Value Chain Analysis

for

Resilient Puna

Ecosystem based Adaptation for sustainable high Andean communities and ecosystems in Peru

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Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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3 Scope

3.1 Objectives

The purpose of this value chain analysis report is to:

- Carry out the analysis of the High Andean crops, South American camelids, and complementary value chains in the regions determined by the Resilient Puna project, with a focus on climate resilience and ecosystem-based adaptation and emphasis on the efficiency of the chain, the relationships of the stages and the identification of critical points; as well as a proposal for the efficiency improvement.
- Identify and prioritise project options in the main value chains within the scope of their implementation and from a climate perspective.
- Establish recommendations for the definition of strategies to make value chains more resilient and help communities and/or producer associations to cope with the present and future impacts of climate change.

3.2 Methodology

The value chain analysis of the native potato, quinoa, South American camelid and ecotourism chains in the regions determined by the Resilient Puna project was carried out using the GIZ Value Links methodological approach (ValueLinks 2.0, Manual on Sustainable Value Chain Development)[1] , as well as complementary methodologies such as SWOT analysis, prospective analysis and stakeholder mapping, using secondary information from different official sources of information, specialised studies and documentation provided by the Resilient Puna project.

Documents associated with INIA databases (National Agricultural Census, National Agricultural Survey), MIDAGRI (volumes, prices, trends, and other selected crop/livestock indicators), and others were also used.

The analysis is complemented with a focus on territorial development and livelihoods of rural high Andean populations, following the review of fieldwork reports developed by the technical teams of the Resilient Puna project carried out between 15 and 20 May 2023, which includes interviews with selected key actors.

[1] Draft July 2017; Andreas Springer-Heinze.

4 The agricultural sector of Peru

4.1 Overview

4.1.1 Country profile

4.1.1.1 Agricultural ecoregions

Peru is divided into several ecoregions based on its diverse natural landscapes, climates, and ecological characteristics. Although there is disagreement over the total number of proposed ecoregions—with Peru's Ministry of Environment (MINAM) recognising 11--Peruvian agriculture is divided into six ecoregions based on climate, geography, and altitude: Costa, Quechua, Puna y Paramo, Bosque seco, Selva alta, and Selva baja. These ecoregions span across the country from the coastal region near the Pacific Ocean to the low jungle (Selva baja) on the Amazonian border with Brazil. Each ecoregion possesses distinct cultural and historical characteristics that influence crop production and productivity levels. For example, grapes are predominantly grown in the coastal region, while coffee production is concentrated in the high jungle (Selva alta). Certain crops like mango and avocado are cultivated throughout the country.

However, the 2012 National Agricultural Census (CENAGRO) conducted by Peru's National Statistics Institute (INEI) groups agricultural areas into three broader natural regions: highlands (sierra), tropical jungle (selva), and coastal (costa), and therefore much of the statistical and macroeconomic analyses are conducted using this typology.

The Costa region of Peru has a long history of plantation agriculture, initially focused on crops like sugar cane and cotton. This agricultural system was characterized by extensive land holdings controlled by a small number of wealthy families. Prior to the Agrarian Reform Law of 1969, a significant portion of the arable coastal land, about 80 %, was owned by just 1.7% of property owners. Surrounding the large coastal estates were numerous smaller farms that produced a variety of food crops for subsistence and local markets. The agricultural land in the Costa region is highly valuable due to its favourable climate, flat terrain, reliable irrigation water, and proximity to major urban centres and export hubs. Despite accounting for only 3.8% of the country's agricultural land, the Costa region contributes approximately 50% of the agricultural GDP. The intensive farming systems in this region are highly productive, allowing for significant economic output.

Traditionally, agriculture in the Selva region of Peru has been dominated by indigenous communities who rely on fishing, hunting, and gathering from the forest for their livelihoods. These traditional strategies are often supplemented by slash-and-burn cultivation practices. In this system, individual plots of land are cultivated for a few years and then left fallow for an extended period to allow the vegetation to regrow and the soil to recover. The slash-and-burn approach typically involves growing multiple crops together in a symbiotic manner, with up to 15 different crops being cultivated in associations that take advantage of the synergies between different plant species. In the last decades, certain areas of the Selva region have seen the emergence of commercial agriculture. This shift has placed a greater emphasis on crops such as coffee, cacao (the source of cocoa), tropical fruits, and oil palm.

Agriculture in the Sierra region of Peru is primarily characterized by small-scale farming systems focused on subsistence production. These farming systems combine the cultivation of staple crops such as potatoes, wheat, and quinoa with livestock rearing. Most farms in this region are less than five hectares in size, and farmers often have dispersed plots located in various micro-environments. These micro-environments differ in terms of altitude, soil quality, water availability, and climate. Encountering this diversity can be difficult for family farming, but it can also be an opportunity to generate resilience and ensure food security. Promoting local agrobiodiversity with varieties adapted to different agroclimatic conditions also means resistance to different adverse conditions, which, due to climate change, are difficult to predict (droughts, frosts, etc.).

However, food production in the Sierra region is often inadequate and based on traditional practices and do not meet the consumption needs of households, leading many farmers to seek additional income through off-farm activities. Smallholder farmers in the Sierra region make use of the diverse ecological niches available to them. In high-altitude areas, livestock is grazed, and specialized tubers like native potatoes, mashua, olluco, oca, and maca are grown. At intermediate altitudes, farmers cultivate grains such as wheat, barley, rye, and maize, along with pulses, fruits, berries, and vegetables. In the inter-Andean valleys, various types of fruits like avocado, orange, lemon, and banana are grown.

4.1.1.2 Traditional and non-traditional crops

In Peru, there are four distinct types of agriculture which reflect the diverse range of crops, production scales, technologies, and market orientations present in the country (OECD, 2017). Each type has its own characteristics and significance in terms of economic viability, cultural heritage, and potential for domestic consumption and export markets. The types are:

1. Non-traditional export agriculture:
    - Involves the cultivation of crops like mango, avocado, olives, asparagus, and grapes;
    - Practiced on large land areas with advanced technology;
    - Highly profitable due to export-oriented production.
2. Extensive agriculture for traditional crops:
    - Focuses on growing crops like potatoes, rice, yellow maize, sugar cane, onion, coffee, and cocoa;
    - Primarily practiced on smaller land areas;
    - Utilizes varying levels of technology;
    - Serves both domestic and overseas markets.
3. Agriculture linked with traditional Andean crops:
    - Specifically associated with crops such as quinoa, kiwicha (Amaranthus caudatus), cañihua (Chenopodium pallidicaule), tarwi (Lupinus mutabilis), palm heart, sacha inchi (Plukenetia volubilis), and tara (Caesalpinia spinosa);
    - These crops have untapped export potential;
    - Cultivation methods often retain traditional practices.
4. Subsistence farming:
    - Involves the cultivation of crops like wheat, barley, ulluco (Ullucus tuberosus), broad bean, oca (Oxalis tuberosa), yucca, plantain, haricot bean, sweetcorn, and maize.
    - Primarily for self-consumption and local markets.
    - Practiced by small-scale farmers.

4.1.2 The agricultural sector and the Peruvian economy

Agriculture plays a significant role in Peru's economy, contributing to gross domestic product (GDP), exports, job creation, and food security. In 2014, the combined GDP of agriculture, hunting, forestry, and fisheries sectors accounted for 6.2% of Peru's GDP. From 2003 to 2014, the real sector GDP in agriculture grew at an average annual rate of 3.2%, with livestock experiencing the fastest growth at 5.4%, followed by agriculture at 3.3%, and fisheries at 2.0%.

Peru's agricultural exports, including agribusiness exports, reached USD 7.978 billion in 2014, constituting 20.7% of the total export value. Key agricultural exports included unroasted coffee, onions, fresh grapes, fish oil, and fresh and chilled asparagus. The major export markets for Peru's agricultural products were the European Union, the United States, Latin America and the Caribbean, and China. Peru is a leading exporter of coffee, asparagus, quinoa, and organic bananas, and there has been notable growth in the export sales of dairy products, citrus fruits, avocados, and cocoa.

Employment in the farming sector accounted for 26.6% of Peru's employed population in 2014, representing a decrease from 35.2% in 2001. Approximately 4 million people were employed in the sector in 2014 (OECD, 2017).

4.1.2.1 Structural transformation

Peru's agricultural sector has experienced a gradual decline in its share of the economy and employment, which is consistent with the concept of structural change observed in developing countries. In economies with relatively low-income levels, agriculture typically employs a large portion of the population but utilizes labour with relatively low productivity. As economies develop, there is a shift of labour from agriculture to higher-productivity sectors like manufacturing and services, leading to a convergence of returns to labour across sectors through factor markets (World Bank, 2017).

In Peru, a similar pattern of structural transformation has occurred alongside economic growth. The share of agriculture in the overall economy and the proportion of agricultural workers in total employment have both declined. However, the pace of structural transformation has been slow, and the composition of GDP has remained relatively stable since the early 1990s. During the period of 1990-2015, all three sectors—agriculture, industry, and services—grew at comparable rates. The services sector made the largest contribution to GDP growth (around 3%), followed by the industry sector (1.8%), and the agriculture sector (0.3%). As a significant number of the poor are employed in agriculture and services, these sectors have contributed the most to income increases among the poor. Agriculture, in particular, has played a crucial role in reducing extreme poverty (World Bank, 2017).

Peru's path of structural transformation aligns with the general pattern described in the World Development Report of 2008, termed as the agriculture-based, pre-transition, transition, urbanizing, and developed stages. Currently, Peru can be classified as an urbanizing economy, as the share of agriculture value-added in total GDP has declined to levels seen in other urbanizing economies.

While Peru's structural transformation follows similar patterns observed in other countries, there are some notable differences. The decline in the share of agricultural employment has been slow in Peru compared to other urbanizing economies in the region. Over the past 20 years, labour has transitioned from low-productivity rural agriculture to relatively higher-productivity informal urban sector jobs in services.

However, agriculture still employs around one-quarter of the population, a higher proportion than in many other urbanizing economies.

Despite the declining share of agriculture in Peru's overall economy, the sector has witnessed absolute growth in terms of volume and value of agricultural production. From 2000 to 2015, agriculture GDP in Peru grew at an average annual rate of 3.3%, outpacing regional peers. This growth has been driven by the increasing orientation of the sector toward external markets. Although the agriculture sector's importance in overall GDP has decreased, its significance in exports has increased. The share of agriculture and food exports as a percentage of total GDP rose from 1.6% in 1998 to 3.2% in 2014, mainly due to the growth of non-traditional agricultural exports.

4.1.3 Changes in land use

The growth and structural transformation of Peru's economy have resulted in significant changes in land use patterns. Between 1994 and 2012, approximately 3.36 million hectares (ha) of land were converted to productive use, representing a 9.5% expansion. Although this increase is substantial, it is smaller than the expansion observed in the previous inter-census period from 1972 to 1994, when over 11 million ha were converted. Interestingly, the importance of agriculture has been on the rise. In the first inter-census period, 1.1 million ha (16% of the increase) were converted to agricultural use, whereas in the second inter-census period, 1.64 million ha (49% of the total increase) were converted for agricultural purposes.

According to the National Agricultural Census (CENAGRO 2012), in the high South Andes of Peru, 77% of hectares in the target area are natural pastures, while only 8% of the land is for agricultural use. As shown in the table below, in Apurimac and Cusco, agriculture land use is higher than in Lima, Arequipa and Puno.

Table 1: Land uses (surface area in hectares) in the prioritized districts by department. Source: CENAGRO (2012)[2]

Department	Total area (ha)	Agricultural land	Natural pastures	Forests and woodlands	Other uses
Apurímac	622,082	12%	54%	9%	26%
Arequipa	915,486	3%	87%	2%	8%
Cusco	924,925	12%	75%	5%	7%
Lima	74,908	1%	96%	0%	3%
Puno	502,468	4%	89%	0%	7%
Total	**3,039,869**	**8%**	**77%**	**4%**	**11%**

While the expansion of the agricultural frontier has had limited impact on the allocation of land to major cropping systems, with the same 15 crops accounting for 85% of total harvested area in both 1994 and 2012, there have been significant dynamics at play. Two key developments characterize the expansion of agriculture in Peru: the rapid growth of high-value crops and the substitution of annual crops with permanent crops and managed pastures.

