Medicinal plant cultivation and value chains in Bolivia

A field study of traditional knowledge, practices and environments

Melissa Herbas

Examensarbete/Självständigt arbete i Biologi • 15 hp
Sveriges lantbruksuniversitet, SLU
Fakulteten för landskapsarkitektur, trädgårds- och växtproduktionsvetenskap
Institutionen för Biosystem och Teknologi
Trädgårdsingenjör: odling – kandidatprogram
Alnarp 2025

1

Medicinal plant cultivation and value chains in Bolivia - A field study of traditional knowledge, practices and environments

Odling och värdekedjor av medicinalväxter i Bolivia – En fältstudie av traditionell kunskap, odlingspraxis och miljöer

Handledare:	**Rodomiro Octavio Ortiz Rios, SLU, Department of Plant Breeding**
Bitr. handledare:	Claudia Sainz Villabrandt, CABI, Plantwise Bolivia
Examinator:	Lotta Nordmark, SLU, Department of Biosystems and Technology

Omfattning:	15 hp
Nivå och fördjupning:	Grundnivå, G2E
Kurstitel:	Självständigt arbete i Biologi
Kurskod:	EX0855
Program/utbildning:	Trädgårdsingenjörsprogrammet -Odling
Kursansvarig inst.:	Biosystem och Teknologi
Utgivningsort:	Alnarp
Utgivningsår:	2025
Omslagsbild:	Foto av Melissa Herbas 2025
Upphovsrätt:	Alla bilder används med upphovspersonens tillstånd.
Nyckelord (Key Words):	Medicinal plants, Plant defense, Traditional knowledge, Value Chains, Secondery Metabolites, Wild harvesting, Ethnobotany, Bolivia, Muña *Minthostachys mollis,* Wira Wira *Gnaphalium dombeyanum*)

Sveriges lantbruksuniversitet
Fakultet landskapsarkitektur, trädgårds- och växtproduktionsvetenskap
Institutionen för Biosystem och teknologi

Abstract

Medicinal plants play a curtail role in healthcare and livelihoods in Bolivia, despite that the cultivation and commercialization remain largely informal and non-documented. This study explores how native medicinal plants are cultivated, used, and integrated into local value chains in Cochabamba, Bolivia. Through semi-structured interviews with farmers, vendors and traditional practitioners in combination with market observations and field visits, the study examines traditional knowledge in relation to scientific and regulatory frameworks. The findings show that most medicinal plants including Muña (*Minthostachys mollis*) and Wira Wira (*Gnaphalium dombeyanum*) are predominantly wild harvested under conditions that enhance their medicinal potency. Local practices emphasize that harsher climates provide the best quality medicinal plants. The study aligns this theory with ecological principles of stress-induced metabolite production. The commercialization remains largely informal with gaps between national regulations and actual market practices. The study highlights the need for sustainable cultivation strategies, stronger value chain development and biochemical validation of traditional remedies. By combining traditional and scientific knowledge, Bolivia's medicinal plants hold large potential for healthcare and biodiversity conservation and for contributing to economic resilience and addressing global health challenges such as noncommunicable diseases.

Key words: Medicinal plants, Plant defense, Traditional knowledge, Value Chains, Secondery Metabolites, Wild harvesting, Ethnobotany, Bolivia, Muña *Minthostachys mollis,* Wira Wira *Gnaphalium dombeyanum*)

Sammanfattning

Medicinalväxter spelar en omfattande roll i hälso- och sjukvård samt försörjning i Bolivia, trots att odling och kommersialisering till stor del är informell och odokumenterad. Denna studie undersöker hur inhemska medicinalväxter odlas, används och integreras i lokala värdekedjor i Cochabamba, Bolivia. Genom semistrukturerade intervjuer med jordbrukare, försäljare och traditionella utövare, i kombination med marknadsobservationer och fältbesök, analyserar studien traditionell kunskap i relation till vetenskapliga och regulatoriska ramverk. Resultaten visar att de flesta medicinalväxter, inklusive Muña (*Minthostachys mollis*) och Wira Wira (*Gnaphalium dombeyanum*) huvudsakligen skördas vilt under förhållanden som förstärker deras medicinska potens. Lokal kunskap betonar att hårdare klimat ger medicinalväxter av bättre kvalitet, vilket ligger i linje med ekologiska principer för stressinducerad metabolitproduktion. Samtidigt förblir kommersialiseringen till stor del informell, med tydliga skillnader mellan nationella regelverk och faktiska marknadspraktiker. Studien betonar behovet av hållbara odlingsstrategier, starkare värdekedjeutveckling och biokemisk validering av traditionella läkemedel. Genom att kombinera traditionell och vetenskaplig kunskap har Bolivias medicinalväxter stor potential att bidra till hälso- och sjukvård, bevarande av biologisk mångfald samt ekonomisk utveckling och kan även bidra till att hantera globala hälsoutmaningar såsom icke-smittsamma sjukdomar.

Nyckelord: Medicinalväxter, Växt försvar, Traditionell kunskap, Värdekedjor, Sekundära metaboliter, Vild skörd, Etnobotanik, Bolivia Muña Minthostachys mollis, Wira Wira Gnaphalium dombeyanum)

Thank You!

This study was carried out in my birth country, Bolivia, to which I would like to dedicate my deepest gratitude. Having the opportunity to conduct this research has given me a new perspective on life and allowed me to grow both personally and academically. I am proud to be Bolivian and feel fortunate to come from a country so rich in natural resources and beautiful traditions.

This work would not have been possible without the help and support of many people I encountered along the way whom I would like to give a special thanks to.

First, I would like to thank my family for their encouragement throughout this entire process. You have been my foundation and greatest support system.

A special thanks goes to my two supervisors: Claudia Sainz Villabrandt, who inspired me to undertake this project and introduced me to the professional agricultural side of Bolivia, and Rodomiro Octavio Ortiz Rios who provided guidance, encouragement and a solid academic framework that helped elevate this thesis.

I am also grateful to the SLU Mobility Team for selecting me for the Erasmus grant, which made it possible to finance much of this research.

Finally, my deepest appreciation goes to all the people who generously shared their time, knowledge and homes with me during this study: **Juan Gregorio Céspedes Montaño, Juana Aguilar Coaquira, Gerónimo Aguilar Huanco, Gerardo Aguilar Soto, Juan Tunupa Crespo Rocha, Grover Soto Corrales, Iván Paricagua Villca, Teresa Alem Rojo and Carlos Prado Mendoza "Kuska,"**. This entire study is a reflection of your valuable work and dedication. It is an experience I will cherish for the rest of my life.

2 Table of contents

Abstract *3*

Glossary *10*

1 Introduction *12*

1.1 Background **12**
1.1.1 The powerhouse of plants 12
1.1.2 The role of medicinal plants in our society 12

1.2 Problem statement **12**

1.3 Aim and objectives **13**
1.3.1 Aim 13
1.3.2 Objectives 13
1.3.3 Research questions 13
1.3.4 Delimitations 13

2 Context *14*

2.1 Plant defense and its medicinal properties **14**
2.1.1 Alkaloids 14
2.1.2 Phenolic compounds 15
2.1.3 Terpenoids 16

2.2 Historic use of medicinal plants **16**
2.2.1 Before Homo sapiens 16
2.2.2 Historic use of Medicinal Plants in South America 17
2.2.3 The incas medicinal practices 18
2.2.4 Medicinal practice of the Kallawaya 19
2.2.5 The current use of medicinal plants in Bolivia 19

2.3 Bolivia's environments **20**
2.3.1 The Altiplano 20
2.3.2 Mountain Rangers 21
2.3.3 The Eastern Lowlands 22

2.4 Bolivia's agro-industry **22**
2.4.1 Santa Cruz 22
2.4.2 Cochabamba 23
2.4.3 Medicinal plants in Agriculture 24

3 Method *25*

3.1 Initial Fieldwork and resource mapping **25**

3.2 Selection of interview participants and focus plants **25**

3.3 Interviews – Questions **25**

3.4 Field visit to plant locations **26**

3.5 Evaluation of Interviews, Locations, Value Chains, and Focus Plants **26**

3.6 Comparing interviews with official knowledge and research **27**

4 Result *27*

4.1 Initial Fieldwork and resource mapping **27**
4.1.1 Location 1 - Market Calatayud - May 25, 2025. 27
4.1.2 Location 2 - Feria de Plantas Medicinales, Potrero - May 25, 2025. 28
4.1.3 Location 3 - Feria Agroecología Departamental Elemental - June 7, 2025. 30
4.1.4 Location 4 - Campaña de Medicina Tradicional –June 14, 2025 31

4.2 Selection of interview participants and focus plants **32**

4.3 Interview - Answers **37**
4.3.1 (1) How are native medicinal plants cultivated and harvested? 37

4.3.2 (3) How are native medicinal plants sold and used? 38
4.3.3 (3) How are native medicinal plants integrated into local economies? 42

4.4 Field visits and plant locations 43
4.4.1 Potrero 44
4.4.2 Arque 46
4.4.3 Pampa Tambo 48

4.5 Focus plants 49
4.5.1 Muña *Minthostachys mollis* 49
4.5.2 Wira Wira *Gnaphalium dombeyanum* 51

4.6 Comparing interviews with official knowledge and research 52
4.6.1 The quality of the medicinal plant is better if the plant grows in a tough environment. 52
4.6.2 Give back to the land what the land has given to you. 53
4.6.3 Muña as an anti-inflammatory and stomach remedy, as well as an antimicrobial agent in crop storage 54
4.6.4 Wira Wira as a remedy for respiratory problems as well as curing HIV 54

Discussion 56

4.7 Opportunities shown by the study 58
4.7.1 New conventional cultivation methods 58
4.7.2 A possibility for the new generation of conventional crops 59
4.7.3 Increased value through undiscovered properties 59
4.7.4 Double sided reality 59

4.8 Reflections and limitations 60

5 Conclusion 62

6 References 63

7 Annex 70

3 List of Tables

Table 1 Terpenoids classification with number of carbon and isoprene units 16
Table 2 Climate data from three different elevations (1,820 m, 2,550 m, and 3,010 m) in the Yungas region of Bolivia, based on findings from Bach et al. (2003). The data illustrate how key climatic variables change with increasing altitude. 21
Table 3 The production volumes of the most cultivated crops in Bolivia for the agricultural year 2023–2024, measured in metric tons. The data is shown by department and crop type, allowing for a detailed analysis of regional agricultural output. This table is based on official statistics published by the Instituto Nacional de Estadística (INE) Bolivia, retrieved from the section "Bolivia – Produccion Año Agricola por Departamento. 1984-2024" on their official website https://www.ine.gob.bo/index.php/estadisticas-economicas/agropecuaria/agricultura-cuadros-estadisticos/ 23
Table 4 Interview participants for the study and their profession... 32
Table 5 Medicinal plants product and their NOVA-group classifications.. 39
Tabell 6 Summary of climatic characteristics for the three study sites Potrero, Arque, and Pampa Tambo, based on Meteoblue (2025) data. The table presents elevation, seasonal temperature ranges, precipitation and average wind speeds 44
Tabell 7 Selection of Plants Included in the Kallawayas' Pharmacopeia, with Botanical Name, Family, Origin, and Common Names in English and Bolivian Spanish. 70
Tabell 8 Detailed list of interview questions conducted in the field study 72

4 List of Figures

Figure 1 Agricultural terrace zone in Machu Picchu. Photograph by Melissa Herbas, 2018 17
Figure 2 Inca skull showing trephination and gold cranioplasty Source: Marino and Gonzales-Portillo (2000). 18
Figure 3 Map of the Kallawaya region in Bolivia showing Charazani. Source: Salinas Sedó & Salinas Sedó (2022) 19
Figure 4 Map of the Altiplano, showing its location across Bolivia, Peru, Chile, and Argentina, as well as key cities and hydrological features. Source: Wikipedia. (n.d.). Altiplano. https://en.wikipedia.org/wiki/Altiplano.. 20
Figure 5 Geographic distribution of Bolivia's natural regions. This map highlights the Yungas region in red, running along the eastern slopes of the Andeans. The black dot marks the location of Cotapata National Park. The eastern lowlands are shown in various shades: the Amazon region in dark green, the Chiquitania in light green, and the Chaco in yellow. Source: https://es.m.wikipedia.org/wiki/Archivo:Mapa_de_Bolivia_%28regiones_naturales%29.svg 22
Figure 6 Market Calatayud in Cochabamba on May 28th, 2025 Crowded market with narrow, packed passages on the left, a vendor selling herbs in bunches in the center and processed natural medicines to the right Photograph by Claudia Villabrant, 2025 27
Figure 7 Market Calatayud in Cochabamba on May 28th, 2025 Stand selling fresh plants. The blue bags at the bottom are those used for purchasing plants in bulk during the morning. Photographs taken by Claudia Villabrant (2025) 28
Figure 8 Feria de plantas medicinales de Potrero: Images from the medicinal plant market in Potrero, Cochabamba on May 25ht 2025. Local vendor in traditional clothing selling freshly harvested native medicinal plants. Photograph by Melissa Herbas, 2025 29
Figure 9 Feria de plantas medicinales de Potrero: Top: Stalls selling medicinal plants with handwritten instructions hanging above. Bottom: Close-up photographs of the handwritten instructions, each with a corresponding sample of the plant attached. Photographs Melissa Herbas, 2025 29
Figure 10 Feria Agroecologia Departamental Elemental. Top: Stall selling horticultural produce alongside informational pamphlets on agroecology practices. Bottom: Vendor offering horticultural produce from their Huerta together with seeds in small packages. Photograph Melissa Herbas, 2025 30
Figure 11 Feria Agroecologia Departamental Elemental. Left: Stall selling processed natural medicines using native medicinal plants. Right: Stall selling products made from coconut oil by former student from University of San Simon. Photograph by Melissa Herbas, 2025 31
Figure 12 Campaña de Medicina Tradicional. A stall selling processed natural medicines alongside dried medicinal herbs. Photograph Melissa Herbas, 2025 31
Figure 13 Campaña de Medicina Tradicional. Left: Stall selling Shampoo infused with native medicinal plants. Right: Up-close picture of shampoo with ingredient list. Photograph by Melissa Herbas, 2025 32
Figure 14 Left: Agri-tour guide selling grafted avocado trees and providing instructions on their care. Right: Agri-tour guide holding a medicinal plant and explaining its uses to the thesis supervisor. Photograph by Melissa Herbas, 2025 33
Figure 15 Transdisciplinary naturista preforming a traditional cleansing ritual Photograph provided by the transdisciplinary Naturista 34
Figure 16 Quechuan Naturista with his wife, daughter and dog at his huera. Photograph provided by the Quechuan Naturista 34
Figure 17 Farmer family in Arque. Top: Farmer Grandfather standing in a field of fava beans (Vicia faba). Bottom: Farmer Father standing in a field of Andean lupin beans (Lupinus mutabilis. Photographs by Melissa Herbas, 2025 35
Figure 18 Jampiri (traditional healer). Left: Performing traditional healing methods. Right: Providing conventional treatments in combination with traditional medicine. Photographs scanned from Revista Informativa del Servicio de Medicina Tradicional, Caja Petrolera de Salud, Cochabamba, Bolivia. 36
Figure 19 Technical Agricultarist holding a Bromeliad (Neoregelia) with his collection of Orchids hanging above. Photograph by Melissa Herbas, 2025 36
Figure 20 Holistic Naturista observing a flower. Photo retrieved from Los Muros (n.d.) 37
Figure 21 Herbal mix purchased at the Calatayud market, produced by Laboratorio Artesanal Pronabel. Photograph Melissa Herbas, 2025 41
Figure 22 Satellite image of Potrero, Cochabamba, Bolivia, showing the field sitewith blue tag (17°18′57.8″S, 66°18′49.7″W) and the walking route (blue line) from the drop-off point by the local bus (white dot). Adapted from Google Earth Pro, © 2025 Maxar Technolo 44
Figure 23 Vegetation and landscapes in Potrero, Cochabamba, during the dry season. Left: View of a hillside with native shrubs and perennial grasses, showing denser green vegetation along a tributary of the Río Chocoya. Middle: Pathway through a Eucalyptus plantation. Right: Valley landscape with a mix of montane grasslands, shrublands, and patches of introduced pine (Pinus spp.). Photographs taken by Melissa Herbas & Claudia Villabrant 45

Figure 24 Satelite image of Arque. Point 1 (17°49′21.4″S, 66°23′39.4″W) marks the main residential house of the Aguilar family. Point 2 (17°47′19.5″S, 66°24′30.7″W) marks their second residential house and the highest point of their agricultural land. Adapted from Google Earth Pro, © 2025 Maxar Technologies. 46
Figure 25 Vegetation and landscapes in Arque. Top: Farmer Daughter overlooking a freshly harvested potato (Solanum tuberosum) field, with wild native vegetation surrounding the area. The white square shows area of piles where harvested potatoes are stored. Bottom: View from point 2 in figure 24 towards point 1, showing harvested agricultural plots and patches of dried vegetation. Photographs Melissa Herbas, 2025 47
Figure 26 Satellite image of Pampa Tambo in close proximity to the Corani hydroelectric plant. The image shows the location of the Pampa Tambo tourist center (blue marker) situated in the foothill mountain area. Adapted from Google Earth Pro (© 2025 Maxar Technologies). 48
Figure 27 Vegetation and landscape of Pampa Tambo, showing wild terrain at the top of the image going down to a newly established agricultural plot. A small shed with chickens and pigs grazing the land is visible. Photograph Melissa Herbas, 2025.. 49
Figure 28 Muña (Minthostachys mollis) harvested in Arque, from the land of the Farmer Family. Photograph Melissa Herbas, 2025 50
Figure 29 Wira Wira (Gnaphalium/Pseudognaphalium spp.) from the land of the Farmer Family. Photograph Melissa Herbas, 2025 51
Figure 30 Climate graphs for Colomi (~40 km from station), Arque (~50 km from station), and Potrero (~18 km from station) generated with Meteoblue. The graphs show interpolated climate data adjusted for distance, elevation, and topography, including monthly average temperature (°C), precipitation (mm), and wind speed (m/s). Despite slight variations due to altitude and location, all sites follow similar seasonal patterns since the data is derived from the same weather station. 72

Glossary

Term	Definition
Aguayos	Traditional handwoven Andean textiles, often used for carrying goods, babies or as clothing.
Altiplano	The high plateau region of the central Andes reaching parts of Bolivia, Peru, Chile and Argentina with altitudes above 3,500 m a.s.l.
Andes	A mountain range along the western edge of South America, central to Andean culture and ecosystems.
Arroba	A traditional unit of weight used in Bolivia, equivalent to approximately 11.5 kilograms.
Bloqueos	Road blockades, a common form of protest in Bolivia where groups block highways to press political or social demands.
Caja Petrolera de Salud	A Bolivian social security health institution originally serving workers of the oil sector.
Centro de Tecnología Agroindustrial (**CTA**)	Bolivian Agro-industrial Technology Center that develops processing methods for agricultural products.
Chapare	A tropical region in Cochabamba, Bolivia known for coca cultivation, agroforestry and great biodiversity.
Dystrudepts	A subgroup of Inceptisol soils characterized by low fertility and acidic conditions.
El Niño	A periodic climatic phenomenon characterized by warming of the Pacific Ocean causing droughts and floods in South America.
Gypsisols	Gypsum-rich soils
Histic Humaquepts	Wet soils rich in organic matter found in depressions with poor drainage.
Huertas	Small-scale household or community gardens used for cultivating vegetables, medicinal plants and herbs.
Jampiri	A traditional healer in Andean communities, often knowledgeable in plant-based remedies and ancestral healing practices.
m.a.s.l.	Meters above sea level
Manual para el Registro Sanitario de Productos Naturales Tradicionales Artesanales (**PNTA**)	Official Bolivian guideline for the sanitary registration of artisanal traditional natural products.

Movimiento Agroecológico Boliviano (**MAB**)	Bolivian Agroecological Movement, a collective promoting ecological agriculture and food sovereignty.
Naturista	A practitioner of natural medicine in Bolivia who uses plants and traditional remedies.
Noncommunicable diseases (**NCD**)	Chronic diseases not transmitted between people, such as diabetes, cancer and cardiovascular disease.
NOVA- Qualification	System that groups foods by level of processing, recognized by FAO/WHO as a tool in nutrition research and policy.
Placaquods	Wet soils with a dense, slowly permeable subsurface horizon that impedes drainage.
Registro Único Nacional de Medicina Tradicional Ancestral Boliviana (**RUMETRAB**)	National registry for practitioners of ancestral traditional medicine in Bolivia, created under Law No. 459 (2013).
Servicio Departamental de Salud (**SEDES**)	Regional health service authority in Bolivia, part of the decentralized health system.
Solonchaks	Saline soils
Spodic Dystrudepts	Acidic soils with a spodic horizon, containing organic matter and aluminum.
Surazos	Strong cold winds from the south that affect Bolivia’s valleys and lowlands in Santa Cruz.
Trufi	A shared taxi or minibus operating on fixed routes in Bolivia.
Tukuypaq	From Quechua *tukuy* (“everything, complete”) and *paq* (“for, intended for”), meaning “for complete benefit.”
Unidad de Medicina Tradicional (**UNIMED**)	Traditional Medicine Unit within Bolivia’s health system.
Xerosols	Arid soils
Yungas	A forested and humid region on the eastern slopes of the Andes, well known for coca cultivation and diverse ecosystems.

1 Introduction

1.1 Background

1.1.1 The powerhouse of plants

Plants are among the most essential organisms on earth, providing the foundation for both ecosystems and human survival (Knapp, 2019). In today's world, they function as the primary producers of life and form the basis of the global food web. Through photosynthesis, plants capture carbon from the atmosphere and convert it into organic energy that sustains life on all trophic levels, all while also producing oxygen (Raven, Evert, & Eichhorn, 2012). Because of their unique ability the continuity of life ultimately depends on the plants' capacity to fix and transform carbon into organic forms. Beyond their role in sustaining life the plants also possess sophisticated biochemical mechanisms with dual functions (Barnum et al., 2021). These mechanisms act as defenses against environmental stress while also producing therapeutic compounds that can support human health (Pathak, 2023). Given these multifunction's, the importance of plants goes beyond just sustaining life but also covers to sustain the overall quality of life of humans.

Medicinal plants have been used by humans for millennia for theis medicinal properties and have played a key role in the development of modern medicine (Sen & Samanta, 2015). A classic example of this is the bark of the weeping willow (*Salix babylonica*) traditionally used to relieve pain. Desborough and Keeling (2017) explain that the salicylic acid found in willow bark has therapeutic properties and has been used by humans for thousands of years. Traces of its use go back 3,500 years when ancient Egyptians prepared infusions with the plant bark to relieve pain. Its application continued in the era of the ancient Greeks, and much later in 1897 the chemist Felix Hoffmann succeeded in synthesizing acetylsalicylic acid from salicylic acid, producing what is today known worldwide as aspirin. Other examples of plant defenses providing humans with therapeutic properties is the liquid latex produced by the poppy flower *(Papaver somniferum)*. The latex deters herbivores to continue eating on the plant and is simultaneously used in medicine in the form of morphine (Raven, Evert, & Eichhorn, 2012). Another example are anthocyanins, they give plants their vibrant red and purple colors to protect them from harmful UV light, while in humans they act as powerful antioxidants that help prevent DNA deterioration (Bendokas et al., 2020).

