties. Some communities use CWR as a direct food product, using them an alternative to satisfy their nutritional needs. However, increasing problems like land use change, road construction, and human population migration may represent a threat to the ecosystems that shelter these CWR, and thus to the CWR themselves (Hunter, 2008). In the State of the World's Plant Genetic Resources for Food and Agriculture report from 2010, Bolivia reported 38 underutilized CWR species for which various conservation activities were taking place, but little full-scale breeding (FAO, 2010).

Until the execution of the GEF project on CWR, there was little effort to try to conserve these resources *in situ*, with more emphasis on *ex situ* conservation. PROINPA Foundation (Fundación Promoción e Investigación de Productos Andinos – Research and promotion of Andean products) and AGRECOL Andes (Agricultura y Ecología; Agriculture and Ecology) are two national institutions that have worked on projects related to WCR. PROINPA started during the 90s to build gene banks for tubers and other Andean roots as well as for quinoa and other Andean grains. These gene banks also worked with rural communities and introduced the idea of local gardens for some crop varieties and also some CWR that were used for breeding new crops (Rojas, et al. 2001; Terrazas *et al*, 2005; Garcia and Cadima, 2003).

AGRECOL Andes has noted the importance of CWR both for breeding new crops adapted to specific climates and soils, and for use as food sources. AGRECOL Andes has promoted different local seed exchange events among local producers and workshops focused on techniques to improve the use of traditional crops (IFOAM, n. d.; APECO, 2005).

In the remainder of the thesis I will cover in Chapter 2 the methodology I used and the reason why I chose the variables I chose. Chapter 3 covers the results. Chapter 4 is a synthesis of the results, where I summarize for each of my species the state of each municipality according to the variables I have considered. Chapter 5 and 6 cover conclusions and recommendations.

Chapter 2

METHODS

Assessment for CWR conservation

The new targets set by the CBD in 2010 (CBD, 2010) suggest that in order to decrease the loss of genetic diversity of crop and other wild species of plants conservation programs for *in situ* conservation of crop and selected wild species should be included in national biodiversity strategy and action plans. *The State of the World's Plant Genetic Resources for Food and Agriculture* (PGFRA) report suggests that in order to achieve an effective conservation of PGRFA in areas that are not protected, social and economic issues must be addressed (FAO, 2010).

The assessment of threats to, and conservation status of, CWR has often been neglected (Maxted et al 2008). CWR are a public good and their conservation has a strong link with public institutions focused on natural-resource management and conservation, and the need to build awareness of and support for conservation in society. Therefore governments should include conservation strategies in their national plans. Sometimes these national strategies and action plans are developed in or borrowed from different countries, however, and hence pay little attention to local contexts. Alcorn (2005) suggests that conservation projects should take a closer look at cultural habits, function, and shape of communities closely related to the conservation of certain species or ecosystems.

During this study I did an assessment of the effects of certain threats to selected crop wild species, and also assessed the social and economic conditions that might contribute to successful conservation projects.. There is no established methodology for conducting this kind of assessment, but I used the literature, including experiences from past conservation projects, to assess threats and opportunities that can have an impact on the conservation success of the selected species. In the next part I will explain how I selected the species, and the threats and opportunities included in my analysis.

Selected species

For the purpose of this thesis, I decided to concentrate my analysis on 9 species selected from a project executed in Bolivia by the Government with financial support of GEF. The GEF-supported project on CWR increased interest in the *in situ* conservation of CWRs in Bolivia, and was the first step in generating a detailed taxonomic list and distribution of collection points for CWR in the country. The geographic information for some *ex situ* samples was also verified in the course of the GEF-supported project, providing new distribution information for the species. More research has been done with three genera (potato, peanut and quinoa) than any others in Bolivia. This was the main reason to choose these genera for this study.

In Bolivia, most CWRs have no direct commercial use *per se,* although they are often used at the local level. For instance, in the north of Potosí, some wild varieties of quinoa produce a black grain that is used locally by producers to make crackers. In Cochabamba, some wild potato relatives that are known locally are used in food preparation. Some wild species of peanut are used as food for farm animals (Mora et al, 2009). Until recently, there were no urban or distant markets for these resources. Without commercial markets, CWR conservation is often less attractive to peasants and farmers, who prefer to invest in crop production that yields greater economic benefit, or other activities that yield a return, such as mining. More recently, there has been some attempt by companies and NGOs to try to create markets for CWR products, though progress has been slow (AOPEB, 2011).

The GEF-supported project rules precluded access to all data collected for all CWR species in Bolivia and also restricted the number of species per genus for which I was entitled to have data. In coordination with project administrators, it was determined that I would have access to all the collection-point data for three species from each of the three genera of interest. Distribution of these 3 genera covers parts of the Andes, Inter-Andean and valleys, and lowlands region. The species chosen had at least two described potential uses, like resistance to some plant disease or insects, tolerance to temperature or precipitation change, or as food or medicine. This information was retrieved from the Red Book of crop wild relatives from Bolivia (Mora et al., 2009).

A second variable considered in selecting the target species was the percentage of land in each municipality housing the species that is registered with clear property rights. For this part of the analysis, images with information on land tenure process were used and later mapped onto geo-referenced municipalities. In order to have species that represent three levels of established property rights, the following were selected:

1. One species whose range encompassed an area with a high percent of land registered (50% to 100%)
2. One species whose range encompassed an area with a moderate percent of land registered (20% to 50%)
3. One species whose range encompassed an area with a low percent of land registered (0 to 19%)

IUCN risk category was not a variable used for choosing any of the species, as all are under some level of threat category according to the

Red Book (Mora et al., 2009). Below I give a brief description of each of the species selected.

1) Peanut (*Arachis sp.)*

Arachis hypogea. In Bolivia, wild species of peanut are distributed in lowlands of the Chaco region, which includes departments of Chuquisaca, Santa Cruz and Tarija. All wild peanut species have a characteristic that makes them vulnerable to disturbance. They are all geocarpic (plants that fruit below ground) and this limits their seed dispersal. Therefore, their distribution is limited. In general, wild peanut relatives, unlike the domesticated peanut crop, have a preference for dry to sub-humid habitats, sandy soils, open spaces in the middle of *chaqueño* dry woodland[1] or *cerrado* type forests. It is possible to find them as part of weed communities, on roadsides, and clearings (Atahuachi & Guzmán, 2008).

Atahuachi and Guzmán (2008) created a summary of the taxonomy, distribution and ecology of peanut WCR. They found 20 species of wild peanut in Bolivia, of which 12 are endemic to the country. I

[1]Chaqueño dry woodland is composed of low forests, schrubs, dry savannas, and humid soils that cover the mountain range and part of the Chiquitania in Santa Cruz, Chuquisaca and Tarija. Its altitude is between 300 m and 600 m close to the bottom of Andean mountains (Killen, et al, 1993).

reviewed the ones described in the Red Book and chose the following based on my criteria above:

Arachis batizocoi. This wild peanut species grows in open areas in "soto" forest (forest composed of young trees, shrubs and weeds). This species prefers well-drained sandy soils and mountainous habitats with soils derived from sandstone (Atahuachi, 2009). This species is housed in municipalities with well established land tenure. This species is resistant to drought and also resistant to diseases such as early spot (Mora et al, 2009).

Arachis duranensis This wild peanut species grows in open areas, as a roadside weed, and, less frequently, on the edge of "soto" forest. The area where it is found is a transitional biographical strip between Chaco and the Bolivian-Tucuman area, with a dry tropical bioclimate (Atahuachi, 2009). This species is found in municipalities with moderate amounts of land registered in the tenure process*. A.* duranensis is drought tolerant and resistant to rust. It is considered an ancestor of the tetraploid species *Arachis hypogeaea* and *A. monticola* (Mora et al, 2009).

Arachis ringonii. This wild peanut species apparently used to grow on sandy soils in the streets of the city of Santa Cruz. The species reported in the Red Book were found in house gardens (Atahuachi, 2009).

It seems that urban development is the main threat to this species, as land is used for housing and roads are paved. This species is found in municipalities with relatively low amounts of land registered in the tenure process. It is important for its capacity of inter-species crosses and the hybrids produced have high fertility (Mora et al, 2009).

2) Potato (*Solanum sp.*)

Solanum tuberosum is the crop we know as potato. The crop is best adapted to cool climates such as the tropical highlands with mean daily temperatures between 15 and 18°C as encountered in its center of origin, the mountains of South America. Higher temperatures favor foliar development and retard tuberization (Ewing and Struik, 1992). Lower temperatures would hamper early plant development (Haverkort, 1990).

According to Patiño *et al* (2008), there are 34 wild species of potato in Bolivia, of which 21 are endemic. Some of these species are distributed over large areas, while others are only found locally. These latter species are identified as being vulnerable to the expansion of agriculture and urban borders, as well as to changes in temperature and precipitation regimes. Below is a brief description of the three species chosen for this genera.

Solanum alandiae. This species prefers disturbed areas near cropland. It is common on the edge of streams and riverbanks and grows in the inter- Andean valleys (Patiño, 2009). This species is found in municipalities with a relatively high percentage of land registered in the tenure process. It is important for its resistance to potato wart disease, soft rot and flea beetles (Mora et al, 2009).

Solanum boliviense* subsp. *astleyi. This species is found in the upper montane ecological belt. It grows in zones with stony soils where small tree species, shrubs, and cacti grow (Patiño, 2009). This subspecies is found in areas with relatively little land registered in the tenure process. This subspecies is resistant to pathogenic fungi, to bacteria, bacteria wilt, and a virus (PVY). It also has resistance to beetles, flea beetle, and nematodes, and frost (Mora et al, 2009).

Solanum gandarillasii. This species is associated with thickets of short trees or “soto” forest species or with xeric forests. It is found to grow on poor hard, dry clay soils (Patio, 2009). This species is found in areas with moderate amounts of land registered in the tenure process. It is drought resistant and resistant to attack by insects such as tarnished plant bug (Mora et al, 2009).

3) Quinoa (*Chenopodium sp.*)

Quinoa is well adapted to the low temperatures occurring on the Andean *Altiplano*. The seeds are likely to germinate rapidly even at low temperatures (Bois et al, 2006). Most wild species are found in the high Andean region, where they are found among potato, wheat, tarwi, corn and faba bean crops. They are also associated with grassy and herbaceous patches. In the valley region, they are also found in the middle of herbaceous vegetation where soils are semi-humid and dry in the middle (Rojas et al, 2008).

Chenopodium hircinum. This species is found in the xeric semiarid Puna region in the middle of fields of potato and barley. Its habitat is foothills on dry saline soil rather than the hillside or near the salt flats (Mamani et al, 2009). There is a relatively low percentage of land registered in the tenure process in areas where this species is found. Its leaves and grains are widely used in cooking by rural inhabitants. It is used also as a medicinal plant (Mora et al, 2009).

Chenopodium hircinum* subsp. *eu-hircinum. This subspecies grows in the middle of fields of cultivated potato, barley, and maize. These crops can be on plains or hillsides. In the valley regions, the species is found in “soto” forest (Mamani et al, 2009). Land tenure is well established in areas where this species is found. This species is used for cooking and seems to have a resistance to drought (Mora et al, 2009).

Chenopodium hircinum* subsp. *catamarcensis. This species is found in fields where potato, regular quinoa, “oca”, “izaño”, maize, barley, and vegetables grow. These crops are found in plains, hillsides and valley bottoms where soils are dry and lack irrigation (Mamani et al, 2009). This species covers an area with medium land tenure. The uses are mainly for cooking and as a medicinal plant (Mora et al, 2009).

Selection of municipalities

After selecting the species, I obtained the original shape files with the collection points for the GEF project. These files come only with the geo-referenced points. To create approximate range maps for each species, I used an ArcGIS tool, developed at Kew Botanical Gardens, called the Conservation Assessment Tool – CATS (Moat, 2007). This tool is the same as that used in the Red Book of CWR for Bolivia (Mora et al., 2009). Given the distribution points of a single species, the tool identifies a polygon that encompasses all distribution points. This is the species distribution area. For each point, the CATS tool finds the relation between each point and delimits the polygons for subpopulations of the species.

This last variable is called the Rapoport area. I used these polygons that represent the subspecies distribution area and found which municipalities where in these areas. I did not use other areas calculated with CATS as topography in Bolivia is diverse and species distribution is heterogeneous in this geography. In total, 93 municipalities were selected (many housing more than one species). For the quinoa species I had to apply another vegetation filter. This species grows in an altitude range over 2600 m. and covers Inter-Andean valleys. This part of the country is not flat and vegetation is grouped in different patches according to their requirements. Quinoa usually grows in association with particular types of vegetation. Therefore, once I had the distribution areas, I used a vegetation map to overlay over these areas. Then I used the intersect tool, so only the vegetation that was associated with the distribution points that was inside the Rapoport area (subspecies), could be selected. This reduced the number of municipalities considered for quinoa.

Below, I introduce the indicators I used to represent threats to each species, as well as those used to indicate the municipalities where social and economic conditions might prove favorable to conservation projects. I end with a summary table indicating the relationship between each indicator and potential conservation outcomes.

Potential Threats to CWR

Ideally, I would have included in this analysis information on deforestation, fires, and land use change, because these are important threats to the status of CWR. These data, however, were not available in the needed formats. I therefore focused on threats from climate change, mining concessions, oil concessions, and population growth (as a proxy for land-use change and disturbance).

Climate change. The challenges caused by temperature and precipitation regime changes around the world are a good reason to look for crops that are resistant/tolerant to these variations, or have broad enough climatological ranges that they can continue to persist in at least part of their range even under climate change. Jarvis et al (2008) concluded that some CWR are more vulnerable than others to climate variations, such as temperature increase and precipitation decrease. Some wild potato relatives can actually benefit from predicted climate changes.

I assumed the distributions for my target species were determined by temperature and precipitation requirements, and used the areas of their distributions to determine the range of temperature and precipitation regimes in which the species could persist. Climate data came from 26 weather stations distributed throughout Bolivia, and extended from 1994 to 2009. For temperature, the monthly average was used to calculate the annual average and then the 15-year average. I did the same for precipitation.

Using the analyst tool from ArcGis, I used the nearest neighbor interpolation tool to produce a map with the temperature and precipitation ranges in the country. By overlapping the area of distribution for each species, it was possible to establish the boundaries for temperature and precipitation for each one of the species and then compare that with the expected climate changes in different regions.

I then reviewed climate-change predictions for South America, and chose the one produced by Urritia and Vuille (2009). Their model was the only one adapted to the Andean mountain chain and its influence on climatological outcomes for the rest of the continent (Table 1).

After I produced the maps with current temperature and precipitation distribution. I calculated the temperature and precipitation range for each species. I then determined future climate conditions in each of the municipalities, and identified those where the new temperature or precipitation regimes were assumed to fall outside of the species' tolerance.

Table 1.

Climatic model for tropical Andes – Simulations for the end of the 21st century (Urritia, R. & Vuille, M. 2009)

Model	Scenario	Variations	Temp	Rain	Notes
Hadley Centre Regional Climate Modeling System Precis (HadRM3)	RCM-A2 RCM-20C A2 has higher temperatures than B2	T increase 2-4°C depending place. B2 PP. increase south of 0 °S except the Andean region	West Slope Increase 1.5°C Eastern up decrease - 0.8°C Eastern low decrease -0.6°C	West slope (-50mm) East up 220 mm East down (-380mm)	Year projections 2071–2100. South America 10°NA27°S and 86°WÀ44°W 50km x 50km

Mining activity and oil concessions. One of the major economic pillars in Bolivia is the extraction of minerals and petroleum. In 2008, mining activity contributed 54% of the country's GDP, with the extraction of hydrocarbons contributing 11.34% (INE, 2008).

Both activities can produce landscape and environmental effects that negatively impact species, including CWR. Mining activity alters soil characteristics (density, texture, carbon levels, pH), and also causes water pollution (Indorante et al*,* 1981; Adler et al, 2007), among other things. At the same time, both mining and oil extraction often provide more economic resources than agricultural activities, and may cause a net loss of the agrarian labor force. This may further erode support for conservation of wild crop relatives.

The hypothesis for this variable is thus that municipalities with more mining/oil concessions will pose greater threats to CWR, both in terms of destruction of resources and habitat, and in terms of lower interest in conservation status. Nationwide data on mining and oil concessions are available for 2006 and 2001, respectively. (Super Intendencia de Hidrocarburos, 2001, SERGEOTECMIN, 2006).

Population. Most environmental assessments that analyze the sociopolitical situation of a region to evaluate or measure the impact of a certain project include population. Some places of biodiversity interest are under pressure from population density and growth; growing populations co-opt more resources and accelerate land-use change (USAID, 2005). Some publications reflect that a reduction in rates of population increase can promote environmental sustainability (Saito & Spurling, 1992; Stedman-Edwards, 1997). Population dynamics can have different effect over different ranges. For example in some areas with low population density, increases in population may present an opportunity for conservation of CWR species, both because some species prefer slightly disturbed habitats, and because they can thrive in home gardens or under the stewardship of agrarian populations.

This variable was analyzed using the population growth rate from 1992 to 2001 and the population density in 2001 (INE & PNUD, 2005). For each species, the analysis was done using a dispersion graph, with population growth rate on the Y-axis, and population density in 2001 on the X-axis. Each point represents the situation in each municipality where a particular species is present. I analyzed each dispersion graph for positive, negative, or neutral impact on the species based on its growth preferences. For instance, for a species that *requires* significant amounts of undisturbed habitat, high population density and/or high population growth rates are considered a threat. For a species that requires moderate amounts of disturbance to persist, the extremes of both population density (very high or very low) and growth rate (very high or very low) were considered detrimental to survival. See Tables 3-5 for the analysis for each species.

Social and Economic Conditions Providing Opportunities for Successful Conservation

In this section I describe the socio-political and economic indicators that I have used in my analysis and represent “opportunities” for successful conservation projects. I have selected these variables after reviewing the literature on what does and doesn’t work in conservation. At the end of this section I present a chart summarizing the species and the potential impact each variable could have on them. Table 2 presents a summary of the variables that were used for this part of the study and their hypotheses.

Table 2.

Hypotheses for each variable

Variable	**Effect**	
Literacy rate	↑	Positive for conservation
Women in government	↑	Positive for conservation
People in agricultural labor	↑	Positive for conservation
Land Tenure	↑	Positive for conservation
Mining concessions	↓	Negative for conservation
Oil concessions	↓	Negative for conservation
* Climate	Depends on current climatic tolerances	
* Population	Depends on how well species tolerate disturbance	

Literacy Rate. Communities with basic education (people can read and write) can improve their ability to design, participate in, and execute a conservation project (Murphree, 2005; Wilson 2005), and to determine the relative benefits of each project. With some external financial support, they can also systematize their knowledge and implement it in a conservation strategy (Colchester, 1995; Wilkie et al, 2006). Education can also strengthen evaluation and feedback processes. Some communities could even claim intellectual properties for their traditional knowledge or their crop varieties obtained from CWR's. Basic education would help them to understand and manage these intellectual properties systems and international rules.

The hypothesis for literacy rate is the same for all species considered; conservation outcomes are assumed to improve as literacy rates increase. The data on literacy rates are taken from the last census in 2001 (INE & PNUD, 2005). Using ArcGis, I created a map for this variable.

Women involved in local government. Gender equity can be an indicator of social justice in particular locations. High levels of women participating in local government could reflect the right to participate at all levels of the policymaking process, the right to self-representation and autonomy and the right to political, economic and cultural self-determination (Brechin et al, 2002). With the new decentralization model in Bolivia, each local government should allow women to participate as representatives in the management or governance process.

The World Bank supports projects that include gender equity. For example, it takes into account the local mores such as whether women can be in the presence of unrelated men (Gross et al, 2001). Women are also often the stewards of CWRs. While men usually take care of commercial domesticated crops and are concerned with increasing production, women (either as individuals or in groups) often preserve wild varieties and seeds for food security (Shiva, 1999; PROINPA n.d. and FAO, 2010).

My hypothesis is that more women participating in local government leads to more positive conservation outcomes. Data on gender distribution in local governments are available from the last election in 2010 (ACOBOL, 2010). These data were mapped for each of the 93 municipalities.

People involved in agricultural activity. Traditional agriculture often depends on crop diversity, and smallholders often plant different species and varieties of crops in different spatial and temporal cropping systems to reduce risk and ensure stabilized yields (Altiere & Merrick, 1988; FAO, 2010). As farms and output grow, however, this pattern of heterogeneity on the landscape can give way to greater homogeneity and extensive monocultures. In general, I hypothesized that the higher the percent of the labor force engaged in agricultural activities, the higher the likelihood that the populace would see the value of conservation activities devoted to CWR. The exception was extensive large-scale, commercialized agricultural production, which I took to have a negative impact on many CWRs.