The area under high-value crops, particularly vegetables and fruits for export, has expanded significantly. Traditional export commodities like coffee, cocoa, and palm oil have also experienced growth. While the area planted with these crops remains relatively

[2] IV Censo Nacional Agropecuario 2012 - Base de Datos REDATAM (inei.gob.pe)

small, their economic impact is substantial. In 2015, 9% of agriculture value-added was generated on just 235,000 ha through high-value vegetable production, compared to 13.5% generated on 1.2 million ha planted with cereals.

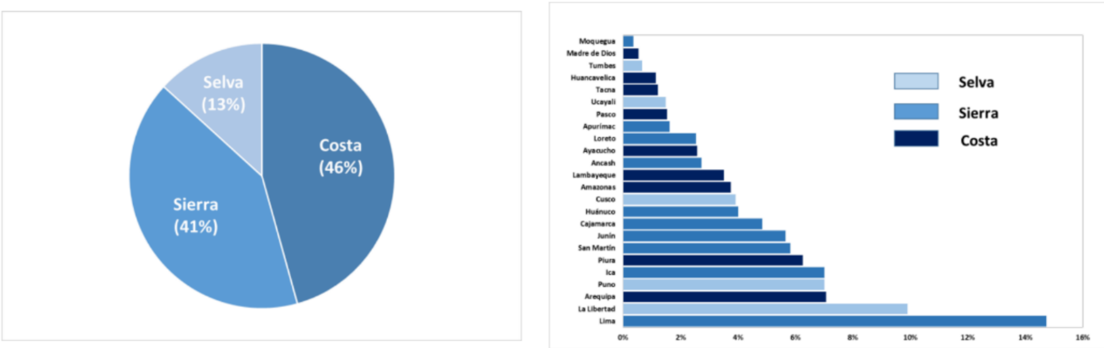
Permanent crops have gained in area, especially in the Selva region, where they have replaced annual crops. In the Sierra region, some previously cultivated land has been converted to improved natural pasture, while in the Costa region, the area under annual crops has expanded, but the expansion of permanent crops has been even more rapid.

Table *2* Crop expansion and contribution to agriculture added value (1995, 2015). Source: World Bank (2017)

Product	Area harvested (ha) 1995	Area harvested ha) 2015	Increase (ha)	Increase (%)	Share of ag GDP 2015
Live animals and animal products					39.6
Agriculture products					60.4
Cereals		**1,292,036**			**13.8**
Maize	375,197	513,804	138,607	37	4.2
Rice, Paddy	239,453	399,501	169,048	67	8.1
Quinoa	18,729	69,303	50,574	270	0.4
Horticulture		**234,036**			**9.0**
Asparagus	20,126	33,870	13,744	137	3.6
Artichoke	200	5,513	5,313	2,657	0.4
Fruits and Nuts		**437,327**			**11.2**
Avocados	6,115	33,989	27,874	456	1.4
Grapes	10,702	26,650	15,948	60	2.7
Mango	7,854	29,733	21,879	279	0.6
Plantain / Banana	69,401	167,839	98,438	142	2.3
Legumes		**281,011**			**1.4**
Beans, dried	61,920	76,770	14,850	24	0.6
Sugars		**119,019**			**2.4**
Sugar crops	59,603	84,574	24,971	42	1.9
Roots and Tubers		**495,892**			**9.1**
Potatoes	188,531	316,535	128,004	68	6.7
Cassava	51,791	101,453	49,662	96	1.3
Stimulant crops and species		**505,771**			**5.6**
Cocoa	36,324	120,374	84,050	231	1.4
Coffee	164,230	379,189	214,959	131	3.8
Oils seeds		**68,115**			**1.0**
Oil palm	5,188	43,140	37,952	732	0.7
Others		**167,454**			**6.7**
Cotton	123,681	26,711	-96,970	-78	0.6

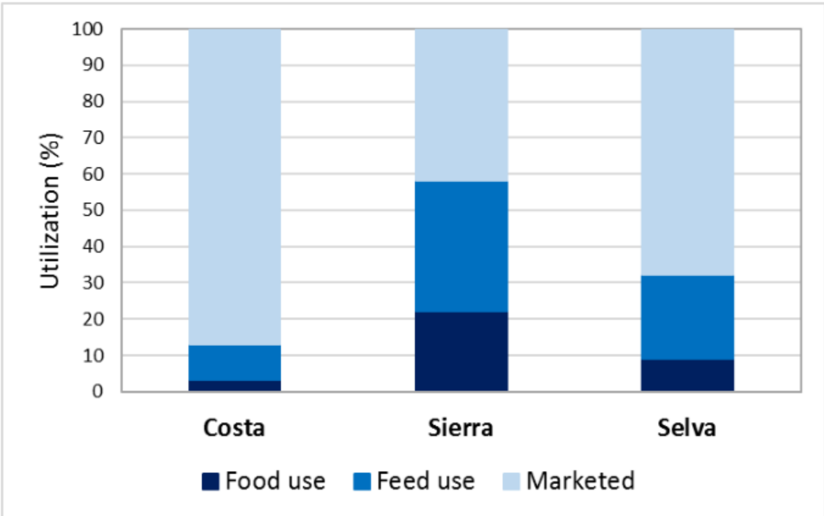
These changes in land use patterns have led to increasing specialization in agriculture production at both the regional and departmental levels. The Costa region contributes the largest share (49%) to agricultural GDP, followed by the Sierra region (37%), and the Selva region has the smallest contribution (14%). Agriculture output varies significantly among departments, with 10 out of 24 departments accounting for 71.4% of overall agriculture value-added. The livestock sub-sector also exhibits concentration, as 83% of livestock value-added is generated by the top 10 departments, with Lima and La Libertad contributing nearly 50%.

Figure 1 Distribution of agricultural GDP by natural region and department (2015). Source: World Bank (2017)



Peruvian farms have become more connected to markets over time, reflecting increased commercial orientation. However, the degree of market integration varies across the natural regions. In the Costa region, more than 81 % of the harvested area is dedicated to market-oriented crops, while in the Selva region, it is 67 %. In contrast, only 42 % of the harvested area in the Sierra region is devoted to market-oriented crops, indicating a significant focus on subsistence in this region.

Figure 2 Utilization of agricultural production by natural region (2015). Source: World Bank (2017)



4.1.4 Farming systems

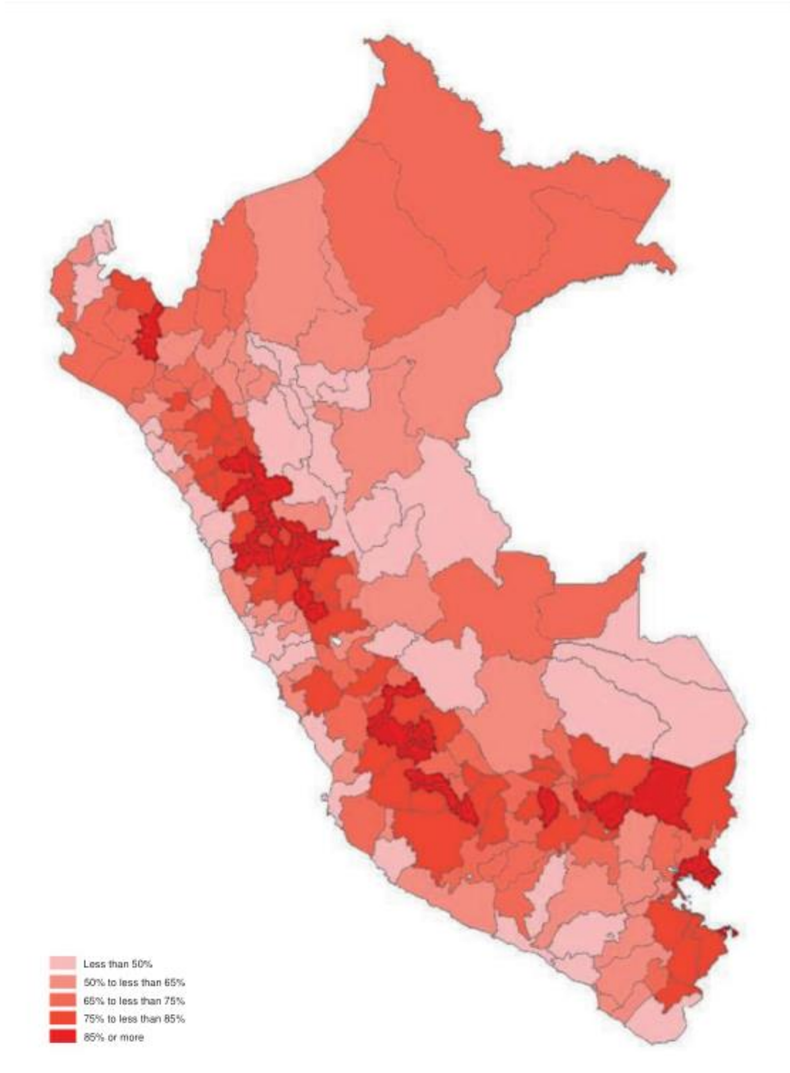
In Peru, according to data from the last National Agricultural Census (CENAGRO) 2012, family farming[3] represents 97% of all agricultural units out of a total of 2.2 million agricultural units, mainly concentrated in the Andean region. The remaining 3% is considered enterprise agriculture. Similarly, this family farming sector employs more than 3 million people (83% of the agricultural labour force) and generates about 80% of the food products consumed in the national market. However, they account for only 6% of the agricultural area. They have greater access to local and regional markets, but

[3] Law Nº 30355, Law for the Promotion and Development of Family Farming: "is the way of life and production managed by a family (head of household, spouse, sons and daughters), and whose members are the main labour force for agricultural, forestry, fishing, livestock and aquaculture activities within the productive units they manage or own".

operate in a context marked by the limitations of technological change and precarious access to agricultural equipment, credit, inputs and services.

The result of applying the Family Farming typology[4] to all the country's Agricultural Units (UA) shows that the majority belong to Subsistence Family Farming (AFS for it Spanish acronym) with 88% of the total number of UA in Peru. In second place, far behind, is Intermediate Family Farming (AFI) with 10% of the country's AUs. In third place, much further behind, comes Consolidated Family Farming (AFC), representing only 2% of the Uas in the country.

Figure 3 Rate of subsistence-level farming. Source: CENAGRO (2012)



The distribution of agricultural land in Peru is highly unequal. While small-scale farmers constitute a large proportion of the farming population, they control a relatively small share of total agricultural land. Approximately 77% of agricultural land is controlled by just 23,000 large-scale commercial farms with holdings exceeding 100 hectares, which represent only 1% of all farming units. This unequal distribution of land, coupled with the

[4] MIDAGRI has classified Family Farming into 3 categories: Subsistence (less than 2 ha); Intermediate (2-5 ha); Consolidated (5-10 ha).

predominance of small farms, poses challenges as small farm sizes are associated with higher levels of subsistence production.