1.1.2 The role of medicinal plants in our society

Alongside the plants being the fundamental building blocks of life and improving overall quality of it, they also hold deep cultural significance and environmental importance (Schaal, 2019; Raven, 2021). They provide critical ecosystem services such as mitigating pollution and maintaining climatic stability their importance is further reinforced (Cardinale et al., 2012). Plants possess mechanisms that adsorb and accumulate harmful pollutants within their biomass, enabling them to regenerate and restore healthy environments (Mukherjee, 2015). Beyond these remarkable mechanisms the plants also carry profound cultural value. According to the World Health Organization (WHO) in 2024, nearly 65-80% of the world's population continues to rely on medicinal plants as their primary form of medicine. This practice is rooted in traditions that are passed down through generations. To honor the great value of plants, it is essential to study and cherish and recognize their potential.

1.2 Problem statement

As global life expectancy has increased with humans living to be 80 years and older, a rise in chronic noncommunicable diseases (NCDs) threatens the quality of life in those extended years (Kowalczyk et al., 2024). According to the WHO (2024) conditions such as cancer, cardiovascular disease, diabetes and chronic respiratory illness account for nearly 75% of global deaths each year. The WHO (2024) identify behavioral risk factors like unhealthy diets and physical inactivity as two of the most significant drivers of this global burden. Additionally the nutritional quality of modern foods has declined at alarming rates, leaving populations with weaker immune systems than earlier generations (Bhardwaj et al., 2024). The consequences are especially large in developing countries, where under-resourced health systems struggle to cope with the combined pressures of chronic disease and insufficient nutrition (Mukherjee, 2015).

Alongside the direct threats to human health environmental challenges add another layer of consequences. They threaten humanity indirectly by placing great pressure on wildlife, biodiversity and natural habitats (Cardinale et al., 2012; Ibisch et al., 2001 Sen & Samanta, 2014). These ecosystems that have sustained human life for millennia by providing clean air, water, food and medicine and are now under greater stress than ever before (Cardinale et al., 2012; Ibisch et al., 2001). Biodiversity loss and ecosystem degradation have already caused severe declines in wildlife populations including many medicinal plants that have supported human health for thousands of years (Janni & Bastien, 2000). Despite this destruction, medicinal plants continue to play a vital role in healthcare for 65–80% of the world's population, particularly in developing regions (WHO, 2024). Beyond their therapeutic and nutritional benefits the plants also provide economic opportunities by strengthening local healthcare systems, and reducing reliance on imported medicines (Akerele, 1993). As humanity faces this dual challenge of rising chronic disease and accelerating environmental decline the need to study, conserve and utilize medicinal plants has never been more important.

1.3 Aim and objectives

1.3.1 Aim

Because of the contribution the medicinal plants have had on the health of humans throughout history and the great potential they possess. The aim of this study is to explore the role of Bolivia's native medicinal plants by investigating their cultivation, uses and socio-economic significance.

1.3.2 Objectives

To achieve the aim this study pursues the following objectives:

1. Document how native medicinal plants are cultivated and harvested.
2. Examine how these plants are used, processed, and sold in local contexts.
3. Analyze how medicinal plants are integrated into local economies and value chains.
4. Evaluate the socio-environmental significance of these species through field observations and stakeholder interviews.

1.3.3 Research questions

To reach the stated objectives the study is guided by three central research questions:

1. **How are native medicinal plants cultivated and harvested?**
2. **How are native medicinal plants used and sold?**
3. **How are native medicinal plants integrated into local economies?**

1.3.4 Delimitations

Geographical limits - The study was done on selected sites and markets in the Cochabamba, Bolivia (Arque, Potrero, Calatayud and Pampa Tambo) other Bolivian regions are outside the study area.

Temporal limits - Fieldwork took place only once during the dry season (June–August 2025) and the results only reflects on the seasonal availability and practices during this period.

Methodical limits - The study uses qualitative methods by semi-structured interviews, participant observation and market scans. It does not include laboratory analysis of plant compounds, clinical trials or quantitative analysis.

2 Context

2.1 Plant defense and its medicinal properties

Plants through their evolution have developed sophisticated defense systems such as the systemic acquired resistance (SAR) (Kowalczyk et al., 2024). When the plant is under stress the SAR is activated and triggers the production of secondary metabolites. These are non-essential organic compounds that protects the plants against harmful pathogens, herbivores and environments (Grassmann et al., 2002). These metabolites as well as being central to plant defense also mediate interactions with the environment. There are three major groups of secondary metabolites produced by the plants: alkaloids, phenolic compounds and terpenoids (isoprenoids), each one with unique features and roles in the plant defense response (Kowalczyk et al., 2024; Grassmann et al., 2002; Raven, Evert, & Eichhorn, 2012). Remarkably, the same compounds that protects the plants also provide significant benefits for humans. These secondary metabolites hold therapeutic potential that supports the overall human health and well-being (Grassmann et al., 2002). Throughout the years the secondary metabolites have been extracted and used in pharmaceuticals for pain relief, cardiovascular protection, and the treatment of various diseases (Sen & Samanta, 2015; Lila, 2004; Kowalczyk et al., 2024; Grassmann et al., 2002). Products like Aspirin, morphine and essential oils are all derived from these secondary metabolites showcasing how the plant defense chemistry has contributed to modern medicine in diverse ways (Sen & Samanta, 2015). Despite the great success of these products, only a small fraction of plant species has been studied scientifically for their medicinal potential, leaving many properties still undiscovered (Ibisch & Mérida, 2004). Unlocking these defense properties could not only reveal how plants protect themselves, but also how their chemistry can be used to improve human health and combat chronic, non-communicable diseases in the future.

2.1.1 Alkaloids

Alkaloids are recognized as one of the most important groups of secondary metabolites in both plant defense and modern medicine (Raven, Evert, & Eichhorn, 2012). They are a diverse group of nitrogen-containing organic compounds with potent pharmaceutical properties. Natural plant products from which alkaloids are a significant part of, are estimated to account for the ingredients of around 40% of pharmaceuticals. This represents an annual global market valued at \$20 billion of pharmaceuticals from natural products (Ibisch & Mérida, 2004). A well-known example of alkaloids is morphine a benzylisoquinoline alkaloid (BIA) produced by the opium poppy (*Papaver somniferum*) (Desborough & Keeling, 2017). When the poppy plant is injured, by herbivore grazing for example, it exudes a latex rich in alkaloids that functions as a chemical defense (Konno, 2011). Humans have learned to use this natural defense for therapeutic purposes by transforming it into morphine, one of the most effective analgesics in medical history (Sen & Samanta, 2015).

However, the transformation and extraction of plant-derived compounds is difficult because of their chemical complexity, instability and variable absorption into the human body. Lila (2004) explains that many of these compounds are prone to degradation during the extraction. These challenges indicate that careful processing and refining are often necessary to obtain stable and effective bioactive compounds from plants. Despite these challenges Sen and Samanta (2015) emphasize that morphine has remained essential in clinical practice worldwide as the global market for plant-derived medicines continues to expand. Even if it the extraction method is complex, they continue to say that phytotherapies alone represent an industry worth about $14 billion annually, with demand for natural product-based drugs steadily increasing. Morphine is therefore a great example of how a plant's defensive chemistry that originally evolved to deter herbivores has now been transformed by humans into a basic essential of modern pharmaceuticals and one of the most pain-relieving drugs ever made.

2.1.2 Phenolic compounds

Phenolic compounds are a large and diverse group of secondary metabolites in plants, including flavonoids, tannins, salicylic acid and lignans (Raven, Evert, & Eichhorn, 2012). They play an essential role in plant survival by protecting against UV radiation, pathogens, herbivores and environmental stress. They are often produced in larger amounts when plants are under stress or infection (Grassmann et al., 2002; Kowalczyk et al., 2024).

For humans, phenolic compounds provide a wide range of health benefits. They function as potent antioxidants and anti-inflammatory agents that contribute to cardiovascular protection. They also show antimicrobial properties and promising anticancer and neuroprotective effects (Grassmann et al., 2002; Sen & Samanta, 2015). Because of their versatility many phenolic-rich plants have been used in traditional medicine throughout time. Two examples are willow bark for pain or chamomile (*Matricaria chamomilla L*) for digestion and relaxation (Sen & Samanta, 2015). Their function is seen very important today as modern research continues to highlight their therapeutic and nutritional importance (Sen & Samanta, 2015; Desborough & Keeling, 2017).

A well-known group of Phenolic compounds known for their versatile use are Anthocyanins a subgroup of the flavonoids. They are responsible for the red and purple pigmentation that protects plants against UV light, and act as a natural sunscreen by absorbing radiation and preventing damage to plant tissues (Raven, Evert & Eichhorn, 2012). Remarkably, they also help protect human cells from oxidative stress and DNA damage when consumed (Lila, 2004; Raven, Evert, & Eichhorn, 2012). In a study by Li et al. (1993), Arabidopsis thaliana plants exposed to UV-B light produced higher levels of flavonoids including anthocyanins. The production increased significantly under higher UV-B intensity. The researchers also examined Arabidopsis mutants (tt4 and tt5) that are unable to produce anthocyanins and found the mutants to be significantly more sensitive to UV-B light. This strongly supports the conclusion that anthocyanins play a crucial protective role against UV radiation, because Arabidopsis produces them as part of its defense mechanism in response to elevated UV levels.

In addition to protecting plants anthocyanins also support human health in remarkable ways. They have been shown to exhibit anti-inflammatory effects and improve cardiovascular and eye health (Kowalczyk et al., 2024; Cassidy et al. (2015), In an analysis of 2,375 participants from the Framingham Heart Study Offspring Cohort, they found that higher anthocyanin intake in the diest correlated with lower levels of inflammation. Participants with lower intake had higher levels of IL-1β, sVCAM-1 and C-reactive protein, all key markers of inflammation in the body.

In vitro studies have further demonstrated that anthocyanins have proven antioxidant and anticancer effects on cells (Kowalczyk et al., 2024). Anthocyanins such as cyanidin and cyanidin-3-O-β-D-glucoside protect DNA from oxidative damage by neutralizing reactive oxygen species and inhibiting xanthine oxidase (XO), the enzyme responsible for producing ROS. Because of this this dual mechanism anthocyanins provide significant protection against oxidative stress (Acquaviva et al., 2003). Amorini et al. (2001) further stated that cyanidins are among the most potent antioxidants found in dietary plants and beyond their antioxidant activity they also exhibit notable anticancer properties. Feng et al. (2007) demonstrated that cyanidin-3-rutinoside induces apoptosis in leukemia and lymphoma cell lines by increasing superoxide levels, which activate stress-related protein kinases p38 MAPK and JNK. These kinases then trigger mitochondrial apoptosis via the protein Bim that effectively kills harmful cancer cells.

2.1.3 Terpenoids

The third major group of secondary metabolites produced by plants are the terpenoids (isoprenoids) that are classified by the number of isoprene units (C_5H_8) they contain (Raven, Evert, & Eichhorn, 2012). This classification ranges from hemiterpenoids with a single isoprene unit to polyterpenoids with multiple isoprene units (as seen in Table 1). Terpenoids represent one of the most diverse classes of natural products and play crucial roles in plant survival and reproductive fitness. Their adaptive traits have been shaped by natural selection to help plants cope with both biotic and abiotic stress factors (Dorman & Deans, 2000; Wink, 2003). Their ecological roles range from direct defenses when acting as repellents, irritants or poisons against herbivores or pathogens (Sen & Samanta, 2015). To indirect defenses such as producing volatile organic compounds (VOCs) that attract the natural enemies of herbivores (Maffei, Gertsch, & Appendino, 2011). Certain terpenoids also act as allelochemicals and inhibit the growth and germination of competing plants seeds (Maffei, Gertsch, & Appendino, 2011). Additionally, terpenoids also contribute to abiotic stress tolerance by protecting plants from reactive oxygen species (Grassmann et al., 2002).

***Table 1** Terpenoids classification with number of carbon and isoprene units*

Classification	Isoprene units	Carbon atoms
Hemiterpenoids	1	5
Monoterpenoids	2	10
Sesquiterpenoids	3	15
Diterpenoids	4	20
Sesterpenoids	5	25
Triterpenoids	6	30
Tetraterpenoids	8	40
Polyterpenoids	>8	>40

Beyond their ecological functions, the terpenoids have long been recognized for their medicinal and therapeutic properties for human use in the form of essential oils (Maffei, Gertsch, & Appendino, 2011). Monoterpenes and sesquiterpenes that are highly volatile are responsible for the characteristic aromas of many plants and are widely used in traditional and modern medicine (Raven, Evert, & Eichhorn, 2012). They possess diverse phrenological properties including being anti-inflammatory, antioxidant, antimicrobial, analgesic, anticancer and having neuroprotective activities (Sen & Samanta, 2025; Grassmann et al., 2002; Dorman & Deans, 2000). For example beta-caryophyllene selectively binds to CB2 receptors in humans that regulate immune responses and inflammation and by that execute potent anti-inflammatory effects (Maffei, Gertsch, & Appendino, 2011). Essential oils that are rich in terpenoids, such as those from oregano (*Origanum vulgare* L.), thyme (*Thymus vulgaris* L) and clove (*Syzygium aromaticum*) exhibit strong antimicrobial activity and are also used as food preservatives (Maffei, Gertsch, & Appendino, 2011). In addition, compounds like thymoquinone from the thyme display neuroprotective effects that influence the central nervous system. Another example of therapeutic use of terpenoids is peppermint (*Mentha x piperita*) oil. It functions play out when being applied in treatment of gastrointestinal disorders such as irritable bowel syndrome (Maffei, Gertsch, & Appendino, 2011). Despite the long history of use by these essential oils, the precise molecular mechanisms of many terpenoid-based medicines is still largely unknown and is still being investigated.

2.2 Historic use of medicinal plants

2.2.1 Before Homo sapiens

Studies on the medicinal properties of plants are extensive and continue to grow to this day. However, the therapeutic use of plants to treat health conditions dates back before the time of scientific research and even before the emergence of *Homo sapiens*. A study by Hardy et al. (2012) analyzed hardened dental calculus from Neanderthal teeth and identified medicinal plant compounds in them. These compounds included azulenes and coumarins. The azulenes found were azulene, dihydroazulene, 4,6,8-trimethylazulene and chamazulene which are all compounds present in the medicinal plant yarrow (*Achillea millefolium*). The coumarins found were 4,5,7-trimethylcoumarin and 4-methylherniarin that occur in chamomile. Since both plants have low nutritional value and a bitter taste the findings suggest their use was likely for self-medication.

2.2.2 Historic use of Medicinal Plants in South America

While evidence from Neanderthals reveals the prehistoric roots of plant-based healing, it is through ancient civilizations such as the Mayas and the Incas that more organized and complex systems of agriculture and herbal medicine have been discovered (Sen & Samanta, 2015). The Inca civilization that existed during the 15th & 16th century was a major center of plant domestication during their time. They systematically cultivated not only staple food crops such as potatoes, maize and nuts but also medicinal plants (Von Hagen, 1961). Traces of these sophisticated agricultural systems remain visible today in Machu Picchu, Peru. Here preserved and restored agricultural terraces show evidence of their advanced cultivation practices (as seen in Figure 1).

***Figure 1** Agricultural terrace zone in Machu Picchu. Photograph by Melissa Herbas, 2018*

During the time of the Incas, medicine and spiritual practices were deeply intertwined (Marino & Gonzales-Portillo, 2000). When an individual got sick, a healer known in Quechua (the acient local language still used today) as a *hampi-camayoc* ("remedy keeper") would be summoned. Treatments often began with fasting, purging or the administration of special roots brew called Ayahuasca (Ruffell et al., 2023). The ayahuasca is a hallucinogenic brew that was consumed by both healer and patient and was believed to give visions that could provide insights and guidance for treatment (Ruffell et al., 2023; Von Hagen, 1961). Although it is difficult to prove whether ayahuasca directly gave medical diagnoses and treatment methods, evidence still remains that Incas possessed extensive knowledge of medicinal plants of which many are still used today (Marino & Gonzales-Portillo, 2000; Ruffell et al., 2023). Whether this knowledge originated from the hallucinogenic experiences induced by ayahuasca remains uncertain.

Ayahuasca continues to be used today as an entheogenic psychedelic plant brew in spiritual and religious contexts (Ruffell et al., 2023). It consists of two plants: the ayahuasca vine (*Banisteriopsis caapi*) and chacruna (*Psychotria viridis*) that contains psychoactive compound dimethyltryptamine (DMT) (Ruffell et al., 2023). Even if ayahuasca is still being used today in traditional medicine it's important to note that the compound DMT is classified as a "Schedule I" controlled substance under the UN Convention on Psychotropic Substances. It is internationally illegal to possess and may only be used for highly restricted medical or scientific purposes with strict governmental approval (United Nations Office on Drugs and Crime, 2023).

2.2.3 The incas medicinal practices

The Incan civilization with their spiritual perspective on healing also demonstrated another remarkable side of sophisticated medical practices. They developed advanced surgical techniques that included the use of anesthetics and operative procedures (Marino & Gonzales-Portillo, 2000). Among these were trephination and even cranioplasties where gold plates were used to repair skull defects (as seen in Figure 2). In their study on Inca and pre-Columbian trephination Marino and Gonzales-Portillo (2000) found archaeological evidence showing clear signs of healing in approximately 70% of skulls that had underwent these repairs. This indicated that many patients survived these procedures. They further stated that this survival rate was exceptionally high compared to the nearly 100% fatality rate of trephination procedures in 18th-century Europe.

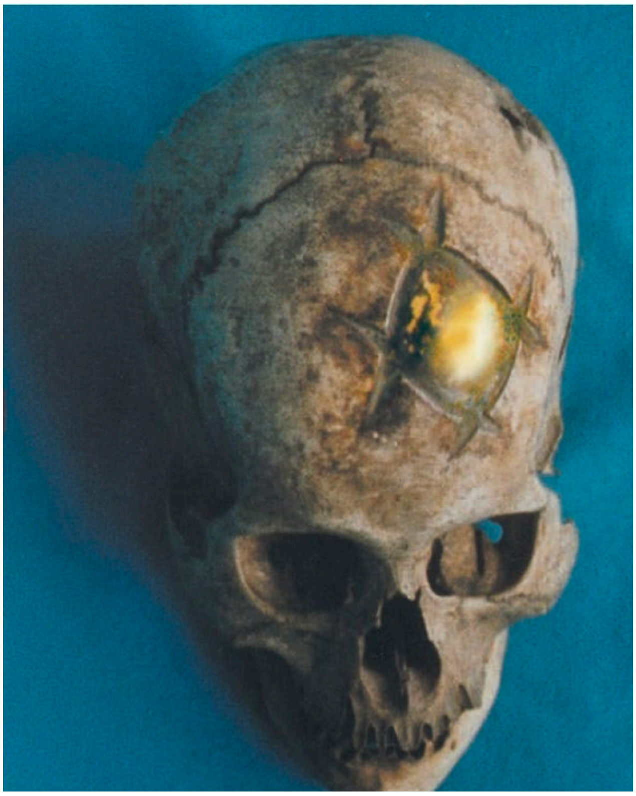

Figure 2 *Inca skull showing trephination and gold cranioplasty Source: Marino and Gonzales-Portillo (2000)*

Marino and Gonzales-Portillo (2000) suggest that this high survival rate may have been due to the use of antiseptics like Peru balsam, tannins and saponins that are all derived from medicinal plants. They further stated that as an anesthetic, the Incas used coca (*Erythroxylum coca*) leaves. These leaves are known for their numbing effects to bear with pain. By chewing on the leaves, they could achieve both stimulation and localized anesthetic effects. Today coca leaves are still chewed in Bolivia, Peru and Colombia today for their ability to elevate mood, aid digestion, suppress appetite and to cope with the high altitudes of these regions (personal communication, May–July 2025). But the plant also has a controversial aspect as it serves as the raw material for producing cocaine, a highly addictive Schedule II drug (DEA Museum, n.d.).

Coca leaves and ayahuasca have both become subjects of international debate that contribute to the controversial reputation of herbal medicine in the Andean region (Ruffell et al., 2023). Historically, these plants were used in a variety of cultural and medicinal practices with their effects on human health to be dependent largely on dosage and preparation (Ruffell et al., 2023). While some of these herbs are now classified as drugs, the therapeutic use by the Andean cultures have been shown to have beneficial medicinal properties (Mendoza, 2003).

2.2.4 Medicinal practice of the Kallawaya

During the time of the Incas a distinct ethnic group called the *Kallawaya* existed. They were known for their traditions and extensive knowledge of herbal medicine (Janni & Bastien, 2000). They were located in the Charazani region on Bolivia that is now a part of La Paz one of the biggest cities in Bolivia (as seen in Figure 3) (Fischer, 2023). Through their resilient adaptation in social environments the Kallawayas outlived many populations through time. They existed long before the Inca Empire and were influenced by earlier cultures such as Tiwanaku (200–1000 CE) and Mollo (1100–1450 CE) (Fischer, 2023). In the time of the Incas, they became the Incans trusted allies and lived together in a poly-ethnic society. The Kallawaya supported the Incas in battles and helped administer their regions, which then led to their integration into the Incan elite network (Fischer, 2023).