The last two censuses report the two main working groups for each municipality. Crop-based agricultural workers are aggregated with those raising cattle or other livestock, and with those working in fisheries. The data used are from the last census in 2001 (INE & PNUD, 2005). Again, I mapped the percent of people working on agriculture for each of 93 municipalities.

Land Tenure. One of the objectives of the present government is to grant land tenure to all national citizens with a legitimate claim. According to Wells et al (1999), Murphree (2005), and Borrini-Feyerabend and Tarnowski (2005), possessing rights to land and its resources by law promotes the interest and participation of communities and local governments in conservation projects. For example, Gartlan (2004) compared 2 projects in Cameroon and concluded that biodiversity conservation projects cannot succeed where there is ambiguity and antagonism over land tenure.

The hypothesis for land tenure is: municipalities with more land under ownership have more interest in engaging in conservation projects. The data available have been collected from 2006 to 2009 (INRA, 2010).

Following I summarize the hypotheses for each genera. Some variables have the same hypotheses for all the species (table 3, 4 and 5).

Table 3.

Hypotheses and predictions for peanut. Arachis spp.

Variables	***Arachis batizocoi***	***A. duranensis***	***A. rigonii***
Climate change	Each species has its own temperature range and its own Primary threat to these species is an increase in precipitation.		
Population	Species can tolerate moderate disturbance (moderate density and growth combinations).	Species can tolerate moderate disturbance (moderate density and growth combinations)	Species requires relatively low disturbance.
Mining/Oil Concession	Municipalities with more mining/oil concessions are not interested in CWR as a source to improve their local crops and hence their agronomic production.		
Literacy Rate	Higher rates of literacy are assumed to be beneficial to conservation outcomes.		
Women in Gov	Higher levels of women participating in local government are assumed beneficial for conservation outcomes		
Persons in Agriculture	More people involved in agriculture activities have more interest in alternatives to improve their crops, as well as to open new markets in urban areas. For peanut, there can be a threat in terms of producers where commercial landowners are involved.		
Land Tenure	A higher percent of land with property rights is positive. However, if category of use is for commercial cropland, there is a threat.		

Table 4.

Hypotheses and predictions for potato. Solanum spp.

Variables	***Solanum alandiae***	***S. boliviense subsp. astleyi***	***S. gandarillasii***
Climate change	Each species has its own temperature range and its own precipitation range. An increase in temperature and a decrease in precipitation can be harmful for these species.		
Population	High density and high growth rate put this species in danger.	Species can tolerate even high growth and low density	Species can tolerate even high growth and low density
Mining/Oil Concession	Municipalities with more mining/oil concessions are not interested in CWR as a source to improve their local crops and hence their agronomic production.		
Literacy Rate	Same as table 3		
Women in Gov			
Persons in Agriculture			
Land Tenure			

Table 5.

Hypothesis and predictions for quinoa species. Chenopodium spp.

Variables	***C. hircinum***	***C. hircinum subsp. catamarcensis***	***C. hircinum subsp. eu-hircinum***
Climate change	An increase in temperature and a decrease on precipitation can be harmful for these species.		
Population	Species can tolerate even high growth and low density. High density and high growth rate put these species in danger.		
Mining/Oil Concession	Same as table 3		
Literacy Rate			
Women in Gov			
Persons in Agriculture			
Land Tenure			

Chapter 3

RESULTS

Following, I will present the results for each of the variables in the same order I presented them above, in methods. After each variable general introduction, I will include then the results for the species. The first two variables results are presented in charts or for population in dispersion graphs. The rest of the results are presented in maps where the positive values are shaded in black. The negative values will be presented in white, and a light green color is used for the areas where no data was obtained or generated. The other images produced in this thesis are located in the appendix section.

Climate change

I extracted the list of municipalities that would suffer an increase/decrease of temperature and precipitation (in percent) compared to the values that were found for each species range. Some of the municipalities will have an increase or decrease only in the temperature or the precipitation, not necessarily both of them. The following charts show the results of this comparison.

Peanut species and climate change

In the following table (6) the ranges for each of the selected species for peanut are given. This were used to identify the municipalities that have projected average temperature or average precipitation that would fall outside of a species current tolerance.

Table 6.

Tolerable temperature and precipitation range for peanut species

Variable	***Arachis batizocoi***	***A. duranensis***	***A. rigonii***
Climate change	Temperature range from 20.62 to 23.63 °C Precipitation range is from 240 to 849 mm.	Temperature range from 22.50 to 24.79 °C Precipitation range is from 702 to 849 mm.	Temperature 25.13 °C Precipitation average is 450 mm.

There is a decrease in temperature in the Lowlands of –0.6 °C. While this doesn't appear (using this simple analysis) to affect the distribution of *Arachis batizocol* (only three municipalities out of 10 are affected), it does threaten *Arachis durenensis* (Entre Rios) in one of its six municipalities, and *A. ringonii* in the only municipality in which it exists (Santa Cruz).

The precipitation in this region is projected to increase around 24.66% by 2070 (Urritia and Vuille, 2009); this increase causes projected precipitation to exceed current tolerable limits for almost every municipality in which any of the three species exists (see Tables 6, 8, and 9). The limitations to this analysis should be noted; in particular, the peanut species considered may have broader tolerances than current distributions indicate, but sub-populations found in particular municipalities may also have lower tolerances, due to adaptation to specific local conditions.

Table 7.

Municipalities with a change of average precipitation in excess of the tolerable range for Arachis batizocoi

Municipality	**Av. PPT %**	**24.6% PPT**
Boyuibe	695.42	866.499
Machareti	774.45	964.964
Huacaya	771.87	961.751

Table 8.

Municipalities with a change of average temperature and average precipitation in excess of the tolerable range for Arachis duranensis.

Municipality	**Av. T**	**RCMA2 T**	**Av. PPT %**	**24.6% PPT**
Boyuibe			695.42	866.499
Machareti			774.45	964.964
Entre Rios	22.42	21.48	732.86	913.152
Villa Montes			810.94	1010.439
Carapari			830.58	1034.907
Yacuiba			833.34	1038.347

Table 9.

Municipalities with a change of average temperature and average precipitation beyond the tolerable range for Arachis ringonii.

Municipality	**Av. T**	**RCMA2 T**	**Av. PPT %**	**24.6% PPT**
Santa Cruz	25.05	24.40	995.261	1234.123

Potato species and climate change

The temperature range for the potato species is very similar except for *Solanum boliviense* subsp. *astleyi* that has a more narrow temperature range (Table 10). The precipitation range is wider for *S. alandiae* and again narrower for *S boliviense* subsp. *astleyi.*

Table 10.

Tolerable temperature and precipitation range for potato species

Variable	***Solanum alandiae***	***S. boliviense subsp. astleyi***	***S. gandarillasii***
Climate change	Temperature range from 15.92 to 19.29 °C Precipitation range is from 23 to 552 mm.	Temperature range from 11.96 to 12.83 °C Precipitation range is from 68 to 130 mm.	Temperature range from 15.45 to 19 °C Precipitation range is from 117 to 540 mm.

The eastern slope of the Andean mountain chain houses the three potato species under consideration. Projected climate changes for this region include a temperature decrease of 0.8 ^{o}C, and a decrease in precipitation of 250 mm, which is 17.24% of the current annual average precipitation for the region (Table 11, 12 and 13). As with peanuts, shifts in precipitation threaten current populations of potato more so than shifts in temperature. The projected temperature changes are not projected to affect *S. boliviense* subsp. *astleyi* or *S. gandarillasii* at all; it affects *S. alandiae* in only one of the 19 municipalities in which it exists.

Decrease of precipitation affects both municipalities where *S. boliviense* subsp. *astleyi* is present; it affects 8 of the 22 municipalities where *S. gandarillasii* is present. Only three out of 19 municipalities are affected by this decrease for *S. alandiae*.

Table 11.

Municipalities with a change of average precipitation in excess of the tolerable range for Solanum boliviense subsp. *astleyi*

Municipality	**Av. PPT %**	**17.24% PPT**
Betanzos	295.45	244.51
Puna	177.70	147.06

Table 12.

Municipalities with a change of average precipitation beyond the tolerable range for Solanum gandarillasii.

Municipality	**Av. PPT %**	**17.24% PPT**
Comarapa	126.77	104.92
Pampa Grande	47.92	39.66
Saipina	82.83	68.55
Moromoro	24.75	20.49
Trigal	23.39	19.36
Quirusillas	24.36	20.16
Vallegrande	61.41	50.82
Villa Serrano	89.87	74.38

Table 13.

Municipalities with a change of average temperature and average precipitation beyond the tolerable range for Solanum alandiae.

Municipality	**Av. T**	**RCMA2 T**	**Av. PPT %**	**17.24% PPT**
Totora	14.43	13.31		
Moromoro			24.75	20.49
Trigal			23.39	19.36
Quirusillas			24.36	20.16

Quinoa species and climate change

Quinoa species have a very similar temperature range. Precipitation range is also similar except for *C. hircinum subsp. catamarcensis* where the range goes only to 400 mm. The other two species (Table 14) have precipitation ranges that go from the 20s to values higher than 500 mm.

Table 14.

Tolerable temperature and precipitation range for quinoa species

Variable	***C. hircinum***	***C. hircinum subsp. catamarcensis***	***C. hircinum subsp. eu-hircinum***
Climate change	Temperature range from 10.48 to 21.35 °C Precipitation range is from 23 to 530 mm.	Temperature range from 12.03 to 19 °C Precipitation range is from 50 to 400 mm.	Temperature range from 7.75 to 18.89 °C Precipitation range is from 25 to 569 mm.

Urritia and Vuille (2009) project temperature increases in the high Andean zones of Bolivia to be 1.5 °C, while precipitation is projected to decrease by 10 mm. In contrast to potato and peanut, it is projected temperature changes that are projected to present the greatest threat to current populations of quinoa. In particular, temperature increases threaten *Chenopodium hircinum* subsp. *eu-hircinum* in 9 of the 59 municipalities in which it currently exists (Table 17); threatens *Chenopodium hircinum* subsp. *catamarcensis* (Table 16) in 2 of 24 municipalities, and there is no threat for *Chenopodium hircinum* (Table 15). In contrast, each of the three species are threatened by precipitation decrease in just two of their municipalities.

Table 15.

Municipalities with a change of average precipitation beyond the tolerable range for Chenopodium hircinum.

Municipality	**Av. PPT %**	**25% PPT**
Moromoro	24.75	18.566
Trigal	23.39	17.545

Table 16.

Municipalities with a change of average temperature beyond the tolerable range for Chenopodium hircinum subsp. *catamarcensis.*

Municipality	**Av. T**	**RCMA2 T**
Pojo	18.36	20.40
Comarapa	18.91	20.63

Table 17.

Municipalities with a change of average temperature and average precipitation beyond the tolerable range for Chenopodium hircinum subsp. *eu-hircinum.*

Municipality	**Av. T**	**RCMA2 T**	**Av. PPT %**	**25% PPT**
Pojo	18.36	20.40		
Comarapa	18.91	20.63		
Pampa Grande	18.80	20.47		
Aiquile	18.11	19.47		
Pasorapa	17.95	19.18		
Moromoro	18.39	19.90	24.75	18.56
Villa Serrano	18.39	20.11		
Sopachuy	17.53	19.44		
Tarvita	18.35	19.69		
Pucara			18.35	21

Mining concessions

Mining concessions are thought to threaten conservation prospects for CWR, both because they can destroy habitat and because they can shift priorities away from agriculturally based activities. There are few mining concessions in the area occupied by peanut (Fig. 2). The municipalities where potatoes reside have some mining activity, but it is still not significant (Fig 3). However, in the high Andean regions encompassing the quinoa species, there are often significant mining concessions (Fig. 4 and 5).

I have produced maps where black shows areas that are favorable for conservation, while white shows areas that are unfavorable. Therefore, the scale for this map has been reversed, with black representing the lowest levels of percent area occupied by mining concessions, and white showing the highest levels. The lowest value for this variable is 0% and the highest is 44%. The four categories used in the synthesis were: 0 to 11% (🡇), 12 to 22% (🡄), 23 to 33% (🡆) and 34 to 44% (🡅).

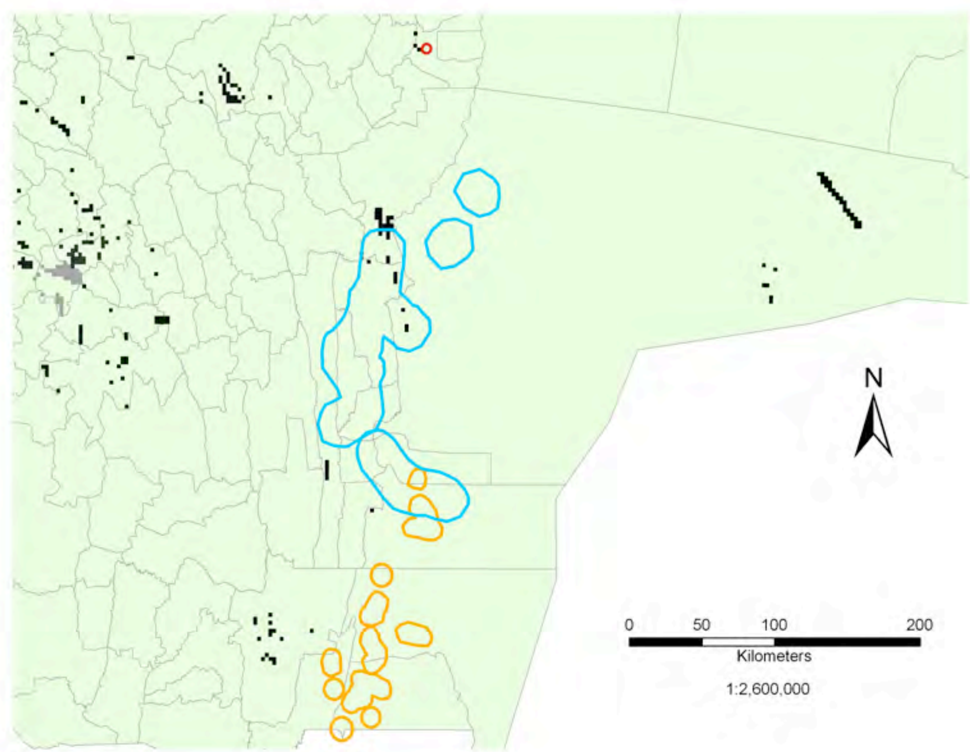
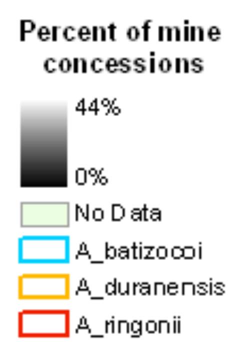


Fig. 2. Percent of mine concessions for peanut distribution



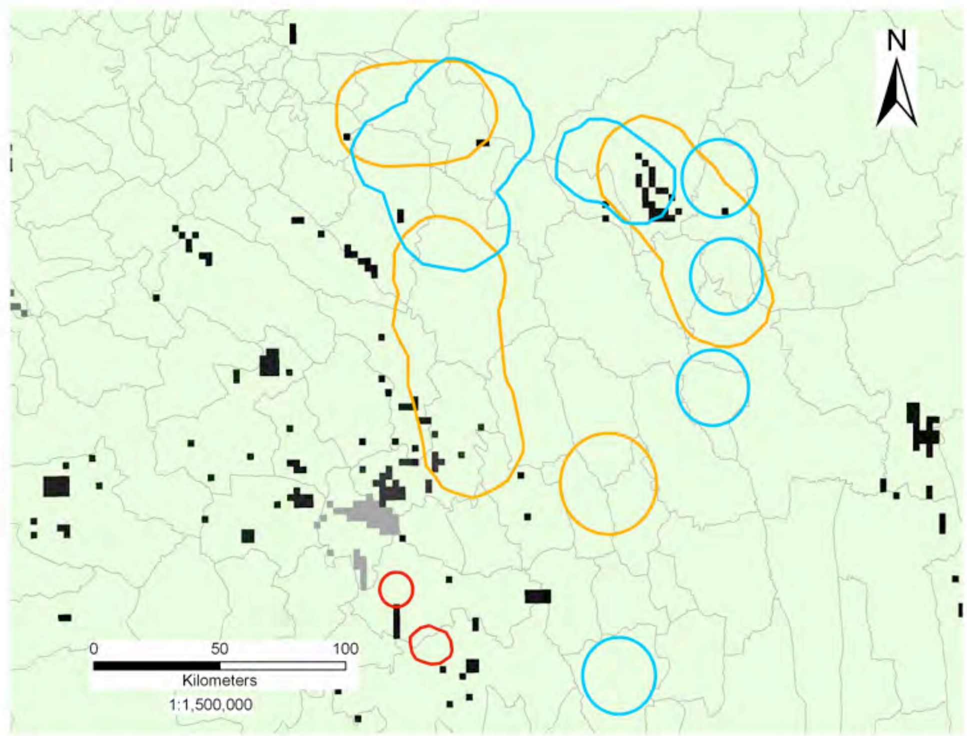
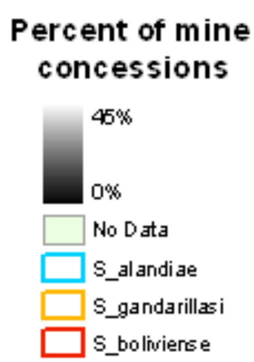


Fig. 3. Percent of mine concessions for potato distribution



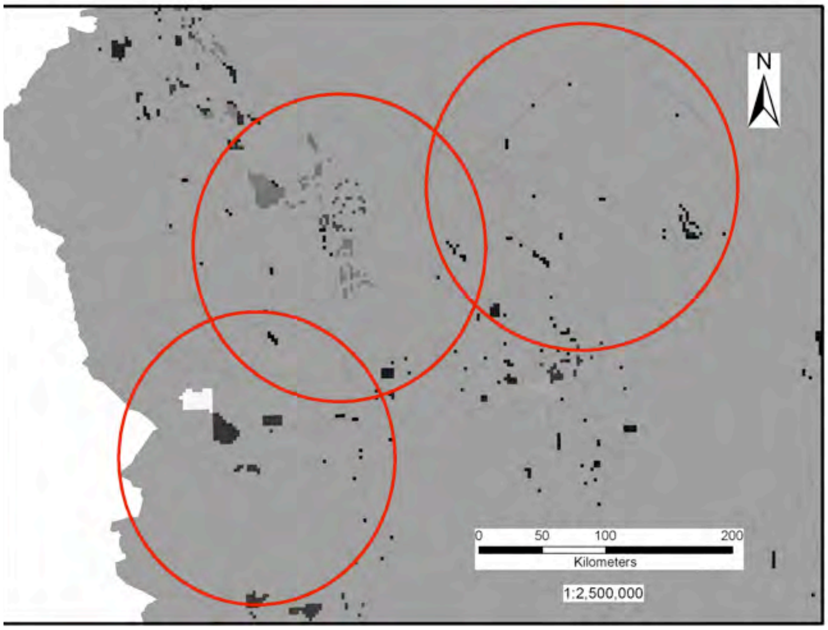


Fig. 4 **Percent of mine concessions for *C. hircinum***

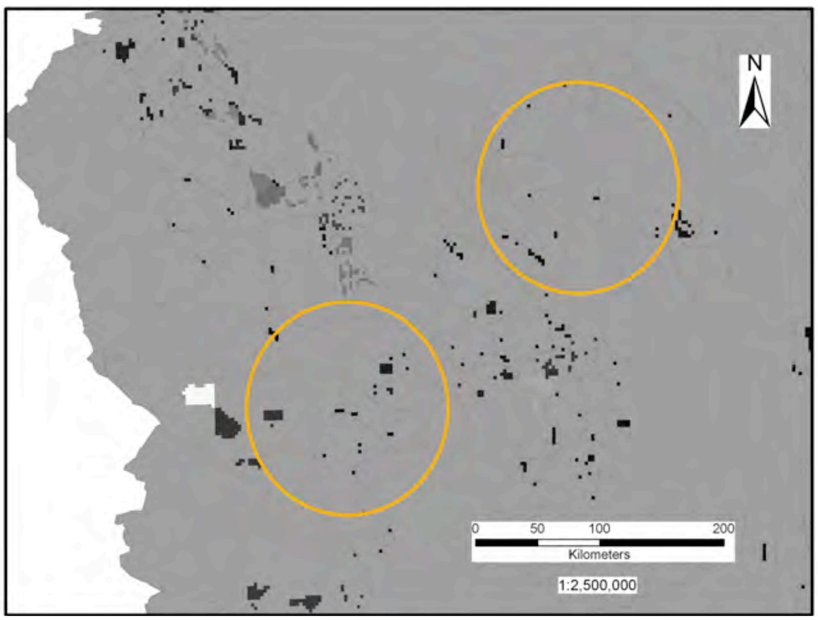
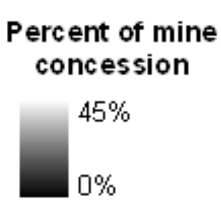


Fig. 5 Percent of mine concessions for C. *hircinum subsp. catamarcensis*



Oil concessions

The distribution of oil concessions is in sharp contrast to the distribution of mining concessions. Municipalities housing peanut have relatively high levels of oil-extraction activity—at times reaching more than 80% of their land with identifiable oil concessions (Fig. 6). The municipalities housing potato, on the other hand, have no oil concessions (Fig 7), and the quinoa distribution includes only two municipalities any oil activities, both with a fairly low percentage of the land devoted to oil concessions (Fig. 8 and 9).