Table *3* Distribution of landholdings (2012). Source: World Bank (2017) based on CENAGRO (2012)

Size of farm	Producers		Area	
	Number	Share (%)	Number (ha)	Share (%)
Without land	47,467	2.10	0	0.00
< 0.5	507,137	22.43	99,700	0.26
0.5 to 1	324,706	14.36	204,933	0.53
1 to 5	922,572	40.80	1,964,119	5.07
5 to 10	218,564	9.67	1,418,311	3.66
10 to 15	81,937	3.62	595,696	1.54
15 to 20	36,337	1.61	595,696	1.54
20 to 100	98,798	4.37	3,692,042	9.53
> 100	23,455	1.04	29,841,281	77.02
TOTAL	2,260,973	100	38,742,465	100

Also, analysing the 2012 National Agrarian Census, land tenure in the High Andes generally appears to be dominated by private regime, in average 48% of the agricultural units[5] in the prioritized districts of the Resilient Puna project (varying from 24% to 86% depending on the region), followed by communal land regime, for 44% of agricultural units in average (variation from 1% to 70 % depending on the department). Tenant and Possessors regimes are less common in the target area of the project. Traditional herder communities living in the High Andes tend to combine private and collective regimes as an alternative form for strengthening land tenure, treating grasslands as common resources which are accessed, used and controlled collectively, usually under open access or communal land tenure regimes.[6]

Table *4*: Land tenure in the prioritized districts by department. Source: CENAGRO (2012)

Department	Private Property	Communal Property	Tenant	Possessors[7]	Other	Total Agricultural Units
Apurímac	73%	19%	4%	3%	1%	62,753
Arequipa	86%	1%	7%	2%	4%	58,592
Cusco	24%	70%	3%	1%	1%	168,961
Lima	73%	5%	10%	11%	1%	1,921
Puno	75%	15%	5%	1%	4%	12,691
Total	48%	44%	4%	2%	2%	304,918

[5] It is defined as the land or set of land used totally or partially for agricultural production including livestock, conducted as an economic unit, by an agricultural producer, regardless of size, tenure regime or legal status. (CENAGRO, 2012)
[6] Damonte, G., M. Glave, S. Rodríguez and A. Ramos. 2016. 'The evolution of collective land tenure regimes in pastoralist societies: lessons from Andean countries. IDS Working Paper No. 480. Brighton: Institute of Development Studies.
[7] People who informally occupied land.

4.1.5 Climate change and agriculture

Generally, biodiversity plays a crucial role in maintaining vital functions and services for agriculture. It has been affected both directly and indirectly by climate change, such as shifts in temperature, precipitation, and other indicators, like stronger winds leading to soil erosion. A study analysing 11,012 bird and vascular plant species projects that by the 2050s, over 50% of these species will likely experience reductions of at least 45% in their climatic niche, with 10% facing the risk of extinction. Although they are currently not under immediate threat, they could become vulnerable in the future due to the impacts of climate change. Tropical high Andean grasslands (paramos and punas) and montane forests are expected to undergo adverse changes in species richness and experience high turnover rates (Lozano et al, 2021).

Peru's agriculture sector is highly susceptible to the impacts of climate change, with various climatic hazards posing significant challenges. Droughts, floods, frost, and cold waves are the main hazards that affect agricultural activities in the country. These hazards have adverse effects on crop growth and livestock, leading to reduced yields and economic losses.

Climate change's impact on agriculture in certain Andean regions has led to a notable decline in production, prompting many families to migrate in search of better opportunities. While this migration helps fulfil their consumption needs, it also reduces the available labour force, potentially negatively affecting future harvests in terms of both quantity and diversity of food consumption (Blackmore et al., 2021). The Andean region's diverse agro-climatic zones, challenging geographical conditions, developing economies, and various agricultural production systems and typologies make these areas more susceptible to the effects of climate change. This vulnerability is exacerbated as a significant portion of the population depends on agriculture for their livelihoods (Lozano et al., 2021).

The vulnerability of the agriculture sector to climate change is expected to worsen in the future, particularly due to the projected increase in the frequency and intensity of the El Niño-Southern Oscillation (ENSO) phenomenon. ENSO is a climatic disruption triggered by elevated sea-water temperatures, and it directly influences precipitation patterns in Peru. During pronounced ENSO events, extreme weather conditions occur, often causing extensive flooding and destructive landslides, primarily in the northern coastal regions of the country.

Climate change will have a significant impact on agriculture in Peru, particularly through its effect on water availability. As the storage capacity of glaciers diminishes, the flow of many rivers in Peru will decrease during the dry season, leading to more frequent and severe droughts. Conversely, during the rainy season, there will be an increase in river flows, resulting in more frequent and severe flooding events. These changes will introduce greater hydrological uncertainty, making it more challenging to plan and design hydraulic infrastructure for water management (BID & CEPAL, 2014).

Recent analysis indicates that the relationship between temperature and agricultural yields in Peru is non-linear. While temperature initially has a positive effect on yields, there is a threshold beyond which further temperature increases become detrimental. For instance, an increase of 1 °C above the optimal level during the average growing season would lead to yield reductions of over 10% in the Sierra region and nearly 20% in the Costa region (Aragón et al., 2021).

The potential impacts of climate change on Peru's agricultural sector are concerning. Even a modest increase of 1 °C in average temperatures, which is an optimistic scenario based on current projections, could have devastating consequences. Nationally, important crops such as rice, maize, potato, and sugar cane would likely experience decreased production. The cumulative losses resulting from a 1 °C rise in temperature could amount to around PEN (Peruvian sol) 5 billion, equivalent to 24% of agricultural GDP (BID & CEPAL, 2014).

Projections through 2094 suggest that rice would be the most affected crop, with production expected to decrease by 15 to 30%. Maize would also suffer a significant decline of approximately 10%. Potato and sugar cane production would face losses of around 5% each. However, the impacts of increasing average temperature on certain crops, such as coffee, would be more varied. Coffee production may initially increase during an initial period but could decline slightly once the temperature rise becomes more pronounced (BID & CEPAL, 2014).

The negative impacts of climate change on agriculture in Peru can be mitigated through various human actions. Shifting the location of production is one strategy, where crops like commercial potatoes, maize, and beans in the Sierra region could be moved to higher altitudes, potentially replacing native potatoes or grazing areas. This shift would require plant breeding efforts to develop varieties adapted to new agro-climatic conditions. Similarly, in the Selva region, cacao and coffee production may become less viable, leading to the adoption of alternative crops better suited to higher temperatures, such as banana or cassava.

Alongside shifting production locations, Peruvian farmers will need to adjust their management practices to cope with changing rainfall patterns. Investing in irrigation infrastructure is one approach, as currently, only about 36% of cropland is irrigated. Expanding irrigation coverage could help protect agriculture from climate change, but the high cost of infrastructure limits the pace of expansion. The limited access to credit faced by these farming families and their limited purchasing power also prevents them from obtaining more efficient irrigation systems (Flores et al, 2020). During the 2023 field visit conducted as part of this study, it was also observed that there is no established market system for these irrigation systems. As a result, there is a lack of spare parts and qualified personnel capable of maintaining these infrastructures in optimal condition, especially considering the various challenges posed by climate change (such as frosts). To enhance water use efficiency in the short term, alternative water harvesting and conservation techniques, along with the adoption of water-efficient crops and varieties, present viable options.

While various technologies and practices to enhance climate resilience exist in Peru, their adoption rates remain low. Best practices and ancestral knowledge related to EbA (Ecosystem-based Adaptation) are not adequately disseminated and scaled-up. A major hindrance is the lack of sufficient financial products and support for climate-resilient and sustainable development. Financial institutions perceive high investment risks, particularly in the agricultural sector, leading to an absence or severe limitation of financial assistance. Furthermore, there is a notable lack of capacity, especially within local government institutions, to effectively integrate EbA and climate resilience into territorial planning, government processes, and monitoring and evaluation (M&E) systems. This hampers the implementation and advancement of climate-resilient strategies at the local level.

Institutional constraints, such as poor coordination and underfunding of policies and programs, also contribute to slow adoption. Addressing these barriers is crucial to promoting widespread adoption and increasing agricultural resilience in the face of climate change.

4.2 Value chain development in Peru

Over the past 25 years, Peru has successfully captured a significant share of global markets for agricultural products. It started diversifying its exports away from traditional commodities like coffee, cocoa, sugar, and cotton in the mid-1980s, with asparagus being the first successful export. This expansion paved the way for diversification into various high-value products for export, establishing Peru as a world leader in horticultural production.

The development of value chains for high-value agricultural exports (e.g., coffee, cocoa, bananas) required substantial investments in irrigation infrastructure, processing and storage facilities, and logistics. Additionally, investments in market coordination, value chain integration, compliance with quality and safety standards, and meeting market entry requirements were crucial. Both physical infrastructure and soft investments were necessary for the success of Peru's export-oriented agriculture (World Bank, 2017)..

Peru currently exports a wide range of horticultural products, but it has the potential to further diversify its export offerings. Ongoing identification of new opportunities is facilitated by the country's diverse natural regions and the increasing capacity of Peruvian firms to access advanced technology and innovative production and processing methods. Expectations are high for the growth of blackberry and pomegranate exports, and other specialty and niche products are also attracting attention as potential export options for Peru.

Despite the significant progress made in Peru's horticulture subsector and the promising future prospects, there have been missed opportunities to create additional value by strengthening backward and forward linkages and generating opportunities in related industries. An example is the table grape industry, which has expanded greatly over the past two decades, making Peru the second-largest global supplier. However, a significant portion of the value generated in this industry goes to foreign actors (Fernandez-Stark et al., 2016).

Research indicates that Peruvian producers and agribusiness firms captured only around 35 % of the retail price in the importing country, and the overall net benefits for Peru were even lower due to the importation of production inputs. To capture more value from the table grape supply chain, it is suggested to rely more on locally procured inputs and services. This includes exploring local sourcing for packaging materials (such as wooden crates and plastic bags) and the trellises used to support the vines. Utilizing local inputs would not only boost the emerging forestry and plastics industries but also enhance the retention of value within Peru.

Another area with attractive opportunities for generating additional value in the horticulture export sector is human capital. Skilled labour is in short supply for horticultural production and processing, and investing in technical training and skill development programs for industry workers can significantly improve productivity and efficiency throughout the supply chain.

The extent of job creation resulting from Peru's agricultural export boom is a topic of debate. While it is commonly asserted that the boom has generated a significant number of jobs, there is little consensus on the actual figures. Some studies estimate that the horticultural export industry, composed of around 400 firms, has created over 100,000 jobs. These firms have been under pressure to meet labour standards required by importing markets, leading to improvements in employment conditions (Schuster & Maertens, 2017). However, concerns have been raised about the uneven nature of development in the subsector, particularly regarding the limited opportunities for small-scale farmers to participate in value chains for horticultural exports.

4.2.1 Smallholder value chains

In Peru, the importance of family farming recognised given that it predominates over other forms of agriculture and has a significant share in most regions. Therefore, fostering and advancing family farming is vital for promoting decentralized development in the country. Peru's "Second Agrarian Reform" was launched in 2021 to create greater social inclusion of smallholder farmers, who supply more than 80% of the food consumed by nearly 32 million people.

The reform consists of nine central components that include concrete measures to promote the competitiveness of smallholder farmers and improve their productivity, which will enable them to access new markets and obtain higher incomes for the benefit of families. An example of one such component is the promotion of water sowing and harvesting (a term adopted from Latin America), representing an ancestral process that involves collecting and infiltrating (sowing) rainwater, surface runoff, and groundwater for later recovery (harvesting) and use elsewhere.

Given the objective of improving the well-being of rural households, there is a valid question about whether deliberate efforts should be made to promote a more inclusive form of agricultural growth. The answer to this question depends, in part, on the opportunities available to connect smallholder farmers with domestic markets, rather than relying solely on high-value export markets (e.g., coffee, cocoa, banana).

The involvement of smallholder farmers in export-oriented value chains is influenced by various factors such as product characteristics, production structure, value chain organization, demand nature, and buyer motivations. Buyers, including assemblers, processors, and exporters, play a crucial role in determining the extent to which smallholder participation is possible, considering aspects like costs, product quality, supply reliability, and compliance risks. Government interventions, often with support from development organizations, aim to create a more level playing field, encouraging prominent buyers to engage with smallholder farmers based on commercial interests and social responsibility objectives.

The ongoing transformation of the food system, influenced by factors like income growth and urbanization, presents significant opportunities for product differentiation in the domestic market. While the penetration of supermarkets has been slower in Peru compared to other similar countries, it still offers potential for farmers to connect with markets, provided they can adapt their products to meet evolving consumer demand. The expansion of local agroindustry, including smaller firms, creates possibilities for collaboration between smallholder farmers and processors/manufacturers of various food products such as fruit juices, dairy products, snack foods, and nutritional supplements. The development of the gastronomy value chain also provides opportunities for smallholder farmers as high-end restaurants increasingly source ingredients directly from local farmers, emphasizing traceability to appeal to socially conscious consumers.