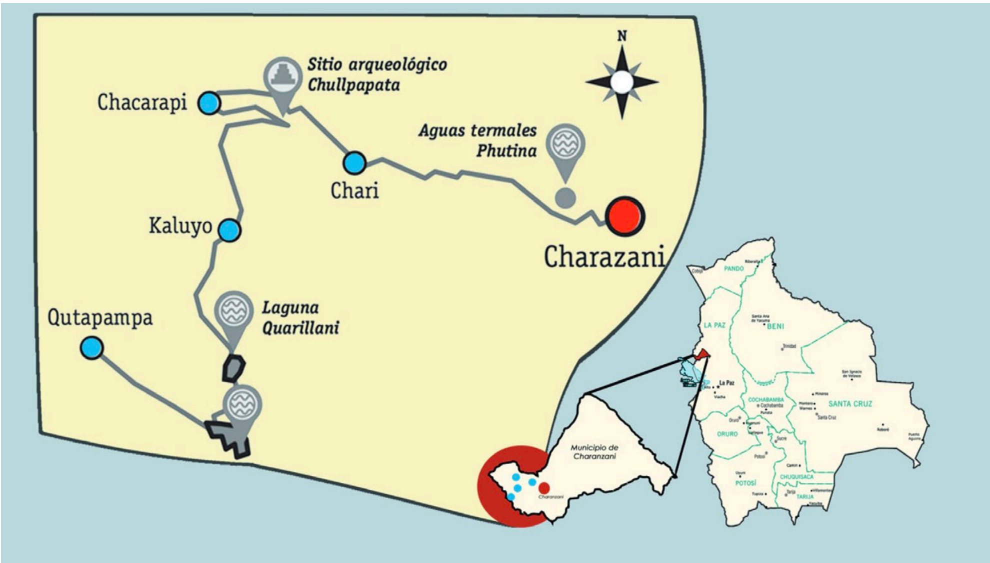

Figure 3 *Map of the Kallawaya region in Bolivia showing Charazani. Source: Salinas Sedó & Salinas Sedó (2022)*

After the Spanish conquest around year 1553 the poly-ethnic dynamics of the Andes began to fade away. To survive within the new colonial system of the Spanish, the Kallawayas adapted by blending their indigenous knowledge with the European knowledge (Fischer, 2023). They maintained great regional influence through the control of gold mines and trade routes between the highlands and lowlands in the Andean region. However, as gold supplies declined the Kallawaya trades shifted to exporting highly demanded medicinal plants like the Cinchona *(Cinchona officinalis)* bark (Kokoska & Fernandez Cusimamani, 2008). This bark was particularly sought after by Jesuit pharmacists during this time (Fischer, 2023). This strategic adaptation shows the foundation for the Kallawayas' enduring resilient identity as healers and herbalists. As well as an adaptative social group. Their traditions continues to define their role in Bolivia today, as there are around 7400 people still belonging to the Kallawaya ethic group (Fischer, 2023, citing Instituto Nacional de Estadística, 2013, p. 50). Many of which still preforms healing rituals today in Bolivia and other South American countries using exotic and regional plants. The Kallawayas' pharmacopoeia is very large and covers over 900 plants. Their adaptable culture that integrated influences from the Tiwanaku, Mollo, Inca and Spanish include both native and introduced plant species some of which are listed in table 7 & 8 in annex (Janni & Bastien, 2000, 2004).

2.2.5 The current use of medicinal plants in Bolivia

In Bolivia, the traditional use of medicinal plants is deeply rooted across its diverse regions and cultures (Kokoska & Fernandez Cusimamani, 2008). The country is recognized for its high biodiversity but simultaneously faces severe pressures from deforestation and biodiversity loss due to the expansion of its agricultural sector (Ibisch & Mérida, 2004). Despite these challenges, medicinal plants continue to serve as a primary source of healthcare for most of the population (Macía et al., 2005). This reliance on medicinal plants reflects a broader cultural tradition within the country's diverse indigenous heritage that extends beyond the practices of the Kallawayas. The Plurinational State of Bolivia is home to 36 distinct indigenous nations and peoples, including the Quechua, Aymara, Guarani, Tacana, Jampiris, Chimanes and the Kallawaya. According to the Mathez-Stiefel and Vandebroek (2011), efforts have been made to address the unorganized information on traditional medicine and to observe how knowledge of medicinal plants has been preserved across generations. They note that transmission occurs through observation, practice and oral communication. With individuals possessing extensive knowledge holding significant cultural and social roles in their communities. As a result of this preserved knowledge and the proven effectiveness of these plants, approximately 80% of Bolivia's population continues to rely on herbal medicine as their primary form of healthcare (WHO, 2019).

2.3 Bolivia's environments

According to Ibisch and Mérida (2004), Bolivia's landscape is extremely diverse and ranges from the high altitudes of the Andes to the lowlands of the Amazon rainforest. This broad range of ecosystems has given rise to an exceptional plant biodiversity. The study mentions Bolivia as one of the world's megadiverse countries ranking among the top 15 nations in terms of biodiversity. They continue to say that Bolivia hosts over 20,000 species of vascular plants and around 20 different soil types and that this biodiversity is rooted in the country's broad geodiversity with altitudes ranging from 100 meters above sea level (m.a.s.l.) to 6500 m.a.s.l. Regions in Bolivia can therefore be divided depending altitude: the Altiplano (3,600 – 4,000 m.a.s.l.), the mountain ranges (500 - 3,500 m.a.s.l.) and the eastern lowlands (100 – 800 m.a.s.l.).

2.3.1 The Altiplano

The Altiplano is the highest region of Bolivia and represents one of the harshest environments in the Andes (Ibisch & Mérida, 2004). The area of the Altiplano extends across Bolivia, Peru, and Chile, through the desert and Northern Puna that reaches into Argentina. The region is home of extreme climatic conditions that include frost, hail, wind, drought, high radiation and poor saline soils that make agriculture a high-risk activity in this region (Sen & Samnta, 2015). Major Bolivian cities in this region include La Paz, El Alto, Oruro, Sucre and Potosí (as seen in Figure 4). The area is classified as part of the "cold tropics," with mean annual temperatures ranging between 0–6°C and frosts occurring almost daily (Ibisch & Mérida, 2004). In the more humid Puna around Lake Titicaca the rainfall ranges between 500–1000 mm annually, while the Desert Puna in the south receives less than 100 mm annually (Ibisch & Mérida, 2004).

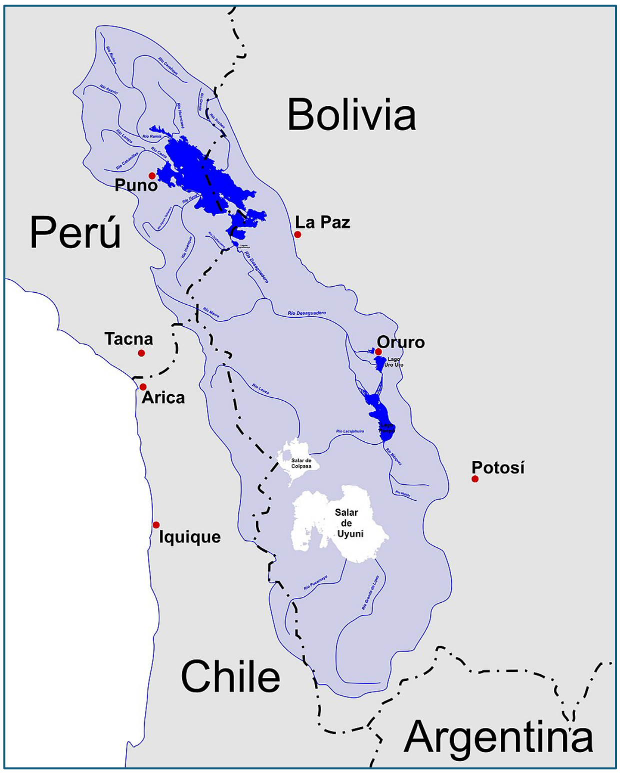

Figure 4 *Map of the Altiplano, showing its location across Bolivia, Peru, Chile, and Argentina, as well as key cities and hydrological features.* Source: *Wikipedia. (n.d.).* Altiplano. https://en.wikipedia.org/wiki/Altiplano

Soils in the Altiplano are typically composed of loose sediments with low in fertility and often requires natural fertilizers to sustain production (Ibisch & Mérida, 2004). In the driest southern parts of the Altiplano, saline soils such as Xerosols, Gypsisols, and Solonchaks dominate. These soils shape landscapes like the Salar de Uyuni that is one of the world's largest salt deserts (Ibisch & Mérida, 2004). Despite these challenges, traditional crops such as quinoa (*Chenopodium quinoa*), potatoes (*Solanum tuberosum*), oca (*Oxalis tuberosa*), kañawa (*Chenopodium pallidicaule*) and barley (*Hordeum vulgare*) are cultivated here (Sen & Samnta, 2015). The local varieties that grown here have adapted well and have developed remarkable adaptations to salinity, cold, frost, drought and poor soils, making them models of resilience (Sen & Samnta, 2015; Ibisch & Mérida, 2004). Because of their the genetic diversity of these crops they provide valuable traits for breeding programs to ensure food security. The harsh climate of the Altiplano also creates an ideal environment for medicinal plants, as the extreme conditions stimulate the production of defense compounds (Huanca-Mamani et al., 2015).

2.3.2 Mountain Rangers

Going down from the Altiplano into the mountain rangers and foothill regions one encounters the *Yungas*, a fertile and cloud-covered forest. Bach et al. (2003) conducted an ecological study in Cotapata National Park located within the Yungas, where they studied the interaction between biotic and abiotic factors. Their research categorized the region's remarkable ecological diversity and made an extensive description of the area. The climate in the Yungas is very humid throughout the whole year with annual rainfall ranging from 2,500 to 3,500 mm. They observed that higher altitudes tend to be more humid and retain more water. The soils in the Yungas are highly acidic (pH below 4) and nutrient-poor with a top layer made of a thick (about 30 cm) organic layer made up of decomposing leaves and plant material. In terms of soil classification humid Dystrudepts soils are common in the lower elevations of the Yungas. At medium altitudes soils such as Placaquods, Spodic Dystrudepts, and Histic Humaquepts appear. In the highest zones Placaquods soils dominate as these soils are typically formed in cold and wet environments. Detailed list of the Yungas climatic variation can be found in table 2.

Table 2 *Climate data from three different elevations (1,820 m, 2,550 m, and 3,010 m) in the Yungas region of Bolivia, based on findings from Bach et al. (2003). The data illustrate how key climatic variables change with increasing altitude.*

Altitude (m)	Annual Precipitation (mm)	Max Global Radiation (kW/m^2)	Average Relative Humidity (%)	Potential Evapotranspiration (mm)
1820	2500	0.5	90.1	118.25
2550	2500	0.4	96,5	55.31
3010	3-3,5	0.3	97.5	41.23

The study continued to describe the biodiversity and stated that although the Yungas region only covers about 4% of Bolivia's total land area, it accounts for more than 35% of the country's biodiversity. It is particularly noticeable for its high levels of endemism across multiple taxa. Around 60% of Bolivia's Orchidaceae species are found in the Yungas and over 40% of these are unique to this region alone. Similar patterns of endemism were observed in other plant families such as Solanaceae, Poaceae, and Bromeliaceae. This exceptional concentration of unique species makes the Yungas one of the most ecologically significant and irreplaceable ecoregions in Bolivia (Ibisch & Mérida, 2004). In terms of agricultural production, the Yungas is a major cultivation area for crops such as coffee (*Coffea arabica*), coca (*Erythroxylum coca*), citrus fruits (*Citrus* spp.), bananas (*Musa* spp.) and papayas (*Carica papaya*). Notably, 96% of Bolivia's coffee production originates from this region (Instituto Nacional de Estadística de Bolivia, 2024).

2.3.3 The Eastern Lowlands

The Eastern Lowlands of Bolivia extend from the humid Amazon rainforest in the north-east to the semi-arid Gran Chaco in the south-east. As illustrated in Figure 5, this region corresponds to the green and yellow areas of the map and represents the flattest part of the country (Ibisch & Mérida, 2004). The landscape is defined by two major river systems; the Amazon Basin and the Pilcomayo River. These rivers sustain soil fertility, biodiversity and habitat diversity through the continuous processes of erosion, sedimentation, and nutrient cycling in this area (Ibisch & Mérida, 2004).

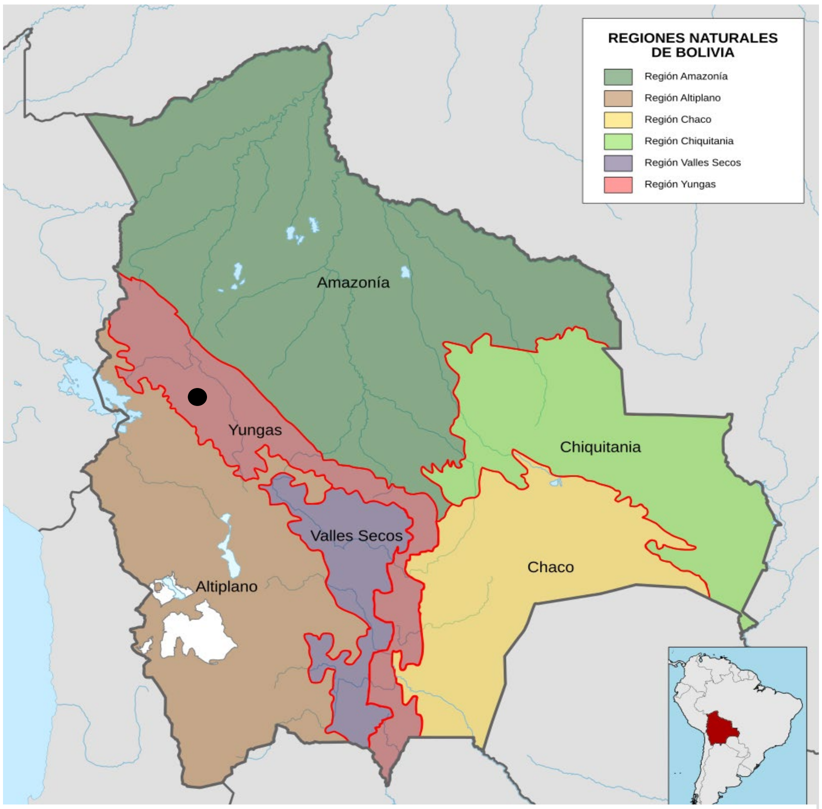

Figure 5 *Geographic distribution of Bolivia's natural regions. This map highlights the Yungas region in red, running along the eastern slopes of the Andeans. The black dot marks the location of Cotapata National Park. The eastern lowlands are shown in various shades: the Amazon region in dark green, the Chiquitania in light green, and the Chaco in yellow. Source:* *https://es.m.wikipedia.org/wiki/Archivo:Mapa_de_Bolivia_%28regiones_naturales%29.svg*

Ibisch and Mérida, (2004) continue to explain that the climate of the Bolivian lowlands is mostly tropical with average annual temperatures ranging between 20°C and 27°C. Rainfall is highest in the Amazonian north and decreases progressively toward the drier southern Gran Chaco. This region is vulnerable to extreme weather events such as *El Niño*, that can cause excessive rainfall and flooding, and *Surazos* that are cold southern winds that may temporarily lower average temperatures by up to 10°C. While these climatic phenomena can significantly affect agriculture they have also contributed to the development of native plant species that are highly resilient to climatic stress.

In addition, Ibisch and Mérida (2004) further describe that in areas more prone to flooding, rich alluvial soils are formed from sediments carried down from the Andes and Yungas. These soils are enriched with minerals and nutrients deposited during flood events, while the seasonal decomposition of forest matter increases humus content and improves soil structure. This prevents flooded soils from becoming overly compact and promotes drainage. As a result, regions such as Santa Cruz have become home to extensive monoculture agricultural practices.

2.4 Bolivia's agro-industry

2.4.1 Santa Cruz

The agroindustry in Santa Cruz is the largest of the country with soy (*Glycine max*), sugarcane (*Saccharum officinarum*), maize (*Zea mays*) and sorghum (*Sorghum bicolor*) dominating the market. Most of the countries' agroindustry is cultivated this region (as demonstrated in Table 3). Peralta-Rivero did an investigation in 2020 about the agroindustry in the lowlands and concluded that there are two agricultural models being followed in the lowlands: the agro-industrial model and the traditional family model.

The agro-industrial model is characterized by large-scale capital-intensive operations. That rely heavily on advanced technologies and external inputs such as chemical fertilizers and pesticides. This model typically focuses on monocultures and involves higher production costs. In contrast, the family-based model operates on a smaller scale that emphasizes on crop diversification and traditional farming practices with minimal use of external inputs.

Table 3 *The production volumes of the most cultivated crops in Bolivia for the agricultural year 2023–2024, measured in metric tons. The data is shown by department and crop type, allowing for a detailed analysis of regional agricultural output. This table is based on official statistics published by the Instituto Nacional de Estadistica (INE) Bolivia, retrieved from the section "Bolivia – Produccion Año Agricola por Departamento. 1984-2024" on their official website* *https://www.ine.gob.bo/index.php/estadisticas-economicas/agropecuaria/agricultura-cuadros-estadisticos/*

Top 5 Cultivated crops in Bolivia		**Top 5 Cultivated crops in Santa Cruz**		
Crop	Production (metric tons)	Crop	Production (metric tons)	Percent of total production in Santa Cruz
Sugarcane *Saccharum officinarum*	11 447 542,5	**Sugarcane** *Saccharum officinarum*	10 790 780,0	94%
Soybean *Glycine max*	3 216 439,8	**Soybean** *Glycine max*	3 117 815,5	97%
Sorghum *Sorghum bicolor*	1 771 084,9	**Sorghum** *Sorghum bicolor*	1 765 356,4	99%
Potatoes *Solanum tuberosum*	1 382 382,5	**Maize** *Zea mays*	552 302,4	49%
Maize *Zea mays*	1 118 419,3	**Rice** *Oryza sativa*	303 025,3	70%*

*Calculated with the total amount of rice production of 434 028 metric tons

Peralta-Rivero (2020) further explains that the agro-industrial model really took off in the 1980s and has been expanding ever since. Two major reforms were key to this growth: Supreme Decree No. 21060 that opened the door for free import and export of agricultural goods, and Law No. 1715 in the 1990s that made it easier for private and foreign investors to acquire land in Bolivia. These changes brought in new capital and boosted the production of crops like soy, sugarcane, maize and sorghum to new levels. But this rapid growth has also come with serious environmental costs. In regions like Santa Cruz and the Yungas the agro-industry has driven large-scale deforestation and biodiversity loss. Between 2009 and 2019 more than 25 million hectares of land were affected by wild and human-made fires, with 6.4 million hectares lost in 2019 alone.

2.4.2 Cochabamba

Cochabamba's agroindustry is rooted in a mix of valleys, high plateaus and tropical lowlands that gives the region an incredible biodiversity. Despite its vast biodiversity most of this potential is underused because many products are only sold fresh, making farmers dependent on unstable prices and short shelf life. In an effort to change that the Centro de Tecnología Agroindustrial (CTA) at the University of San Simón was founded in 1980. By the late 1990s it had built pilot plants that helped roughly 450 families earn an extra income by turning local aromatic plants into essential oils and other value-added products (Ibisch & Gerkmann, 2000; CTA, 2000; Hellin & Higman, 2005). This region at the same time struggled with environmental stress as the Rocha River that runs through the valley, was heavily polluted by industrial waste, detergents, and tannery effluents. These pollutions led to degraded fish and insect populations in the river and the surrounding areas (Baudoin et al., 2016). Farmers in Colomi, an area located in the foothill mountains outside of Cochabamba also report that shifting rainfall patterns. This made the seasons less predictable and harder to grow and preserve traditional crops like potatoes and oca that depend on clean water and steady weather for processing (Saxena et al., 2016; Hellin & Higman, 2005). This leads to an economic depression in rural Andean and Southern regions, driving the migration of people to big cities like Cochabamba more (Aillón Gómez, 2021)

Cochabamba's modern agriculture has also been shaped by the production of coca. In the tropical *Chapare* region of Cochabamba, the coca fields have grown from around 2,500–3,000 hectares in the early 1970s to nearly 40,000 hectares by 1989 (Barrientos & Schug, 2006). Farmers chose coca because it is easier to grow as it is more adaptable to poor soils and far more profitable than state-promoted crops (Barrientos & Schug, 2006). But there is a more harsh reality behind the increased interest in farming coca. The increase in production is directly and deeply correlated with the production of cocaine (Grisaffi, 2021). Unfortunately the local cocaine trade is embedded within the social and economic fabric of the Chapare region. This makes the demand for coca leaves to surpass the supply at times and thereby increases the price making it even more lucrative (Barrientos & Schug, 2006). Despite various government programs to reduce coca production through crop substitution most of them had limited success (Barrientos & Schug, 2006). This region today shows two sides of the agricultural future: one side shows innovation through initiatives like CTA that demonstrates how biodiversity can be transformed into sustainable rural livelihood. While the other side shows water pollution, deforestation and climate stress with the underline the risks of continuing with business as usual making coca production a more attractive alternative (Ibisch, 2001; Baudoin et al., 2015; Grisaffi, 2021).

2.4.3 Medicinal plants in Agriculture

Alongside the expansion of agro-industries, Bolivia's diverse landscapes continue to support the production of native medicinal plants that not only offer therapeutic properties but also hold agricultural and ecological importance. In the traditional family-based model described by Peralta-Rivero (2020), these plants are often grown alongside food crops and form part of diverse agroecosystems that support both health and the livelihood of people. The study further explains that these systems often rely on ecological knowledge passed down from generations, with practices including seed saving, wildcrafting and seasonal harvesting. While agro-industries in Bolivia increasingly focus on export-oriented monocultures, the cultivation of medicinal plants remains a more local, diverse and culturally significant form of agriculture (Vandebroek & Balick, 2012). These plants provide ecological benefits such as supporting pollinators and enhancing soil health as well as contributing to economic resilience by being able to produce higher value products such as essential oils, ointments and tinctures (CTA, 2020)

In addition to their therapeutic and ecological value, many native medicinal plants also work as natural insect repellents, further increasing their relevance in sustainable farming systems. Species such as Muña (*Minthostachys mollis*), Paico (*Chenopodium ambrosioides*) and Ruda (*Ruta chalepensis*) produce volatile compounds that deter insects, making them important allies in ecological pest management (Ibisch & Mérida, 2004).

3 Method

To obtain the aim and to answer the research questions: **(1)How are native medicinal plants cultivated and harvested? (2) How are native medicinal plants used and sold? And (3) How are native medicinal plants integrated into local economies?** this study applied a semi-structured interview method, complemented by field visits and a document review. The semi-structured interviews combines pre-prepared guiding questions with the flexibility to explore emerging topics during the time of the conversations. The questions were primarily open-ended and often began with *why*, *how*, or *when*, in order to encourage detailed responses. This design was chosen because it allows for comparison across participants and captures the depth and diversity of traditional knowledge related to native medicinal plants. The method follows standards in qualitative research by Kvale and Brinkmann (2015) and Bernard (2017), whose academic works are very recognized in ethnobotanical and socio-cultural studies. The study was done in 6 stages all stated bellow (3.1 to 3.6)

3.1 Initial Fieldwork and resource mapping

The first stage involved informal discussions and observations with local residents to identify locations where native medicinal plants are commonly sold, practiced with or cultivated. This initial step acted as an entry point into relevant networks and provided trust-building opportunities, which are essential in qualitative research (Bernard, 2017). This step also helped identify potential participants who were knowledgeable, accessible, and willing to engage in the interviews.

3.2 Selection of interview participants and focus plants

A purposeful sampling strategy was used mentioned by Patton (2015) was used to select interview participants based on their expertise and roles. Preference was given to individuals with practical experience, official responsibilities or direct engagement in medicinal plant work, such as agricultural technicians, *naturistas* (traditional healers), rural farmers and producers. Initial contact with participants included asking questions about their profession, expertise and preferred interview setting. This allowed for better preparation and adaptation of the interviews.