The color scale for this variable is like that for mining concessions, with black assigned to low percentages and white to high. The highest value for this variable is 99.95% and the lowest is 0%; the quartile distributions are: 0 to 25% (🡇), 26 to 50% (🡄), 51 to 75% (🡆) and 76 to 100% (🡅)

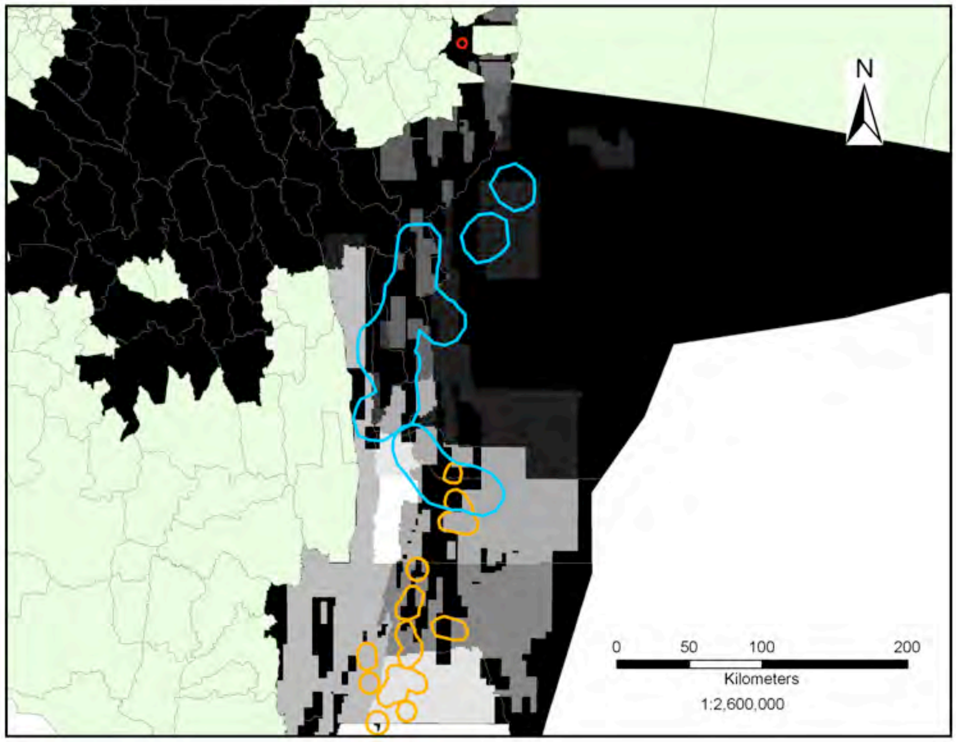
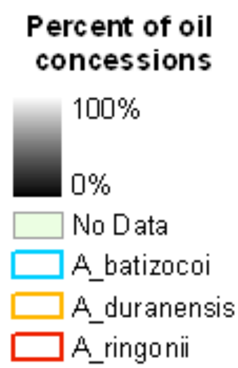


Fig. 6 Percent of oil concessions for peanut distribution.



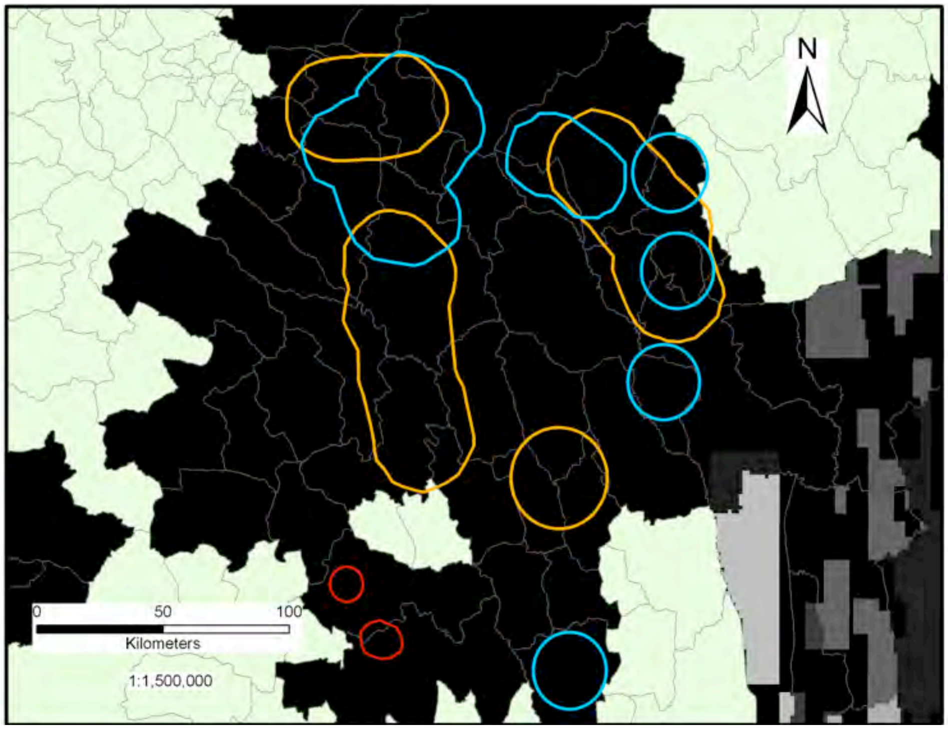


Fig. 7 Percent of oil concessions for potato distribution.

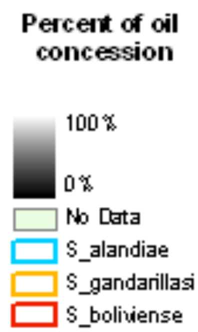
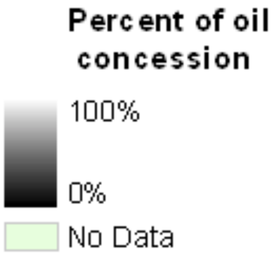


Fig. 8 **Percent of oil concessions for *C. hircinum***

Fig. 9 Percent of oil concessions for C. *hircinum subsp. catamarcensis*



Population

Different species are affected differently by population growth. Some species thrive in disturbed environments, such as the edges of agricultural fields and roads, or along city streets, and can therefore benefit from growing populations. Others require more pristine conditions.

For each species, I produced scatter plots of current population density (x axis) and population growth rates (19912-2001; y axis), and then used the hypotheses listed in Tables 3, 4 and 5 to “guesstimate” regions of the graph (i.e., the combinations of current population densities and growth rates) that might be favorable or unfavorable for each species. I show only three of those scatter plots here and the other six are included in the appendix in order to allow for a bigger size. *A. batizocoi* can tolerate relatively high disturbance, and so can tolerate high population growth rates across a range of current densities. I therefore categorize population dynamics as “favorable” for *A. batizocoi* for all of the municipalities in which it currently exists *except* for Camiri (Figure 10). *S. gandarillasii* (Figure 11) can similarly tolerate relatively high disturbance, and so I categorized as “favorable” the population dynamics in all but Sucre and Vacas municipalities (the two on the far right of the graph). *Chenopodium hircinum s*ubsp*. catamarcensis* can tolerate high growth and low density.

However, high density and high growth rate put this species under threat as well as low density and low growth rate. This is why Totora and Uyuni (the two below 0 on the left corner) are qualified negative threat (Figure 12).

In the case of potato, figure 3 corresponds to *Solanum gandarillasi*, where population density goes over 1000 persons per Km^2. *Solanum alandiae* has low population density but some municipalities have a growth rate over 3. The situation with *S. boliviense* subsp*. astleyi* is different, where there is low population density and the growth rate is lower than 2.

Figure 4 for *Chenopodium hircinum* subsp*. catamarcensis* is present in a municipality that has low population density but some municipalities present high growth rates. *C. hircinum* subsp*. catamarcensis* and C. *hircinum* subsp*. eu-hircinum* are present in municipalities where there is high population density and growth rate.

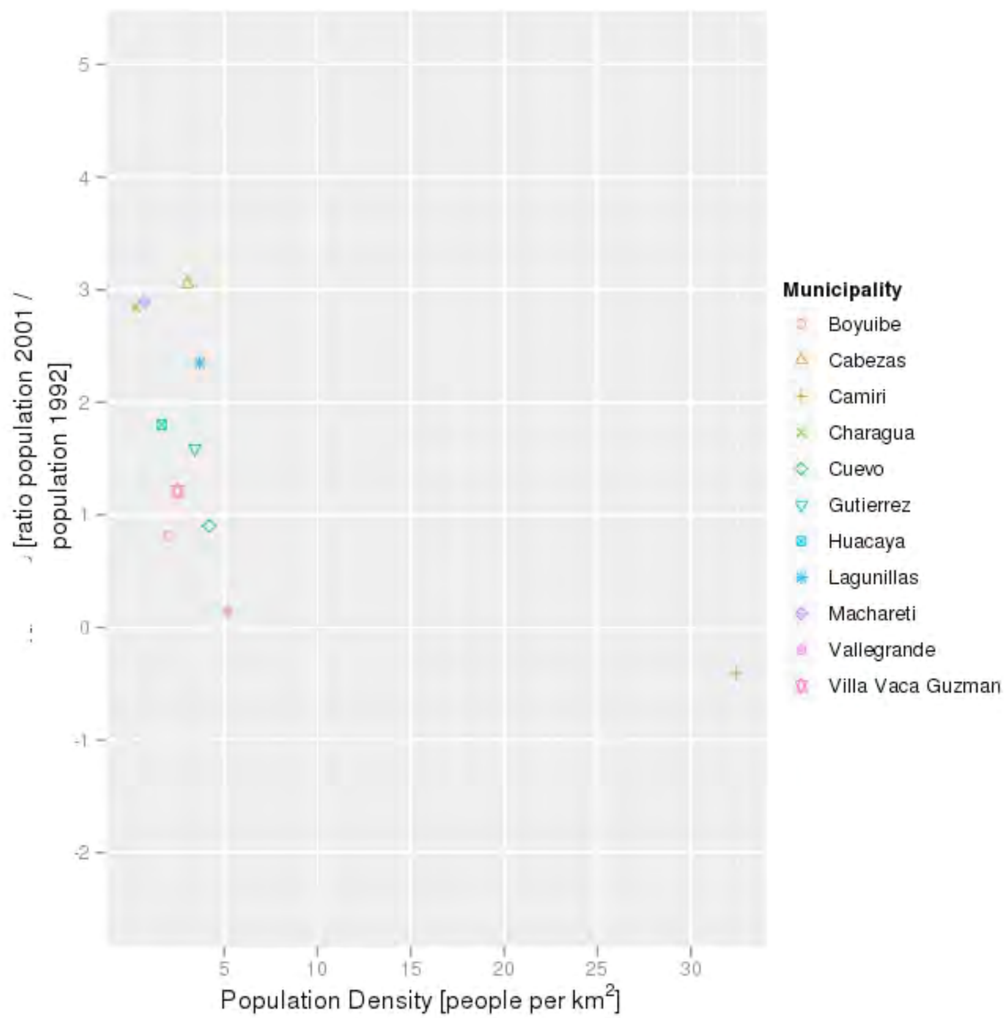


Fig 10. Population dynamics for *Arachis batizocoi.*

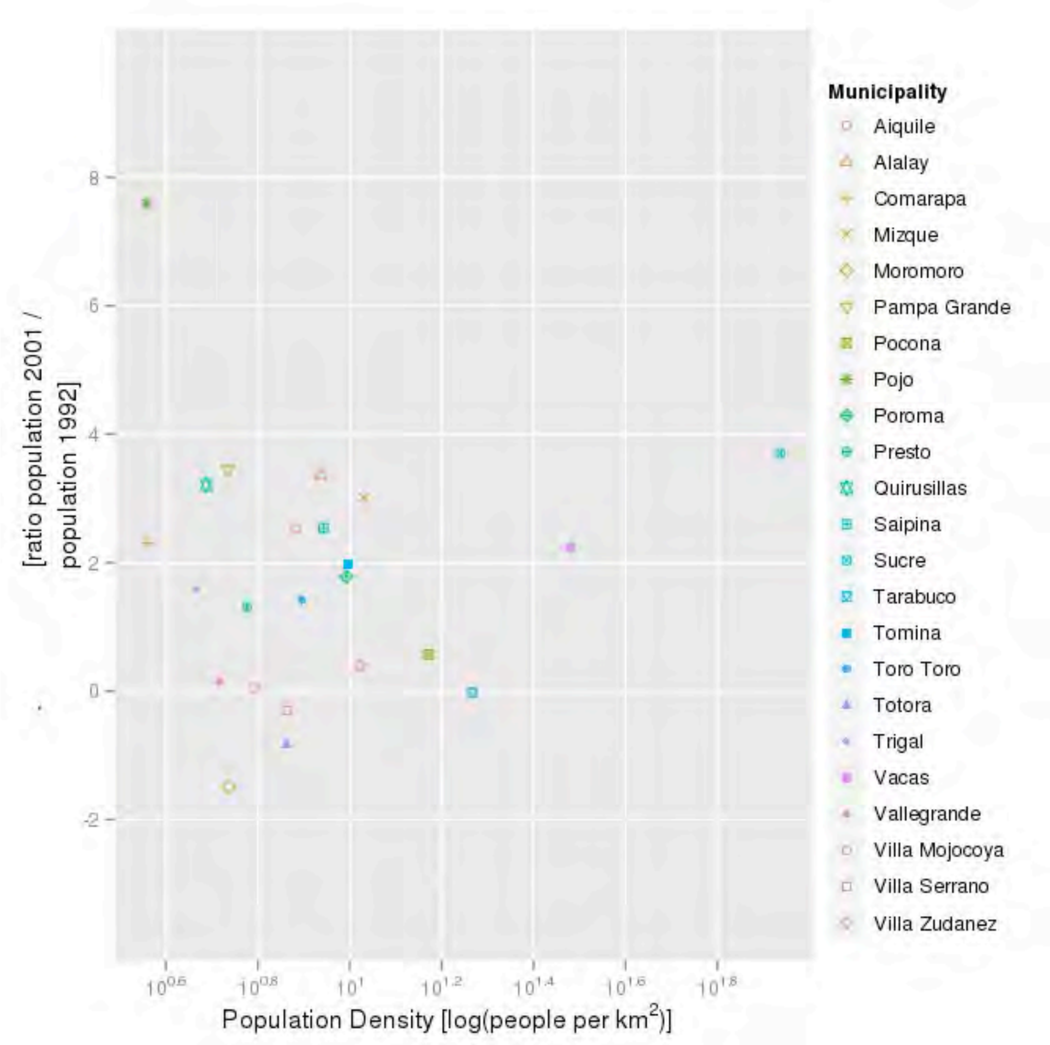


Fig 11. Population dynamics for *Solanum gandarillasii.*

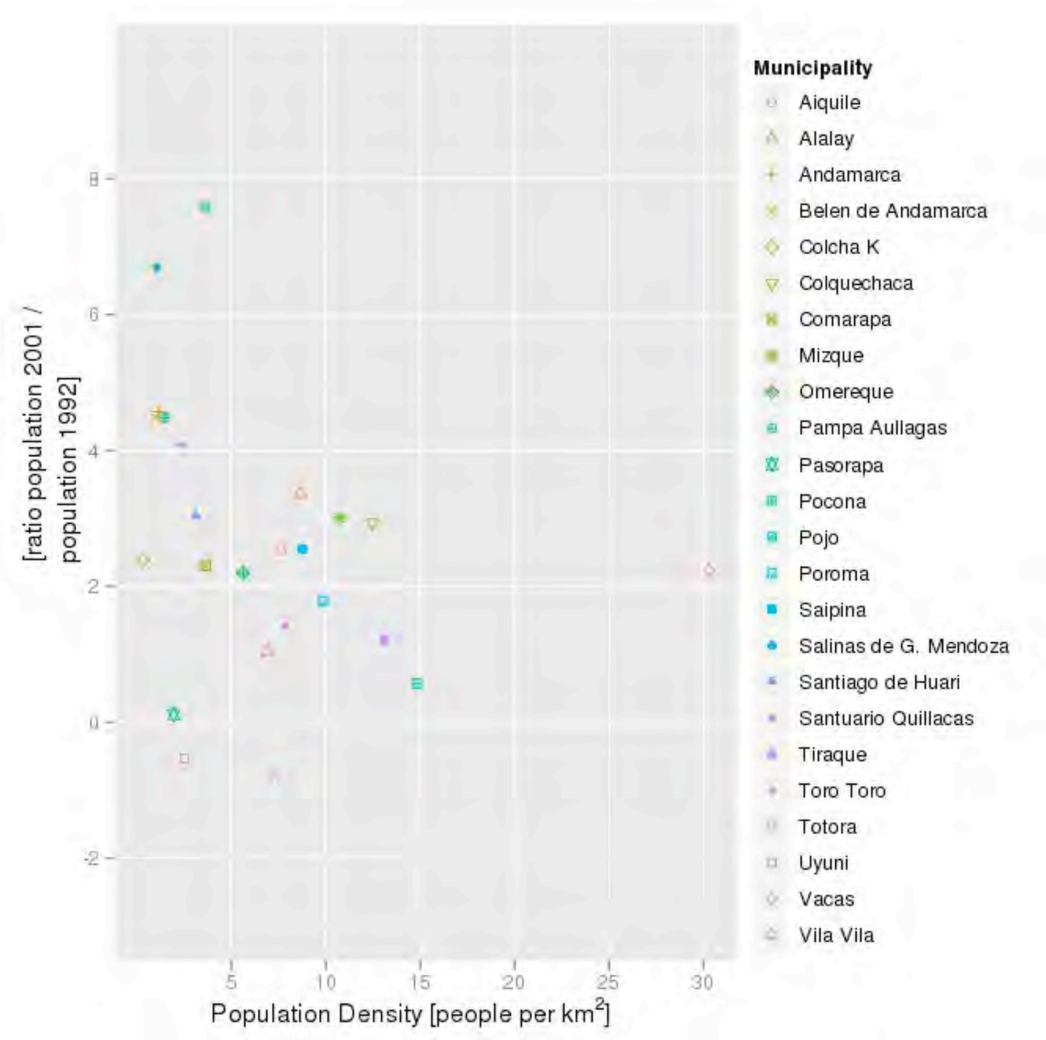


Fig 12. Population dynamics for *Chenopodium hircinum* subsp. *catamarcensis*

Literacy Rate

In general this variable was hypothesized to be a positive variable as it may increase the likelihood of establishing effective conservation programs. In the eastern region of Bolivia (Fig. 13) and the high Andean zone (Fig. 15 and 16) levels of literacy are relatively high. The inter-Andean valleys, where potato and quinoa are found, have literacy rates that fall below 60% (Fig. 14), though no municipalities in which my 9 target species are found have literacy rates that fall below 40%. This could represent a challenge when executing conservation projects compared to higher literacy rates with peanut. However, as we may see in other variables, there might be a correlation between higher literacy rate and more interest in high economic value activities like oil extraction.

The maximum literacy rate for any municipality under consideration was 96% and the lowest was about 40%. I divided this range into quartiles, and assigned them into “highly unfavorable for conservation” (40 to 54%, 🡇); somewhat unfavorable (54% to 68%; 🡄); somewhat favorable (68% to 72%; 🡆); and highly favorable (72% to 96%; 🡅).