There is a concern that most benefits will be captured by wealthier farmers who possess the necessary resources, knowledge, and skills to leverage support from the government or development organizations. To address this, a step-wise approach may be more effective, starting with small changes and continual upgrades, focusing on farmers who are less likely to be integrated into value chain developments. While product differentiation strategies offer opportunities for some smallholder farmers in specialized domestic markets, traditional markets will remain the main outlet for most farmers. To improve competitiveness and economic opportunities for these farmers, it is important to reduce costs, increase production and productivity, and enhance resilience in the face of a changing environment.

5 Resilient Puna value chain analysis

5.1 Selection of project-related agricultural value chains

5.1.1 Product overview

Agricultural activity is defined as the production, breeding or cultivation of plants or animals, or the maintenance of agricultural land in a suitable condition for pasture or crops. According to the last National Agricultural Census of 2012, 2,213,506 agricultural units were registered in Peru. In terms of agricultural area, this involved 38,742,465 ha, which represents an average of 17.5 ha of land per AU.

According to the 2012 Agricultural Census, in the provinces prioritized by the Resilient Puna project in Arequipa, Apurímac, Cusco, Lima and Puno, there is an agricultural area of 145,728 ha, of which 79% is located in the Suni region and only 21% in the Puna region. The crops with the largest area in the Suni region are alfalfa, starchy maize and native potato (13% of the crop area in the Suni region each) followed by fodder oats with 11% and white potatoes with 9%, beans occupy an area of 6%, other important crops are hard yellow maize, grain barley and quinoa with 4%, 4% and 3% of the crop area in the Suni region, respectively.

In the Puna region, there are fewer cultivated areas, however, native potato crops stand out with 22%, followed by fodder crops such as fodder oats with 17% and alfalfa with 10%. Bitter potato and white potato varieties occupy 7% and 6% respectively. Other important crops in the Puna region include rye grass (6%), quinoa (4%) and grain barley (4%).

5.1.2 Territorial overview

The Andes are very valuable spaces in terms of genetic, biological and cultural diversity in relation to their altitude. Excluding the coastal and jungle regions, there are eight natural regions in the Andes:

1. **Maritime Yunga**: From 500 to 2300 masl on the western flank of the Peruvian Andes, equivalent to a pre-montane to low montane altitudinal level.
2. **Fluvial Yunga**: From 1000 to 2300 masl on the eastern flank, equivalent to a low montane floor.
3. **Quechua**: From 2300 to 3500 masl, equivalent to a high mountain floor.
4. **Suni**: 3500 to 4000 masl, equivalent to a subalpine floor.
5. **Puna**: From 4000 to 4800 masl, equivalent to an alpine floor.
6. **Janca**: From 4800 to 6768 masl, equivalent to a snow floor.
7. **High Jungle Region**: From 400 to 1000 masl
8. **Selva Baja Region**: From 83 to 400 masl

It should be noted that in the Puna region there are only 239,948 ha of agricultural land at the national level, compared to the Suni region, which has around 1,273,852 ha.

Table *5* Hectares of agricultural land per Andean natural region. Source: INEI (2012).

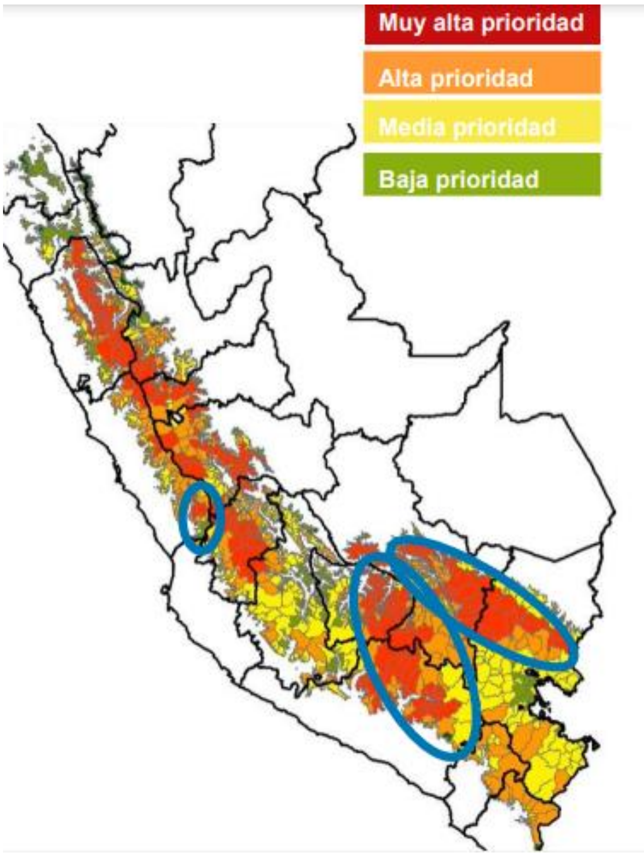
Altitudinal Floor	Hectares of agricultural land at national level
Costa	**1,406,441**
River Yunga	**820,740**

Altitudinal Floor	Hectares of agricultural land at national level
Quechua	**1,572,767**
Suni	**1,273,852**
Puna	**239,948**
Janca	**1,948**
Rupa Rupa (high forest)	**626,613**
Omagua (lowland rainforest)	**832,215**
Maritime Yunga	**350,484**
Total	**7,125,008**

The project has prioritised 58 districts for intervention, based on 91 districts initially identified as high priority in the in the regions of Apurimac, Arequipa, Cusco, Puno, and the Nor Yauyos Cochas Landscape Reserve (NYC) due to climate risk to drought in agricultural and livestock lands (GRACC-MIDAGRI Plan data); key ecosystems (ha of bofedals, glaciers, humid puna, dry puna); area of influence to areas with deglaciation; land degradation and elevation (3,500 masl).

The 58 districts prioritized by the project respond to social criteria (# of organizations, presence of the state, conflict); economic criteria (MERESEs potential and presence of camelids) and ecological criteria (greater number of hectares of degraded wetlands and grasslands).

Figure 4 Intervention areas prioritised by the Resilient Puna project. Source: Concept Note Resilient Puna, GIZ



The Resilient Puna project prioritizes the territories of Lima (Yauyos), Apurímac, Cusco, Puno, and Arequipa, which fall within the natural regions of Suni and Puna, situated between 3,500 masl and 4,000 masl. In these areas, there is currently a total agricultural area of 145,728 ha.

Table *6* Hectares of agricultural land in the districts prioritised by the Resilient Puna proposal in Peru. Source: INEI (2012).

	Apurímac	Arequipa	Cusco	Lima	Puno	Total
Sunni	12,348	5,745	54,784	3,184	38,454	**114,514**
Puna	1,048	2,483	12,020	22	15,641	**31,214**
Total	**13,396**	**8,227**	**66,804**	**3,206**	**54,095**	

5.1.3 Identifying project-relevant value chains

At the regional level, in the districts prioritized by the Resilient Puna project, Apurímac has a higher proportion of cultivated area of potato, starchy maize and beans. In the case of Arequipa, crops such as alfalfa are more important than other crops. It is followed by starchy maize, fodder oats, potatoes and green beans. In the case of Cusco, there is a greater diversification of crops such as different varieties distributed equally between potatoes, starchy maize, cocoa, coffee and in Puno, the cultivation of native potatoes, fodder oats and alfalfa stand out.

Figure *5* Productive profile of prioritised districts in Apurimac. Source: SIEA – MIDAGRI (2019)

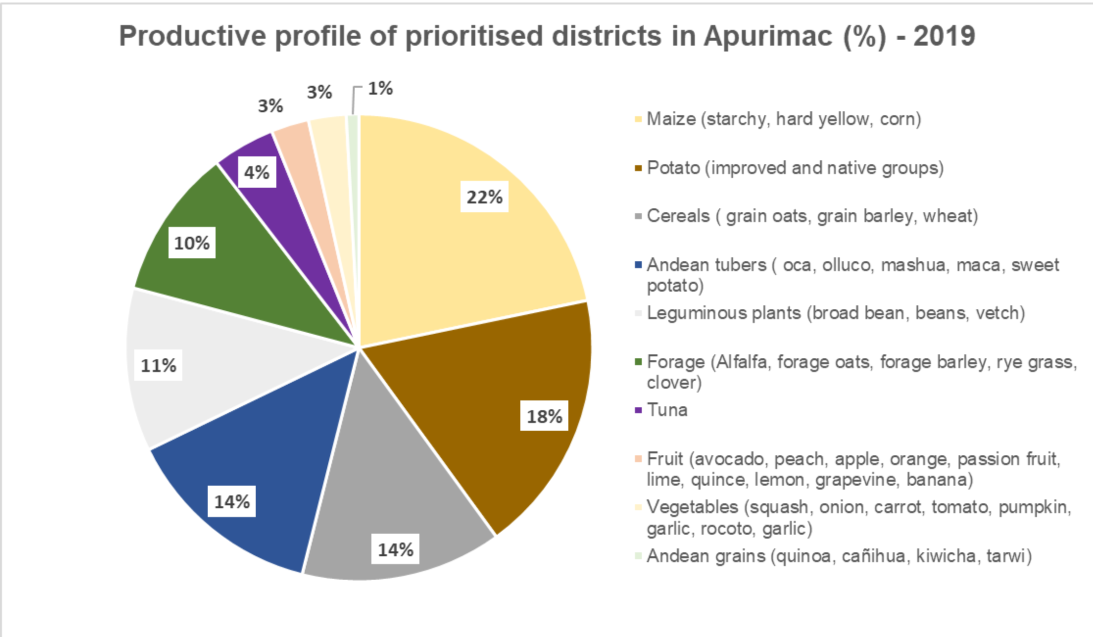


Figure *6* Productive profile of prioritised districts in Arequipa. Source: SIEA – MIDAGRI (2019)

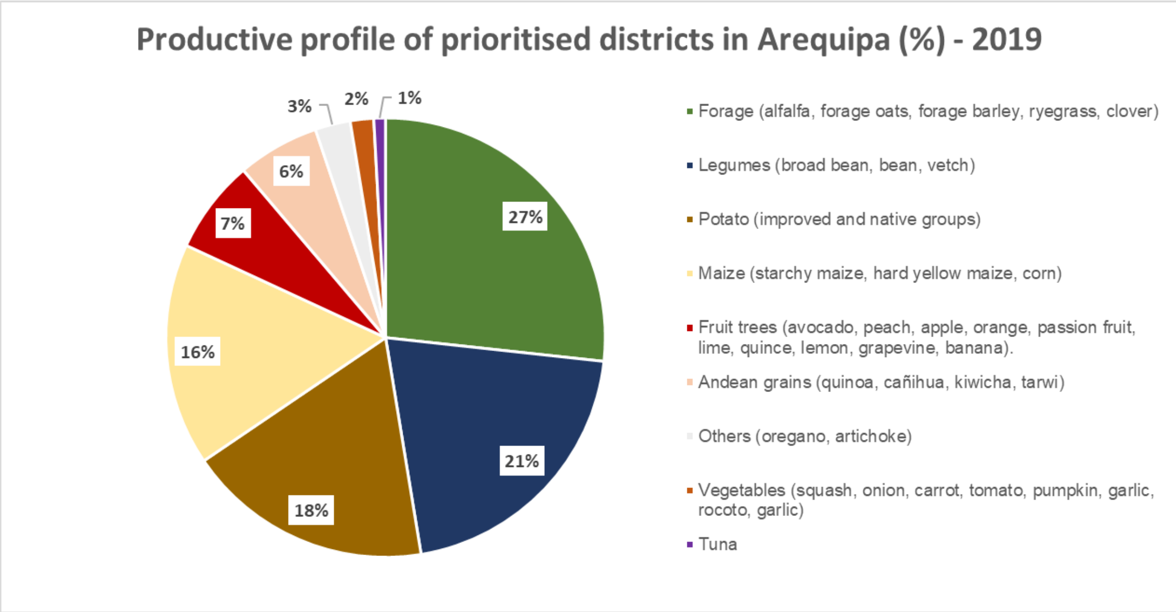


Figure *7* Productive profile of prioritised districts in Cusco. Source: SIEA – MIDAGRI (2019)