The focus plants were chosen according to four criteria:

- High frequency of mention across contexts
- Recognition by both professionals and community members
- Presence at multiple points of the value chain
- Status as a native species to Bolivian ecosystems

3.3 Interviews – Questions

Before each interview the participants were informed about the purpose and background of the study and asked to sign a consent form in accordance with SLU's ethical guidelines for independent student projects. The form translated into Spanish was based on SLU's official template titled *"Consent form for the processing of personal data in independent projects"* found on their webpage. Each participant also received a copy for their own records. An interview template was designed to ensure consistency across the interviews while also allowing space for open-ended responses.

Interviews were conducted in Spanish as this is the official language in Bolivia, with translation into indigenous languages (Quechua, Aymara, Guaraní) when needed.

The questions were divided into three segments and were designed to ensure that the participants could provide a clear and comprehensive responses to the three core research questions of this study. A detailed list of interview questions can be found in table 9 in annex. This structure ensured both coverage of core topics and flexibility for participants to expand on areas of importance to them (Kvale & Brinkmann, 2015)

1. **Personal and Practical Background**
   This section is aimed at building trust and establishing the participant's credibility by including questions about their work background and the origin of their knowledge.
2. **Medicinal Plant Practices and Knowledge**
   At this stage, participants were more engaged, allowing for in-depth questions regarding plant usage, cultivation and value chain that directly addressed research questions *(1) How are native medicinal plants cultivated and harvested?* and *(2) How are the native medicinal plants used and sold?*
3. **Community Impact and Future Outlook**
   This final segment addressed broader topics such as regulations, cultural values and transmission of medicinal plant knowledge to the future generations. This last segment was designed to answer research question number *(3) How are they integrated into local economies?*

3.4 Field visit to plant locations

The interviews were complemented by field visits to sites where medicinal plants are grown. The use of multiple evidence sources (interviews, observations, and documents) strengthened the credibility of the results (Denzin, 2017). These visits required preparations that included suited clothing and equipment because of the variation of terrains and weather conditions.

Visits were documented with GPS coordinates, photographs and field notes on plant morphology, growing conditions and surrounding ecosystems. With the consent of landowners or custodians small plant samples were collected for observation and photographic documentation, always following ethical fieldwork practices.

3.5 Evaluation of Interviews, Locations, Value Chains, and Focus Plants

Data from interviews and field visits were reviewed and organized according to the three interview segments. An analysis of the answers was applied to identify noticeable patterns, contrasts and differences across the answers. Information that was repeated across multiple participants were viewed as especially significant.

Field locations were evaluated using tools such as Google Earth Pro and satellite imagery to assess altitude, topography and the surrounding vegetation. Data such as climate conditions and soil type were gathered from local agricultural databases and weather stations by Metoblue (2025)

The value chains of selected medicinal plants were mapped out using a combination of data from the interviews and observations from markets, fairs, shops and rural visits. This included identifying stages such as cultivation, harvesting, processing and sale.

The focus plants were evaluated through direct observation, morphological description and photographic documentation. Their traditional uses were cross-checked with literature from both ethnobotanical sources and peer-reviewed scientific publications. Ensuring that both cultural accuracy and scientific background were considered and compared.

3.6 Comparing interviews with official knowledge and research

Once all the interviews, field observations and focus plant information were gathered and organized the next step is to discuss, evaluate and compare the findings with official and scientific sources. Government websites such as those of the Bolivian Ministry of Health and Ministry of Rural Development and Land were used to check how well the interview data aligned with national policies or documented practices.

Additionally academic databases like Google Scholar and Web of Science were used to find peer-reviewed research that either supported or contradicted the knowledge shared by participants. This helps to provide a broader context and to show how traditional knowledge overlaps or differs from scientific understandings.

4 Result

4.1 Initial Fieldwork and resource mapping

The initial phase of the study included field visits to four locations in Cochabamba including markets and fairs in combination with updates from local news channels, social media channels and informal conversations with local residents. The initial phase was used to identify key locations where native medicinal plants are sold, discussed and used. The interactions led to the discovery of a specialized market that served as a central point when engaging with stakeholders directly involved in the trade and use of native medicinal plants.

The initial field observations were carried out at four locations: **(1)** Market Calatayud, Cochabamba, **(2)** *Feria Anual de Plantas Medicinales*, Potrero, **(3)** *Feria Agroecología Departamental Elemental*, Cochabamba and **(4)** *Campaña de Medicina Tradicional*, Cochabamba.

4.1.1 Location 1 - Market Calatayud - May 25, 2025.

Figure 6 *Market Calatayud in Cochabamba on May 28th, 2025 Crowded market with narrow, packed passages on the left, a vendor selling herbs in bunches in the center and processed natural medicines to the right Photograph by Claudia Villabrant, 2025*

This central market in Cochabamba is a key trading location for fresh produce and medicinal plants. It was the most frequently recommended and mentioned site by residents and professionals during preliminary inquiries and later interviews (personal communication, May–July 2025). According to personal communication with vendors during the visit, fresh herbs and merchandise arrive on Tuesdays and Saturdays around 04:00 a.m. to the market through the delivered by trucks from the countryside. The products are sold in bulk typically by the *arroba* (11.5 kg) or half arroba. Local stand vendors purchase these quantities and then resell them in smaller portions. Instead of weighing the herbs they prepare bunches that are sold at a higher price to establish a profit margin. When asking several stands what the origin of the plants, they only said that they come from the countryside. No one knew the exact location where the plants were harvested.

Calatayud is considered the primary entry point for commercially sold native medicinal plants in Cochabamba. Vendors from other markets across the city come here to source their merchandise. On Tuesdays and Saturdays, the market becomes extremely crowded with hallways packed to the point where passing is difficult (as shown in Figure 6). The prices of the medicinal plants increase the further the plants travel from this source. This is the reason why mornings at Calatayud are busiest as customers come early to secure the lowest price possible. One vendor with over 20 years of experience of selling herbs, reported that on these market days most of her stock is sold out by lunchtime. When asked about unsold medicinal plants, she explained that the remaining herbs are dried and later sold at a lower price than the fresh ones. But the price is still a higher price than the purchase cost to ensure a consistent profit. Further observing the market, it was clear that all the vendors had dried medicinal plants in bags hanging from their stalls with herbs they have dried themselves (as seen in Figure 6)

***Figure** 7 Market Calatayud in Cochabamba on May 28^{th}, 2025 Stand selling fresh plants. The blue bags at the bottom are those used for purchasing plants in bulk during the morning. Photographs taken by Claudia Villabrant (2025)*

In addition to fresh and dried medicinal plants, the markets offer a range of processed natural medicines (as seen on the right side of Figure 6). These products include creams, pomades and soaps infused with native and exotic medicinal plants, as well as capsules, medicinal plant syrups, tinctures, essential oils, raw medicinal oils and oil infusions.

4.1.2 Location 2 - Feria de Plantas Medicinales, Potrero - May 25, 2025.

This annual medicinal plant fair was organized by the municipality of Potrero, Cochabamba to promote and showcase locally harvested medicinal plants from Potrero. The event was identified through a TikTok video posted by *Revista Informativ* (2025) and was also announced in a segment broadcast by the local news channel *Unitel* (personal communication, May 2025).

At the annual fair of traditional medicine, native medicinal plants were sold freshly cut from the surrounding area of Potrero (as seen in Figure 8). According to informal conversations with the vendors the herbs were harvested either that same morning or the day before to provide the freshest product possible. Some stalls had plants with instructions on display to inform customers of their use (as seen in Figure 9). In addition to the locally sourced herbs, medicinal plants from the market at location 1 were also sold. This because some native species do not grow in the immediate area. Although these non-local plants were available, they were less displayed and not as integrated into the main stalls

Figure 8 Feria de plantas medicinales de Potrero: Images from the medicinal plant market in Potrero, Cochabamba on May 25ht 2025. Local vendor in traditional clothing selling freshly harvested native medicinal plants. Photograph by Melissa Herbas, 2025

***Figure 9** Feria de plantas medicinales de Potrero: Top: Stalls selling medicinal plants with handwritten instructions hanging above. Bottom: Close-up photographs of the handwritten instructions, each with a corresponding sample of the plant attached. Photographs Melissa Herbas, 2025*

4.1.3 Location 3 - Feria Agroecología Departamental Elemental - June 7, 2025.

This was an annual market organized by the *Movimiento Agroecológico Boliviano (MAB)* in collaboration with the Agricultural department of the University of San Simon. The aim was to promote and showcase agroecological practices within local communities in Cochabamba. The event was identified through personal communication (2025) and was promoted via a Facebook event created by MAB (2025).

This market had stalls offering locally harvested horticultural products from what are referred to in Bolivia as *Huertas* (small-scale market gardens). The stalls sold seasonal vegetables, fruits, and herbs alongside small plants, seeds and grafted trees. As the fair was an initiative to promote agroecology, many stalls also provided information about cultivation methods. They also offered instructions on planting and caring for the plants, seeds, and grafted trees (as seen in figure 10).

Figure 10 *Feria Agroecologia Departamental Elemental. Top: Stall selling horticultural produce alongside informational pamphlets on agroecology practices. Bottom: Vendor offering horticultural produce from their Huerta together with seeds in small packages. Photograph Melissa Herbas, 2025*

In addition, the fair also had stalls with locally processed products such as natural medicines, oils (e.g., coconut and avocado), skincare items, homemade natural fertilizers, kefir and yogurt (as seen in figure 11). All processed products were made by the vendors themselves, who aimed to inform buyers about their production processes while selling. Several of these vendors had studied at the University of San Simón and had established their businesses through university-supported initiatives.

Figure 11 *Feria Agroecologia Departamental Elemental. Left: Stall selling processed natural medicines using native medicinal plants. Right: Stall selling products made from coconut oil by former student from University of San Simon. Photograph by Melissa Herbas, 2025*

4.1.4 Location 4 - Campaña de Medicina Tradicional –June 14, 2025

Location 4 was a public health campaign promoting traditional medicine and was organized by *La Unidad de Medicina Tradicional del Servicio Departamental de Salud (SEDES)* in Cochabamba. SEDES is the official department of health in Bolivia. The event was held at Plaza 14 de Septiembre and was publicized by the local news outlet *Opinión* (2025)

Figure 12 *Campaña de Medicina Tradicional. A stall selling processed natural medicines alongside dried medicinal herbs. Photograph Melissa Herbas, 2025*

The stalls at location 4 offered processed traditional medicines in the form of syrups, tinctures, ointments and cremes (as seen in Figure 12). They also had ultra processed products made from native medicinal plants with additives (as seen in figure 13). The vendors, who were also the producers of these products provided information on their uses and their production. Although when asking in depth question about the production many vendors refeed to the production prosses as confidential.

Figure 13 *Campaña de Medicina Tradicional. Left: Stall selling Shampoo infused with native medicinal plants. Right: Up-close picture of shampoo with ingredient list. Photograph by Melissa Herbas, 2025*

4.2 Selection of interview participants and focus plants

The selection of interview participants was a result from the sampling strategy described in chapter 3.2. The participants were chosen based on their broad and extensive knowledge and participation in the value chain of the medicinal plants. The interview participants are named after their profession and are listed in table 4. The participants will be presented in relation to the locations where they were contacted alongside the relevant criteria they had for being chosen for this study.

Table 4 *Interview participants for the study and their profession*

No.	Interview Participants
1	Agri-Tour guide
2	Transdisciplinary Naturista
3	Quechua Naturista
4	Essential oil Lady
	Farmer Family
5	Farmer daughter
6	Father farmer
7	Grandfather farmer
8	Jampiri
9	Holistic Naturista
10	Technical Agriculturist

At location 1, the Calatayud market, requests to conduct formal interviews were respectfully declined by the vendors. While they were willing to answer questions informally on-site, they said that participating in a formal interview would require more time than they could spare during business hours.

At location 2, Feria de Plantas Medicinales, Potrero, contact was established with interview participant 1 **"*Agri-Tour guide*"** who is a local guide and farmer of areas where native medicinal plants are grown and collected. He works as a tour guide that specializes in the locations where medicinal plants are harvested in Potrero. Additionally, he also cultivates avocados, citrus and grafted avocado and citrus trees. He was selected as a formal interview participant due to his extensive knowledge of plant science and his familiarity with the local environment where medicinal plants are found. Having grown up in Potrero and maintained close ties to the area since his childhood, he possesses both practical experience and a deep understanding of the region's natural resources.

Figure 14 *Left: Agri-tour guide selling grafted avocado trees and providing instructions on their care. Right: Agri-tour guide (wearing a yellow hat) holding a medicinal plant and explaining its uses to the thesis supervisor. Photograph by Melissa Herbas, 2025*

At location 3, the Agroecology Fair no interview participants were engaged directly. However, through recommendations and personal communication with stall vendors and former students of the University of San Simón, interview participant no.2 and 3 were found. It was two naturistas that came highly recommended by the staff from the fair. In Bolivia, naturista refers to a natural health practitioner and are recognized under Law No. 459, *Ley de Medicina Tradicional Ancestral Boliviana* (Bolivia, 2013).

Interview participant no. 3 is called **"*Transdisciplinary Naturista*"** whose practice focuses on intercultural and complementary traditional medicine. He works with the prevention and treatment of diseases through natural medicine including therapies for depression and insomnia. He also offers spiritual cleansings and exorcisms. He conducts courses, seminars, and workshops to educate participants about traditional natural medicine. These workshops are held at his cultural center and museum of traditional medicine: *Centro Cultural Kuska*, located in the city center of Cochabamba (Centro Cultural Kuska, n.d.).

Figure 15 *Transdisciplinary naturista preforming a traditional cleansing ritual Photograph provided by the transdisciplinary Naturista*

Figure 16 *Quechuan Naturista with his wife, daughter and dog at his huera. Photograph provided by the Quechuan Naturista*

Interview participant 3 is ***"Quechuan Naturista"*** a traditional Quechua natural doctor who works with a holistic approach that treats the mind, body and soul all as one. He spends two days a week at his office in the city center of Cochabamba curing patients together with his father who also is a naturista. The rest of the week he spends at his own Huerta where he teaches his community about permaculture and traditional medicine. He also travels regularly to rural areas to collect herbs and to guide local farmers on sustainable harvesting of medicinal plants and the principles of permaculture.

At location 4 the campaign promoting traditional medicine, contact was made with vendors to arrange a formal interview, but none could be conducted due to conflicting schedules and vendor travel. During an examination of the products sold at the market, a WhatsApp number was identified of an essential oil's product of Muña. The number belonged to a lady producing these Essentials oils. She became interview participant 4 and will be referred to as the "**Essential Oils Lady**"

In addition to the four locations visited, personal contacts and communications with local families and relatives of the author were conducted and three additional participants were identified for interviews. In Bolivia many professional and community connections are established through personal recommendations, these referrals are considered valuable sources for identifying knowledgeable individuals.

Interview participants 6, 7 & 8 are all part of a long-established family of farmers. The participating members from the family are referred to as **"Farmer daughter", "Farmer Father"** and **"Farmer Grandfather"**. They live in the rural area of Arque in the Cochabamba district and has resided there for many generations, where they are dedicated to agricultural practices. On their land they grow both agricultural crops together with fruit trees and herbaceous plants. Numerous native medicinal plants grow naturally there which they use both in agricultural practices and for medicinal purposes. They were selected to provide insight into local farmers' knowledge of native medicinal plants in the Cochabamba region.

***Figure 17** Farmer family in Arque. Top: Farmer Grandfather standing in a field of fava beans (Vicia faba). Bottom: Farmer Father standing in a field of Andean lupin beans (Lupinus mutabilis. Photographs by Melissa Herbas, 2025*

Interview participant 9 was a *Médico Tradicional Jampiri* referred to as ***"Jampiri"*** in the study. He works at *La Caja Petrolera de Salud* a public health insurance institution in Bolivia that provides medical services through hospitals, clinics, and pharmacies. While the institution primarily focuses on pharmaceutical medicine, they also offer traditional medicine as an alternative or in combination with conventional treatments. Jampiri performs traditional healing practices (as seen in figure 18-Left) and a transdisciplinary approach integrating the use of native medicinal plants with pharmaceutical medicine (as seen in Figure 18-Right). His position within one of Bolivia's largest health insurance providers makes him a valuable candidate for this study.

Figure 18 Jampiri *(traditional healer). Left: Performing traditional healing methods. Right: Providing conventional treatments in combination with traditional medicine. Photographs scanned from* Revista Informativa del Servicio de Medicina Tradicional, Caja Petrolera de Salud, Cochabamba, Bolivia.

Interview participant 9 is a superior agricultural technician with nearly 40 years of experience working in rural areas referred to as ***"Technical Agriculturist"***. He has collaborated extensively with farmers to support rural development for years and is a professor at the University of San Simón in the Faculty of Rural and Territorial Development. His expertise in the landscapes and regions of Bolivia, combined with his long-standing work with local farmers provides him with deep insight into the country's natural resources. He has also participated in numerous projects involving native medicinal plants, this made him a strong candidate for an interview in this study.

Figure 19 *Technical Agricultarist holding a Bromeliad (Neoregelia) with his collection of Orchids hanging above. Photograph by Melissa Herbas, 2025*

Figure 20 Holistic Naturista observing a flower. Photo retrieved from Los Muros (n.d.)

Interview participant number 10 was a ***"Holistic Naturista"*** a natural healer and author specializing in native medicinal plants. Similar to the Quechuan naturista she adopts a holistic approach that integrates the body, mind and soul to her practice. She has over 20 years of experience in plant-based healing, acquiring her knowledge from a Kallawaya healer and complementing it with academic literature and extensive fieldwork. Her work involves frequent visits to rural areas of Bolivia, where she supports local farmers in improving their health using native medicinal plants. During these visits she both shares and gains knowledge about the medicinal plants of the region. She is also the author of "*Con-versando con las flores"*, a book that is about the traditional medicinal knowledge of Bolivia's Indigenous peoples through metaphorical conversations with flowers.

All the interview participants work with native medicinal plants but focus on different stages of the value chain. The diverse expertise they offer spanning from cultivation, foraging, usage, and transformation ensures an extensive perspective of the native medicinal plant sector in Cochabamba, Bolivia. The diversity of their precises allows for a more complete understanding of how medicinal plants are produced, utilized, and commercialized. The multi-perspective approach provides valuable insights into both traditional and modern practices, as well as the socio-economic and cultural understandings of native medicinal plant use.

4.3 Interview - Answers

The research questions **(1) How are native medicinal plants cultivated and harvested? (2) How are native medicinal plants used and sold? (3) How are native medicinal plants integrated into local economies?** could be answered through the understanding of the participants answers during the semi-structured interviews.

4.3.1 (1) How are native medicinal plants cultivated and harvested?

None of the participants knew of any place or person cultivating native medicinal plants in a commercial or organized setting. These plants are instead typically harvested from the wild or from the edges of private lands, making the practice more like foraging. But some human cultivation intervention still occurs. The Quechua Naturista, Jampiri, and the Holistic naturista all explained that harvesting plants from the wild carries great responsibility to give back to the land. To honor this, they do not collect all the medicinal plants they encounter on the site but instead leave some left to mature and produce seeds. Once the seeds are ripe, they return to collect them and disperse them in various locations where they believe the plants will thrive during the right time.

This practice is rooted in long-lasting experience and careful observation of the land and its seasonal patterns. In the case of Jampiri and the Quechua Naturista the knowledge was passed down through generations, as their parents taught them how to identify plants and areas where they grow and when to scatter the seeds to maximize germination success. They explained that the rural community possesses a deep understanding of how the land functions and the many resources it offers.

Although the rural community may not have formal academic training in agriculture or horticultural practices, their knowledge of native wild plants is both extensive and highly valuable. The interview participants explained that the rural farmers may not always know that the plants growing on their land have medicinal properties, but they know the plants' growth cycles and the environment they thrive in. This because they have lived together with these plants and gotten to know them through years of observation. By the rural community collaborating with naturistas, great value can be added to the plants on their land. Naturistas like the participants in this study can gain valuable insights into the native medicinal plants' growth cycles from the rural farmers and can in return teach them about their medicinal purposes and how to use them.

The Quechuan Naturista, Holistic naturista, and Jampiri had extensive contact with many farmers from rural areas where they exchanged their knowledge in a collaborative setting. Quechuan Naturista explained that he would sometimes visit rural communities to gather medicinal plants from their land while providing farmers with extra income in return. However, this harvesting practice presented challenges because once the farmers realized they could earn money from their non-cultivated plants, they began collecting them very extensively. This destructible practice went against the principle of giving back to the land. As a solution the Quechuan naturista became actively involved in the harvesting process and started teaching rural farmers not to remove every plant but instead adopt a long-term mindset. By leaving some plants in place and dispersing seeds, they could ensure a larger and more sustainable harvest in the coming years. in that way the Quechua Naturista could also ensure a long-term supply of native medicinal plants.

The timing of medicinal plant harvesting is considered by the Holistic Naturista to be a crucial factor in ensuring maximum potency. She explained that each plant has its own peak period of medicinal strength that is influenced by external factors such as the season, rainfall, and lunar cycles. According to her, during spring when the first seedlings emerge is a particularly favorable time for harvesting medicinal plants. She explained that the young plants at this stage have a higher concentration of beneficial properties. She also emphasized the importance of knowing which plant part to harvest and continued to say that some species store their medicinal properties in specific organs such as flowers, bark, roots or leaves. But that the chemical profile of a plant shifts dynamically through its growth period. For example, a plant whose leaves are medicinal may lose those properties in the leaves once it begins to flower.

The Holistic Naturistas' theory also extended to the effects of rainfall as harvesting immediately after rain dilutes a plant's medicinal properties and reduces its effectiveness. Instead, she recommended waiting several days after rainfall for the plants to dry slightly this would ensure maximum potency. She added by saying that seasonal conditions were also important when harvesting. She considered that the dry season particularly from April to June was the optimal harvesting period for many species. During this period the medicinal compounds are concentrated in the plant parts that are accessible.

She added to say that the lunar cycle is very influential and stated that a full moon in the dry season of April was the most auspicious time to harvest. In her explanation, the moon influences all fluids on Earth including plant sap, and during the full moon its gravitational pull draws sap from deep within the roots into the above-ground parts. Because of this it makes the medicinal properties more accessible

4.3.2 (3) How are native medicinal plants sold and used?

To answer this question, the value chain of native medicinal plants has been mapped out. It illustrates the full sequence of activities of medicinal plants from their origin in the wild to their final use by consumers. The value chain is divided into 5 parts: Inputs, Production, Processing, Distribution, and Consumption to identify how economic, social, and ecological value is created, transformed, or lost during different stages. This approach provides a structured way of understanding not only how medicinal plants are sold and used, but also how traditional practices and cultural values influence throughout the chain.