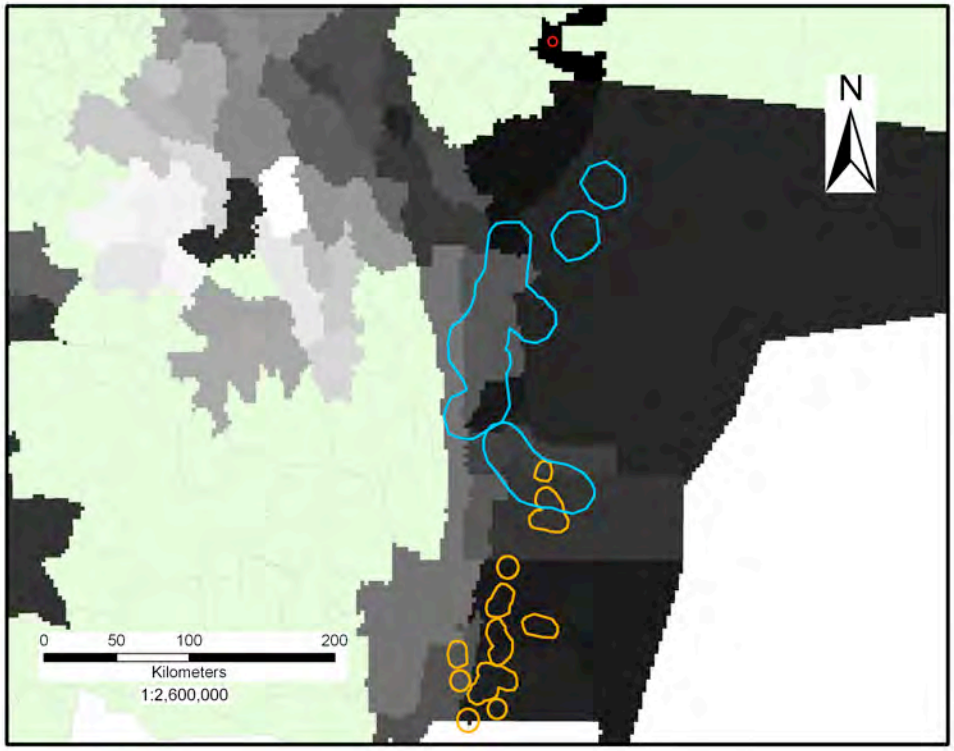
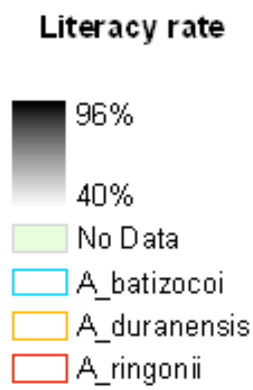


Fig. 13 Literacy Rate for peanut species



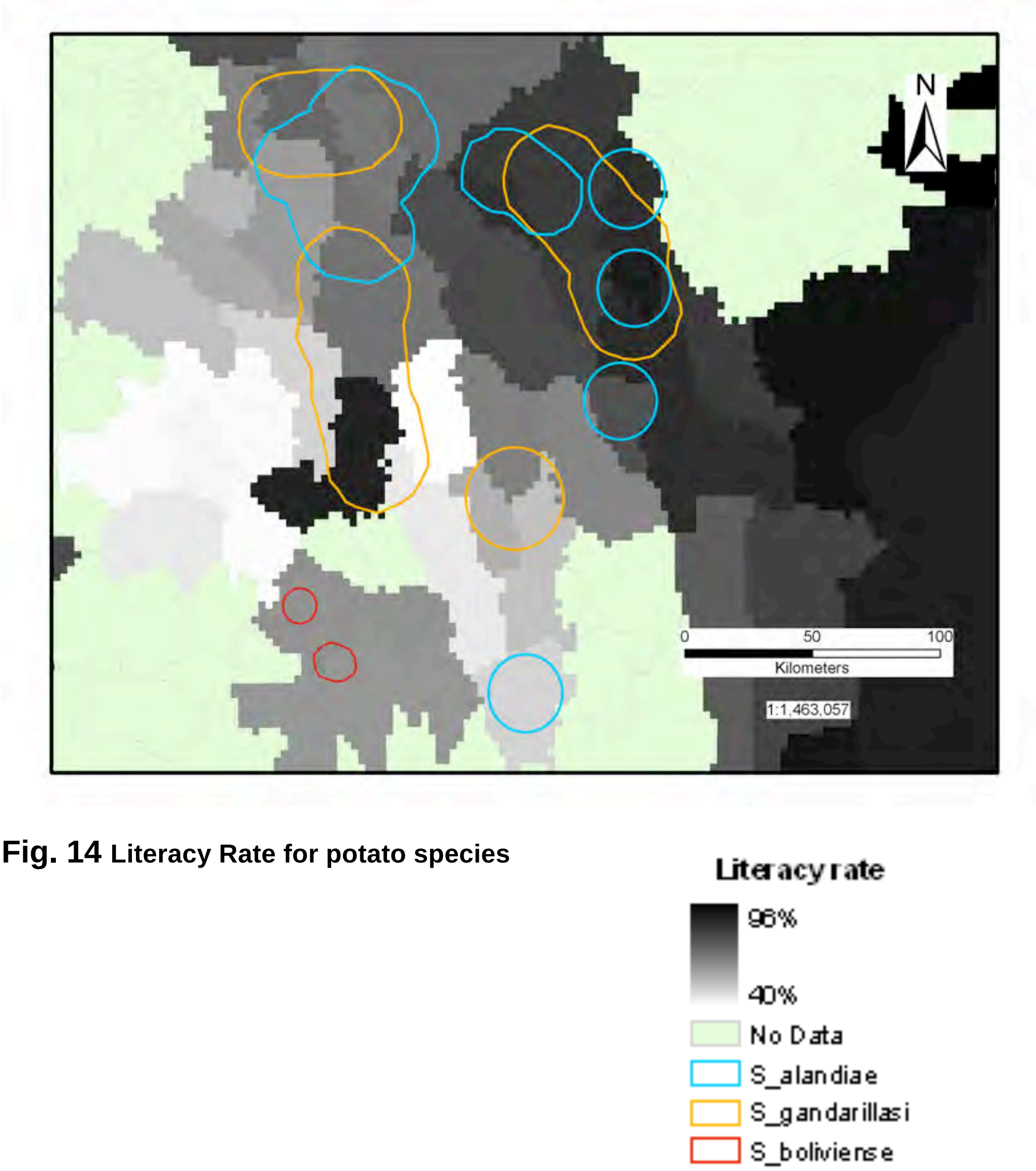


Fig. 14 Literacy Rate for potato species

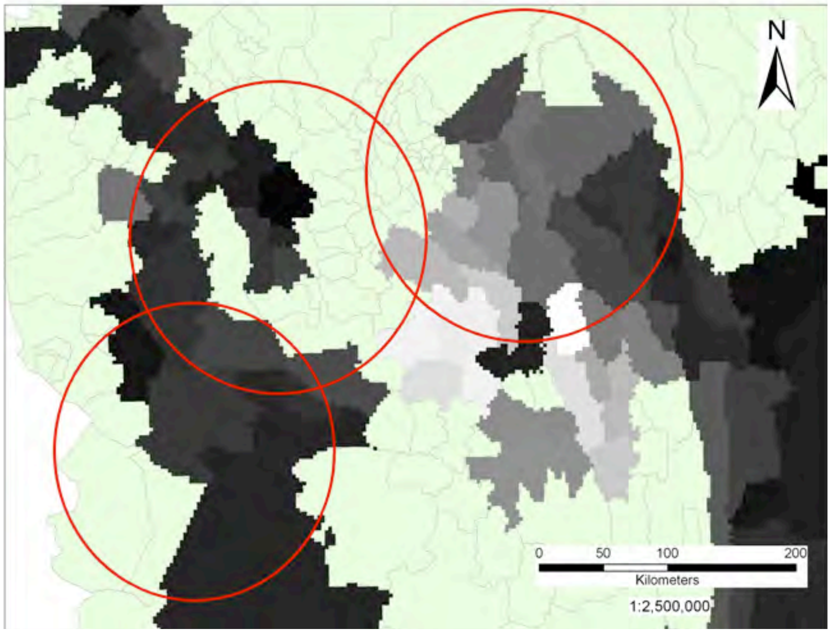


Fig. 15

Literacy Rate

for *C. hircinum*

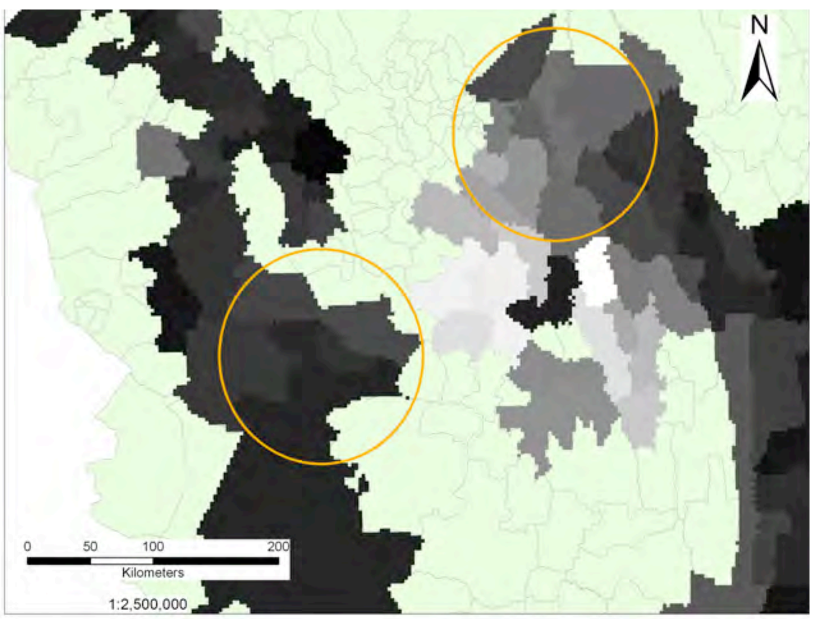
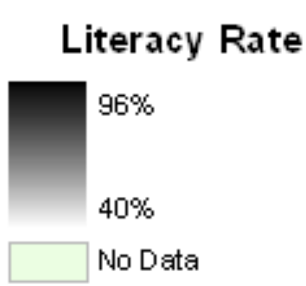


Fig. 16 Literacy

Rate for *C.*

hircinum



Women in municipalities

A greater proportion of female participation in government is assumed to improve the prospects for successful conservation. This indicator may be a surrogate of how much women are included in decision making processes. All municipalities have some female representation in government, with the lowest level being 20% and the highest being 100%.

The eastern region in Bolivia that encompasses the existing populations of peanut CWR have an average of 40% to 60% of women elected and involved in municipal government (Fig. 17). A very similar situation occurs in the Inter-Andean valleys, where potato is distributed (Fig. 18). The Choque Cota municipality in Oruro has 100% female representation in the government. This is where *Chenopodium hircinum* and *Chenopodium hircinum* subsp. *eu-hircinum* grow (Fig. 19 and 20). For the next section of synthesis, the municipalities were again divided into quartiles; those having 20 to 40% representation of women were deemed unfavorable for conservation outcomes (🡇); those from 40 to 60% were deemed somewhat unfavorable (🡄); those from 60 to 80% were deemed somewhat favorable (➔); and those from 80 to 100% highly favorable (🡅).

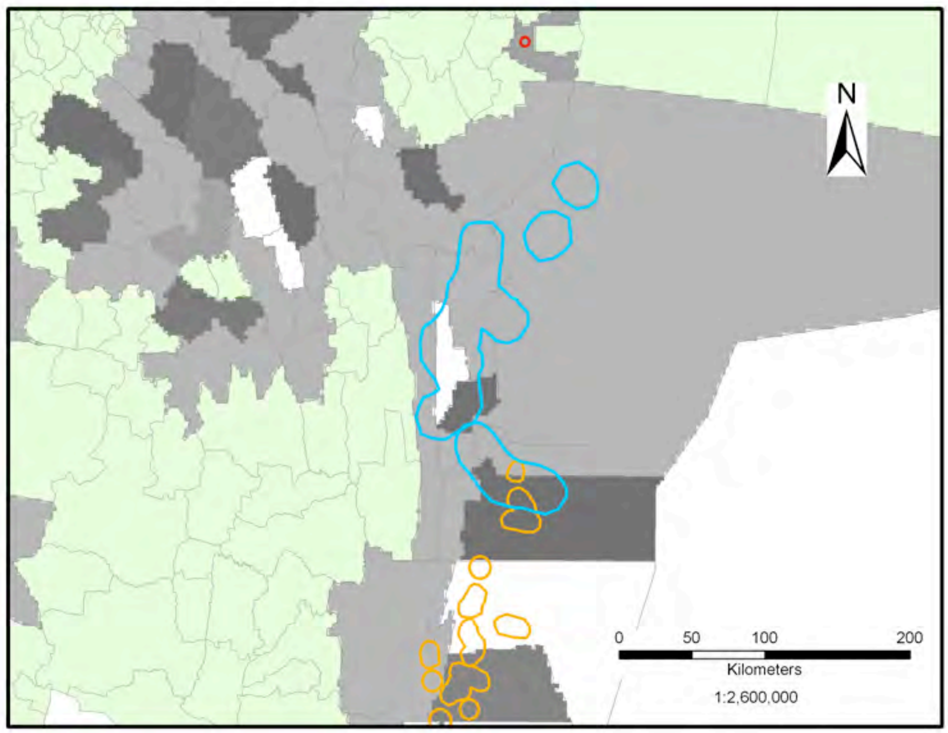
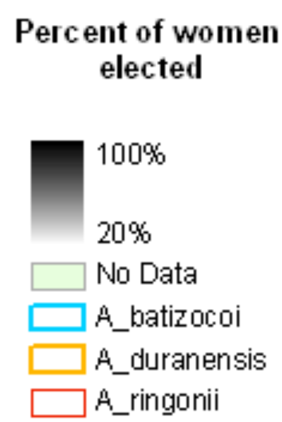


Fig. 17 Percent of women involved in local government for peanut distribution



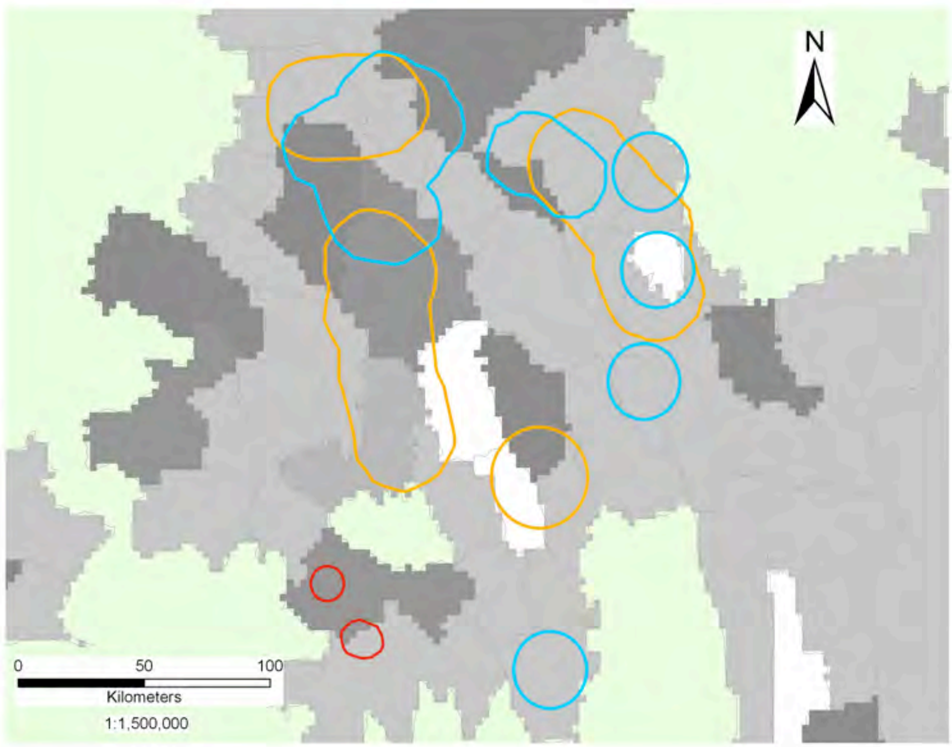


Fig. 18 Percent of women involved in local government for potato distribution

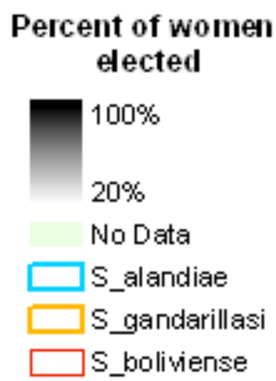


Fig. 19 Percent of women involved in local government *C. hircinum*

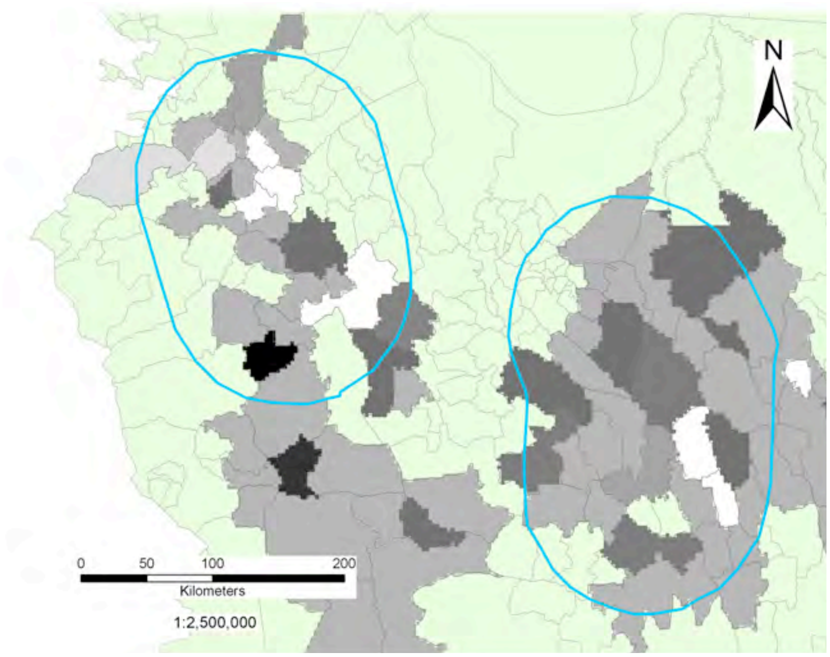
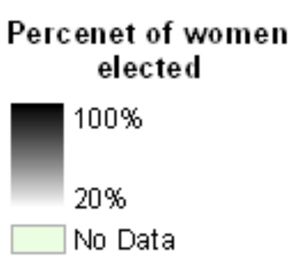


Fig. 20 Percent of women involved in local government C. *hircinum* subsp*. eu-hircinum*



Percent of workers involved in agriculture activity

The hypothesis for this variable is that more people involved in agricultural activities could engage into CWR conservation projects. With the exception of La Paz, El Alto, Oruro, Sucre and Santa Cruz, the municipalities that I chose for this analysis are all rural municipalities. In general, the rural municipalities of Bolivia have a high percentage of people involved in agricultural activity, while employment in urban municipalities is focused on such activities as construction, commerce, and retail. These percentages can hide differences in the types of agriculture, however. In the eastern part of the country, where peanut grows, agricultural activities tend to be large-scale and extensive (Fig. 21). In contrast, agricultural activities in the areas of potato distribution (Fig. 22), agriculture is more intensive and on smaller scales. Quinoa is found mainly in areas where there is significant subsistence agriculture (Fig. 23 and 24).

The lowest value for this variable is 12.8% and the highest is 84%. The scale was divided in four categories: 12.8 to 30.6% (🡇), 30.7 to 48.4% (🡄), 48.5 to 66.2% (🡆) and 66.3 to 84% (🡅).