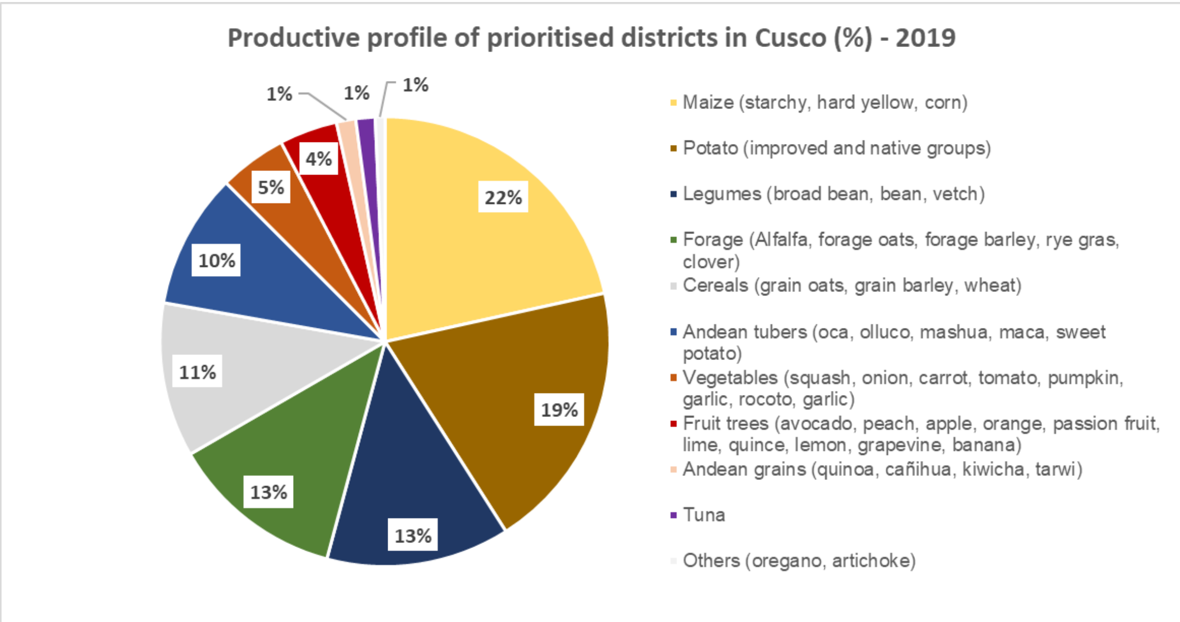
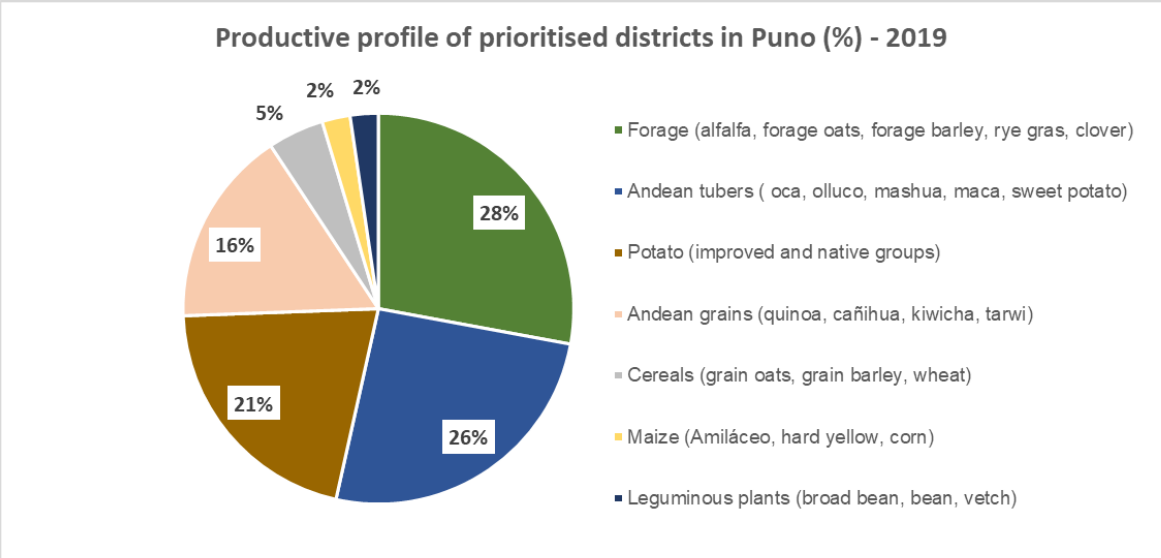


Figure *8* Productive profile of prioritised districts in Puno. Source: SIEA – MIDAGRI (2019)



Livestock production in the Southern High Andes of Peru (SHAP) is characterized by the presence of both native and introduced animals. Among the former, there are South American camelids (alpaca, vicuña, llama and guanaco) and guinea pigs (Cavia porcellus); both have been domesticated throughout the Andean territory and now there are improved breeds as a result of the implementation of technologies. The latter include animals such as sheep, which have been widely distributed in the Andes for both wool and meat. There are also cattle, goats and pigs in the lower areas, as well as poultry.

High Andean production of South American camelids is mainly based on extensive grazing of natural grasslands, mainly bofedales, humid puna grasslands and dry puna grasslands. According to MIDAGRI's Annual Livestock and Poultry Statistics Review 2021, the camelid population (units) in the departments of Resilient Puna is as follows:

Table *7* Camelid population (units) in the Resilient Puna departments. Source: MIDAGRI (2021).

DEPARTMENT	ALPACA	LLAMA	VICUÑA
APURÍMAC	212,220	72,280	12, 849
AREQUIPA	471,546	94,372	45,243
CUSCO	673,731	144,965	7,966
PUNO	2,030,525	359, 415	25,475
LIMA	46,625	18,780	1,365
NATIONAL TOTAL	4,484,888	1,075,425	166,428

According to CENAGRO (2012), the alpaca population in the Suni region was 25,593 heads; in the Puna region the total was 50,068 heads. In the departments selected by the project, the distribution was as follows:

Figure *9*: Average number of Alpaca heads in the Suni region. Source: CENAGRO (2012)

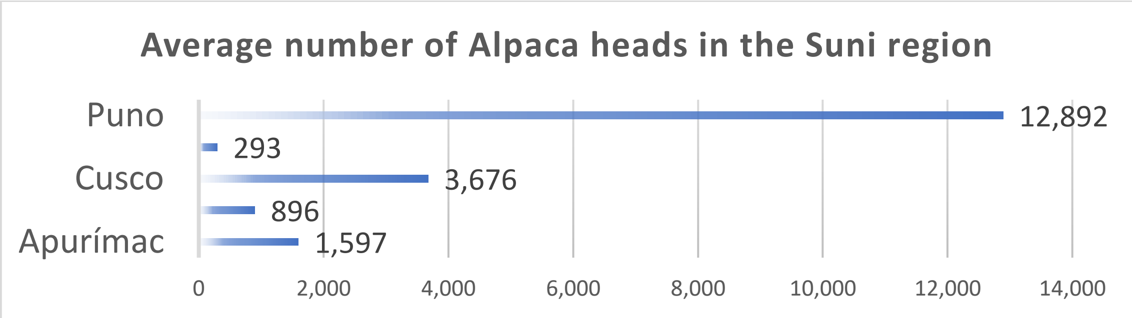
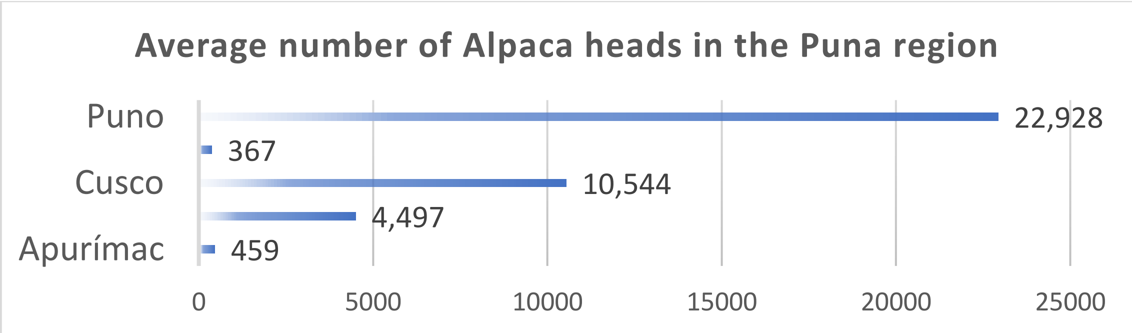


Figure 10: Average number of Alpaca heads in the Puna region. Source: CENAGRO (2012)



As can be seen, Puno is the department with the highest percentage of representation in both regions; 50.4% in the Suni region and 45.8% in the Puna region. Likewise, the departments selected by the project represent 76% and 77.5% respectively of the average number of alpaca heads.

Finally, **within the prioritised districts** in each department, according to CENAGRO 2012, the alpaca population (units) was as follows:

Table *8* Alpaca population. Source: CENAGRO (2012)

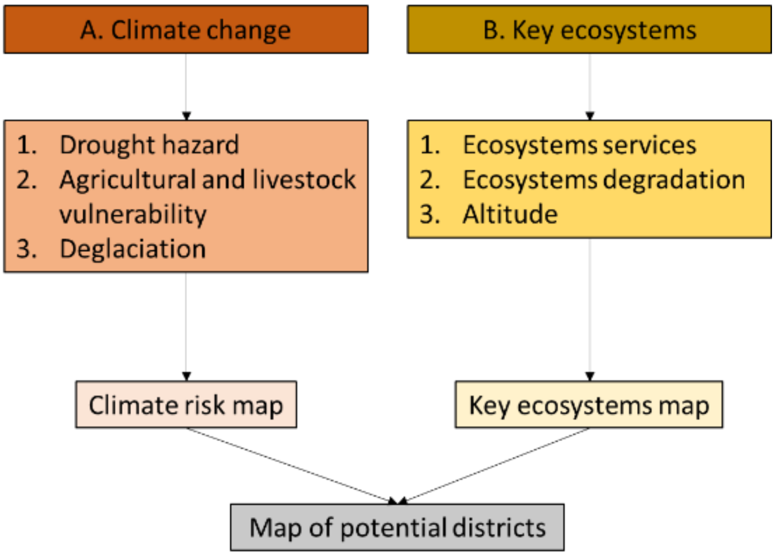
DEPARTMENT	AGRICULTURAL UNITS	ALPACA
APURÍMAC (12)	1,297	98,401
AREQUIPA (13)	3,342	210,102
CUSCO (25)	8,658	367,214
PUNO (9)	4,946	302,138
LIMA (4)	325	18,260

5.1.4 Multiple-criteria decision analysis (MCDA) on value chain selection

The project focuses on vulnerable communities - mainly small farmers and alpaqueros - dependent on High Andean ecosystems, located above 3500 masl. Priority is given to the higher elevations.

To identify intervention districts, a set of priority districts was identified using a multi-criteria spatial analysis method that integrated climatic and ecosystem criteria. The first stage considered the following criteria: a) vulnerable communities: i) altitude above 3500 masl, including a buffer zone up to 2800 masl); b) ecosystems: i) presence of puna ecosystems and ii) areas with the largest area of degraded land; c) climate: i) presence of glaciers with high or very high risk of glaciation and ii) presence of agricultural and livestock lands with high or very high risk of drought and high climate vulnerability.

Figure *11*: Climatic and ecosystem criteria. Source: Project target areas (2022)



Based on the results of this first stage, in a participatory process, the project partners focused the actions on the largest block of priority areas in the SHAP where it is possible to achieve a greater impact. Thus, 91 districts in the regions of Arequipa, Cusco, Apurimac and Puno were prioritized. In addition to the target areas in the south resulting from the methodology presented, the partners have decided to include the Nor Yauyos Cochas Landscape Reserve (NYC) to the project because this site has extensive experience in implementing EbA measures together with local stakeholders, international cooperation and the development of payments for ecosystem services that can serve as a best practice to scale up and replicate in the other project areas.