4.3.2.1 Inputs

The initial input in the value chain of medicinal plants is more labor-intensive than economic. As stated before, the plants are harvested from the wild and not from areas where they are cultivated. Because of this there are very few material and economic inputs at the beginning of the value chain. Within the framework of traditional medicine and the idea of "giving back to the land" and the practice of collecting and dispersing windborne seeds replace the initial economic input of buying seeds. This is a major difference from conventional farming methods.

4.3.2.2 Production

In the production line of the value chain the cultivation process is minimal as it only requires dispersing seeds. But harvesting and collecting require more effort because the plants often grow in areas that are difficult to access, making the labor input high. The Agri-tour guide made an important statement about the collection and said that "*The quality of the medicinal plant is better if the plant grows in a tough environment*". This statement was repeated throughout the other interviews and during the market visits. Collectors sometimes work in high-risk environments, such as steep mountain slopes or wild terrains with possibly poisonous animals. This makes the service of harvesting and collecting not only labor-intensive but also presents a great physical risk. It is still a primitive way of collecting and harvesting as no extensive machines are necessary and it is all harvested by hand using scissors, secateurs or knifes. The plants are usually carried in *Aguayos* that is the traditional fabric used to carry items on the back by the farmers (as seen in figure 25).

4.3.2.3 Processing and Consumption

The medicinal plants have many uses and are offered in different processes treatments depending on the purpose, knowledge and economic availability. By the observations from the field visits and through the conducted interviews it's established that the medicinal plants are sold in unprocessed to ultra processed form according to the NOVA-Food classification system. A detailed list of the products and their classification can be found in table 5.

***Table 5** Medicinal plants product and their NOVA-group classifications*

NOVA- Group	**Product**
1. Unprocessed /Minimally processed	Fresh Herbs / Dried Single Herbs, Essential oil[1]
2. Processed culinary ingredients	Essential oils[2], Waxes, Oils and Butters
3. Processed	Dried herbal mixes, Tinctures, Oil infusions. Pomades, Cremes & Herbal Syrups without additives[3]
4. Ultra-processed foods	Pomades, Cremes & Herbal Syrups with additives[3]

[1] Essential oil directly extracted from product for direct use in aromatherapy
[2] Essential oil used as an ingredient in further preparations
[3]Additives include preservatives, flavorings, stabilizers and coloring agents.

Unprocessed /Minimally processed product

The most simple and common way to find medicinal plant products are in fresh or dried form. And the most common method of use is through warm infusions consumed as herbal teas. This practice is often done without the guidance or recommendation of a naturista. Jampiri the naturista working at the Bolivian health insurance fund, explained that he frequently encounters people who self-medicate by preparing infusions of plants such as chamomile, boldo (*Peumus boldus*), and coca leaves among other. He believes that this is the most common way medicinal plants are used. Observations made in both general food shops and specialized medicinal markets confirms this statement that herbal teas are the most widely available medicinal products. Furthermore, in the informal conversations with residents during the introduction of the study the majority recommended a type of tea they typically had at home for treating mild ailments such as fatigue, stomach discomfort, or headaches.

In some cases, warm infusions are made for soaking the feet or even as herbal baths. This practice is believed to improve circulation, reduce swelling, draw out fatigue and remove toxins from the body. The warm infusion allows the body to relax and focus its energy on healing together with the plant's aromas that infuse the water. The Holistic naturista and Quechua Naturista said that the herbal soaks are made with different herbs and are customized to the patient's needs. They explained that the ache or problem of one person is not the same as the same ache for another person. For this reason, it is important to view traditional practices from a holistic perspective that includes the body, mind, and soul to get to the root of the problem.

A less common tradition is by topical application and wrap the medicinal plants around infected or wounded areas of the body. The study supervisor shared that she was advised by the Holistic Naturista to use fresh leaves of llantén (*Plantago major*) as a topical remedy for wounds, insect bites, and skin inflammations. The method involves briefly warming the leaf in hot water to soften its texture and activate its properties. After soaking, the leaf is placed directly over the affected area and then wrapped with a bandage to hold it in place. The leaves remain on the body for several hours and the treatment is repeated over several days for the best possible outcome.

Processed Culinary ingredients

The market also offers several products classified as processed culinary ingredients that are intended to be further prepared or transformed in the household. In many cases Naturistas' do not sell ready medicines but instead recommend products and preparations that the patients can make themselves. Their practice of recommendation further creates a demand for processed culinary ingredients. At all the fairs and markets visited there were stands selling bee products such as honey, beeswax, and pollen, as well as lipid-based products including coconut oil, avocado oil, cocoa butter and almond oil. These products were intended for further preparations as the stall vendors implemented the versatile uses of their products in conversations at the markets.

A common recommendation from the interview participants was to infuse oils with medicinal plants. Warm infusions involve slightly heating the oil and adding the herbs in and letting them infuse for up to an hour. Cold infusions require leaving the herbs in the oil for several weeks or months for it to be ready to use. The infused oil is then intended to be applied directly to the affected area. For example, infusing rosemary (*Rosmarinus officinalis*) in avocado or almond oil is believed to help reduce hair loss, while chamomile infused in olive oil may be applied as a topical pain reliever.

Processed

The market offers several types of home-made herbal mixes, syrups and tinctures. The recipes for these herbal mixes are developed with great care and can be custom-made or pre-mixed according to the specific ailment (as seen in Figure 21).
The transdisciplinary Naturista described the practice of *tukuypaq*, a Quechuan tradition of mixing herbs. In Quechua, *tukuy* means "everything" or "complete" and *paq* means "intended for" or "for the benefit of". Therefore, *tukuypaq* translates to "for complete benefit". The practice of tukuypaq involves combining four herbs that benefit the entire body, divided into four categories: one herbs for the digestive system, one for blood cleansing, one for the nervous

system, and one for strengthening the immune defenses. By drinking this mixture of herbs, it works as a preventative method to increase the overall health.

Figure 21 *Herbal mix purchased at the Calatayud market, produced by Laboratorio Artesanal Pronabel. Photograph Melissa Herbas, 2025*

Another common processed product found is herbal infusions, prepared either in syrups or in honey. The processing increases the product's value, as infusions are sold at higher prices while also extending their shelf life and making medicinal plants easier to consume. Additionally, when the herbs are pre-measured they offer a safer way of use since the dosage is already standardized and accompanied by recommendations.

Ultra-processed foods

While the artisanal market for medicinal plant products is extensive and highly valued there is also another side of the market where ultra-processed products appear. These products contain more additives and are made in bulk. While these products exist, they are generally not considered natural and does not always align with traditional medicine practices. Even so these products are offered and sometimes recommended, though to a much lesser extent than minimally processed alternatives by the Naturistas.

4.3.2.4 Distribution

The commercial distribution of medicinal plants in Bolivia remains largely unregulated with products transported using the most accessible methods available. At the Calatayud market, vendors explained that large trucks regularly deliver medicinal plants on Tuesdays and Saturdays. They are often mixed with other types of merchandise depending on the region of origin. This distribution system lacks proper control over temperature, environmental conditions, and cross-contamination. Thie unorganized system displays an underdeveloped logistical chain in the field. Furthermore, there is no guarantee of freshness of the product since Bolivia frequently experiences *bloqueos.* Bloqueos are road blockages preventing transportation of goods in and out of the cities, organized by labor unions, political groups, or other organizations as a form of protest. These blockages can last for days or even weeks making merchandise to remain in trucks exposed to direct sunlight and unsuitable conditions. This severely compromises the quality and integrity of the plant products that reach the market.

The less commercialized distribution of medicinal plants relies on the personal connections that Naturistas maintain with farming communities in rural areas. This form of exchange is demand-driven and allows for greater flexibility. Unlike the large-scale commercial distribution this practice involves fewer intermediaries enabling transport to adapt more easily to challenges such as bloqueos and other disruptions in transportation.

4.3.3 (3) How are native medicinal plants integrated into local economies?

Through the field visits and interviews it was observed that native medicinal plants enter the local economies mainly through wild harvesting rather than organized cultivation. This makes labor and local knowledge the dominant inputs in their value. Market observations show a clear increase in value from unprocessed material (fresh or dried bunches) to ultra-processed products.

For unprocessed items, the quality and price are shaped by the collector's knowledge of the site and timing of harvest and by primary postharvest handling (cleaning, drying, storage). For processed products the added value is driven by formulation choices, the degree of standardization and the producer's reputation. The vendors at the markets explained price differences as a function of experience and recipe development. The essential oil lady justified her higher prices by pointing out years of refinement and consistent quality. She also noted that cheaper products were often quick-turnover goods with low standards. Because consumers cannot measure product quality except by using them the reputation becomes a key quality assurance. Overall, the value increases with both processing intensity and reputational credibility. In the Bolivian context where word-of-mouth recommendations remain central where trusted producers and vendors can demand higher prices once they have established a good reputation.

Having a market for products harvested from the wild creates opportunities for people to earn extra income without extensive knowledge or major economic inputs. However, this opportunity also comes with responsibilities since Bolivia has regulations deciding the harvesting and commercialization practices of native medicinal plants.

The commercialization of medicinal plants is regulated by both the health sector and the environmental sector. The health sector is supported by Law No. 459 (2013) that formally recognizes ancestral traditional medicine within the National Health System (Bolivia, 2013). The law requires practitioners to be registered in RUMETRAB (Registro Único Nacional de Medicina Tradicional Ancestral Boliviana) (Bolivia, 2013). Its Supreme Decree 2436 (2015) assigns inspection and sanctioning roles to health authorities such as UNIMED (Unidad de Medicina Tradicional) and the Bolivian health service SEDES (Servicio Departamental de Salud). Commercial products like syrups, ointments, tinctures, or essential oils must have sanitary registration through AGEMED (Agencia Estatal de Medicamentos y Tecnologías en Salud), following the guidelines of the PNTA (Manual para el Registro Sanitario de Productos Naturales Tradicionales Artesanales) (Bolivia, 2015).

On the environmental side, harvesting and trade of wild plants are regulated by the General Environmental Law No. 1333 (1992) and the Framework Law of Mother Earth No. 300 (2012), which require sustainable use of biodiversity in protected areas (Bolivia, 1992; Bolivia, 2012). Within these protected areas, the General Regulation of Protected Areas (DS 24781) and SERNAP (Servicio Nacional de Áreas Protegidas) strictly forbid extraction and commercialization of wild species unless prior authorization has been granted (Bolivia, 2020; Bolivia, Ministerio de Medio Ambiente y Agua, 2020). Outside the protected areas, the collection and commercialization must follow environmental law as well as local municipal policies. In practice, this means that market vendors and small laboratories are supervised by the health sector, while collectors and intermediaries must also comply with environmental rules and area-based restrictions.

Although the regulatory framework for native medicinal plants in Bolivia appears well-structured on paper, in practice the market does not follow these guidelines. In the interviews with vendors it was revealed that almost none were formally registered, and some were not even aware of the regulations. The participants also said that there were infrequent inspections and limited market oversight. Because of these facts it became evident that the native medicinal plant market operates on two parallel levels. One side where the state presents an image of protecting biodiversity through laws and regulations, and another side where there exists a largely informal and unregistered market. Several participants also emphasized that legal frameworks do not always align with traditional knowledge and state that because ancestral practices predate the laws that there is no need to follow them.

Some processed products had stamps or labels stating they are in line with regulations. However, when asked further the vendors explained that there is no effective control over labeling. They further explained that it is easy to print a label claiming that a product meets legal requirements when in reality it does not

As for changes in the demand for medicinal plants in the local community the interview participants noted a significant increase during the COVID-19 pandemic. The Holistic Naturista explained that the number of vendors selling medicinal plants such as eucalyptus (*Eucalyptus globulus*), Wira Wira (*Gnaphalium dombeyanum*), Muña, Chamomile, and Ruda rose considerably. According to her, the vendors often walked through the streets wearing masks, selling the plants informally from baskets in an unregulated manner. When asked why she thought there was a sudden increase in interest, she explained that it was difficult during the pandemic to access pharmaceutical medicine as it was short in supply. Other participants also observed this sudden rise in demand. The farming family that had never previously sold eucalyptus experienced a high demand for the plant from people living in the city.

When asked about this sudden rise in interest, the Quechuan naturista reflected that in times of real need that people always turn back to nature to find answers. This because nature is where humans originate from. He emphasized that the principle of "giving back to the land" is not just a saying but a true wisdom to live by because the land will always care for those who care for it.

4.4 Field visits and plant locations

During the study, three sites in Cochabamba; **Potrero, Arque,** and **Pampa Tambo** were visited. To evaluate the climate of the places the Meteoblue tool was used with the coordinates of each location. Since the data for these sites is derived from the same weather station their overall patterns show similar result. Meteoblue tool uses interpolated adjustments made for distance, elevation and topography. All data derived from the Meteoblue tool can be found in figure 30 in annex and the summarized values be found in Table 6. While the overall seasonal patterns are similar, variations in temperature, precipitation, and wind speed occur between sites, mainly due to differences in altitude. It shows that Arque with the highest elevation also has slightly cooler average temperature and receives less rainfall than Potrero and Pampa Tambo.

During the field visits of the sites where medicinal plants grow certain challenges were presents. As previously mentioned through the answers from the interviews native medicinal plants are not cultivated in a commercial or organized setting. Because of this the visits became more of a tour through areas where these plants naturally occur. Since the visits took place during the cold season many of the plants were not in bloom or were in their dormant phase. Additionally, because these plants are foraged from the wild, foragers and harvesters are often reluctant to reveal exact locations. This because it comes with a risk that the sites could be overharvested and could lead to the loss of the collector's livelihood. The three sites visited for this study were accessed with the permission of the landowners or with specific consent to explore the area.

***Tabell 6** Summary of climatic characteristics for the three study sites Potrero, Arque, and Pampa Tambo, based on Meteoblue (2025) data. The table presents elevation, seasonal temperature ranges, precipitation and average wind speeds*

Location	Elevation (m.a.s.l)	Avg. Max Temp (°C) Nov–Jan	Avg. Min Temp (°C) June–July	Rainfall(mm,) rain season Dec-Feb	Rainfall (mm,) Dry season May-Aug	Wind (km/h)
Potrero	2865	22 – 27	7 – 14	80 – 120	>5	6 – 9
Arque	3000-3500	21 – 26	6 – 13	80 – 110	>5	6 – 9
Pampa Tambo	2608	22 – 27	7 – 14	80 – 120	>5	6 – 8

Note. Climate data obtained from Meteoblue (2025) is using all values derived from the nearest weather station in Cochabamba (17.42°S, 66.18°W, 2548 m.a.s.l.) and adjusted through interpolation for each location's coordinates, elevation, and topography.

4.4.1 Potrero

Potrero - Village in Quillacollo province of Cochabamba

The first field visit to the location of where medicinal plants grow was in Potrero, a small village in the Quillacollo Province of Cochabamba. Upon arrival at the local bus stop of Potrero the guide the Agri-tour guide led the way towards the site (as seen in the blue line in Figure 22). The route began along a narrow path through a eucalyptus forest that followed the course of a small irrigation furrow from the tributaries of the Río Chocoya. The eucalyptus forest created a cool, shaded corridor in contrast with the surrounding open hillsides. After a short walk, the trail turned upwards following the route made by grazing cattle from the area. The trail led to the slopes of a small mountain peak where the targeted medicinal plant species were found.

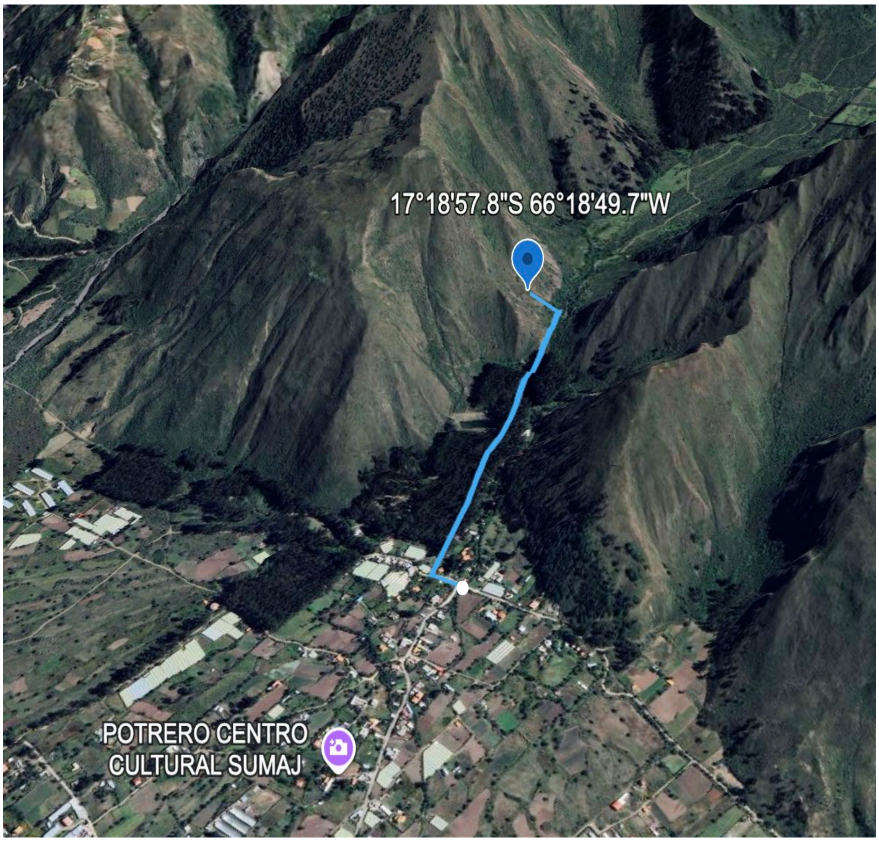

***Figure 22** Satellite image of Potrero, Cochabamba, Bolivia, showing the field sitewith blue tag (17°18'57.8"S, 66°18'49.7"W) and the walking route (blue line) from the drop-off point by the local bus (white dot). Adapted from Google Earth Pro, © 2025 Maxar Technolo*

Potrero is located at approximately 2865 m above sea level and boarders the Tunari National Park on the west side of the Río Chocoya. The area is fed by several tributaries running through it and the vegetation reflects the conditions of a temperate climate with a distinct wet and dry season. The landscape is a mosaic of montane grasslands, shrublands and scattered woodland patches (as seen in Figure 23). On the slopes native vegetation is dominated by hardy shrubs and perennial grasses that are adapted to withstand harsh weathers and low amounts of rainfall. Along the tributaries of the Río Chocoya and in the valley bottoms the vegetation becomes a lot denser and greener. There are also extensive stands of Eucalyptus and Pine (*Pinus* spp.) growing, which the Agri-Tour guide and thesis supervisor explained are introduced species planted for timber, fuelwood, and erosion control but now form a part of the landscape. The Agri-tour guide added that the appearance of the vegetation changes drastically with the seasons. The area turns lush and green during the rainy months of December to February and becomes drier and browner during the dry season from May to August. As the study took place during the dry season the terrain appeared noticeably less green than it would be during the summer months he added. He also said that this area is prone to strong winds and rapidly changing weather not only across seasons but even throughout the day.

Medicinal plants were found throughout the entire area and according to the Agri-tour guide nearly all plants in this landscape have some type of medicinal use. The first encounter with a medicinal plant was in the eucalyptus forest, where leaves are harvested for essential oil production. Continuing into patchy shrub and grasslands species such as Muña, Wira Wira, Molle and others were observed. He also emphasized the importance of seasonal knowledge saying that some species only appear during specific weeks or even days of the year, making these plants highly exclusive and with a greater value. He further explained that plants grown on the most dangerous spots to access were the plants of best quality and that people who are from the area are the most successful in harvesting good quality plans since they know the terrain the best.

***Figure 23** Vegetation and landscapes in Potrero, Cochabamba, during the dry season. Left: View of a hillside with native shrubs and perennial grasses, showing denser green vegetation along a tributary of the Río Chocoya. Middle: Pathway through a Eucalyptus plantation. Right: Valley landscape with a mix of montane grasslands, shrublands, and patches of introduced pine (*Pinus *spp.). Photographs taken by Melissa Herbas & Claudia Villabrant*

4.4.2 Arque

Arque – Town and municipality of Cochabamba

The second field study location was in Arque, a small town about 150 km southwest of the city of Cochabamba. This location was reached by *Trufi*, a type of shared minibus commonly used by the locals. Upon arrival the first site visited was the main residential house of the Farmer Family (as seen in Point 1 in Figure 24). The next day the families second resident was reached that was surrounded with more agricultural fields (as seen in Point 2 in figure 24). It was reached using local mopeds to travel up the terrain to their second house. Between Point 1 and Point 2 the family owned several plots of land where they cultivated various types of crops. At the time of the study most of the crops had already been harvested or was at the end of their season and the land was resting during the dry season. In the areas between and surrounding the agricultural plots the native medicinal plants were found growing. After arriving at Point 2 by moped, observations were made on foot, walking downhill back to Point 1. The route did not follow the main road but instead crossed several agricultural plots in order to observe as much medicinal plants as possible. The Farmer Daughter led the walk and demonstrated the medicinal plants and their purpose along the way from point 1 to point 2.

Figure 24 *Satelite image of Arque. Point 1 (17°49'21.4"S, 66°23'39.4"W) marks the main residential house of the Aguilar family. Point 2 (17°47'19.5"S, 66°24'30.7"W) marks their second residential house and the highest point of their agricultural land. Adapted from Google Earth Pro, © 2025 Maxar Technologies.*

The vegetation in Arque shows a semi-arid highland landscape during the dry season. The freshly harvested potato field in the top Figure 25 shows bare soil with patches of native wild plants along the edges. This mosaic of cultivated and uncultivated spaces is a repeated pattern in this area. According to the Farmer daughter this area has been cultivated for generations preforming crop rotation growing methods with potatoes (*Solanum tuberosum*), fava beans (*Vicia faba*), onions (*Allium cepa*), Andean lupin beans (*Lupinus mutabilis*), maize (*Zea mays*), wheat (*Triticum aestivum*) and other crops. The choice of crop depends on the lands condition and the economic situation of its owners. The surrounding slopes are dominated by drought-tolerant shrubs and grasses that are adapted to limited rainfall. In the wider view (as seen in

Bottom Figure 25) the mountainous terrain shows a patchwork of harvested agricultural plots, areas of natural shrubland and dried herbaceous vegetation. This land is also used for grazing livestock such as sheep, goats and cows which provide natural fertilizer for the soil. She continued to tell that as many families work in this agricultural area the grazing rights are shared amongst them. This meant that animals from different households often feed on the same land.

Across the landscapes of Arque the Farmer Daughter identified numerous medicinal plants including Muña, Wira Wira, and Ruda among many others. She also demonstrated a practical use of the Muña plant as a natural pesticide. She said that a layer of the plant is placed beneath the stored potatoes that are then covered with hay (as seen in top Figure 25). The Muña helps to repel insects and prevent infestation she said and was a practice that her grandparents had used since they were small children.