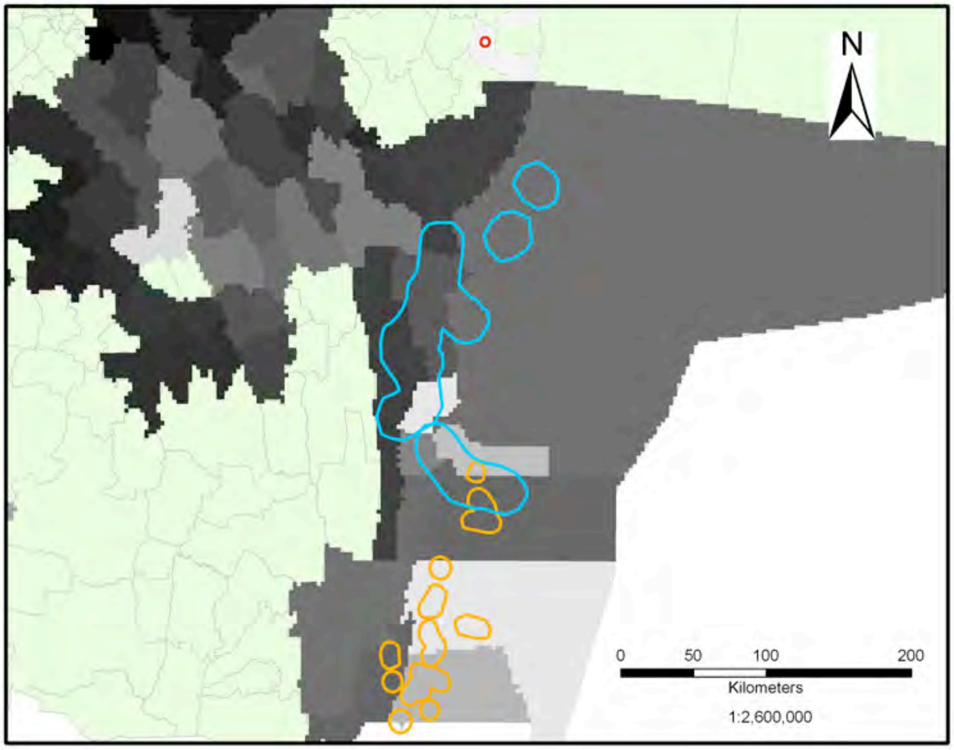
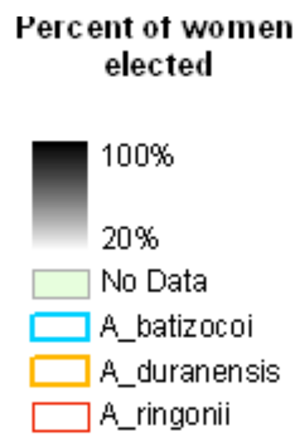


Fig. 21 Percent of workers involved in agriculture activity for peanut distribution



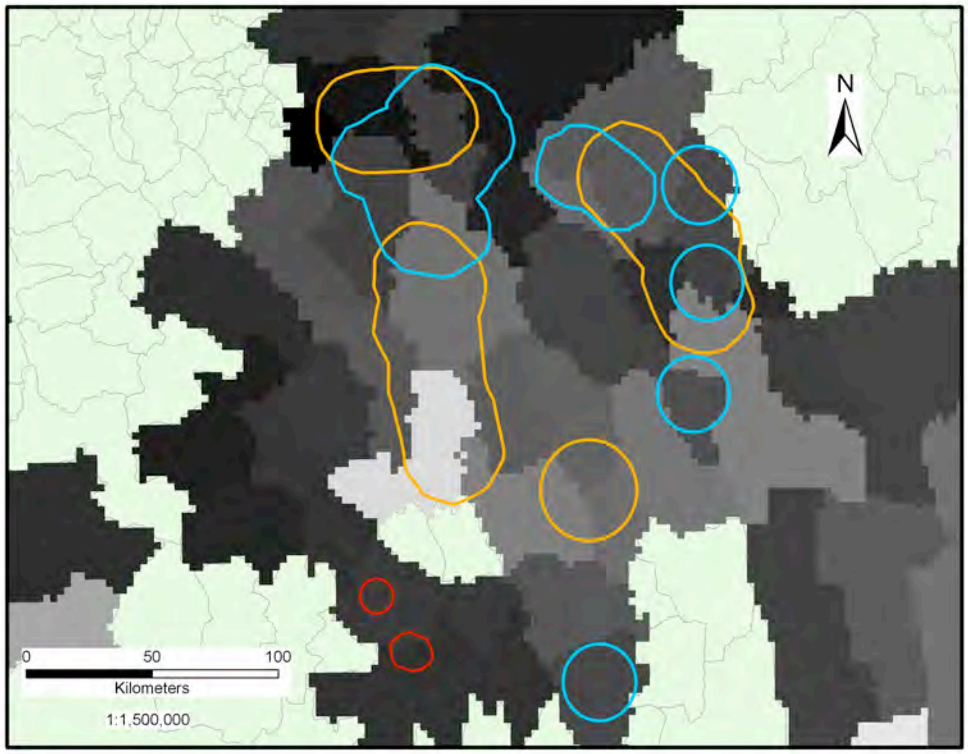
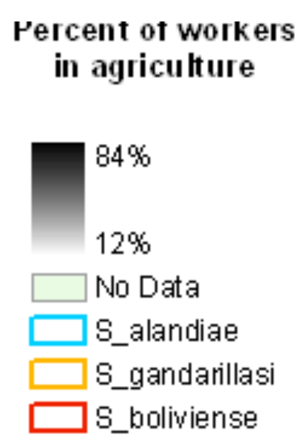


Fig. 22 Percent of workers involved in agriculture activity for potato distribution



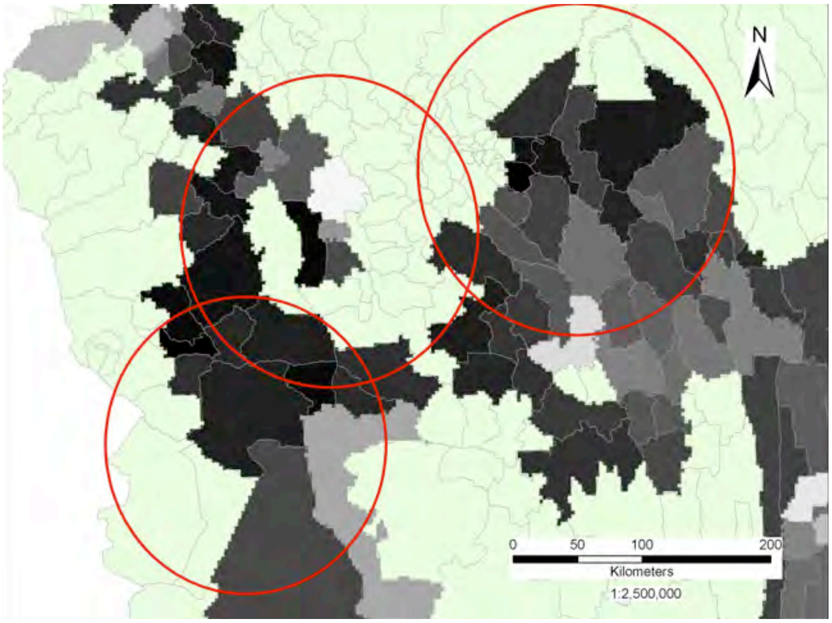


Fig. 23 Percent of workers involved in agriculture activity for *C. hircinum*

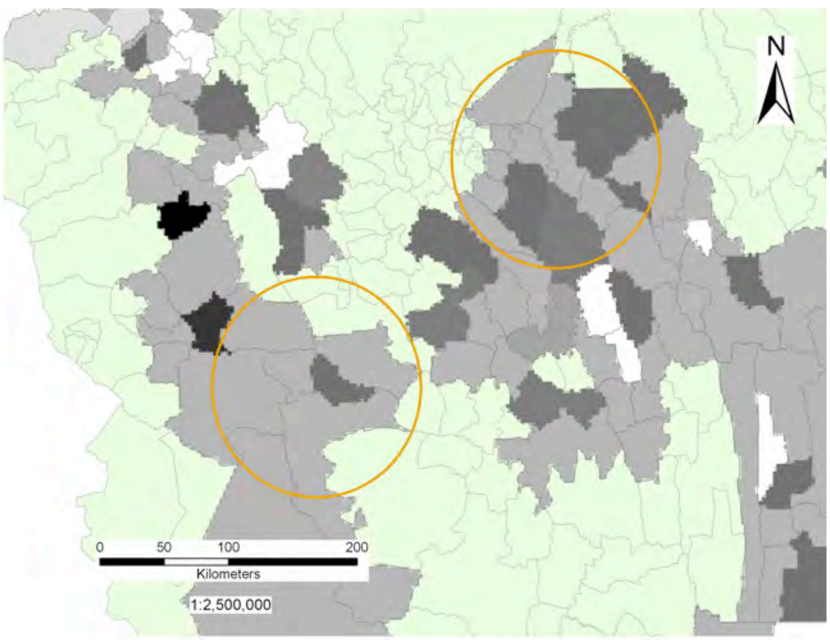
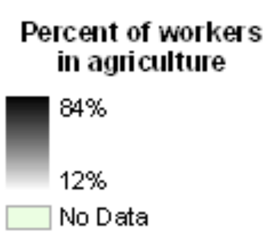


Fig. 24 Percent of workers involved in agriculture activity for C. *hircinum* subsp. *catamarcensis*



Land Tenure

When there is greater certainty over land tenure, there is greater likelihood of successful conservation projects. The advances from land tenure reform have been uneven in Bolivia; with the greatest progress in establishing land tenure taking place in the lowlands in the eastern part of the country, where peanut is distributed (Fig. 25). This is a positive variable for municipalities where peanut is distributed. The outcome is less promising for potato (Fig. 26); most municipalities containing potato populations have a relatively low percentage of land registered under the tenure process. The picture is more mixed for quinoa, with some home municipalities having proceeded quite far in registering land tenure, and others having made less progress (Fig. 27 and 28).

The lowest value for this variable is 0% and the highest is 96.5%. The four categories used for the synthesis were: 0 to 24% (🡇), 25 to 48% (🡄), 49 to 72% (🡆) and 73 to 96.5 (🡅).

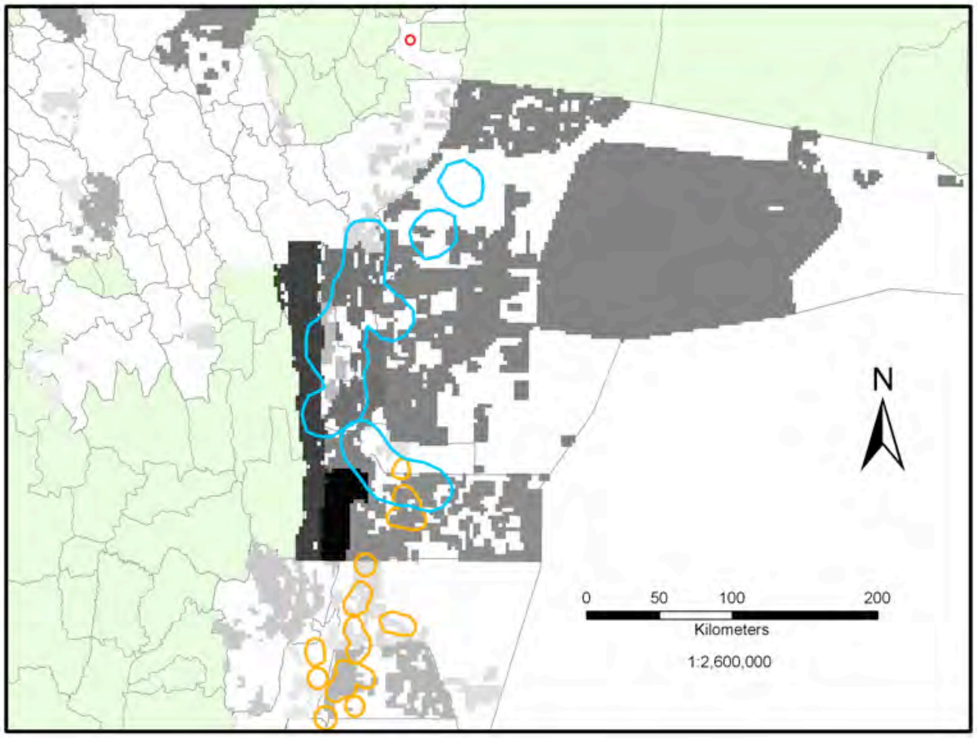


Fig. 25 Percent of land assigned with tenure for peanut distribution

100%
0%
No Data
A_batizocoi
A_duranensis
A_ringonii

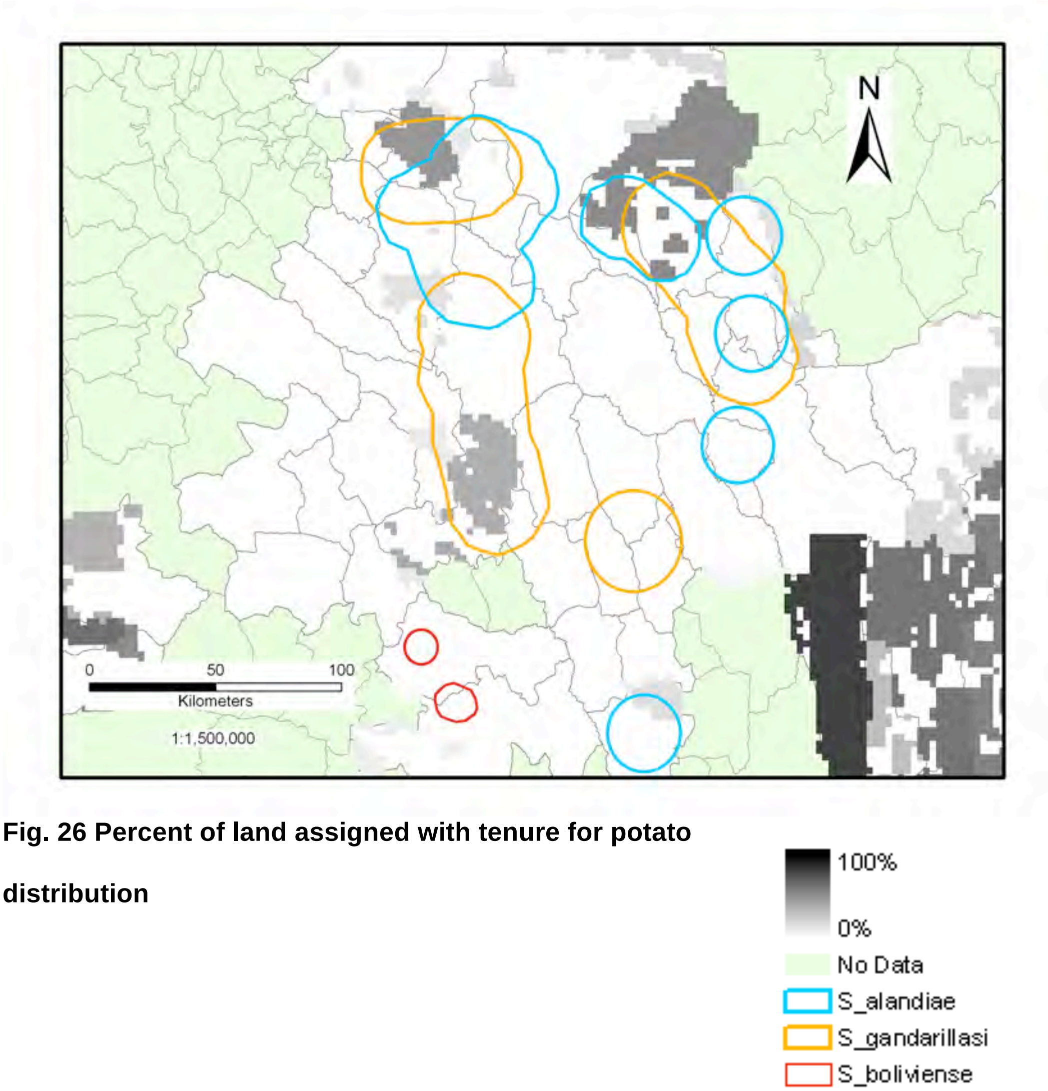


Fig. 26 Percent of land assigned with tenure for potato distribution

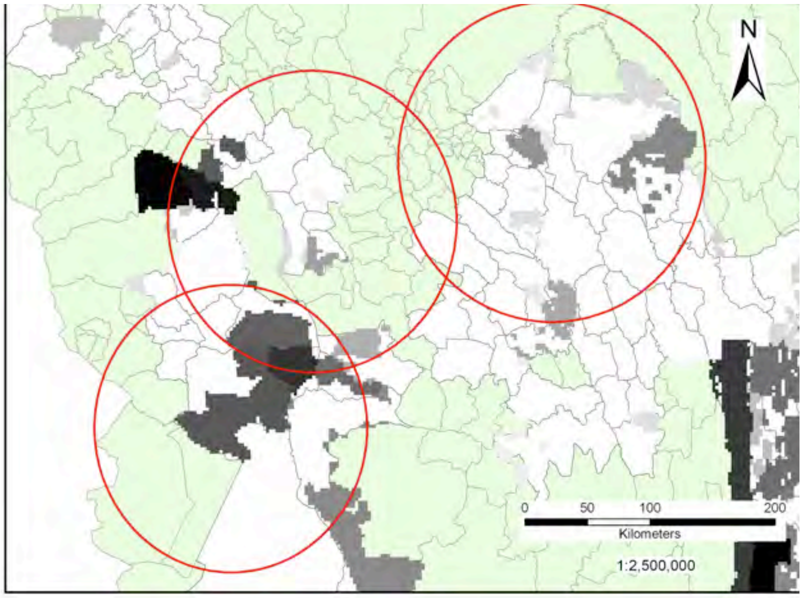


Fig. 27 Percent of workers involved in agriculture activity for *C. hircinum*

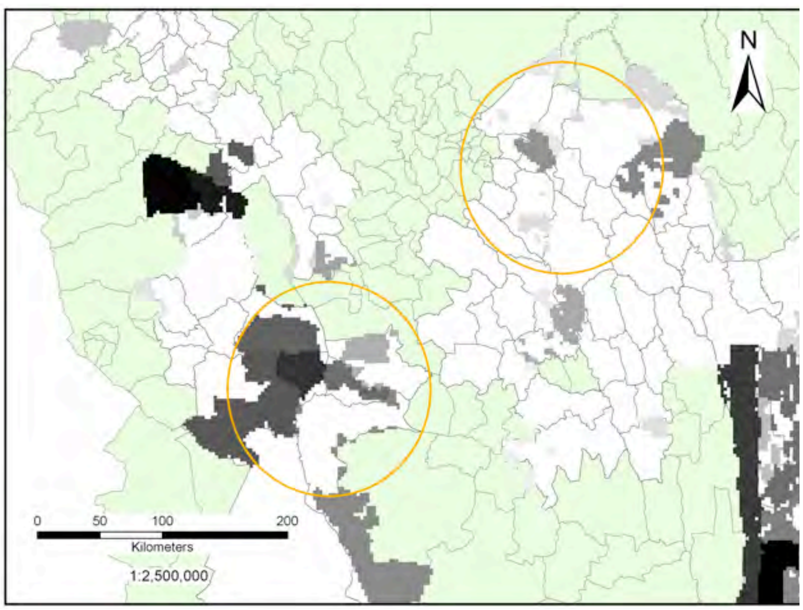
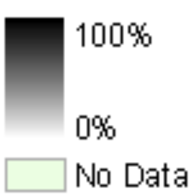


Fig. 28 Percent of workers involved in agriculture activity for C. *hircinum* subsp. *catamarcensis*



The images not included in this section are found in the Appendix. In this section the results are mainly visual, but there is still a need to understand how each of the variables affect the selected species and how can some municipalities be selected according to the combination of threats and opportunities. Conservation makes little sense in places where species are not threatened. It also makes little sense in places where the social and economic conditions are unlikely to favor positive conservation outcomes. I therefore identified municipalities where there was: (a) at least one threat to species—from climate change, mining, oil, or population growth; and (b) a relatively high number of positive social and economic conditions—high literacy, high land tenure, high levels of women in government, and/or a high percentage of the labor force in agriculture. In the next chapter, I present a synthesis of the results for all municipalities, and identify those where conservation projects are needed and likely to be successful, based on the criterion above.

Chapter 4

SYNTHESIS

The results obtained from the analysis are combined in this section in a manner that allows identification of the most promising municipalities for conservation programs for each of the 9 species. I have summarized each possible threat or opportunity as having very favorable prospects for conservation (🡅), somewhat favorable (➔), somewhat unfavorable (🡐) and unfavorable (🡇).

For each species, I identified the municipalities that have some threats to CWR, but also have favorable social and economic conditions that might lead to successful conservation outcomes. I chose this combination in order to find which municipalities having some level of threat could execute CWR conservation projects with few resources given a favorable socioeconomic and political context. Municipalities with more threats would probably need greater resources to achieve favorable conservation outcomes. Note that in this analysis I have not been able to assign “weights” to the relative challenges associated with each variable. For instance, an unfavorable ranking for climate change may be much more difficult to overcome than an unfavorable ranking for literacy, though I have counted an unfavorable ranking as the same in both cases.

Nonetheless, the patterns are instructive, and show for each municipality the factors working in favor of successful conservation outcomes, and those that would have to be overcome to ensure successful outcomes.

Some of these favorable municipalities (places where species are threatened, but conservation projects are likely to be successful) house more than one of the nine species considered, giving them even higher priority for conservation programs. Some of the species considered in this analysis are found in very few municipalities, and in some cases those municipalities had very few indicators of favorable opportunities for conservation. The characteristics of these municipalities were also considered in order to formulate recommendations for conservation of those narrowly distributed species, though it should be recognized that achieving successful conservation of these species is likely to be more difficult.

Peanut – *Arachis* spp.

The three municipalities that appear to be most favorable for conservation of *Arachis batizocoi* are Camiri, Villa Vaca Guzman and Machareti; oil is the common threat in all three municipalities (table 18). For *A. duranensis* the Machareti municipality is the most promising, as all the others have more than one threat (table 19). The prospects for *Arachis* *ringonii*, which only exists in one municipality, are far less promising (table 20).