During the development of the funding proposal, a second phase was carried out, focusing on the enabling conditions to implement the project according to social, economic and environmental factors. In this phase, the area focused on 58 districts located in the departments of Apurímac (10), Arequipa (12), Cusco (23), Lima (4) and Puno (9). The 58 districts are located in 23 provinces: 4 in Apurímac, 5 in Arequipa, 9 in Cusco, 4 in Lima and 9 in Puno. The area covered by the 58 districts is 4,116,475 ha, with a population of 434,109 in 2017 (INEI, 2017).

Figure *12*: Project Implementation Areas. Source: Project target areas (2023)

For the selection of value chains in the selected territories, economic criteria were defined (demand prospects of national and international markets, comparative advantages of production, opportunities for job creation); social criteria were considered (inclusion of disadvantaged groups, food security, the need to improve working conditions, impact of the value chains on local institutions, impact of the value chains on surrounding communities); Environmental criteria were assessed (Impact of the value chains on the environment and of the environment on the chains, compensation for eco-systemic services, "green" opportunities) and Institutional/pragmatic criteria were taken into account (National policy priorities, opportunity for public investment funds, evidence of own initiatives of value chain actors, synergies with other programs).

Complementarity with EbA measures:

- Are the value chains complementary with potential EbA measures selected for the project?

Innovation:

- Is there a potential for innovation?
- What type of innovation is promoted: commercial, technological, institutional?

Market:

- Is there sustained and promising demand?
- In what type(s) of market: local, national or international?
- Is it an emerging, established or declining market?
- Is it a mass or a niche product?
- Do they demand fresh or value-added product?
- Are the actors articulated and do they conduct formal or informal business?

Profitability:

- How profitable is the product? What is the level of profitability?
- How expensive is the technology to add value?
- What is the price behaviour?
- Is there a high or low investment required to go into business?

Production:

- Is there sufficient volume and is it in the required quality?
- What are the problems with higher volume or better-quality product?
- Does it occur all year round or at a specific time? In which months of the year?
- Are there many, few or no production risks?

Technology:

- Is it possible to add value, what kind and in which link of the chain?
- Does the required technology exist?
- Is the necessary infrastructure in place?
- Are there technical quality standards or protocols?
- Are the technologies environmentally friendly and do they prevent deforestation?

Institutionality:

- Are there public or private organizations working in the value or product chain?
- Are they part of prioritized value chains in regional or local government?

Partnership:

- Are producers organized in associations, cooperatives or committees?
- Are they new or established organizations?

Coverage

- It includes a significant number of male and female producers
- It includes a significant number of geographical area or scope.

5.1.4.1 MCDA matrix

The main relevant value chains identified are: High Andean crops (quinoa and native potato), and South American camelids (alpaca and vicuña).

Table *9*:Identified Value Chains

Crops	Production Suni	Production Puna	EbA	Innovation	Market	Profitability	Technology	Institutional	Partnership	Coverage
Alfalfa	13%	10%	+	+	+	+	+	+	+	++
Maize	13%	17%	+	+	+	+	+	+	+	++
Native Potato	**13%**	**22%**	**++**	**++**	**++**	**+**	**++**	**++**	**++**	**++**
Fodder Oats	11%	17%	+	+	+	+	+	+	+	++
White potato	9%	6%	+	+	+	+	+	+	+	+
Broad beans	6%	6%	+	+	+	+	+	+	+	+
Barley	4%	4%	+	+	+	+	+	+	+	+
Quinoa	**3%**	**4%**	**++**	**++**	**++**	**+**	**++**	**++**	**++**	**+**
Yellow potato		7%	++	++	+	+	+	+	+	+
Rye Grass		6%	+	+	+	+	+	+	+	+
Camelids	**50,4%**	**45,8%**	**++**	**++**	**+**	**+**	**+**	**++**	**++**	**++**

5.1.4.2 Complementary value chains

The project stakeholder validation workshop identified the need to incorporate a subset of additional emerging value chains ground-truthed as supplementary for smallholder family farmers in the High Andes (particularly women), who practice subsistence agriculture but also engage in a variety of other activities to supplement their income and ensure food security.

These have been grouped as Andean grains and tubers (kiwicha, cañihua, tarwi, oca, and mashua), guinea pig rearing, textile handicrafts, and community-based tourism.

These nutritious and resilient crops serve as food sources and hold commercial value in various markets. Guinea pig rearing provides an alternative income stream due to the high demand for this traditional protein source. Textile handicrafts capitalize on the artisanal skills and cultural heritage of the farmers, opening doors to local and international markets. Lastly, community-based tourism harnesses the natural beauty and cultural richness of the region, generating income from sustainable tourism practices. The strategic selection of these complementary value chains is intended to uplift the livelihoods of smallholder farmers, enhance their economic resilience, and foster sustainable development within their communities.

5.2 Value chain analysis

5.2.1 High Andean crops value chain: quinoa and potato value chains

5.2.1.1 Quinoa value chain

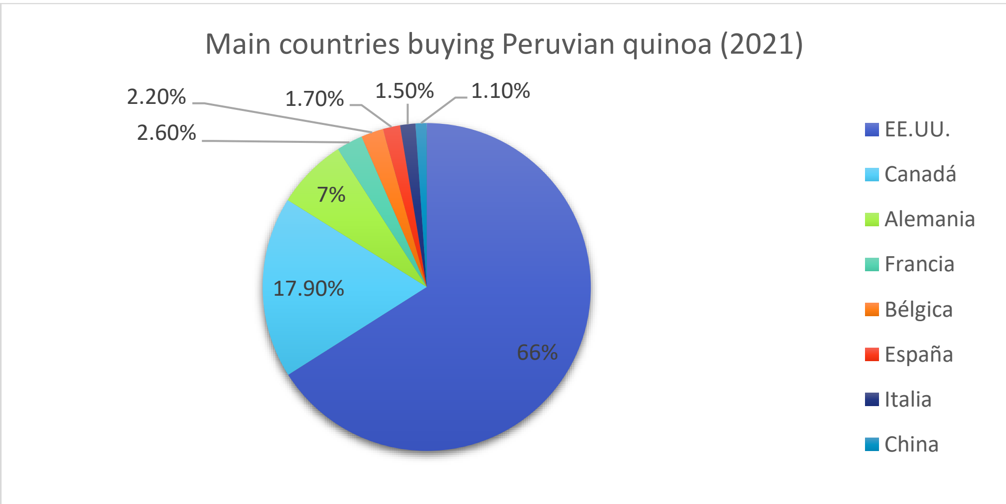
- Markets

Amidst the challenge of meeting the growing demand for high-quality food to feed the global population amidst climate change, quinoa emerges as a significant option due to its nutritional attributes and agronomic adaptability. It holds the potential to contribute significantly to regional and global food security, particularly in regions where food production faces limitations (FAO, n.d.).

In the last 40 years, there has been a huge expansion in quinoa production due to the "superfood" boom. Quinoa-based products are present in many niche markets around the world such as nutraceutical, organic and fair-trade markets (Carimentrand et al., 2015), and in various forms such as ready-to-eat foods, breakfast cereals, healthy snacks, noodles, and beverages.

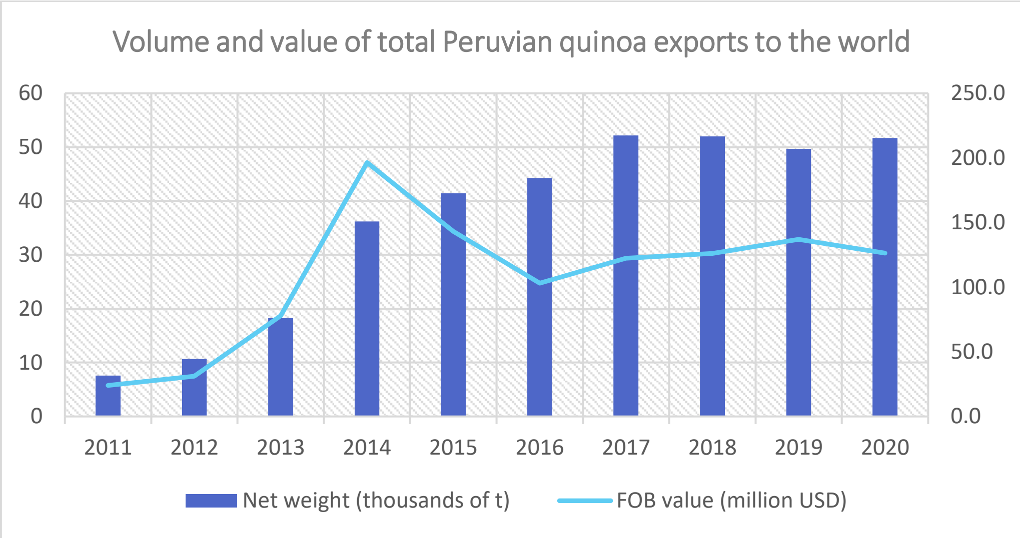
The main destinations for Peruvian quinoa are:

Figure *13*: Main countries buying Peruvian quinoa (2021). Source: TradeMap (2021) in ILO (2023).



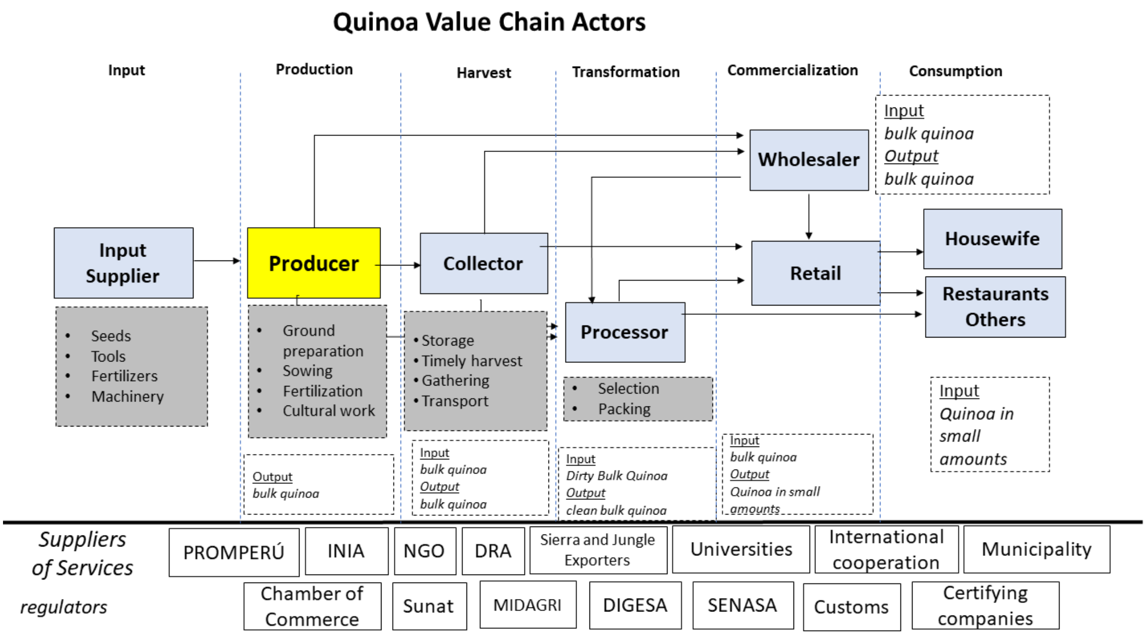
The volume and value of Peru's total exports of quinoa to the world were as follows:

Figure *14*: Volume and value of total Peruvian quinoa exports to the world (2011-2020). Source: ILO (2023).



- Value chain actors

Figure *15*: Quinoa Value chain actors



In Peru, the main quinoa producer organizations are found in Puno, Ayacucho, Cusco and Junín. Most quinoa producers are individual farmers and are not necessarily part of a cooperative or association. However, this situation is changing due to support from local and regional NGOs as well as the government (Carimentrand et al., 2015).