Figure 25 *Vegetation and landscapes in Arque. Top: Farmer Daughter overlooking a freshly harvested potato (Solanum tuberosum) field, with wild native vegetation surrounding the area. The white square shows area of piles where harvested potatoes are stored. Bottom: View from point 2 in figure 24 towards point 1, showing harvested agricultural plots and patches of dried vegetation. Photographs Melissa Herbas, 2025*

4.4.3 Pampa Tambo

Pampa Tambo - Rural Community in the municipality of Colomi in the Chapare region of Cochabamba

The third study site visited was Pampa Tambo that is located at 2,540 m above sea level. This visit was conducted together with the Technical Agriculturist who owns and operates a recently established countryside tourist center. The center provides guests with the unique climate found in the mountain foothills in combination with a learning environment. There a variety of plants are cultivated both outdoors and in greenhouses that are connected to outdoor ponds through an integrated aquaponic system. Pampa Tambo is only accessible by car as there is no public transportation that travels to the site. The located area has been undergoing urbanization where previously untouched land was is now being developed for sale. The surrounding landscape remains largely in its natural state.

The location is notably humid and lies in a zone where clouds frequently settle. Because of the constant high humidity throughout the year, the Technical agriculturist tells that the land around his tourist center rarely needs irrigation. Watering is only needed inside the greenhouses, he added. Additionally, due to the high humidity the surrounding small rivers and water banks remain constantly supplied with water. The high humidity supports the operation of a major hydroelectric facility that generates sustainable electricity from the local water sources. The plant is part of an integrated hydroelectric network in the Corani municipality that plays a significant role in Bolivia's renewable energy production strategy.

Figure 26 *Satellite image of Pampa Tambo in close proximity to the Corani hydroelectric plant. The image shows the location of the Pampa Tambo tourist center (blue marker) situated in the foothill mountain area. Adapted from Google Earth Pro (© 2025 Maxar Technologies).*

Since the areas surrounding Pampa Tambo consist mostly of untouched land they have a rich diversity of wild native species with a significant biodiversity value. The Technical Agriculturist explains that the wild terrain is rarely visited by people due to its difficult access. Although some landowners keep cattle that graze through the wild terrain and create small paths that can be used for exploration, extreme caution is advised as the area is home to many wild and potentially poisonous animals. He further explains that many medicinal plants in this location are particularly of high potency because the untouched wild lands contribute to their strength and quality. He added that a colleague of his specializes in producing essential oils from native medicinal plants such as Muña, and sources them from this area because they contain higher concentrations of essential oil compared to plants from other locations. The Wira Wira sold at the Calatayud market in central Cochabamba is also said to be sourced from the surrounding area, as the plant could be observed growing extensively along the roads leading to the site.

Figure 27 *Vegetation and landscape of Pampa Tambo, showing wild terrain at the top of the image going down to a newly established agricultural plot. A small shed with chickens and pigs grazing the land is visible. Photograph Melissa Herbas, 2025.*

4.5 Focus plants

While the study examines native medicinal plants in general two species stood out by being mentioned most frequently and observed at all visited locations. These two species are Muña (*Minthostachys mollis*) and Wira Wira (*Gnaphalium dombeyanum*). They are therefore chosen as the focus plants and are presented in detail to provide additional insight into their nature, uses and value.

4.5.1 Muña *Minthostachys mollis*

Muña also known as Andean Mint is a perennial aromatic shrub belonging to the family *Lamiaceae*. It has small oval serrated leaves that are green to grey-green in color. During its reproductive season the plant produces clusters of tiny white to whitish-violet flowers. The most recognized characteristic is the intense herby mint smell it gives out. Muña is native to the northern Andean regions of Bolivia, Peru, Ecuador, Colombia and northern Argentina, typically found at altitudes between 2,000 and 3,500 m.a.s.l. It thrives in moderately dry climates often on rocky slopes and highland grasslands. It is well adjusted to the dry weather as it is poorly adapted to areas with excessive moisture.

Figure 28 *Muña (*Minthostachys mollis*) harvested in Arque, from the land of the Farmer Family. Photograph Melissa Herbas, 2025*

The most common way to use Muña is as a warm infusion prepared as tea. The Farmer family recommended to use Muña when experiencing intense colds, describing it as an anti-inflammatory remedy. It is also used as a remedy to stomach irritations and problems. They further stated that it helps alleviate problems related to high altitude. When people from abroad and have difficulty adjusting to the altitude, they are given Muña tea to ease the symptoms. In addition, Muña is also used to help reduce fever. To prepare the infusions all the above-ground parts of the plant can be used. The Farmer Daughter explained that unlike other herbs where primarily the leaves are used, Muña is considered potent in its woody stems as well and they also have the strong and characteristic aroma

Apart from its medicinal uses, Muña is also known for its antifungal and antimicrobial properties and is traditionally used as a repellent during crop storage (as seen in Figure 25) piles of potatoes stored long-term under stacks of hay are often bottom layered with Muña to prevent insect and fungal damage. According to the Technical Agriculturist this practice is commonly observed in rural communities, not only for potatoes but also for other stored produce. He further explained that Muña is also included during the transport of crops to reduce the risk of pest outbreaks. However, this is less common on a larger scale since the availability of Muña is limited. Small-scale farmers on the other hand often travel with their harvested produce accompanied by Muña to increase protection.

The versatile uses of Muña also extend to its role as a culinary ingredient. According to the Quechua Naturista in areas near Lake Titicaca and in high-altitude river regions fish soups are often prepared with Muña. While it is not commonly used in the Bolivian cuisine, it is more frequently used in Peruvian dishes.

At the market, Muña is sold in its unprocessed form as fresh or dried herbs. It is also included in syrups against colds, honey infusions and in processed forms such as essential oils and oil infusions intended for further preparations. The essential oil lady sells a lot of Muña essential oil and explained that adding a few drops of Muña essential oil to a cream and rubbing it on the chest can help relieve symptoms of respiratory discomfort during a cold.

4.5.2 Wira Wira *Gnaphalium dombeyanum*.

The second native medicinal plant examined in this study is Wira Wira a perennial shrub belonging to the *Asteraceae* family. During field visits and interviews with local participants, it was described as typically reaching a height of 30–70 cm. It has leaves that are narrow and lanceolate that are densely covered with white tomentose hairs that give out a silvery-grey appearance. The flowers are small, pale yellow and fuzzy in texture that form clusters at the apices of the stems. Flowering typically occurs during the dry season from June to August

Figure 29 *Wira Wira (*Gnaphalium dombeyanum) *from the land of the Farmer Family. Photograph Melissa Herbas, 2025*

According to local knowledge and field observations, Wira Wira is found at altitudes between 2,000 and 4,200 m.a.s.l. and is native to the Andean regions of Bolivia, Peru, Chile, and Argentina. It thrives in cold environments with well-drained soils and abundant sunlight. It commonly grows on rocky slopes and along the edges of agricultural fields and likes intensive sunlight.

The primary traditional use of Wira Wira is in a warm infusion prepared by immersing the flower tops in hot milk and mixed with honey before consumption. This remedy is recognized for its effectiveness in alleviating respiratory problems such as coughs, asthma, bronchitis and flues. During the interviews, all participants expressed familiarity with this practice emphasizing that it has been passed down through many generations in Bolivia.

In one interview, Jampiri highlighted that Wira Wira is also being explored as a potential treatment for HIV. He described this as a relatively new discovery and mentioned that ongoing research is being conducted. According to him the plant has attracted a lot of interest from foreigners who often travel to Bolivia seeking Wira Wira. They have attempted to bring it back to their country to cultivate it but have remain unsuccessful he said.

The Holistic Naturista during the interview recalled a period when large companies arrived in Bolivia offering high payments for the plant because of growing international demand. Because it was being sold to foreigners at a higher price the local market faced difficulties acquiring it. The reason was because the harvesters and collector received better economic compensation by the foreigners. This increase in demand and intense extraction pressure almost brought the species to local extinction. As a result, the government was compelled to intervene by implementing regulations to protect Wira Wira from overharvesting and to ensure its survival in the country.

The most common form of Wira Wira found in the market was dried flowers sold in bundles. The leaves are more difficult to find at the market since its believed that only the flowers carry the medicinal capacity. Alongside finding dried flowers there are a lot of processed and ultra processed products with Wira Wira. The most common was cough syrups in different forms, either made with honey or with sugar. Honey infused with Wira Wira was also a common product found at the markets.

4.6 Comparing interviews with official knowledge and research

The local knowledge observed and documented in this study is extensive and it covers multiple aspects of medicinal plant use and management. To facilitate comparison with scientific sources two representative statements were chosen to capture the essence of the knowledge shared by participants and field visits. Alongside a comparison of the medicinal properties of the two focus plants described by the participants.

1. "The quality of the medicinal plant is better if the plant grows in a tough environment."
2. "Give back to the land what the land has given to you."
3. Muña as an anti-inflammatory and stomach remedy, as well as an antimicrobial agent in crop storage
4. Wira Wira as a remedy for respiratory problems as well as curing HIV

These statements reflect an ecological understanding of medicinal plant potency under stress conditions, a cultural principle of mutual exchange with nature and a healing-based interpretation of specific plant uses. Together, they summarize the broader perspectives encountered during the study and provide an entry point for cross-checking it with scientific literature.

4.6.1 The quality of the medicinal plant is better if the plant grows in a tough environment.

Local Knowledge: Several participants emphasized that *"the quality of the medicinal plant is better if the plant grows in a tough environment."* When asked to explain what they meant by tough environments they referred to locations that were hard to reach, like rocky slopes or harsh terrains, as the places where the best medicinal plants are found. They also said that areas exposed to sudden climatic changes or extreme conditions are good sites for collecting potent plants.

During the visit to Pampa Tambo this statement was confirmed in the practice. The area is well known by local residents as cold, humid, and is generally avoided because of the harsh weather. Despite the weather it was precisely there that Wira Wira was harvested for commercial markets. According to the participants this was because the plants from Pampa Tambo were considered to be of the highest quality.

The Holistic Naturista also pointed out that medicinal plants that grow in urban areas did not have the same potency as those from the countryside. She explained that city plants are protected by urban architecture and therefore lack the exposure to "natural environments" that reduces their strength.

Scientific Findings: Plants respond to environmental stress by producing a lot of different secondary metabolites that serves as a protective and an adaptive function in the plant. As mentioned in the Context chapter, the systemic acquired resistance (SAR) is a key pathway where plants increase secondary metabolite production under stress situations (Kowalczyk et

al., 2024). Compounds such as Alkaloids, Terpenoids and Phenolic compounds are synthesized in response to abiotic stress factors like UV-B radiation, extreme temperatures, drought as well as to biotic stress such as herbivore bites (Li et al.,1993; Lila, M.A., 2004; Grassmann et al., 2002). For example, anthocyanin accumulation is a common response to cold stress, while the biosynthesis of phenolic compounds can be induced by wounding the plant or by a pathogen attack (De Pascual-Teresa & Sanchez-Ballesta, 2008). This phenomenon, often referred to as "elicitation," mirrors the natural stress conditions and activates biochemical pathways that enhance secondary metabolite formation, making stress conditions a catalyst for heightened medicinal potential in plants (Lila, M.A., 2004).
There is even specific evidence from a species in Bolivia that shows how harsh environments enhance the concentration of bioactive compounds. The Cinchona (*Cinchona spp*.) trees that grow at high altitudes in the Kallawaya valleys show elevated levels of quinine. Quinine is the alkaloid that is historically used to treat malaria (Ibisch & Mérida, 2004). Similar to the example of Cinchona the German chamomile that is exposed to heat stress accumulates higher levels of chamazulene and α-(−)-bisabolol in its essential oils (Ghasemi et al., 2016). Ghasemi (2016) further stated that the quality of raw medicinal plant depends on genetic and environmental factors sucha as climate, soil and ecological variables significantly influencing the chemical composition of medicinal plants. Optimal environmental and ecological conditions that include specific stress conditions are crucial for producing the best yield with good active compounds.

Comparison: There is a strong alignment between the local knowledge and scientific evidence. The participants' observations that harsher climates produce stronger medicinal plants correspond closely with biochemical findings on stress-induced metabolite production.

4.6.2 Give back to the land what the land has given to you.

Local Knowledge: The statement *"Give back to the land what the land has given to you"* was strongly emphasized by the participants in this study. Naturistas highlighted practices such as scattering seeds instead of purchasing them and allowing plants and soils to rest through specific cycles to ensure regeneration. At the same time the participants also pointed out situations that contradict this principle. There were cases where medicinal plants were harvested without regulation and the influence of external economic interests encouraged overharvesting them without any regard for natural regeneration. Additionally, because many of these plants grow in areas with harsh and unpredictable climates the climate variability itself often undermines well-intended efforts at reciprocity. These environmental uncertainties make it difficult to regenerate plant populations despite the practices being aimed towards sustainability. While the ethics of helping the land regenerate remains a core value in local community, its application is increasingly challenged by market pressures, weak governance and environmental changes.

Scientific Findings: The idea of *"giving back to the land what the land has given to you"* is strongly supported in the studies on sustainability and biodiversity. As nature provides essential resources and services that humans rely on for survival like food, clean water, fertile soil and stable climates, natural ecosystems that are cared for continue to provide benefits for future generations (Ibisch & Mérida, 2004). Conservation practices like sustainable farming, forests protection and planting trees are ways of ensuring that ecosystems stay healthy and productive in order to benefit humans (Ibisch & Mérida, 2004). At the same time, the literature shows the risks of not giving back. As overexploitation, deforestation, pollution and poorly designed policies can degrade soils, reduce biodiversity and disrupt ecosystem services (Sen & Samanta, 2015). A clear example in Bolivia was when farmers cleared large forest areas to cultivate fast-growing cash crops (e.g., chili peppers) for quick profits. This led to land degradation and the loss of important water sources in neighboring communities (Ibisch & Mérida, 2004).

Comparison: Both local knowledge and scientific findings align on the principle that humans must "*give back to the land what the land has given to you*" in order to ensure a long-term sustainability. Local participants emphasize reciprocity through practices such as scattering seeds and allowing the land to rest. While also acknowledged threats posed by unregulated harvesting, external economic interest and unpredictable climates. The scientific studies further reinforce these concerns by demonstrating that biodiversity and ecosystem services are essential for human survival. The studies stated that unsustainable practices such as deforestation, overexploitation can rapidly degrade these life-support eco-systems. Together both perspectives highlight he insights that are crucial for understanding and addressing the challenges of sustainability.

4.6.3 Muña as an anti-inflammatory and stomach remedy, as well as an antimicrobial agent in crop storage

Local Knowlagde: The interview participants were all familiar with the local Muña plant and their remedies. They stated that it can work to lower fever levels, as an anti-inflammatory agent, a remedy to ease stomach problems and as an antimicrobial agent for crop storage. The recommended use as a remedy was through the infusion as herbal tea. The farmer family also showed the use of Muña as an antimicrobial agent when storing their potatoes with Muña to prevent infection.

Scientific Findings: The scientific findings confirms the traditional uses of Muña by showing it has anti-inflammatory, digestive, and antimicrobial properties (Herrera Guzmán & Poma Tello, 2019; Linares-Otoya, 2020; Laura-Ticona et al., 2024; Schmidt-Lebuhn, 2008; Espinoza Medrano, 2018). Studies found that extracts of Muña can reduce swelling and inflammation in animals and that *pulegone*, one of its main oils can help control inflammation through different cellular pathways. (Linares-Otoya, 2020). Muña is also widely used as a digestive aid as studies state that infusions of its leaves and stems are effective against stomach pain, gas, colic and even bacterial infections like *Helicobacter pylori* (Herrera Guzmán & Poma Tello, 2019). A study in Peru showed that nearly 70% of people reported improved digestion after drinking Muña tea (Herrera Guzmán & Poma Tello, 2019). Looking beyond the human health the Muña is also proven as an antimicrobial agent as scientific tests confirmed that its leaves and oils reduce potato sprouting, weight loss and insect damage (Schmidt-Lebuhn, 2008). The essential oils have also been proven to fight bacteria such as *Staphylococcus aureus*, fungi, and crop pests like the Andean potato weevil (Laura-Ticona et al., 2024). Together, this evidence supports Muña's value as both a medicinal plant and a natural crop protector

Comparison: There is a clear alignment between the local and scientific knowledge regarding the Muña. The participants' descriptions of Muña as an anti-inflammatory, digestive aid and antimicrobial agent closely correspond with pharmacological studies. It is confirmed by its bioactive compounds such as pulegone and other essential oils that aid these human health problems. Both local practices and laboratory research also highlight its antimicrobial effect in crop storage. This strong alignment suggests that Muña's traditional uses are not only culturally important but also scientifically validated. It reinforces its value both as a medicinal plant and an agricultural resource.

4.6.4 Wira Wira as a remedy for respiratory problems as well as curing HIV

Local Knowlagde: Within the local community the Wira Wira is widely recognized and a highly valued medicinal plant. According to the participants it is commonly prepared as an infusion with milk to treat respiratory problems. The Jampiri even stated that Wira Wira could serve as a cure for HIV patients. Although this was not proven he said that research was being made. During visits and informal conversations Wira Wira was the plant that was most frequently mentioned. Nearly everyone described some kind of personal connection to it. Several participants recalled being given the milk infusion from an early age when suffering from respiratory ailments during childhood. The plant had an increase in use during the COVID-19 pandemic as it was believed to be used as a cure and/or preventative measure.

Scientific Findings: As Wira Wira is most commonly prepared as an infusion in milk rather than in water, it is important to define the chemical differences between the two. Water is polar solvent that primarily extracts hydrophilic compounds such as flavonoids, tannins, glycosides, polar alkaloids, phenolic acids and sugars (Zhang, Lin, & Ye, 2018). Milk on the other hand has a broader spectrum of extraction compounds because it consists of water, fats and proteins (Abd El-Aziz et al., (2023). In addition to all compounds soluble in water, the fat in milk would be able to dissolve lipophilic compounds such as terpenes, essential oils and non-polar alkaloids.

However, by looking at the literature it suggests that this relationship is very complex. In a study on the essential oils of cinnamon and clove extracts in milk, Abd El-Aziz et al. (2023) found that the antimicrobial activities were lower in high-fat milk samples than low-fat milk samples. Suggesting that lipids may interfere because they form a physical barrier around microorganisms. Additionally, milk proteins such as casein can bind phenolic compounds and sometimes stabilizing them but in other cases reduce their bioavailability (Abd El-Aziz et al., 2023). Because this study was done on cinnamon and clove it is uncertain whether the same outcomes would apply to Wira Wira.

Following the chemical principle of "same dissolves same" milk would be expected to extract a broader range of compounds than water. But it's important to note that the final extraction profile depends on the specific characteristics of both the compounds present in Wira Wira and the components of milk that may ultimately influence the effectiveness of the preparation.

The use of Wira Wira as a medicine to treat respiratory problems has been supported by scientific studies confirming its anti-inflammatory and expectorant properties (Chuve et al., 2025; Castañeta et al., 2023). These effects of Wira Wira have been linked to compounds such as flavonoids, tannins and terpenoids found in the plant (Chuve et al., 2025). Recent research has further proposed that the essential oils of Wira Wira, that contain β-eudesmene, rosifoliol and α-pinene could possibly inhibit COVID-19 proteases and therefore show possible antiviral activity (Castañeta et al., 2023). However, the evidence for its effectiveness against COVID-19 remains limited. Most studies and claims are based on molecular hypotheses, small-scale essential oil analyses or ethnobotanical reports with no clinical trials available to confirm its efficacy (Castañeta et al., 2023; Chuve et al., 2025)

In summary, Wira Wira demonstrates promising chemical properties that could support respiratory health, but its role as a remedy for COVID-19 has not been scientifically proven and requires further in vitro, in vivo, and clinical studies. As for Wira Wira serving as a cure for HIV no studies were found that could support this statement. Articles in Spanish, Portuguese, English and Swedish were looked for without any significant findings.

Comparison: Local and scientific knowledge do align in recognizing Wira Wira as a treatment for respiratory problems, with studies linking its effects to compounds like flavonoids, tannins, and terpenoids. The traditional use of milk infusions may enhance extraction of lipophilic compounds although the scientific studies claims that this interaction is very complex and must be tried exclusively with Wira Wira. The claim that Wira Wira could be used as a COVID-19 prevention and even HIV treatment remains uncertain. The current research only provides limited molecular evidence for COVID-19 and none for HIV.

Discussion

The purpose of this study was to gain a better understanding of how native medicinal plants are cultivated, used, commercialized, and regulated by residents and practitioners in Cochabamba, Bolivia. The aim was to explore how local knowledge compares with official knowledge and scientific research to examine how such knowledge can contribute to addressing human health problems in the future. By doing this the study can contribute to add value to traditional knowledge that is often not evidence-based but instead passed down orally through generations.

The key findings were highlighted through answering the three research questions. Looking at research question **(1) How are native medicinal plants cultivated and harvested?** the results show a strong and ongoing practice of wild-harvesting medicinal plants instead of cultivating them. The local knowledge of selecting harvesting areas and areas with harsher climates, aligns with principles of plant physiology regarding environmental stress. This is because stress works act as a trigger for increased production of secondary metabolites. These secondary metabolites are often responsible for the medicinal properties of plants (Kowalczyk et al., 2024). Environmental stress has been shown to increase both the concentration and biological activity of bioactive compounds in medicinal plants. This suggest that plants growing under more harsh conditions may exhibit enhanced levels of bioactive compounds (Pandey et al., 2016; Isah et al., 2018)

The results suggest that cultivation or sourcing strategies that ignore the ecological growing conditions could compromise the medicinal quality of the harvested plants. The result from the local knowledge also emphasized that the land must be respected and cared for in order to sustainably benefit from its many resources. These perspectives align well with broader ecological and sustainability principles, they support the argument made by Mathez-Stiefel and Vandebroek (2011), that traditional knowledge should be integrated with scientific and regulatory frameworks to ensure a more sustainable food and medicine systems.

When mapping out the value chain the study addressed research question **(2) How are the native medicinal plants used and sold?** The findings in the study show how medicinal plants increase in value through processing, accumulated experience in production and producer reputation. The documented use of the medicinal plants in the study for their therapeutic properties could be referred to by the literature. The use of Muña (*Minthostachys mollis*) was described as a remedy for stomachache and colds, and Janni and Bastien (2000) documented that Muña is traditionally used to treat disorders across ten different body systems. Muña was further recognized for its anti-inflammatory properties by the Pan American Health Organization**,** as reported in the *Traditional Health Systems Report* (1999). In addition, the literature could also confirm the use of Muña as an antimicrobial agent in potato storage demonstrated in a study by Schmidt-Lebuhn (2008)**,** and its inhibitory effects against fungi and bacteria were supported by Laura-Ticona et al. (2024)**.**

Because these traditional uses of Muña require minimal processing, handling, and transportation, they can be considered relatively sustainable within their local range of use. However, the literature lacks evidence supporting the effectiveness of Muña as a pest management solution at an industrial or large-scale level of potato farming. One possible reason for this is the volume that would be required, as increased wild harvesting would pose a risk of overexploiting the plant. Alternatively, cultivation under controlled conditions might reduce environmental stress and by that could lower the potency of the plant. This trade-off may help explain why few studies have explored the use of Muña in large-scale pest management systems. One option for future studies could be to investigate the genetic basis of the active compounds responsible for therapeutic and antimicrobial activities. This could be used for future of selective breeding or cultivation strategies.