Table 18.

Summary for Arachis batizocoi

Municipality	**T°**	**PP**	**Min**	**Oil**	**Pop**	**Lit**	**Wom**	**Agr**	**LT**
Cabezas	↑	↑	↑	→	→	↑	↓	→	↓
Charagua	↑	←	↑	↑	→	↑	↓	←	←
Villa Vaca Guzmán	↑	↑	↑	↓	↑	→	↓	→	→
Gutierrez	↑	↑	↑	→	↑	→	↓	→	→
Lagunillas	↑	←	↑	→	→	→	↓	→	↓
Camiri	↑	←	↑	←	←	↑	←	↓	→
Boyuibe	↑	↓	↑	←	↑	↑	↓	↓	↓
Cuevo	↑	↓	↑	↓	↑	↑	↓	←	←
Machareti	↑	↓	↑	←	→	↑	←	→	←
Huacaya	↑	↓	↑	↓	↑	↑	↓	→	↑

T° = Temperature

PP = Precipitation

Min = Percent Mine concessions

Oil = Percent Oil concessions

Pop = Population dynamics

Lit = Literacy rate

Wom = Percent of Women in local government

Agr = Percent of people involved in agriculture

LT = Percent of land tenure process

Table 19.

Summary for Arachis duranensis

Municipality	**T°**	**PP**	**Min**	**Oil**	**Pop**	**Lit**	**Wom**	**Agr**	**LT**
Boyuibe	↑	↓	↑	←	↑	↑	↓	↓	↓
Machareti	↑	↓	↑	←	→	↑	←	→	←
Entre Rios	←	←	↑	↓	↑	→	↓	←	↓
Villa Montes	↑	↓	↑	←	→	↑	↓	↓	↓
Caraparí	↑	↓	↑	↓	↑	→	↓	→	↓
Yacuiba	↑	←	↑	↓	↓	↑	←	↓	←

Table 20.

Summary for Arachis rigonii

Municipality	**T°**	**PP**	**Min**	**Oil**	**Pop**	**Lit**	**Wom**	**Agr**	**LT**
Santa Cruz	↓	↓	↑	←	↓	↑	←	↓	↓

Potato – *Solanum spp.*

The three potato species I considered are mostly threatened by declines in precipitation under climate change, and a lack of land-tenure rights in the municipalities in which they are found. The conservation status of all three is enhanced by the lack of oil concessions in their range.

For *Solanum alandiae*, the four most promising municipalities appear to be Pucara, Villa Serrano, Trigal and Quirusillas (table 21). They do not have favorable climatic conditions. They all have unfavorable or somewhat unfavorable opportunities for women in government. The first two municipalities have also unfavorable indicators for population and the other two have unfavorable outcome for land tenure. There is only one municipality chosen for *Solanum boliviense* subsp. *astleyi*: Betanzos (table 22). The unfavorable variables for this municipality are: decrease of precipitation, low literacy rate, and lack of an adequate land tenure process.

Conditions appear favorable in five municipalities for *Solanum gandarillasii* (table 23): Comarapa, Saipina, Aiquile, Villa Mojocoya and Sucre. The two first municipalities have an unfavorable outcome for precipitation, while the others are unfavorable in population dynamics. The socio political variables that are unfavorable for each are a low percentage of women in the government and relatively low amounts of land registered in the tenure process. Sucre is an urban municipality; therefore it also has a low percent of people involved in agricultural labor.

Table 21.

Summary for Solanum alandiae.

Municipality	**T°**	**PP**	**Min**	**Oil**	**Pop**	**Lit**	**Wom**	**Agr**	**LT**
Pojo	↑	↑	↑	↑	→	→	←	↑	↓
Totora	↓	↑	↑	↑	↓	←	↓	→	↑
Comarapa	↑	↑	↑	↑	→	→	↓	→	←
Pocona	↑	↑	↑	↑	→	→	↓	↑	←
Alalay	↑	↑	↑	↑	→	←	↓	↑	↓
Pampa Grande	↑	↑	↑	↑	→	↑	↓	→	↓
Mizque	↑	↑	↑	↑	→	←	←	→	↓
Omereque	↑	↑	↑	↑	→	→	↓	↑	↓
Saipina	↑	↑	↑	↑	→	↑	←	→	↓
Aiquile	↑	↑	↑	↑	→	→	←	→	↓
Pasorapa	↑	↑	↑	↑	↑	→	↓	→	↓
Moromoro	↑	↓	↑	↑	↓	→	↓	↑	↓
Trigal	↑	↓	↑	↑	↑	↑	↓	→	↓
Quirusillas	↑	↓	↑	↑	↑	↑	↓	↑	↓
Pucara	↑	↑	↑	↑	↓	→	↓	→	↓
Villa Serrano	↑	↑	↑	↑	↓	←	↓	←	↓
Icla	↑	↑	↑	↑	↑	↓	↓	→	↓
Tarvita	↑	↑	↑	↑	↑	↓	↓	→	↓

Table 22.

Summary for Solanum boliviense subsp. astleyi

Municipality	**T°**	**PP**	**Min**	**Oil**	**Pop**	**Lit**	**Wom**	**Agr**	**LT**
Betanzos	↑	↓	↑	↑	↑	↓	←	→	↓
Puna	↑	↓	↑	↑	↓	↓	↓	↑	↓

Table 23.

Summary for Solanum gandarillasii

Municipality	**T°**	**PP**	**Min**	**Oil**	**Pop**	**Lit**	**Wom**	**Agr**	**LT**
Totora	↑	↑	↑	↑	←	←	↓	→	↑
Comarapa	↑	↓	↑	↑	→	←	↓	→	←
Pocona	↑	↑	↑	↑	←	↑	↓	↑	←
Vacas	↑	↑	↑	↑	↓	←	↓	↑	↓
Alalay	↑	↑	↑	↑	←	↑	↓	↑	↓
Pampa Grande	↑	↓	↑	↑	→	→	↓	→	↓
Mizque	↑	↑	↑	↑	→	←	←	←	↓
Saipina	↑	↓	↑	↑	←	→	←	→	↓
Aiquile	↑	↑	↑	↑	←	↑	←	→	↓
Toro Toro	↑	↑	↑	↑	←	↑	↓	→	↓
Moromoro	↑	↓	↑	↑	←	↑	↓	↑	↓
Trigal	↑	↓	↑	↑	↑	↓	↓	→	↓
Quirusillas	↑	↓	↑	↑	→	↓	↓	↑	↓
Vallegrande	↑	↓	↑	↑	↑	←	↓	←	↓
Presto	↑	↑	↑	↑	↑	←	↓	→	↓
Villa Mojocoya	↑	↑	↑	↑	←	↑	←	→	↓
Villa Serrano	↑	↓	↑	↑	←	←	↓	←	↓

Municipality	T°	PP	Min	Oil	Pop	Lit	Wom	Agr	LT
Sucre	↑	↑	→	↑	↓	↑	←	↓	←
Tarabuco	↑	↑	↑	↑	→	↓	↓	←	↓
Tomina	↑	↑	↑	↑	←	←	↓	→	↓
Villa Zudanez	↑	↑	↑	↑	←	←	↓	←	↓

Quinoa – *Chenopodium* spp.

The main threat to quinoa is the lack of an adequate land tenure process in the municipalities where it is found. The municipalities where there is an adequate land tenure process are usually areas where there are communitarian territory bases (TCO for Territorio Comunitario de Origen). This is a special kind of land tenure category that is granted to indigenous groups. These TCOs may differ from other municipal governments in terms of their structures and processes; traditional forms of knowledge and practice would have to be accounted for in any conservation project launched in those regions.

In the case of *Chenopodium hircinum* (table 24) there are seven promising municipalities: Papel Pampa, Villa Poopo, Pojo, El Choro, Sucre, Salinas de Garci Mendoza and Uyuni. First two municipalities have somewhat unfavorable indicators for mining concessions and unfavorable opportunities for women in local government. The other have population dynamics as a threat and one unfavorable opportunity like lack of land tenure, low percentage of people involved in agriculture and low percentage of women participation in government.

Pojo, Comarapa and Uyuni were chosen for *C. hircinum subsp. catamarcensis* (table 25). They have unfavorable trend for temperature and unfavorable population dynamics; in addition, the first is unfavorable for land tenure process while the other two are unfavorable for women represented in local government. The municipalities of Pojo, Comarapa, Papel Pampa, Aiquile and Sucre were chosen for *C. hircinum* subsp. *eu-hircinum* (table 26). Three of these municipalities were chosen previously for other species.

Finally, the municipality of Comarapa houses one potato species and two quinoa species. Papel Pampa houses one potato species and one quinoa species, while Pojo, Sucre and Uyuni house two quinoa species.

Table 24.

Summary for Chenopodium hircinum

Municipality	**T°**	**PP**	**Min**	**Oil**	**Pop**	**Lit**	**Wom**	**Agr**	**LT**
Tiraque	↑	↑	↑	↑	→	→	↓	←	↓
Pojo	↑	↑	↑	↑	↓	→	←	→	↓
Patacamaya	↑	↑	←	↑	↓	↑	↓	←	↓
Sica-Sica	↑	↑	↑	↑	↓	↑	←	←	↓
Totora	↑	↑	↑	↑	↓	←	↓	←	↑
Umala	↑	↑	↑	↑	←	↑	↓	→	↓
Caracollo	↑	↑	→	↑	→	↑	↓	←	↓
Comarapa	↑	↑	↑	↑	↑	→	↓	←	←
Pocona	↑	↑	↑	↑	→	→	↓	→	←
Vacas	↑	↑	↑	↑	←	←	↓	→	↓
Eucaliptus	↑	↑	↑	↑	→	↑	↓	←	↓
Papel Pampa	↑	↑	←	↑	↑	↑	↓	→	→
Oruro	↑	↑	→	↑	↓	↑	←	↓	↓
Alalay	↑	↑	↑	↑	→	←	↓	↑	↓
Pampa Grande	↑	↑	↑	↑	↑	↑	↓	←	↓
Mizque	↑	↑	↑	↑	→	←	←	←	↓
Santiago de Huayllamarca	↑	↑	↑	↑	↑	→	↓	→	↑
Omereque	↑	↑	↑	↑	↑	→	↓	→	↓
Vila Vila	↑	↑	↑	↑	↑	←	↓	←	↓
Saipina	↑	↑	↑	↑	→	↑	←	←	↓
Aiquile	↑	↑	↑	↑	→	→	←	←	↓
El Choro	↑	↑	↑	↑	←	→	←	→	↓
Toro Toro	↑	↑	↑	↑	↑	←	↓	←	↓
Choquecota	↑	↑	↑	↑	↑	↑	↑	→	↓

Municipality	T°	PP	Min	Oil	Pop	Lit	Wom	Agr	LT
Pasorapa	↑	↑	↑	↑	↑	→	↓	←	↓
Corque	↑	↑	↑	↑	↑	↑	↓	→	↓
San Pedro	↑	↑	↑	↑	↑	↓	←	→	↓
Machacamarca	↑	↑	←	↑	←	↑	←	←	↓
Moromoro	↑	↓	↑	↑	↓	→	↓	→	↓
Trigal	↑	↓	↑	↑	↑	↑	↓	←	↓
Villa Poopo	↑	↑	←	↑	↑	→	↓	←	←
Vallegrande	↑	↑	↑	↑	↑	↑	↓	←	↓
Poroma	↑	↑	↑	↑	↑	↓	↓	←	↓
Presto	↑	↑	↑	↑	↑	↓	↓	←	↓
Colquechaca	↑	↑	↑	↑	→	↓	←	→	↓
Ravelo	↑	↑	↑	↑	→	↓	↓	←	↓
Villa Mojocoya	↑	↑	↑	↑	↑	←	←	←	↓
Escara	↑	↑	↑	↑	←	↑	↓	→	↓
Sucre	↑	↑	→	↑	↓	↑	←	↓	←
Andamarca	↑	↑	↑	↑	→	→	↓	→	→
Ocuri	↑	↑	↑	↑	←	↓	↓	←	↓
Belen de Andamarca	↑	↑	↑	↑	→	↑	↑	→	↓
Tarabuco	↑	↑	↑	↑	→	↓	↓	←	↓
Esmeralda	↑	↑	↑	↑	↓	↑	↓	↑	↓
Santiago de Huari	↑	↑	↑	↑	→	→	↓	→	←
Tocobamba	↑	↑	←	↑	→	↓	↓	→	↓
Tinquipaya	↑	↑	↑	↑	→	↓	↓	→	↓
Chipaya	↑	↑	↓	↑	←	↑	↓	→	↓
Salinas de G. Mendoza	↑	↑	↑	↑	←	→	↓	→	→
Pampa Aullagas	↑	↑	↑	↑	→	↑	↓	→	→

Municipality	T°	PP	Min	Oil	Pop	Lit	Wom	Agr	LT
Santuario Quillacas	↑	↑	↑	↑	→	↑	←	→	→
Uyuni	↑	↑	↑	↑	↓	↑	↓	←	←
Colcha"K"	↑	↑	→	↑	↑	↑	↓	←	↓

Table 25.

Summary for Chenopodium hircinum subsp. catamarcensis

Municipality	T°	PP	Min	Oil	Pop	Lit	Wom	Agr	LT
Tiraque	↑	↑	↑	↑	↑	→	↓	↑	↓
Pojo	↓	↑	↑	↑	→	→	←	↑	↓
Totora	↑	↑	↑	↑	↓	←	↓	→	↑
Comarapa	↓	↑	↑	↑	→	→	↓	→	←
Pocona	↑	↑	↑	↑	↑	→	↓	↑	←
Vacas	↑	↑	↑	↑	←	←	↓	↑	↓
Alalay	↑	↑	↑	↑	→	←	↓	↑	↓
Mizque	↑	↑	↑	↑	→	←	←	→	↓
Omereque	↑	↑	↑	↑	→	→	↓	↑	↓
Vila Vila	↑	↑	↑	↑	↑	←	↓	→	↓
Saipina	↑	↑	↑	↑	→	↑	←	→	↓
Aiquile	↑	↑	↑	↑	→	→	←	→	↓
Toro Toro	↑	↑	↑	↑	↑	←	↓	→	↓
Pasorapa	↑	↑	↑	↑	→	→	↓	→	↓
Poroma	↑	↑	↑	↑	↑	↓	↓	→	↓
Colquechaca	↑	↑	↑	↑	→	↓	←	↑	↓
Andamarca	↑	↑	↑	↑	→	→	↓	↑	→

Municipality	**T°**	**PP**	**Min**	**Oil**	**Pop**	**Lit**	**Wom**	**Agr**	**LT**
Belen de Andamarca	↑	↑	↑	↑	→	↑	→	⮦	↓
Santiago de Huari	↑	↑	↑	↑	→	→	↓	⮧	←
Salinas de G. Mendoza	↑	↑	↑	↑	→	→	↓	⮤	→
Pampa Aullagas	↑	↑	↑	↑	→	↑	↓	⮧	↑
Santuario Quillacas	↑	↑	↑	↑	→	↑	←	⮥	→
Uyuni	↑	↑	↑	↑	↓	↑	↓	⮧	←
Colcha"K"	↑	↑	→	↑	→	↑	↓	⮧	↓

Table 26.

Summary for Chenopodium hircinum subsp. eu-hircinum

Municipality	**T°**	**PP**	**Min**	**Oil**	**Pop**	**Lit**	**Wom**	**Agr**	**LT**
La Paz	↑	↑	↑	↑	↓	↑	←	↓	↓
El Alto	↑	↑	→	↑	↓	↑	←	↓	↓
Palca	↑	↑	←	↑	↑	→	↓	↑	↓
Laja	↑	↑	↑	↑	↑	→	↓	↑	↓
Achocalla	↑	↑	→	↑	↓	↑	↓	←	↓
Mecapaca	↑	↑	←	↑	↓	→	↓	↑	↓
Viacha	↑	↑	↑	↑	→	↑	↓	↓	↓
Calamarca	↑	↑	↑	↑	→	↑	↓	→	↓
Sapahaqui	↑	↑	↑	↑	→	→	↓	↑	↓
Collana	↑	↑	↑	↑	→	↑	↓	←	↓
Tiraque	↑	↑	↑	↑	↑	→	↓	↑	↓
Colquencha	↑	↑	→	↑	→	↑	←	→	↓
Ayo-Ayo	↑	↑	↑	↑	↑	↑	↓	↑	↓

Municipality	T°	PP	Min	Oil	Pop	Lit	Wom	Agr	LT
Pojo	↓	↑	↑	↑	←	→	←	↑	↓
Coro Coro	↑	↑	↑	↑	→	↑	↓	↑	↓
Patacamaya	↑	↑	←	↑	↓	↑	↓	←	↓
Sica-Sica	↑	↑	↑	↑	→	↑	←	→	↓
Umala	↑	↑	↑	↑	←	↑	↓	↑	↓
Caracollo	↑	↑	→	↑	↑	↑	↓	→	↓
Comarapa	↓	↑	↑	↑	→	→	↓	→	←
Pocona	↑	↑	↑	↑	↑	→	↓	↑	←
Vacas	↑	↑	↑	↑	↓	←	↓	↑	↓
Eucaliptus	↑	↑	↑	↑	↑	↑	↓	←	↓
Papel Pampa	↑	↑	←	↑	↑	↑	↓	↑	→
Totora	↑	↑	↑	↑	↑	←	↓	→	↑
Alalay	↑	↑	↑	↑	→	←	↓	↑	↓
Pampa Grande	↓	↑	↑	↑	→	↑	↓	→	↓
Mizque	↑	↑	↑	↑	→	←	←	→	↓
Santiago de Huayllamarca	↑	↑	↑	↑	↑	→	↓	↑	↑
Omereque	↑	↑	↑	↑	→	→	↓	↑	↓
Vila Vila	↑	↑	↑	↑	↑	←	↓	→	↓
Saipina	↑	↑	↑	↑	↑	↑	←	→	↓
Aiquile	↓	↑	↑	↑	↑	→	←	→	↓
Toro Toro	↑	↑	↑	↑	↑	←	↓	→	↓
Choquecota	↑	↑	↑	↑	↑	↑	↑	↑	↓
Pasorapa	↓	↑	↑	↑	→	→	↓	→	↓
Corque	↑	↑	↑	↑	→	↑	↓	↑	↓
San Pedro	↑	↑	↑	↑	→	↓	←	↑	↓
Moromoro	↓	↓	↑	↑	↓	→	↓	↑	↓
Poroma	↑	↑	↑	↑	↑	↓	↓	→	↓

Municipality	T°	PP	Min	Oil	Pop	Lit	Wom	Agr	LT
Presto	↑	↑	↑	↑	→	↓	↓	→	↓
Colquechaca	↑	↑	↑	↑	→	↓	←	↑	↓
Ravelo	↑	↑	↑	↑	↑	↓	↓	→	↓
Villa Mojocoya	↑	↑	↑	↑	↑	←	←	→	↓
Pucara	↑	↓	↑	↑	←	→	↓	→	↓
Villa Serrano	↓	↑	↑	↑	↓	←	↓	←	↓
Sucre	↑	↑	→	↑	↓	↑	←	↓	←
Ocuri	↑	↑	↑	↑	→	↓	↓	→	↓
Tarabuco	↑	↑	↑	↑	←	↓	↓	←	↓
Tomina	↑	↑	↑	↑	↑	↓	↓	→	↓
Villa Zudanez	↑	↑	↑	↑	↑	↓	↓	→	↓
Tocobamba	↑	↑	←	↑	↓	↓	↓	↑	↓
Tinquipaya	↑	↑	↑	↑	→	↓	↓	↑	↓
Betanzos	↑	↑	↑	↑	↑	←	←	→	↓
Icla	↑	↑	↑	↑	↑	↓	↓	→	↓
Sopachuy	↓	↑	↑	↑	↓	←	↓	→	↓
Puna	↑	↑	↑	↑	↓	←	↓	↑	↓
Tarvita	↓	↑	↑	↑	↑	↓	↓	→	↓

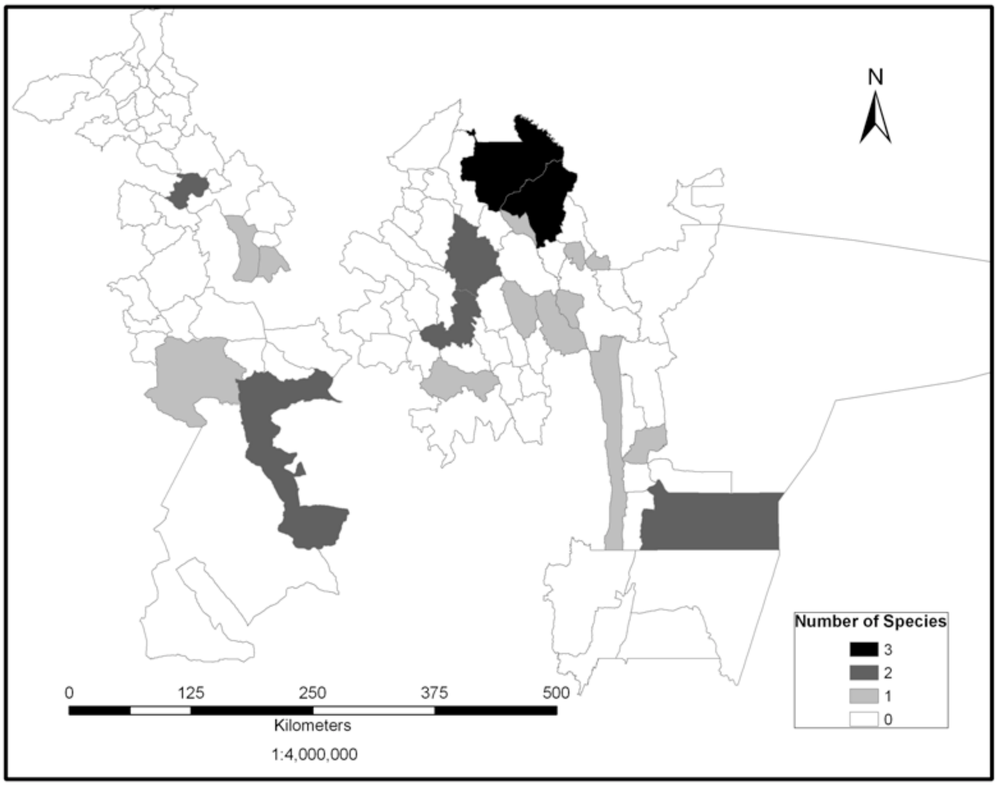


Fig. 29. Final selection of municipalities with most promising conditions for conservation projects.