The department with the highest production of quinoa is Puno, and due to the favourable conditions, organic certification processes were initiated in the 2000s, mainly by NGOs such as the Centre for Urban-Rural Promotion of Juliaca (CPUR) and CIRNMA. Approximately 300 producers obtained organic certification and through the processing and export channels of NGOs, such as Altiplano SAC (CPUR) and Agroindustrias (CIRNMA), marketed organic quinoa from the provinces of San Roman, Chucuito and Azángaro (Carimentrand et al., 2015). Other actors that have also participated in these certification processes have been the International Fund for Agricultural Development (IFAD) and PRONAMACHCS.

The quinoa value chain has two lines of development. On the one hand, there is quinoa destined for the external market, and on the other hand, quinoa for the domestic market, with more production for export.

Producers, whether independent or organized in associations or cooperatives, sell directly to exporters, through agreements or arrangements between these actors. Producers also tend to sell to collectors, who sell to intermediaries, who then sell to exporters, who take the product to external markets for processing and sale abroad.

However, collectors and intermediaries also usually sell to the national industry, which selects and packages the quinoa in bags for distribution in urban markets through wholesalers who supply traders (bodegas, supermarkets, market stalls) for sale to final consumers (households).

Small industries can also be identified that process quinoa and offer products such as quinoa pop, quinoa energy bars, among other presentations. They sell to retailers who deliver these by-products to the final consumers. We can also mention the restaurants that buy quinoa to prepare various dishes; highly segmented food (gourmet restaurants).

At the consumer level, the typical traditional uses of quinoa were essentially based on its use as a grain or as flour (obtained through milling), which was then used to make different breads, soups and fried or cooked products, with few products also using quinoa leaves as an ingredient.

Expanded quinoa is another quinoa product that has been consumed for several millennia, the pearled grain is exposed to high temperatures and pressure, which causes the quinoa to burst, releasing its internal moisture in the form of steam, and thus expand into a light product and is used for direct consumption or for the production of instant cereal or energy bars, but this process causes losses of protein and other nutrients (Angeli et al., 2020).

- Economic analysis

Supply-side analysis

Quinoa is a grain adapted to cold areas of 3,000 masl, but there are varieties adapted to lower and warmer areas. This grain has a high protein content with a high proportion of essential amino acids and also contains minerals such as phosphorus, potassium and calcium, which gives it great potential for national and international consumption due to its nutritional qualities. It also contains saponins, which is a bitter compound that is eliminated by rinsing or scarification before consumption, and is a traditional practice in Andean food systems.

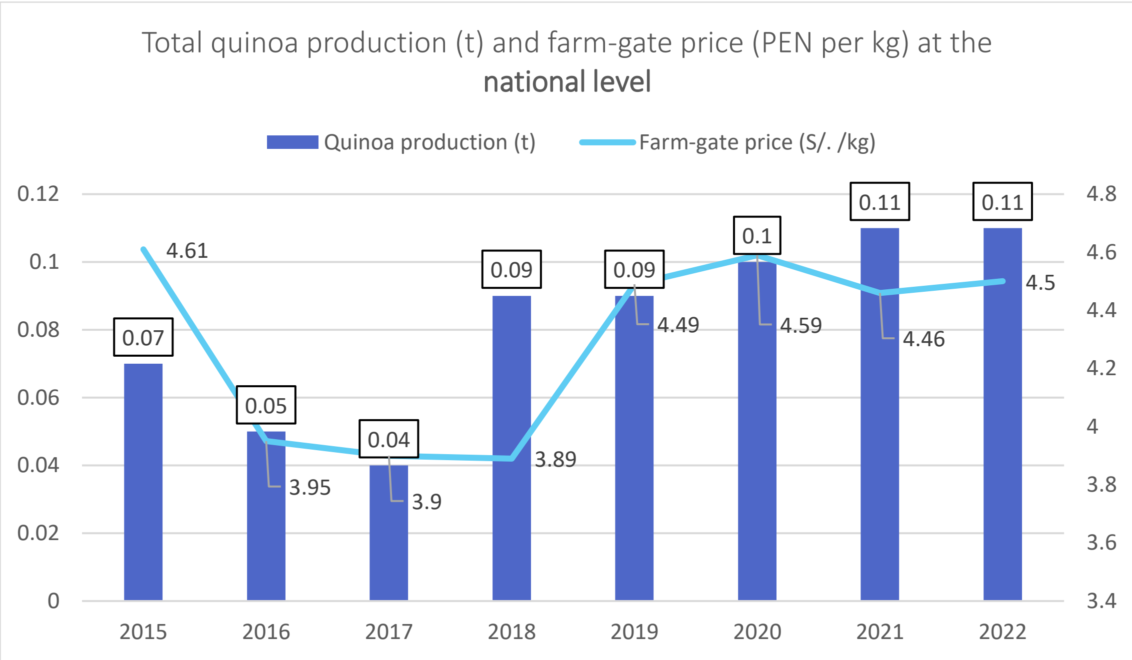
Quinoa is classified into five ecotypes, which differ from each other in adaptation to altitude, tolerance to drought and salinity, and response to photoperiod. The five ecotypes described by Tapia (1997) are: (a) Andean Valley type; (b) altiplano type; (c) salares (salt flats) type; (d) sea level type; and (e) subtropical Yunga type. Some quinoa ecotypes have great potential value that could be used to help the crop better resist and adapt to climate change, extreme weather events and emerging pests and diseases (García et al. 2015; Mújica and Jacobsen 2006).

Quinoa stands out as one of the rare crops that thrives even in challenging climate and soil conditions. Its remarkable ability to adapt to climatic variations and efficient water usage makes it an excellent alternative in the context of climate change. As shifts in the agricultural calendar and extreme temperatures become more frequent (ILO, 2015), quinoa proves to be a resilient choice. Bolivia's National Institute for Agricultural Innovation and Forestry has recognized quinoa as one of the 21 most climate change-resistant seeds, alongside fava beans, maize, amaranth, onions, and other crops.

Peru is one of the main quinoa-producing countries in the world, together with Ecuador and Bolivia (ILO, 2023). Quinoa cultivation is important, particularly in the SHAP region, and generates a production value of PEN 130 million, with an increase of 6% compared to 2020 (MIDAGRI, 2021).

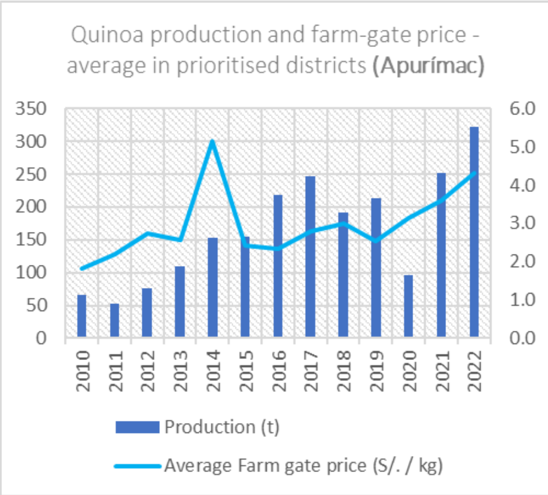
At the national level, the total production of quinoa (tons) and the farm-gate price (PEN per kg) were as follows:

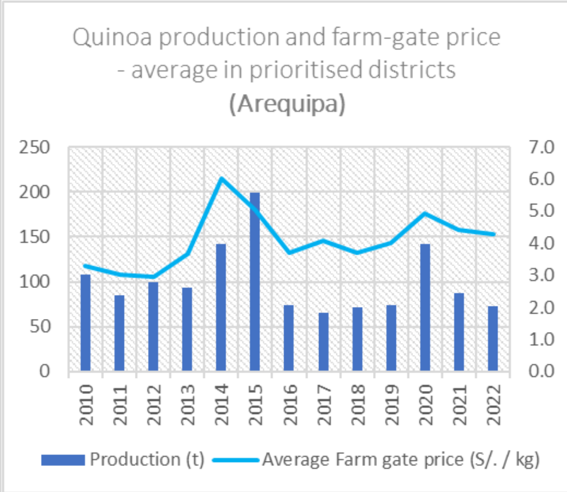
Figure *16*: Quinoa production and farm-gate price at the national level. Source: SIEA – MIDAGRI (2023). Own elaboration.

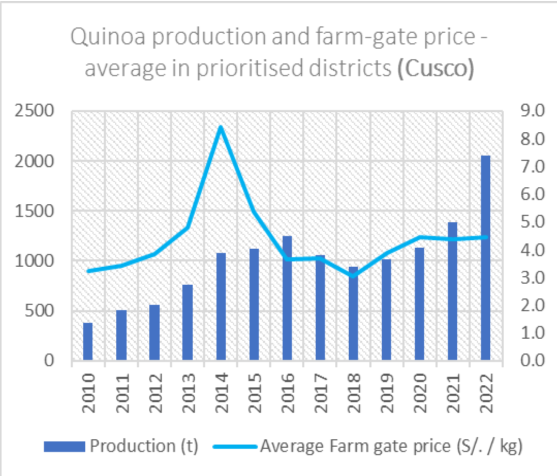


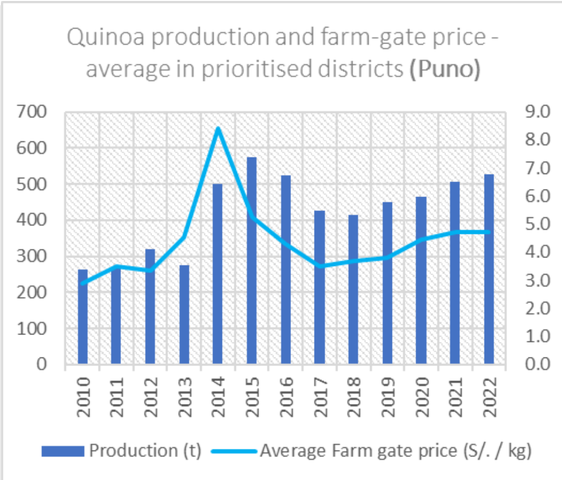
In the last 3 years, the total production of quinoa has remained at 0.11 million tons. The departments that produced the most kg of quinoa in 2022 were Puno, Ayacucho, Cusco, Arequipa and Junín. Now, in the prioritized districts by department, the distribution is as follows:

Figure *17*: Quinoa production and farm-gate price – average in prioritised districts of the Resilient Puna Project. Source: SIEA – MIDAGRI (2023)









The Regional Agrarian Directorate of Puno has estimated the income of the traditional quinoa producers based on the expected yield of 1,350 kg/ha and the average selling price of 7 PEN per kg of quinoa; the gross income would be PEN 9,450 per hectare.

Demand-side analysis

It is important to highlight that the increase in organic quinoa production is due to two main reasons: i) it is the most demanded type of quinoa in the foreign market (Fairlie-Reinoso, 2016); and ii) the economic returns, if well managed, are 50% to 120% higher (depending on market fluctuations) than those of conventional quinoa, despite lower yield rates.

The expansion of demand for organic quinoa has come mainly from the United States, Europe and also in Asian countries that have started to incorporate quinoa into their diets. In Peru, there is also a significant demand for quinoa (Bellamere et al., 2018), which despite the price increase a few years ago, did not vary that much (inelastic demand). About 20% of the population are consumers rather than producers. This situation has allowed the quinoa area to increase, as well as the income of producers (Bellamere et al., 2018).

Pricing and value added

According to INEI (2021), the production costs of one hectare of quinoa cultivated by quinoa producers within the quinoa value chain for the year 2018 of PEN 5,906.2.

The cost of production per t (given the average yield of 2,630 kg/ha) is PEN 2,245.55, or, PEN 2.25 per kg, which is consistent with the national average producer price of quinoa for 2018 of PEN 3.84 per kg of quinoa.

The main item in the costs of quinoa production corresponds to daily wages (23.7% of the total cost), followed by fertilisers (21.8%) and others (14.2%), which includes the renting of yunta,[8] training and specialised consultancy, freight, packaging (including sacks, boxes or javas for storing the harvested product), blankets and short duration nets, minor repairs (not related to equipment), maintenance services, quality certifications (Global Gap, Fair Trade, organic, for example), sanitary certifications (SENASA), work clothes (uniforms, suits, helmets, hats), etc.