As for the second focus plant, Wira Wira (*Gnaphalium dombeyanum*) the findings similarly to Muña, show a strong alignment between local medicinal use and scientific evidence. The Local knowledge describing the use of Wira Wira as a milk-based infusion for respiratory problems was partly supported by scientific studies. These studies identified anti-inflammatory properties linked to flavonoids, tannins, and terpenoids present in the plant (Chuve et al., 2025; Castañeta et al., 2023). However, these studies did not examine milk as the extraction medium, like the locals used it. The use of milk may influence the extraction process it can dissolve both hydrophilic and lipophilic compounds. However, studies by Abd El-Aziz et al. (2023) highlights that such interactions are complex and very compound-specific. Therefore, a direct conclusions regarding the effectiveness of milk-based Wira Wira remedies remain uncertain and require targeted experimental studies for further validation.

Claims regarding the use of Wira Wira as a preventive or curative treatment for COVID-19 were only partially supported by the literature. Castañeta et al. (2023) proposed potential antiviral activity based on molecular docking and essential oil analyses, but these findings lack in vitro, in vivo, or clinical validation. Although the literature could only point out Wira Wira as a potential antiviral agent it is a small step towards a deeper scientific understanding of the plant. Additionally, the increased scientific interest in Wira Wira during the COVID-19 pandemic highlights how periods of global health crises can increase the attention toward traditional medicinal plants that may previously have been overlooked.

Regarding the claim that Wira Wira could cure HIV, no scientific evidence was found to support this statement. This absence of evidence does not particularly exclude the possibility that bioactive compounds that could be identified in future studies, such claims currently remain unproven. At the same time, naturistas that claim that a plant can cure HIV without scientific support may risk undermining their credibility. Only through systematic scientific investigation can it be determined whether such claims could have evidential support.

Although this study documented key aspects of medicinal plant properties and mentioned its uses it did not examine detailed harvesting techniques, knowledge exchange between rural farmers, or the use of medicinal plants in practices such as herbal baths and topical applications that were mentioned as alternative uses. The absence to study these techniques represents a limitation of the study but also highlights important opportunities for future research. Further studies could provide a more comprehensive understanding of how medicinal plant function at the intersection of tradition, sustainability, and governance.

Finally, research question **(3*)* How are native medicinal plants integrated into local economies?** reveals a clear gap between formal regulatory frameworks and actual market practices in Bolivia. Although laws exist to regulate the harvesting and commercialization of native medicinal plants like Environmental Law No. 1333 (1992)**,** that mandates state protection and sustainable use of wild flora, and Law No. 1580 (1994)**,** that ratified the Convention on Biological Diversity and formally committed Bolivia to biodiversity conservation.

The study showed that most interviewed vendors were not formally registered and reported limited awareness of regulations. This shows a clear division between state-led governance and traditional community-based trade systems. Similar dynamics have been described in ethnobotanical research where traditional knowledge systems and informal markets coexist alongside formal regulatory structures (Mathez-Stiefel & Vandebroek, 2011).

The results further show that medicinal plants are primarily integrated into local economies through wild harvesting rather than organized cultivation this makes the labor and site-specific knowledge an important value input (Ibisch & Mérida, 2004). In the market observations it was evident that the value increases along the chain from unprocessed plant material to processed products. As the price differences were strongly influenced by experience, formulation skills and producer reputation (Huanca-Mamani et al., 2015). Because consumers have limited means to assess product quality prior to use, trust and word-of-mouth recommendations function as key quality assurance mechanisms. By consumers having to rely on the reputation it further reinforces the informal economic structures and allows experienced vendors to request higher prices.

4.7 Opportunities shown by the study

4.7.1 New conventional cultivation methods

The findings of this study also show promising opportunities for the future cultivation of native medicinal plants. As found in the results, specific environments where stress factors such as altitude, cold, and drought naturally occur were considered optimal for medicinal plants by the interview participants. This observation aligns with plant physiological theory that explains how abiotic stress can activate defense-related pathways, such as systemic acquired resistance that leads to increased production of secondary metabolites that are often responsible for medicinal properties (Lila, 2004; Grassmann et al., 2002; Kowalczyk et al., 2024). However, in conventional farming systems, cultivation strategies typically focus on maximizing biomass yield by minimizing plant stress as the biosynthesis of secondary metabolites is costly for plants (Raven et al., 2005; Lila, 2004). This presents a challenge for the large-scale cultivation of medicinal plants under conventional, low-stress conditions, as reduced defense responses may grow the risk of lower concentrations of bioactive compounds and because of that could reduced the medicinal potency. Even if total yields are higher the larger quantities of plant material may not achieve the same medicinal effect.

This study also provided insight into how local farmers and naturistas had detailed knowledge regarding the optimal timing for harvesting medicinal plants. The participants emphasized that the potency of medicinal properties is dynamic and varies throughout the growing season. Those observations align with the understandings of secondary metabolite dynamics, where compound concentrations fluctuate in the plant in response to developmental stageand environmental stress exposure (Lila, 2004; Grassmann et al., 2002). By acknowledging local ecological knowledge in combination with biochemical analyses conducted at multiple points during the growing season, it would be possible to identify when and under what stress conditions medicinal plants produce higher concentrations of bioactive compounds.

Based on this understanding, a combined cultivation strategy integrating conventional farming methods could be explored. Plants could initially be grown under favorable conditions to maximize biomass production and after get exposed to controlled stress conditions at specific developmental stages to stimulate the synthesis of the defensive and medicinal secondary metabolites. The reason to induce stress in the plants is based on plant defense theory, which suggests that stress-induced elicitation can enhance secondary metabolite production without necessarily compromising overall plant survival when applied at appropriate intensities and timings (Lila, 2004; Grassmann et al., 2002). If it would be successful it may be possible to enhance medicinal potency while also maintaining acceptable yields. This methos addresses the trade-off between productivity and bioactive compound concentration identified both in the literature and the findings.

In theory this combined induced stress conventional farming system sounds promising, but finding exactly how, when and where the medicinal properties of the plant develop the most is very complex. Firstly, the medicinal properties that are intended to be obtained would have to be identified and go through clinical trials to prove their effectiveness. They would then have to be analyzed through biochemical studies at several different points during the growing season. Additionally, an ecological plant physiology assessment would be required in order to determine under which stress conditions these properties are mostly produced. This approach would demand a transdisciplinary approach involving multiple sectors and would represent a large economic investment.

4.7.2 A possibility for the new generation of conventional crops

But if a study of this magnitude were to be undertaken, it could bring more opportunities than only producing medicinal plants with higher yields and equal or stronger potency. By understanding how plants acquire their medicinal properties, the knowledge could also be applied to conventional crops to enhance their nutritional and functional value. This is possible because secondary metabolites share similar chemical structures and different plants can produce the same types of metabolites (Raven, Evert, & Eichhorn, 2012). If such approach were to be assessed, the quality of commonly cultivated crops could be improved and provide a greater nutritional value. This directly connects back to the problem statement introduced at the beginning of the study, where the WHO (2024) identified unhealthy diets as one of the two most significant factors in the rise of noncommunicable diseases. Cultivating crops with increased nutritional value would allow people to improve their nutrient intake without major changes to their daily habits. The effort would instead come from innovations in cultivation methods.

4.7.3 Increased value through undiscovered properties

To further emphasize the opportunities associated with analyzing bioactive compounds, another important focus to study could be of how medicinal properties are extracted. This study identified that the added value of medicinal plant products increases with the level of processing, accumulated experience in production and producer reputation. At the same time, the results highlighted that extensive studies of extraction methods for usage of medicinal plants remain limited it indicates a clear knowledge gap and reveals significant potential for further research into extraction techniques and their influence on medicinal product potency and value.

By further studying how to best extract the medicinal properties of these plants, products with higher potency could be developed. This knowledge could then further be implemented in the pharmaceutical field. The example of the poppy plant given in the introduction that led to one of the most effective analgesics in human history, really illustrates the profound impact that plants can have on human health (Raven, Evert, & Eichhorn, 2012). Considering that many medicinal plants remain poorly studied, it is likely that additional bioactive compounds with therapeutic potential could be discovered. Only through further targeted experiments and investigations of plant chemistry and extraction methods can such properties be discovered and responsibly utilized.

4.7.4 Double sided reality

While there are many new discoveries to be made it is important to highlight that medicinal plants often have a dual-purpose use of their properties. As mentioned in the context section, plants such as Coca and Ayahuasca have historically been used in Andean communities for medicinal, ritual, and nutritional purposes, including the use of coca leaves as antiseptics and anesthetics to reduce pain and aid healing (Marino & González-Portillo, 2000). However, these same plants also serve as raw material for narcotics or controlled substances, as coca is the primary source for the production of cocaine, classified as a controlled drug under international drug control frameworks (DEA Museum, n.d.).

This double sided reality creates tension between local traditions and formal regulatory systems. It raises questions about who holds the authority to define whether a plant can be classified as a medicine or as a drug. For the local communities these plants represent heritage, health practices, and livelihoods, but from a regulatory perspective they are often viewed as a threats to public health. This creates a narrow line between the plant's recognition as medicine or its classification as a drug.

4.8 Reflections and limitations

The research design of this study was based on qualitative fieldwork in the form of semi-structured interviews and market observations in selected communities of Cochabamba, Bolivia. This approach is well suited for capturing local perspectives, lived experiences and the orally transmitted knowledge in the medicinal plant sector. While the method can gather a broad spectrum of different information the chosen methodology also comes with limitations.

The formulation of the research questions shaped the type of knowledge that could be generated from the study. By asking *how* plants are cultivated, used and commercialized, the study emphasized on practices and experiences rather than quantitative data on yields, chemical composition, or market volumes. This approach can be seen as a strength in terms of documenting traditional knowledge and socio-ecological practices. But shows weakness it its ability to measure the biochemical efficacy of remedies or to evaluate their economic potential at larger scales. Although the study highlighted the importance of integrating local knowledge into broader discussions of sustainability and health through qualitative methods. The study would also benefit by complementing the qualitative findings with quantitative data derived from experimental and biochemical analyses. These insights would have provided a more solid foundation for evaluating the contribution of medicinal plants to local livelihoods and national health systems.

In addition, the qualitative approach in the study does not allow for quantifiable conclusions regarding the economic impact of the medicinal plant market. To obtain such results a more systematic data collection would be required including market prices at different stages of the value chain, production, statistics and yield statistics. By gathering more quantifiable data it could be analyzed through economic models for a better understand of the gains and constraints of medicinal plant commercialization.

Going back to the opportunities of providing biochemical analysis, when comparing local knowledge with scientific research a clear gap was observed. Through the gathering of the data it was observed that many of the native medicinal plants have not yet been extensively investigated. By conducting biochemical analyses of these species, it could provide a stronger validation of their properties and therapeutic potential. This would not only support the preservation of traditional knowledge but also enhance the plants' value within scientific and policy frameworks. Such an approach has been applied in ethnopharmacological research, for example by Vandebroek et al. (2010). They combined traditional knowledge with pharmacological evaluation to support the recognition of medicinal plants within formal health systems. This would not only support the preservation of traditional knowledge but also enhance the plants' value.

To gain an even broader spectrum of the study area the selection of interview participants could have been more extensive. The focus of the interview participants was primarily on producers and practitioners. While the perspectives of processors, policy makers, health authorities and exporters were not addressed. By excluding these professions, it creates a partial picture of the value chain as only the most basic participants were covered. By including processors, policy makers, health authorities and exporters the side of the value chain that had a greater economic value could be investigated.

Lastly, although Bolivia's regulatory framework for medicinal plants was acknowledged, the study did not provide a comprehensive analysis of how these regulations influence harvesting, trade and market formalization. Interviewing and analyzing the perspectives of staff members from institutions like SEDES the Regional health department unit in charge of coordinating traditional medicine practices in Bolivia and UNIMED Traditional Medicine Unit within Bolivia's health system it would have provided a clearer understanding of how policies are implemented in practice. This could have helped reveal where regulations are effective and where enforcement is lacking.

5 Conclusion

There are many opportunities that native medicinal plants have to offer us humans. By looking at them through a broad spectrum and not becoming limited by already reinforced policies and methods, the opportunities can be turned into reality. This is how science works, it begins with a bold idea that is sparked by observing problems. And through the right application of knowledge those ideas can transform into innovative solutions.

This study shows that traditional local knowledge in Cochabamba, Bolivia carries a degree of scientific accuracy. It also highlights both the difficulties and opportunities associated with native medicinal plants. By zooming out and placing the gathered information into a larger perspective, it becomes clear that there is huge potential for future research in this field. It is also important to remember that plants have existed on the planet long before humans. They carry knowledge and adaptive strategies that we have only just begun to understand. Studying these plants further could offer insights that not only could enhance human health today but could also create a more resilient society in the future. A society where people not only live longer but also live healthier and more stable lives in their later years.

I want to end this study by concluding that it has given me valuable insight into the knowledge that can be learnt from nature. By continuing to study and respect this knowledge, we humans could find ways to add greater value not only to our health, but to life itself.

6 References

Abd El-Aziz, M., Salama, H. H., & Sayed, R. S. (2023). Plant extracts and essential oils in the dairy industry: A review. *Foods and Raw Materials, 11*(2), 321–337. https://doi.org/10.21603/2308-4057-2023-2-579

Acquaviva, R., Russo, A., Galvano, F., Galvano, G., Barcellona, M. L., Li Volti, G., & Vanella, A. (2003). Cyanidin and cyanidin 3-O-β-D-glucoside as DNA cleavage protectors and antioxidants. *Cell Biology and Toxicology, 19*(4), 243–252. https://doi.org/10.1023/A:1025378423505

Akerele, O. (1993). Nature's medicinal bounty: Don't throw it away. *World Health Forum, 14*(4), 390–395.

Aillón Gómez, T. (2021). La urdimbre social en la producción del espacio de los mercados de trabajo en la industria de Cochabamba-Bolivia. *Laboreal, 17*(2). https://doi.org/10.4000/laboreal.18509

Amorini, A. M., Fazzina, G., Lazzarino, G., Tavazzi, B., Di Pierro, D., Santucci, R., Sinibaldi, F., Galvano, F., & Galvano, G. (2001). Activity and mechanism of the antioxidant properties of cyanidin-3-O-β-glucopyranoside. *Free Radical Research, 35*(6), 953–966. https://doi.org/10.1080/10715760100301451

Bach, K., Schawe, M., Beck, S., Gerold, G., Gradstein, S. R., & Moraes R., M. (2003). Vegetación, suelos y clima en los diferentes pisos altitudinales de un bosque montano de Yungas, Bolivia: Primeros resultados. *Ecología en Bolivia, 38*(1), 3–14.

Barnum, C. R., Endelman, B. J., & Shih, P. M. (2021). Utilizing plant synthetic biology to improve human health and wellness. *Frontiers in Plant Science, 12,* Article 691462. https://doi.org/10.3389/fpls.2021.691462

Barrientos, J. C., & Schug, W. (2006). The decision of farmers from the tropical region of Cochabamba in Bolivia to cultivate coca instead of state-recommended alternative products. *Agronomía Colombiana, 24*(1), 147–157.

Baudoin, M., Hansen, A. M., & Chumacero, J. P. C. (2016). Soil and water pollution in a river of the Bolivian Andes: The case of the Rocha River. *Frontiers in Public Health, 4,* 20. https://doi.org/10.3389/fpubh.2016.00020

Bendokas, V., Stanys, V., Mažeikienė, I., Trumbeckaite, S., Baniene, R., & Liobikas, J. (2020). Anthocyanins: From the field to the antioxidants in the body. *Antioxidants, 9*(9), 819. https://doi.org/10.3390/antiox9090819

Bernard, H. R. (2017). *Research methods in anthropology: Qualitative and quantitative approaches* (6th ed.). Rowman & Littlefield.

Bhardwaj, R. L., Parashar, A., Parewa, H. P., & Vyas, L. (2024, March 14). An alarming decline in the nutritional quality of foods: The biggest challenge for future generations' health. *Foods, 13*(6), Article 877. https://doi.org/10.3390/foods13060877

Bodeker, C., Bodeker, G., Ong, C. K., Grundy, C. K., Burford, G., & Shein, K. (2005). *WHO global atlas of traditional, complementary and alternative medicine*. World Health Organization.

Bolivia. (1992, April 27). *Ley del Medio Ambiente, Ley No. 1333*. Servicio Nacional de Legislación Ambiental. https://sea.gob.bo/digesto/CompendioII/N/129_L_1333_01.pdf

Bolivia. (2012, October 11). *Ley Marco de la Madre Tierra, Ley No. 300*. Ministerio de Planificación del Desarrollo. https://www.planificacion.gob.bo/uploads/marco-legal/Ley%20N%C2%B0%20300%20MARCO%20DE%20LA%20MADRE%20TIERRA.pdf

Bolivia. (2013, December 19). *Ley de Medicina Tradicional Ancestral Boliviana, Ley No. 459*. Gaceta Oficial del Estado Plurinacional de Bolivia. https://www.lexivox.org/norms/BO-L-N459.xhtml

Bolivia. (2015, August 21). *Decreto Supremo No. 2436: Reglamento de la Ley No. 459 de Medicina Tradicional Ancestral Boliviana*. Gaceta Oficial del Estado Plurinacional de Bolivia. https://www.lexivox.org/norms/BO-DS-N2436.xhtml

Bolivia. (2020, January 13). *Decreto Supremo No. 24781: Reglamento General del Sistema Nacional de Áreas Protegidas*. Tribunal Agroambiental. https://www.tribunalagroambiental.bo/wp-content/uploads/2021/01/ds_24781gaceta.pdf

Bolivia, Ministerio de Medio Ambiente y Agua. (2020, August 7). *SERNAP: En las áreas protegidas nacionales no se permite la extracción y comercialización de plantas*. https://www.mmaya.gob.bo/2020/08/07/sernap-en-las-areas-protegidas-nacionales-no-se-permite-la-extraccion-y-comercializacion-de-plantas/

Caja Petrolera de Salud. (n.d.). *Revista informativa del servicio de medicina tradicional* [Brochure].

Cardinale, B. J., Duffy, J. E., Gonzalez, A., Hooper, D. U., Perrings, C., Venail, P., Narwani, A., Mace, G. M., Tilman, D., Wardle, D. A., Kinzig, A. P., Daily, G. C., Loreau, M., Grace, J. B., Larigauderie, A., Srivastava, D. S., & Naeem, S. (2012). Biodiversity loss and its impact on humanity. *Nature, 486*(7401), 59–67. https://doi.org/10.1038/nature11148

Cassidy, A., Rogers, G., Peterson, J. J., Dwyer, J. T., Lin, H., & Jacques, P. F. (2015). Higher dietary anthocyanin and flavonol intakes are associated with anti-inflammatory effects in a population of U.S. adults. *The American Journal of Clinical Nutrition, 102*(1), 172–181. https://doi.org/10.3945/ajcn.115.108555

Castañeta, G., Huayhua-Llusco, A., Tarqui, S., & Gutiérrez, A. F. (2023). Characterization of terpenoids from *Pseudognaphalium gaudichaudianum* (DC) Anderb., wira-wira by GC/MS, active principles with possible use in COVID-19 infection prevention. *Advances in Medicine and Engineering Interdisciplinary Research, 1*(1). https://doi.org/10.32629/ameir.v1i1.1146

Centro Cultural Kuska. (n.d.). *Centro Cultural Kuska* [Map]. Google Maps. Retrieved August 13, 2025, from https://www.google.com/maps/place/Centro+cultural+Kuska,+Papa+Clemente+10,+Cochabamba

Chuve, T. V., Souza, T. C., Basílio, J. M., & Pereira, L. da C. P. (2025). A importância da planta medicinal Wira Wira em San Matías, Bolívia, fronteira com Cáceres, Mato Grosso, Brasil. *Revista de Comunicação Científica: RCC, 5*(18), 17–28. https://periodicos.unemat.br/index.php/rcc/issue/view/622

CTA. (2000). The "Centro de Tecnología Agroindustrial" program to transform the utilization of the Cochabamba region's vegetal resources. *Horizon Solutions Site.* https://www.solutions-site.org/node/48

De Pascual-Teresa, S., & Sanchez-Ballesta, M. T. (2008). Anthocyanins: From plant to health. *Phytochemistry Reviews, 7*(2), 281–299.

DEA Museum. (n.d.). Coca. In *Cannabis, coca, and poppy: Nature's addictive plants* (Online exhibit). https://museum.dea.gov/exhibits/online-exhibits/cannabis-coca-and-poppy-natures-addictive-plants/coca

Denzin, N. K. (2017). *The research act: A theoretical introduction to sociological methods* (4th ed.). Routledge.

Desborough, M. J. R., & Keeling, D. M. (2017). The aspirin story: From willow to wonder drug. *British Journal of Haematology, 177*(5), 674–683. https://doi.org/10.1111/bjh.14520

Dorman, H. J. D., & Deans, S. G. (2000). Antimicrobial agents from plants: Antibacterial activity of plant volatile oils. *Journal of Applied Microbiology, 88*(2), 308–316. https://doi.org/10.1046/j.1365-2672.2000.00969.x

Espinoza Medrano, D. A. (2018). *Efecto antiinflamatorio de un gel elaborado a base de extracto seco de hojas de Minthostachys mollis (muña) en Rattus rattus* [Bachelor's thesis, Facultad de Ciencias de la Salud, Escuela Profesional de Farmacia y Bioquímica]. Chimbote, Perú.