The map on figure 29 shows the 19 selected municipalities for all the 9 species and marks those that house more than one species. These municipalities could be promising candidates to start a pilot CWR conservation project; CWRs face at least one threat in each, but the social and economic conditions suggest potentially favorable outcomes where conservation projects could be launched.

Chapter 5

CONCLUSIONS & RECOMMENDATIONS

Any successful conservation project should take into account the different threats and opportunities present in the local context. Therefore it is not possible to design a blueprint conservation plan for all of the species analyzed here.

In general peanut is primarily threatened by:

- Increases in precipitation
- A relatively small agricultural labor force and relatively low empowerment of women (as measured by percent in governments)
- Significant percent of oil concessions

But has to its advantage:

- Relatively low threats from changes in temperature.
- Found in places with favorable (human) population dynamics and high literacy rates.

This situation is different for *Arachis ringonii*. This species is only found in one municipality, where it is threaten by temperature decrease, precipitation increase, and oil concessions. The opportunities are not favorable for population dynamics (as it is a fast growing urban area), there are few people involved in agricultural labor, and there is a relatively low level of land registered in the tenure process.

Potato is primarily threatened by:

– Decreases in precipitation

– Relatively low empowerment of women (as measured by percent in governments)

– Relatively small proportion of land whose tenure has been recognized/registered.

But has to its advantage:

– A large agricultural labor force

– A lack of oil and mining activities

The case for *Solanum boliviense* subsp. *astleyi*, which has also a small distribution area, is more promising than the one for *A. ringonii.* The threat for this species is precipitation decrease. The lack of mining and oil concessions in this area, and the opportunity of favorable population dynamics and people involved in agriculture, can compensate the unfavorable literacy rate and low participation of women in local governments.

Quinoa is primarily threatened by:

– Increases in temperature in a few municipalities

– Relatively low empowerment of women (as measured by percent in governments)

– Relatively small proportion of land whose tenure has been recognized/registered.

But has to its advantage:

– A high proportion of subsistence agriculturalists

– A lack of oil and mining activities

The species that had the smallest distribution area for quinoa is *Chenopodium hircinum* and has at least two municipalities that could be considered for a pilot conservation project.

The resources are simply not available to start conservation projects for CWR in every municipality in Bolivia. The results of this assessment could be used to identify priority areas for conservation, as well as helping determine the resources that might be required in each case. In general, one might consider placing conservation projects in areas where there are a few threats to CWR (otherwise conservation is not required) and social and economic conditions favor potentially positive outcomes for conservation projects. In some cases, however, where species ranges are severely restricted, one might need to consider establishing conservation projects in areas where threats are numerous, and socioeconomic conditions are not favorable to conservation. Greater resources may need to be concentrated in those municipalities relative to others where threats are lower and opportunities for successful outcomes greater.

This analysis leads to several conclusions:

- Bolivia would benefit from a clear national-level framework on food security and biodiversity that would have as one priority the conservation of crop wild relatives.

- There is a strong connection between land tenure and conservation efforts. Therefore, the land tenure process going on in Bolivia should be maintained or strengthened in the near term, in order to enhance the prospects for successful conservation projects. Because this process is already occurring, and enjoys widespread public support, it is one of the potential barriers to conservation in Bolivia that can be most easily overcome.

- The potential impacts of climate change on CWRs are sobering. While both precipitation changes and temperature changes threaten crop wild relatives, the greater impacts in this study are found to be related to precipitation change. More research is needed, however, to understand how projected climate changes will truly “downscale” to the different biogeographic regions of Bolivia. Supporting research into climate change, climate-change adaptation, and assisted migration (relocation of CWRs) in Bolivia’s universities and research institutions could enhance prospects for conservation of CWRs, and increase the capacity to identify those populations of CWR that are most threatened by climate change.

- Bolivian residents should be educated on the benefits of conserving and using CWRs. Such benefits include the resilience of production, enhanced nutritional value of diets based on locally produced foods, and potential commercial opportunities. Rural residents in particular could benefit from such outreach programs, which should include inexpensive approaches to maintaining CWRs in local fields and household gardens.

- The central government and the municipalities should create and promote internal markets for new products based on CWR (like pasta made of quinoa or peanut oil).

- Municipalities that look the most promising with respect to the potential for conserving CWRs should receive support, either from the central government or the NGOs, in operationalizing conservation programs. This could include training in how to secure the property rights for endemic genetic material.

- The results of this study could be used to identify a handful of municipalities in which pilot conservation projects could be established. This conservation programs should be integrative, covering conservation of species, education, the land tenure process, research, *in situ* conservation in gardens (that can be managed by community women), and crop improvement.

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APPENDIX A

MAPS FOR OTHER RESULTS

In this section I include the maps that were not presented in the Results chapter.

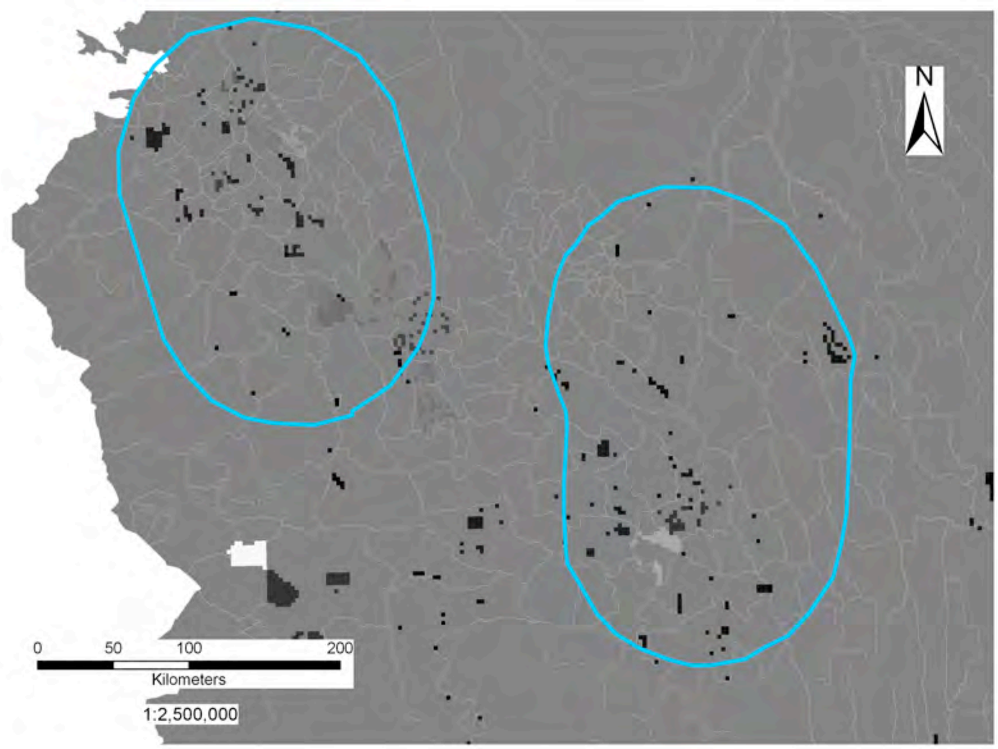
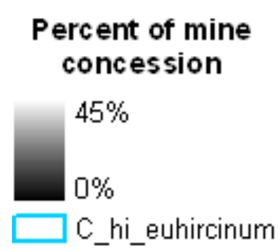


Fig. 30. Mining concessions for ***Chenopodium hircinum*** **subsp.** ***eu-hircinum.***