Feng, R., Ni, H.-M., Wang, S. Y., Tourkova, I. L., Shurin, M. R., Harada, H., & Yin, X.-M. (2007). Cyanidin-3-rutinoside, a natural polyphenol antioxidant, selectively kills leukemic cells by induction of oxidative stress. *Journal of Biological Chemistry, 282*(18), 13468–13476. https://doi.org/10.1074/jbc.M610616200

Fischer, E. (2023). Kallawaya, Inc.—The making of the Kallawaya (1532–2008): A historical, relational, and comparative approach. *Estudios Atacameños. Arqueología y antropología surandinas, 69,* e5216. https://doi.org/10.22199/issn.0718-1043-2023-0005

Ghasemi, M., Babaeian Jelodar, N., Modarresi, M., Bagheri, N., & Jamali, A. (2016). Increase of chamazulene and α-bisabolol contents of the essential oil of German chamomile (*Matricaria chamomilla* L.) using salicylic acid treatments under normal and heat stress conditions. *Foods, 5*(3), 56. https://doi.org/10.3390/foods5030056

Google. (n.d.). *Market Calatayud* [Map]. Google Maps. Retrieved August 12, 2025, from https://www.google.com/maps/place/Market+Calatayud/@-17.3984067,-66.1528665,717m

Google. (2025). *Potrero, Cochabamba, Bolivia (17°18'57.8"S 66°18'49.7"W)* [Map]. Google Maps. https://www.google.com/maps/place/17%C2%B018'57.8%22S+66%C2%B018'49.7%22W

Google Earth Pro. (2025). *Potrero, Cochabamba, Bolivia* [Satellite image]. Maxar Technologies. Retrieved August 14, 2025, from https://earth.google.com/

Grassmann, J., Hippeli, S., & Elstner, E. F. (2002). Plant's defence and its benefits for animals and medicine: Role of phenolics and terpenoids in avoiding oxygen stress. *Plant Physiology and Biochemistry, 40*(6–8), 471–478. https://doi.org/10.1016/S0981-9428(02)01395-5

Grisaffi, T. (2021). Why is the drug trade not violent? Cocaine production and the embedded economy in the Chapare, Bolivia. *Development and Change, 53*(3), 576–599. https://doi.org/10.1111/dech.12696

Hardy, K., Buckley, S., Collins, M. J., Estalrrich, A., Brothwell, D., Copeland, L., García-Tabernero, A., García-Vargas, S., de la Rasilla, M., Lalueza-Fox, C., Huguet, R., Bastir, M., Santamaría, D., Madella, M., Wilson, J., Fernández Cortés, Á., & Rosas, A. (2012). Neanderthal medics? Evidence for food, cooking, and medicinal plants entrapped in dental calculus. *Naturwissenschaften, 99*(8), 617–626. https://doi.org/10.1007/s00114-012-0942-0

Hellin, J., & Higman, S. (2005). Crop diversity and livelihood security in the Andes. *Laboreal, 1*(1), 1–12.

Herrera Guzmán, A. B., & Poma Tello, V. S. (2019). Efectividad del uso de la muña (*Minthostachys mollis*) y del romero (*Rosmarinus officinalis*) como insecticidas de productos almacenados, centro poblado San Juan de Rancas, distrito de Carhuamayo – Pasco 2018 [Tesis de pregrado, Universidad Nacional Daniel Alcides Carrión].

Huanca-Mamani, W., Loza, C., Lara, A., & Miranda, H. (2015). An ethnobotanical survey of medicinal plants commercialized in the markets of La Paz and El Alto, Bolivia. *National Herbarium of Bolivia & Missouri Botanical Garden.*

Ibisch, P. L. (2001). Bolivia is a megadiversity country and a developing country. In W. Barthlott, M. Winiger, & P. L. Ibisch (Eds.), *Biodiversity: A challenge for development research and policy* (pp. 213–232). Springer. https://doi.org/10.1007/978-3-662-06071-1_15

Ibisch, P. L., & Gerkmann, B. (2000). Establishing ethnobotanical conservation: The case of the CTA in Cochabamba, Bolivia. *Horizon Solutions Site.*

Ibisch, P. L., & Mérida, G. (Eds.). (2004). *Biodiversity: The richness of Bolivia. State of knowledge and conservation*. Editorial FAN.

Instituto Nacional de Estadística. (n.d.). *Agricultura – cuadros estadísticos.* https://www.ine.gob.bo/index.php/estadisticas-economicas/agropecuaria/agricultura-cuadros-estadisticos/

Janni, K. D., & Bastien, J. W. (2000). Establishing ethnobotanical conservation priorities: A case study of the Kallawaya pharmacopoeia. *SIDA, Contributions to Botany, 19*(2), 387–398. https://www.jstor.org/stable/41968946

Janni, K. D., & Bastien, J. W. (2004). Exotic botanicals in the Kallawaya pharmacopoeia. *Economic Botany, 58*(Supplement), S274–S279. https://doi.org/10.1663/0013-0001(2004)58[S274:EBITKP]2.0.CO;2

Knapp, S. (2019). People and plants: The unbreakable bond. *Plants, People, Planet, 1*(1), 14–19. https://doi.org/10.1002/ppp3.4

Kokoska, L., & Fernandez Cusimamani, E. (2008). Bolivian plant extracts: Traditional medicine. In R. R. Watson & V. R. Preedy (Eds.), *Botanical medicine in clinical practice* (pp. 40–45). CAB International. https://doi.org/10.1079/9781845934132.0040

Konno, K. (2011). Plant latex and other exudates as plant defense systems: Roles of various defense chemicals and proteins contained therein. *Phytochemistry, 72*(13), 1510–1530. https://doi.org/10.1016/j.phytochem.2011.02.016

Kowalczyk, T., Muskała, M., Merecz-Sadowska, A., Sikora, J., Picot, L., & Sitarek, P. (2024). Anti-inflammatory and anticancer effects of anthocyanins in in vitro and in vivo studies. *Antioxidants, 13*(9), 1143. https://doi.org/10.3390/antiox13091143

Kvale, S., & Brinkmann, S. (2015). *InterViews: Learning the craft of qualitative research interviewing* (3rd ed.). Sage.

Laura-Ticona, J., Chambi-Rodríguez, A. D., & Coaquira-Quispe, J. J. (2024). Efecto antimicrobiano in vitro de aceite esencial de eucalipto (*Eucalyptus globulus*) y muña (*Minthostachys mollis*) frente a bacterias causantes de infecciones urinarias. *Revista de Investigaciones Altoandinas, 26*(1), 36–45. https://doi.org/10.18271/ria.2024.586

Li, J., Ou-Lee, T.-M., Raba, R., Amundson, R. G., & Last, R. L. (1993). Arabidopsis flavonoid mutants are hypersensitive to UV-B irradiation. *The Plant Cell, 5*(2), 171–179. https://doi.org/10.1105/tpc.5.2.171

Lila, M. A. (2004). Anthocyanins and human health: An in vitro investigative approach. *Journal of Biomedicine and Biotechnology, 2004*(5), 306–313. https://doi.org/10.1155/S111072430440401X

Linares-Otoya, V. (2020). Consideraciones para el uso y estudio de la “muña” peruana *Minthostachys mollis* (Kunth) Griseb. y *Minthostachys setosa* (Briq.) Epling: Avances y vacíos en la investigación. *Ethnobotany Research & Applications, 19,* 29. https://doi.org/10.32859/era.19.29.1-9

Los Muros. (n.d.). *Alimentos desde y para la vida: Todo lo que se va dando y llega apareciendo en la naturaleza es parte de lo que necesitamos* [Photograph]. Retrieved August 14, 2025, from https://losmuros.org/2777/alimentos-desde-y-para-la-vida-todo-lo-que-se-va-dando-y-llega-apareciendo-en-la-naturaleza-es-parte-de-lo-que-necesitamos-por-Holistic%20naturista-alem-rojo/

Macía, M. J., García, E., & Vidaurre, P. J. (2005). An ethnobotanical survey of medicinal plants commercialized in the markets of La Paz and El Alto, Bolivia. *Journal of Ethnopharmacology, 97*(2), 337–350. https://doi.org/10.1016/j.jep.2004.11.022

Maffei, M. E., Gertsch, J., & Appendino, G. (2011). Plant volatiles: Production, function and pharmacology. *Natural Product Reports, 28*(8), 1359–1380. https://doi.org/10.1039/c1np00021g

Marino, R., Jr., & Gonzales-Portillo, M. (2000). Preconquest Peruvian neurosurgeons: A study of Inca and pre-Columbian trephination and the art of medicine in ancient Peru. *Neurosurgery, 47*(4), 940–950. https://doi.org/10.1097/00006123-200010000-00033

Mathez-Stiefel, S.-L., & Vandebroek, I. (2011). Distribution and transmission of medicinal plant knowledge in the Andean Highlands: A case study from Peru and Bolivia. *Evidence-Based Complementary and Alternative Medicine, 2011,* 1–12.

Mendoza, R. G. (2003). Lords of the medicine bag: Medical science and traditional practice in ancient Peru and South America. In H. Selin & H. Shapiro (Eds.), *Medicine across cultures: History and practice of medicine in non-Western cultures* (Vol. 3, pp. 225–257). Springer. https://doi.org/10.1007/0-306-48094-8_12

Meteoblue. (2025). *Climate averages for Cochabamba, Bolivia (17.42° S, 66.18° W)* [Data set]. https://www.meteoblue.com/

Movimiento Agroecológico Boliviano (MAB). (2025, June 7). *Feria agroecología departamental elemental* [Facebook event]. Facebook. https://www.facebook.com/events/981941607149097

Mukherjee, J. (Ed.). (2015). *Biotechnological applications of biodiversity* (Vol. 147). Springer. https://doi.org/10.1007/978-3-662-45097-0

NOVA Food Classification System. (2018). *The NOVA Food Classification System*. Center for Epidemiological Studies in Health and Nutrition, School of Public Health, Universidade de São Paulo. https://educhange.com/wp-content/uploads/2018/09/NOVA-Food-Classification-EduChange.pdf

Opinión. (2025, June 14). Campaña de medicina tradicional instala feria en la plaza 14 de septiembre. *Opinión.* https://www.opinion.com.bo/articulo/cochabamba/campana-medicina-tradicional-instala-feria-plaza-14-septiembre/20250614084303974508.html

Patton, M. Q. (2015). *Qualitative research & evaluation methods: Integrating theory and practice* (4th ed.). Sage.

Pathak, N. (2023). From defense molecules in plants to therapeutic agents. *Pharmacognosy Reviews, 17*(34), 105–530.

Peralta-Rivero, C. (2020). Impactos y tendencias del modelo agroindustrial en las tierras bajas de Bolivia. *Mundos Rurales, 15*(1), 5–24. https://www.researchgate.net/publication/344366746

Raven, P. H. (2021). Plants make our existence possible. *Plants, People, Planet.* https://doi.org/10.1002/ppp3.10173

Raven, P. H., Evert, R. F., & Eichhorn, S. E. (2012). *Raven biology of plants* (8th ed.). W. H. Freeman and Company. https://www.academia.edu/44966632/Raven_Biology_of_Plants

Revista Informativ. (2025, July 13). Feria anual de plantas medicinales en Potrero, Cochabamba [Video]. *TikTok.* https://www.tiktok.com/@revistainformativ/video/7507472331573431608

Ruffell, S. G. D., Crosland-Wood, M., Palmer, R., Netzband, N., Tsang, W., Weiss, B., Gandy, S., Cowley-Court, T., Halman, A., McHerron, D., Jong, A., Kennedy, T., White, E., Perkins, D., Terhune, D. B., & Sarris, J. (2023). Ayahuasca: A review of historical, pharmacological, and therapeutic aspects. *Psychiatry and Clinical Neurosciences Reports, 2*(4), e146. https://doi.org/10.1002/pcn5.146

Salinas Sedó, G., & Salinas Sedó, G. M. (2022). El rol de la medicina tradicional Kallawaya en la salud intercultural en Bolivia. *Revista Ciencia y Cultura, 27*(50), 39–56. http://www.scielo.org.bo/pdf/rcc/v27n50/2077-3323-rcc-27-50-39.pdf

Saxena, A., Quiroga, R., & Haddad, N. (2016). Indigenous food systems and climate change: Impacts in Colomi, Cochabamba, Bolivia. *Frontiers in Public Health, 4,* 20. https://doi.org/10.3389/fpubh.2016.00020

Schaal, B. (2019). Plants and people: Our shared history and future. *Plants, People, Planet, 1*(1). https://doi.org/10.1002/ppp3.12

Schmidt-Lebuhn, A. N. (2008). Ethnobotany, biochemistry and pharmacology of *Minthostachys* (Lamiaceae). *Journal of Ethnopharmacology, 118*(2), 343–353. https://doi.org/10.1016/j.jep.2008.05.030

Sen, T., & Samanta, S. K. (2015). Medicinal plants, human health and biodiversity: A broad review. In J. Mukherjee (Ed.), *Biotechnological applications of biodiversity* (Vol. 147, pp. 59–110). Springer. https://doi.org/10.1007/10_2014_273

United Nations Office on Drugs and Crime. (2023). *World drug report 2023: Psychedelics* (Booklet 3, Chapter 2). https://www.unodc.org/res/WDR-2023/WDR23_B3_CH2_psychedelics.pdf

Vandebroek, I., & Balick, M. J. (2012). Globalization and loss of plant knowledge: Challenging the paradigm. *PLOS ONE, 7*(5), e37643. https://doi.org/10.1371/journal.pone.0037643

Von Hagen, V. W. (1961). *The ancient sun kingdoms of the Americas: Aztec, Maya, Inca.* World Publishing Company.

Wikipedia. (n.d.). *Altiplano.* In *Wikipedia.* Retrieved August 1, 2025, from https://en.wikipedia.org/wiki/Altiplano

Wink, M. (2003). Evolution of secondary metabolites from an ecological and molecular phylogenetic perspective. *Phytochemistry, 64*(1), 3–19. https://doi.org/10.1016/S0031-9422(03)00300-5

World Health Organization. (2019). *WHO global report on traditional and complementary medicine 2019* (ISBN 978-92-4-151543-6). Author. https://iris.who.int/bitstream/handle/10665/312342/9789241515436-eng.pdf

Zhang, Q.-W., Lin, L.-G., & Ye, W.-C. (2018). Techniques for extraction and isolation of natural products: A comprehensive review. *Chinese Medicine, 13,* 20. https://doi.org/10.1186/s13020-018-0177-x

7 Annex

***Tabell** 7 Selection of Plants Included in the Kallawayas' Pharmacopeia, with Botanical Name, Family, Origin, and Common Names in English and Bolivian Spanish.*

Botanical Name	Family	Origin	Common Name (English)	Common Name (Bolivian Spanish)
Althea officinalis	Malvaceae	Europe	Marshmallow	Malvavisco
Aloe vera	Liliaceae	Africa	Aloe Vera	Sábila
Artemisia absinthium	Asteraceae	Europe	Wormwood	Ajenjo
Borago officinalis	Boraginaceae	Europe	Borage	Borraja
Capsella bursa-pastoris	Cruciferae	Eurasia	Shepherd's Purse	Bolsa de pastor
Digitalis purpurea	Scrophulariaceae	Mediterranean	Foxglove	Dedalera
Equisetum arvense	Equisetaceae	Europe	Horsetail	Cola de caballo
Eucalyptus globulus	Myrtaceae	Australia	Blue Gum Eucalyptus	Eucalipto
Eugenia myrtomimenta	Myrtaceae	Europe	Brush Cherry	Arrayán / Cereza austral?
Euphorbia huachangana	Euphorbiaceae	Europe	Spurge	Lechtezma / Tártago
Foeniculum vulgare	Umbelliferae	Eurasia	Fennel	Hinojo
Gentiana lutea	Gentianaceae	Eurasia	Yellow Gentian	Genciana amarilla
Iris germanica	Iridaceae	Mediterranean	German Iris	Lirio alemán
Malva parviflora	Malvaceae	Mediterranean	Small-flower Mallow	Malva pequeña
Malva sylvestris	Malvaceae	Mediterranean	Common Mallow	Malva común
Matricaria chamomilla	Asteraceae	Eurasia	Chamomile	Manzanilla
Myristica fragrans	Myristicaceae	Indonesia	Nutmeg	Nuez moscada
Papaver somniferum	Papaveraceae	Asia	Opium Poppy	Amapola
Rosmarinus officinalis	Lamiaceae	Mediterranean	Rosemary	Romero
Rumex conglomeratus	Polygonaceae	Eurasia	Clustered Dock	Acedera
Rumex crispus	Polygonaceae	Eurasia	Curled Dock	Lengua de vaca
Ruta chalepensis	Rutaceae	Europe	Fringed Rue	Ruda
Ruta graveolens	Rutaceae	Europe	Common Rue	Ruda
Sambucus nigra	Caprifoliaceae	Europe	Elderberry	Sauco
Senecio graveolens	Asteraceae	Europe	Groundsel	Chachacoma
Sonchus asper	Asteraceae	Eurasia	Prickly Sow-thistle	Cardo / Cerrajón
Sonchus oleraceus	Asteraceae	Eurasia	Common Sow-thistle	Cerrajón
Verbascum thapsus	Scrophulariaceae	Eurasia	Common Mullein	Gordolobo
Viola odorata	Violaceae	Eurasia	Sweet Violet	Violeta

Note. *Botanical names, families, and origins are adapted from Janni and Bastien (2004). The columns "Common Name (English)" and "Common Name (Bolivian Spanish)" were added by the author using information from online botanical databases and regional ethnobotanical sources.*

Tabell 8 *Selection of Plants Included in the Kallawayas' Pharmacopeia, with Botanical Name, Family, Origin, and Common Names in English and Bolivian Spanish.*

Scientific Name	Family	Common Name (English)	Common Name (Bolivian Spanish)
Ambrosia peruviana	Asteraceae	Peruvian ragweed	Altamisa
Azorella biloba	Apiaceae	Azorella	Azorella
Baccharis pentandii	Asteraceae	Baccharis	Bacaris
Calceolaria cuneiformis	Scrophulariaceae	Slipperwort	Calcéola
Calceolaria aff. engleriana	Scrophulariaceae	Slipperwort (Engler)	Calcéola (Engler)
Chenopodium ambrosioides	Chenopodiaceae	Epazote / Wormseed	Paico
Cinchona calvisa	Rubiaceae	Quinine tree	Quina
Datura sanguinea	Solanaceae	Angel's trumpet	Floripondio
Equisetum bogotense	Equisetaceae	Andean horsetail	Cola de caballo andina
Erythroxylum coca	Erythroxylaceae	Coca	Coca
Gentiana lutea	Gentianaceae	Yellow gentian	Genciana amarilla
Gnaphalium quadichaudium	Asteraceae	Cudweed	Sacha manzanilla
Minthostachys andina	Lamiaceae	Andean mint	Muña
Mutisia acuminata	Asteraceae	Mutisia	Mutisia
Myroxylon balsamum	Fabaceae	Balsam tree	Bálsamo del Peru
Nasturtium officinale	Brassicaceae	Watercress	Berro
Nicotiana rustica	Solanaceae	Wild tobacco	Tabaco silvestre
Peperomia inaequalifolia	Piperaceae	Peperomia	Peperomia
Plantago tomentosa	Plantaginaceae	Woolly plantain	Llanten lanudo
Polypodium angustifolium	Polypodiaceae	Polypody fern	Helecho polipodio
Polystichum aculeatum	Polypodiaceae	Holly fern	Helecho acebo
Psoralea pubescens	Fabaceae	Psoralea	Psoralea
Psittacanthus cuneifolius	Loranthaceae	Mistletoe	Muérdago
Salvia haenkii	Lamiaceae	Sage	Salvia
Senecio tephosiodes	Asteraceae	Senecio	Senecio
Solanum radicans	Solanaceae	Nightshade	Hierba mora
Urtica flabellata	Urticaceae	Nettle	Ortiga
Verbena hispida	Verbenaceae	Vervain	Verbena

Note. *Botanical names and families are adapted from Janni and Bastien (2000). The columns "Common Name (English)" and "Common Name (Bolivian Spanish)" were added by the author using information from online botanical databases and regional ethnobotanical sources.*

Tabell 8 *Detailed list of interview questions conducted in the field study*

Segment 1: Personal and Practical Background
– How did you begin working with medicinal plants? – Where does your knowledge c ome from? – How do you continue learning or updating your knowledge?
Segment 2: Medicinal Plant Practices and Knowledge
– Where do you obtain your herbs from? – If cultivated: What factors are important for successful cultivation? – If wild-harvested: Where are the plants collected? What determines a good harvesting spot? – How do you assess the quality of the herbs? – What contributes to their potency? – How are the plants used in your practice? – How do you relate your knowledge to scientific practices? – Can you describe your own value chain?
Segment 3: Community Impact and Future Outlook
– Are there any legal or cultural regulations around the use of medicinal plants? – What value do these plants provide to the local community? – Have you noticed changes in the use of medicinal plants over time? – What opportunities or challenges do you see for the future of medicinal plants? – How do you plan to pass on your knowledge to the next generations?

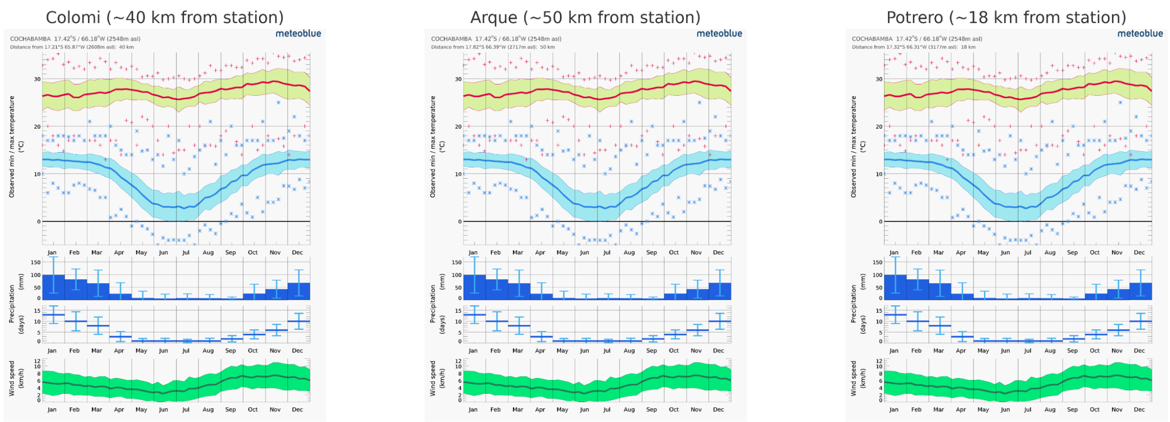

Figure 30 *Climate graphs for Colomi (~40 km from station), Arque (~50 km from station), and Potrero (~18 km from station) generated with Meteoblue. The graphs show interpolated climate data adjusted for distance, elevation, and topography, including monthly average temperature (°C), precipitation (mm), and wind speed (m/s). Despite slight variations due to altitude and location, all sites follow similar seasonal patterns since the data is derived from the same weather station.*

Publishing and archiving

Approved students' theses at SLU are published electronically. As a student, you have the copyright to your own work and need to approve the electronic publishing. If you check the box for **YES**, the full text (pdf file) and metadata will be visible and searchable online. If you check the box for **NO**, only the metadata and the abstract will be visible and searchable online. Nevertheless, when the document is uploaded it will still be archived as a digital file. If you are more than one author, the checked box will be applied to all authors. Read about SLU's publishing agreement here:

- https://www.slu.se/en/subweb/library/publish-and-analyse/register-and-publish/agreement-for-publishing/.

☒ YES, Melissa Herbas hereby give permission to publish the present thesis in accordance with the SLU agreement regarding the transfer of the right to publish a work.

☐ NO, I/we do not give permission to publish the present work. The work will still be archived and its metadata and abstract will be visible and searchable.