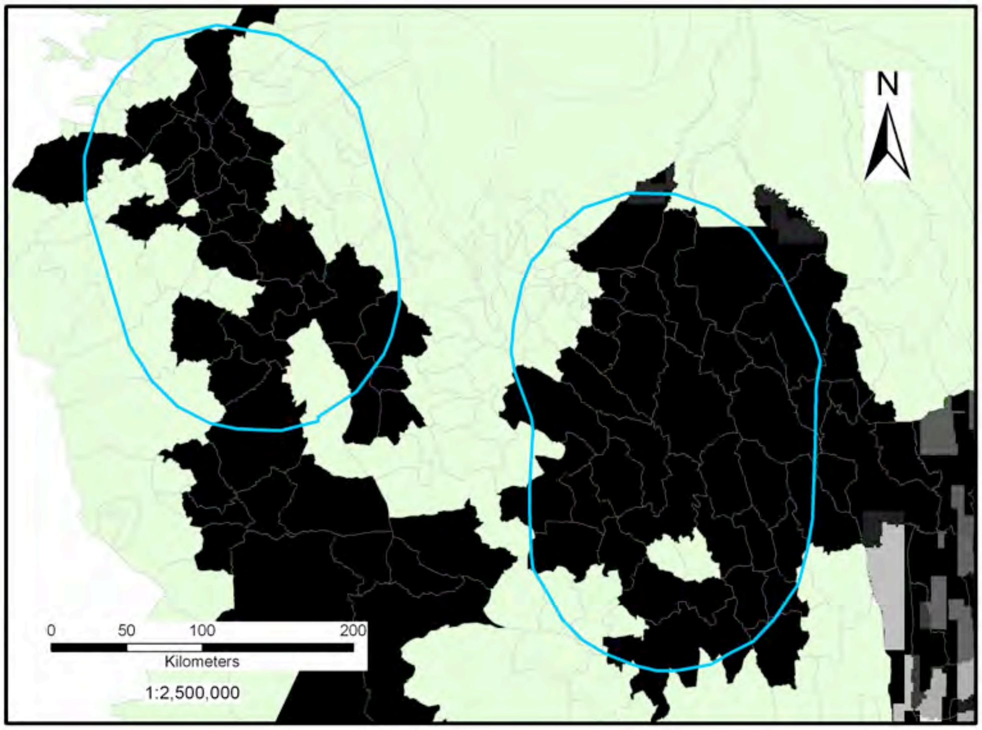


Fig. 31. Oil concessions for *Chenopodium hircinum* subsp. *eu-hircinum.*

Percent of oil concession

100%

0%

No Data

C_hi_euhircinum

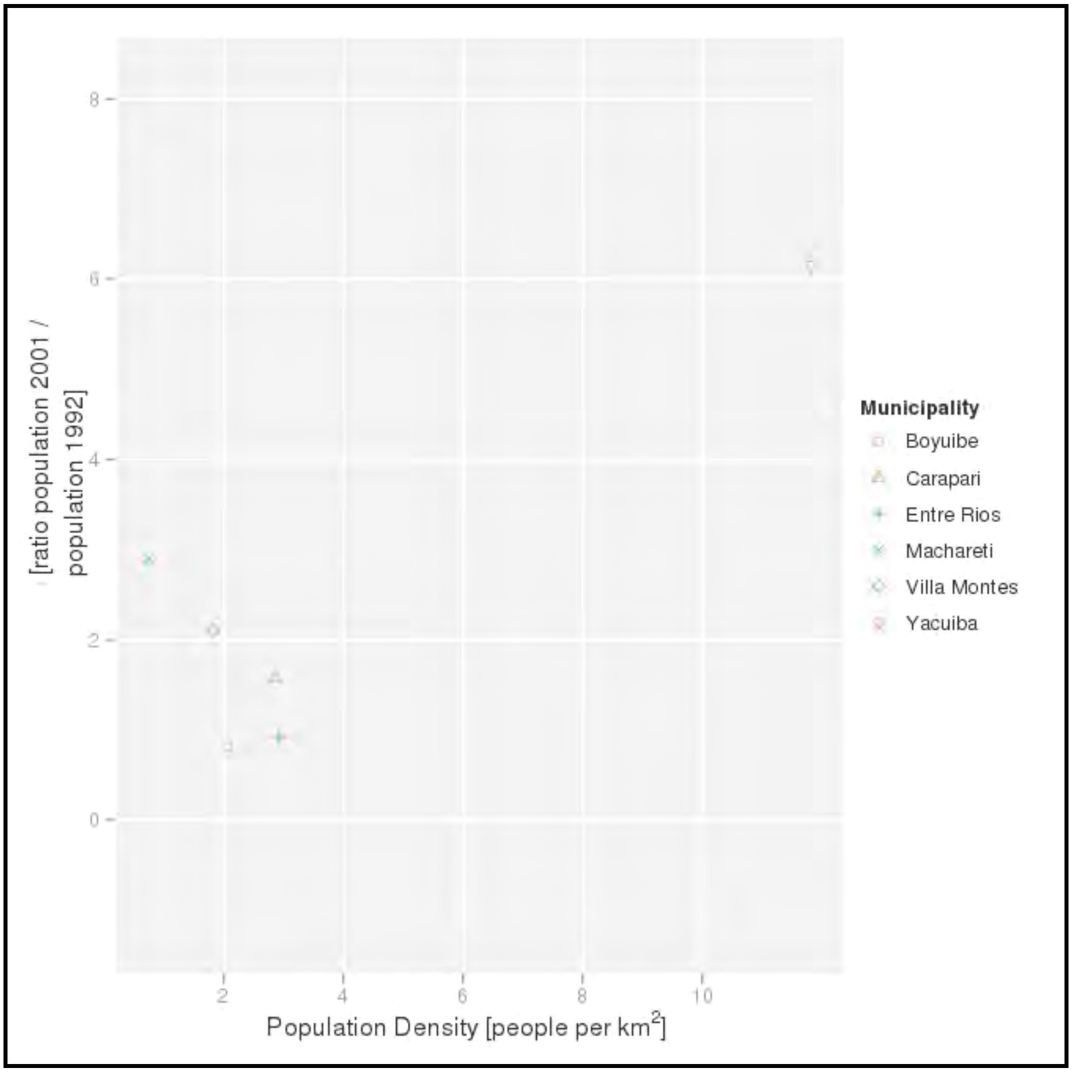


Fig. 32. Population dynamics for *Arachis duranensis*,

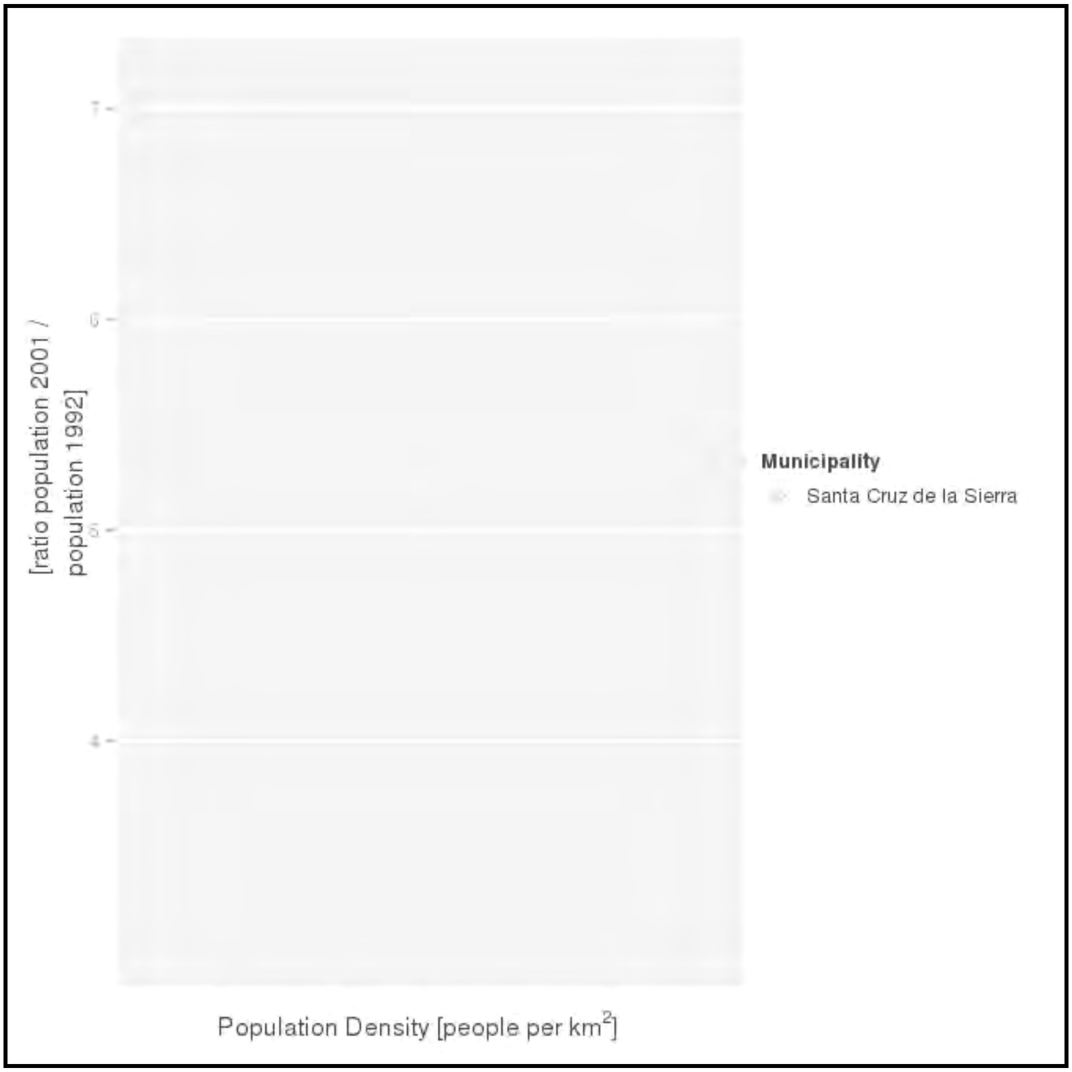


Fig. 33. Population dynamics for *Arachis ringonii.*

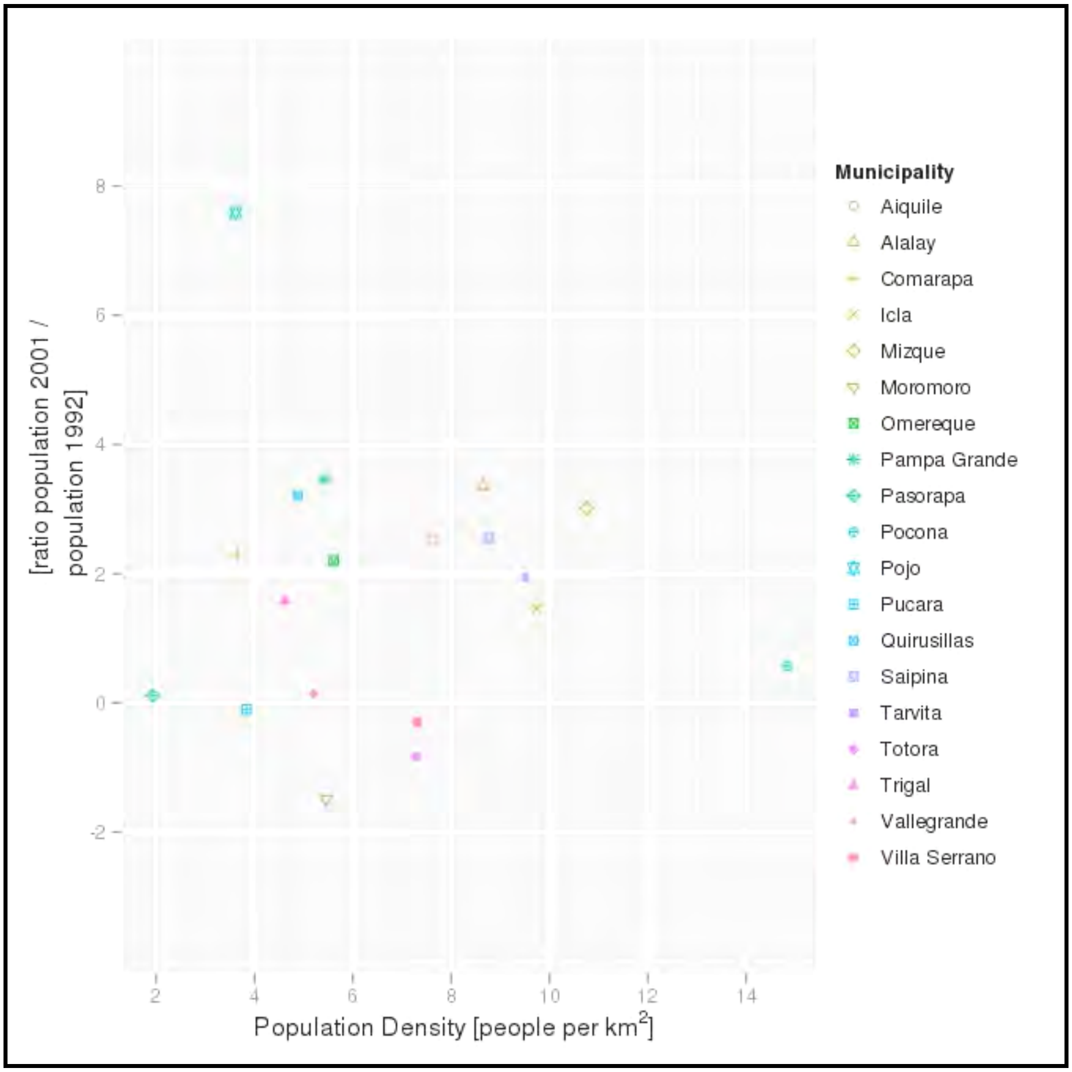


Fig. 34. Population dynamics for *Solanum alandiae.*

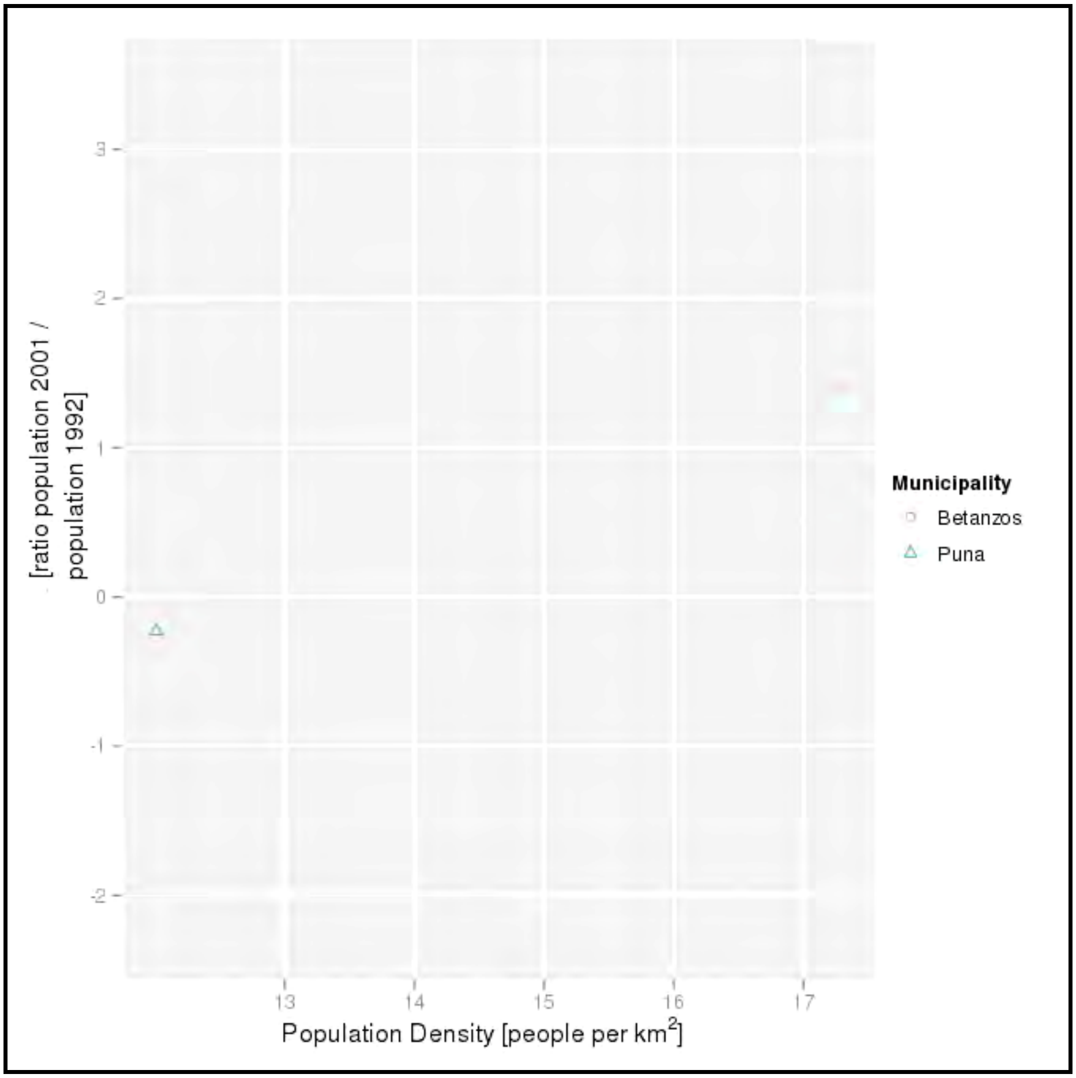


Fig. 35. Population dynamics for *Solanum boliviense* subsp. *astleyi.*

Fig. 36. Population dynamics for *Chenopodium hircinum.*

Fig. 37. Population dynamics for *Chenopodium hircinum* subsp. *eu-hircinum*.

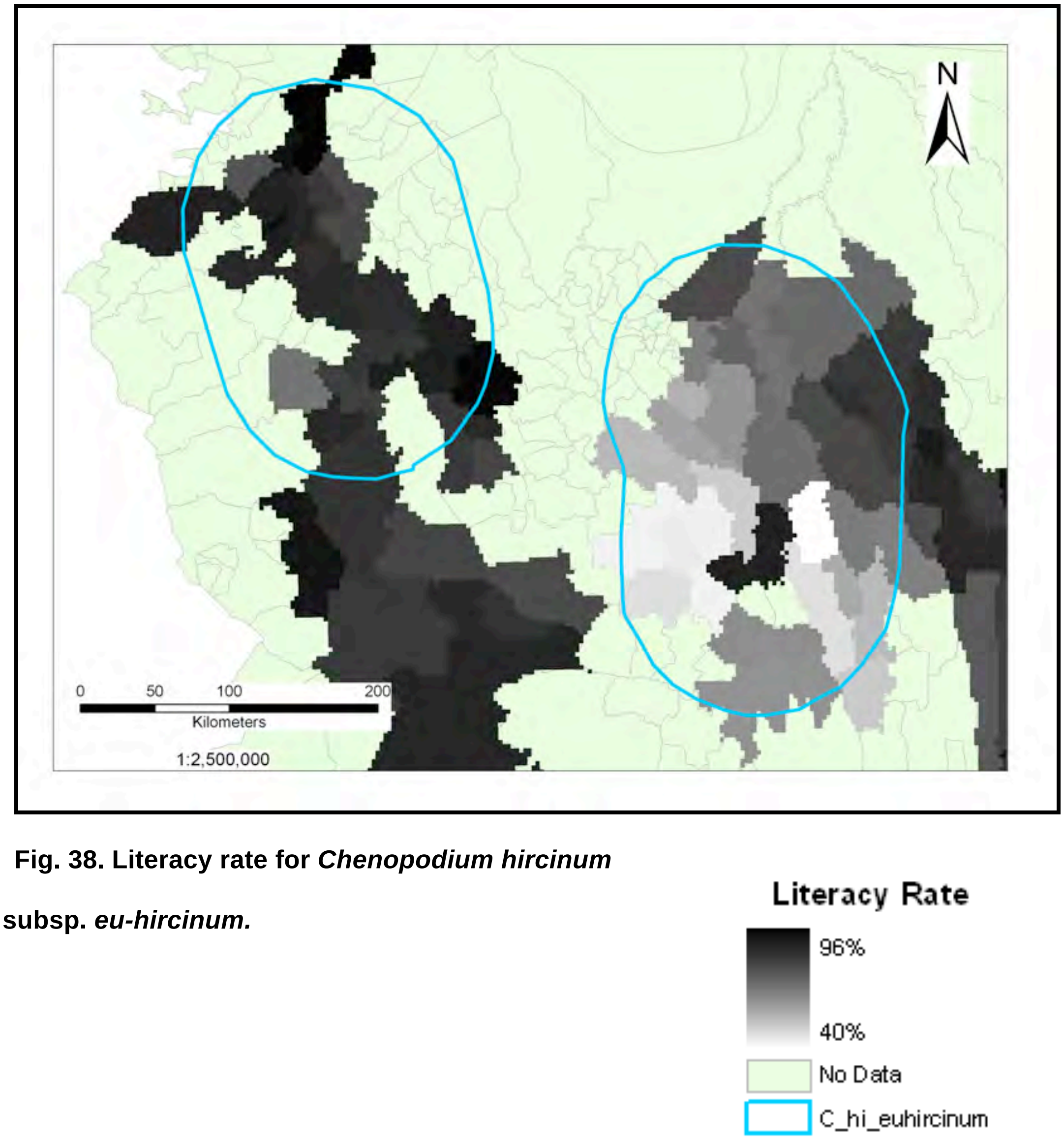


Fig. 38. Literacy rate for *Chenopodium hircinum* subsp. *eu-hircinum.*

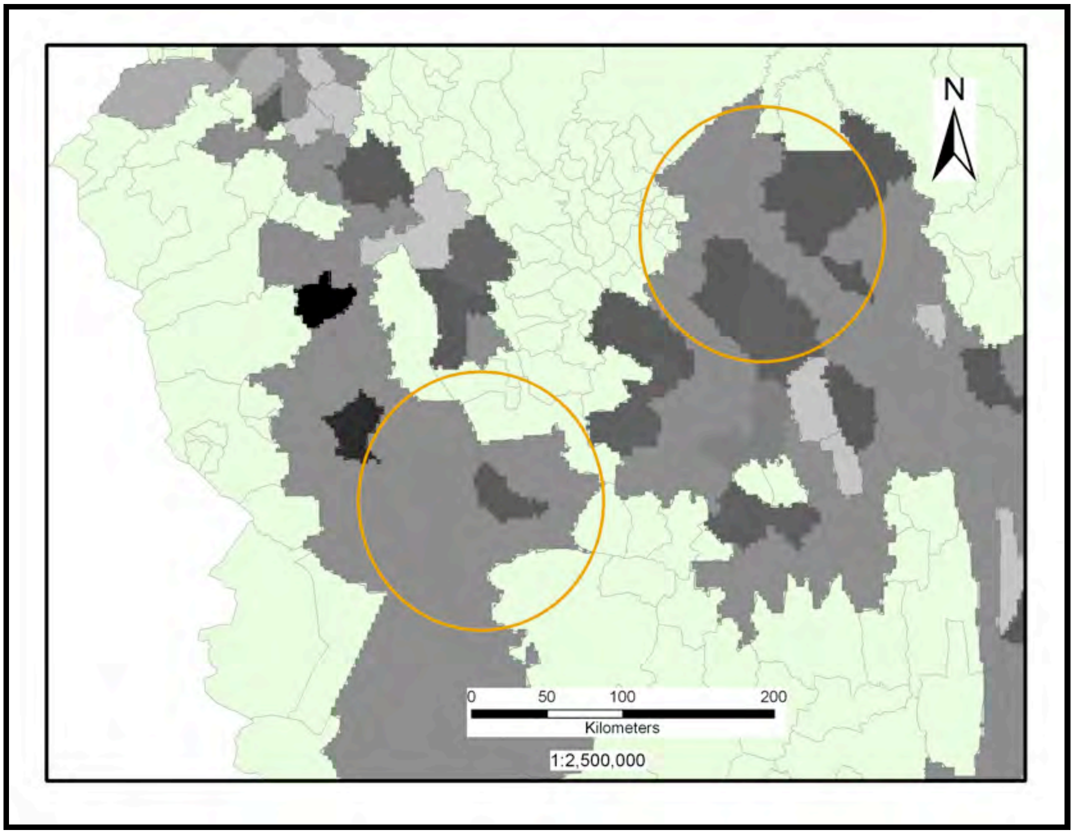
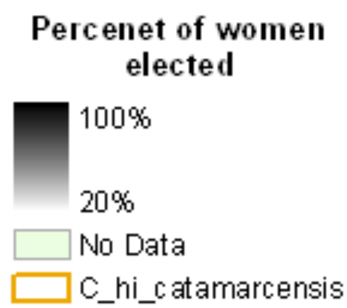


Fig. 39. Women in local government for

Chenopodium hircinum* subsp. *catamarcensis.



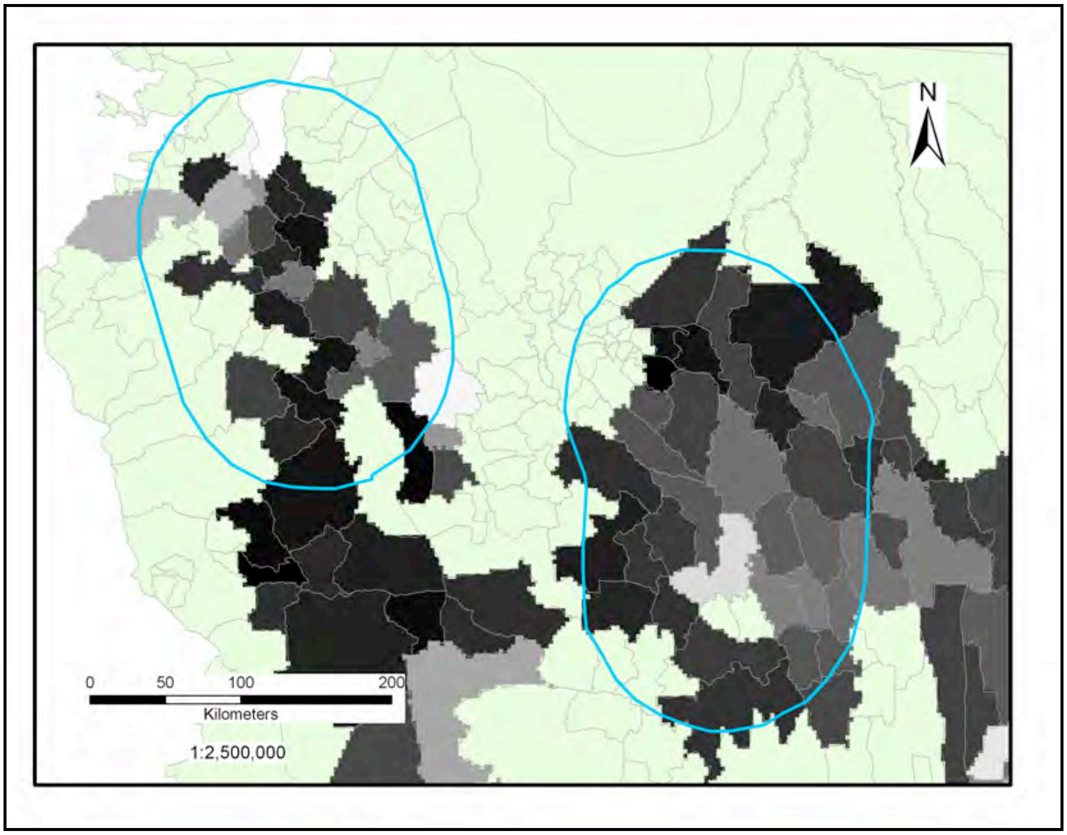
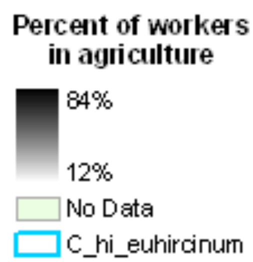


Fig. 40. Workers involved in agricultural labor for

Chenopodium hircinum **subsp.** ***eu-hircinum.***



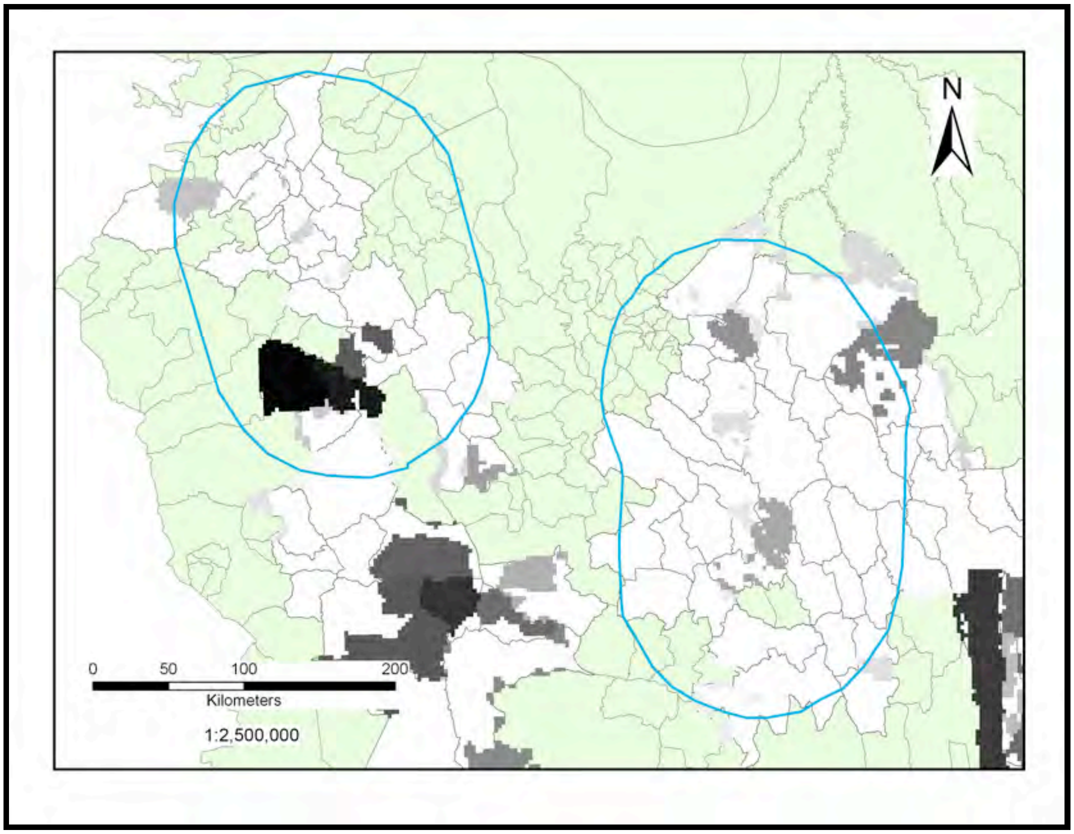
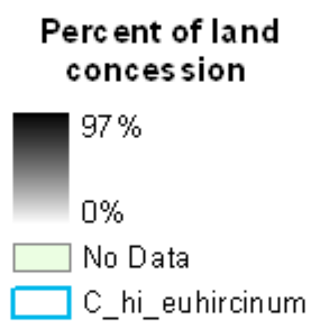


Fig. 41. Land tenure process for *Chenopodium hircinum* subsp. *eu-hircinum.*



BIOGRAPHICAL SKETCH

Cecilia Gonzalez-Paredes was born in La Paz, Bolivia. She received the degree of Bachelor of Biology from Universidad Autónoma de Guadalajara, México in 2001. She taught the class of Introduction to Botany at Universidad Mayor de San Andrés during spring 2002. During the following years, she worked for REDESMA (Red de Desarrollo Sostenible y Medio Ambiente - Sustainable Development and Environment Network). During her last 3 years in REDESMA she was in charge of the Network, publishing bimonthly bulletins, building the website contents and coordinating activities with other NGO's and government units. In 2006, she moved to Germany and under the sponsorship of InWent, participated from the professional training program on Conservation of Biodiversity. In 2008, she entered the Graduate School at Arizona State University.

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