In the destination markets, organic quinoa is sold at EUR 8.40-9.15 per kg (equivalent to PEN 33.6-36.6 per kg), while conventional quinoa is sold at EUR 5.6 per kg (equivalent to PEN 22.4 per kg).

- Climate change

Quinoa has many qualities that make it resilient to climate change (Balakrishnan et al., 2022, Hinojosa, et al, 2018):

- It exhibits drought and heat tolerance, requiring less water compared to other crops.
- Quinoa demands fewer agricultural inputs for successful growth.
- The crop demonstrates tolerance to salinity.
- Rich in protein, micronutrients, and other beneficial compounds such as antioxidants, prebiotic fibres, and bioactive peptides, quinoa offers a sustainable alternative to meat consumption and contributes to reducing emissions linked to livestock farming.

Despite its high adaptability, quinoa is not immune to the negative impacts of climate change, which can adversely affect its production and yield. Areas once suitable for quinoa cultivation may no longer have the necessary conditions for sustained production. As temperatures rise and exceed the crop's optimum threshold, production and yield decline. For instance, in Puno, a 1 °C temperature increase results in a reduction of 112.2 Mt in production and 169.1 kg per ha in yield. Additionally, increased rainfall by 300 mm leads to a reduction of 75.78 Mt in production and 127 kg per ha in yield (Carrasco, 2016). Drought is another significant challenge that quinoa producers face, causing water scarcity for irrigation. In Ayaviri, Puno, the entire quinoa harvest was lost during the 2023 season.

Research conducted by Espinoza (2016) in the Andean regions of Peru identified three quinoa varieties that performed exceptionally well across various parameters, demonstrating significant yields, good quality, and adaptability to climate change. These varieties are Salcedo INIA, Blanca Junin, and Pasankalla. As climate change continues to exert its influence, there is a need to remodel and redefine new policies, such as scientific-technological policies concerning hydrology, irrigation fundamentals, agricultural production of Andean food crops in the region, and environment and land use planning throughout the country.

- Agricultural practices

The agro-climatic requirements for quinoa cultivation involve essential considerations in crop rotation, including factors such as weed presence, residual fertilization, pests,

[8] Yunta is an ancestral technique that consists of opening up the earth using the strength of two animals, chiefly bulls, which are yoked together by a yoke attached to their horns.

residual pesticides, soil preparation, and water availability, among other crucial aspects (FAO-UNALM, 2016). To optimize quinoa planting, the following recommendations are suggested:

- Plant quinoa after potato cultivation, but only if the field has not been infected with the fungus Phoma exigua var. foveata, which causes gangrene disease in potatoes and brown stem rot disease in quinoa.
- After cultivating potatoes and other Andean tuberous roots like oca, ensure that the fields are free of nematodes, particularly the oca nematode (Thecavermiculatus andinus sp).
- Following nitrogen-fixing legumes, consider beans (Vicia faba), peas (Pisum sativum), and tarwi (Lupinus mutabilis) as recommended choices in the highlands.

Moreover, considering the potential expansion of the global quinoa supply and the likelihood of reduced quinoa prices, there is an incentive to diversify and produce different Andean grains with comparable or superior nutritional values, such as kiwicha and cañihua. Additionally, cultivating leguminous plants like tarwi offers an alternative option.

- Barriers and opportunities

Producers of quinoa face a significant barrier in the form of the low market price they receive for their crops. The inadequate income levels (ILO, 2023), limited formal employment opportunities, and insufficient food availability among family quinoa farmers in Peru pose considerable challenges to economic development. This situation is influenced by six key factors:

1. Low levels of productivity and quality.
2. Weak collaboration and coordination among stakeholders within the value chain.
3. Insufficient levels of associativity among quinoa farmers.
4. Low per capita consumption rates.
5. Limited technological advancements for high value-added production and processing.
6. Inadequate public-private coordination and collaboration to enhance the chain's competitiveness.

When it comes to organic quinoa, the primary challenge lies in the uncertainty caused by its low profitability compared to high production costs. This uncertainty stems from several factors, including low productivity levels, depressed market prices, a decline in organic production alongside an increase in conventional production, and ineffective coordination between public and private institutions addressing quinoa value chain issues (ILO, 2023).

Consequently, this situation escalates the risk of resorting to chemical fertilizers or pesticides, leading to soil nutrient loss and adverse effects, such as water contamination and ecosystem degradation, ultimately reducing soil productivity (UN, 2022). This forms a vicious cycle that negatively impacts the livelihoods of producers.

However, quinoa producers in Peru can explore an opportunity tied to the development of community-based tourism in their localities. This activity offers significant benefits by directly impacting families and contributing to the economic development of the region. In 2016, MINCETUR and UNWTO launched the first tourism prototype called "The Quinoa Route" in Puno. This initiative aimed to offer visitors a unique way of exploring the destination while getting acquainted with the lifestyle of local producers through production centres that serve as interpretation centres for their respective regions (MINCETUR, 2016).

Gender issues

In the agriculture sector, over half a million women actively participate, making up a quarter of the Economically Active Population (EAP). These women play a crucial role in ensuring the country's food security while also fulfilling various responsibilities, including caring for their families, contributing to the sustainability of natural resources, and preserving biodiversity (Andina, 2021).

The Gender Equality Plan 2013-2017, developed by the Ministry of Women and Vulnerable Populations, acknowledges the challenging employment conditions faced by women in sectors like agro-industry, agriculture, and domestic work in its national diagnosis.

In general terms, in terms of agricultural land, on average women drive between 30% and 34% less total agricultural land than men in the regions of Cusco, Puno and Apurimac, a very large gap, smaller in Arequipa with 18% of the total and 15% in non-agricultural land. It is worth noting that the available non-agricultural land per capita (mainly grassland) in Arequipa and Puno exceeds several times that of Cusco and Apurimac and the national average.

These gender gaps are considerable, similar to the national level, which limits the prospects of raising women's income due to lack of innovation and diversification to increase land and labour productivity.

In Puno, subsistence consumption and animal feed production predominate, accounting for more than 80% of the cultivated area. For subsistence consumption, women cultivate more area than men in all four regions, particularly in Apurímac and Puno, but below the national average. On the other hand, the largest area cultivated for commercialisation by women is in Cusco and Arequipa, followed by Apurímac, with a gap in favour of women in Apurímac and Arequipa. Both results show the low connection women producers have with markets and their greater concern than men for feeding their families.

According to ILO (2015), the following gender gaps associated with the quinoa value chain have been found in Andean regions:

- The increase in demand for quinoa in recent years has generated salaried labour for men and women, mainly in harvesting, threshing, weeding and hilling activities. However, in some Andean regions there are wage differences between men and women, which can be explained by the fact that women's work in agriculture is considered complementary to that of men, even though it is salaried.
- Although women are mostly involved in the commercialisation of quinoa, they do not have the options and information to be able to sell to the highest bidder, given that both the collector and the company are the ones who set the prices according to their perspective.
- There is an absence of norms that promote self-employment considering the gender approach in the quinoa value chain, there is no Regional Plan for Gender Equality in Puno, nor ordinances that promote the participation of women in the production, commercialisation and transformation of quinoa.

- The neutral view of women's productive and reproductive work is still maintained: women are still considered to be solely responsible for reproductive work and are associated with care work and health and education issues, while men play a productive role and are economic providers. However, in practice, it is the women who are responsible for both tasks, because the men migrate to work in other paid jobs such as mining, construction and transport, between the quinoa ripening periods.
- The women's associations interviewed have less knowledge about certified quinoa production for export than the mixed producer associations, which implies a gender gap insofar as they will have lower incomes and will only sell to the local market.

SWOT analysis

Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis of the quinoa value chain (adapted from Hirich et al, 2021).

Table *10*: SWOT of the quinoa value chain

Strengths	Weaknesses
In terms of cultivation: ● Quinoa is more profitable compared to cereals. ● Tolerance of quinoa to various stresses that characterize the region including drought and salinity. ● Quinoa by-products such as leaves, straw and saponin could potentially be valorised. ● Low requirement in terms of agricultural inputs (fertilizers, management, pesticides, etc.). At the gastronomic level: ● High nutritional value compared to cereals. ● Quinoa seeds are gluten-free with low sugar content, making it an optimal food for diabetic and coeliac consumers. ● Fast cooking. ● Versatility of quinoa-based recipes.	At the production level: ● Poor organization of producers among those who have adopted quinoa. ● Quinoa is labour-intensive with very few mechanized operations (especially in the post-harvest phase). ● Problems linked to the establishment of quinoa at field level (low germination). ● Lack of availability of good quality seed. ● Sensitivity to diseases such as downy mildew. ● Bird attacks (during emergence and maturity). ● High post-harvest costs. In value-added and marketing: ● Basic marketing channels. ● Lack of promotion and communication around quinoa-based products.
Opportunities	**Threats**
● Willingness of national and international development agencies to promote and	● Competitiveness of local quinoa products vis-à-vis imported products.

accelerate the process of adoption of quinoa in the area. ● Availability of national and international agricultural fairs for exhibition of quinoa products. ● Increased interest in healthy food consumption by individual consumers and restaurants. ● Growing international market for quinoa. ● Promotion of quinoa at the international level through the "Superfoods" brand promoted by MINCETUR. ● There are initiatives to obtain quinoa with a denomination of origin, which will allow it to be differentiated on the international market. ● In the face of a possible expansion of world supply and the fall in the price of quinoa, there is an incentive to produce different Andean grains with similar or higher nutritional values, such as kiwicha and cañihua; and leguminous plants such as tarwi.	● Substitutes are numerous. ● High cost and slow organic certification process. ● Quinoa production is facing risk due to climate conditions, especially droughts and changes in maximum and minimum temperatures. Temperature decreases yield and quality, while droughts, and therefore the lack of water to irrigate the crops, can led huge losses. ● Loss of varietal purity and genetic yield due to the use of seed harvested over many years. ● Increase in international competitors, mainly Bolivia. ● Some European countries, such as France and Spain, are increasing their quinoa crops, offering them to the US market at lower prices than those of Peruvian origin.

5.2.1.2 <u>Native potato value chain</u>

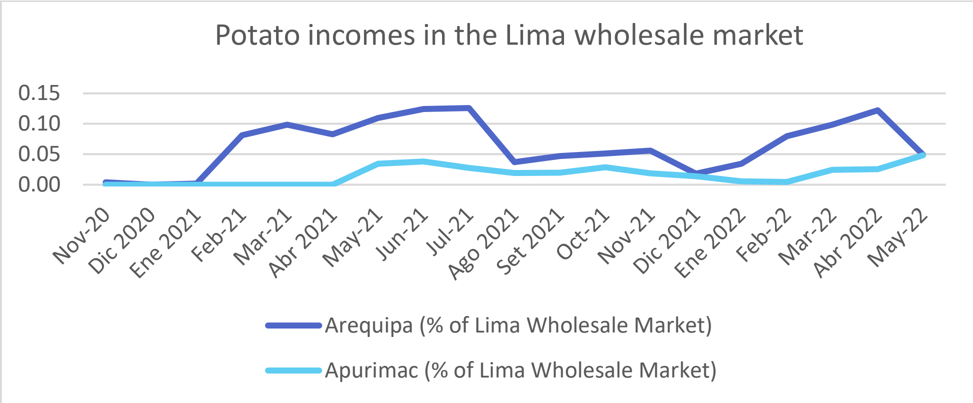
- Markets

In Peru, potato consumption has grown significantly reaching 83 kg per capita consumed annually in 2017 compared to the average per capita consumption in Latin America of 25 kg (Devaux, 2019); therefore, Peru is the largest potato consumer in Latin America (MIDAGRI 2020).

In the last 20 years, the demand for native potatoes has grown significantly in urban markets, going from being a product of ethnic consumption (bought by migrants from the highlands belonging to popular sectors) to being a "gourmet" product, with a sustained demand in the upper and middle sectors of society.

At the national level, the main market is the wholesale market of Lima, where the main potato supplying departments are Junín, Ayacucho, and Huánuco, but the importance of the departments of Arequipa and Apurímac to this market increases between the months of February and July where Arequipa contributes between 8% and 13% of the potato income to the market, while Apurímac contributes between 2% and 5% of the potato income to this market.

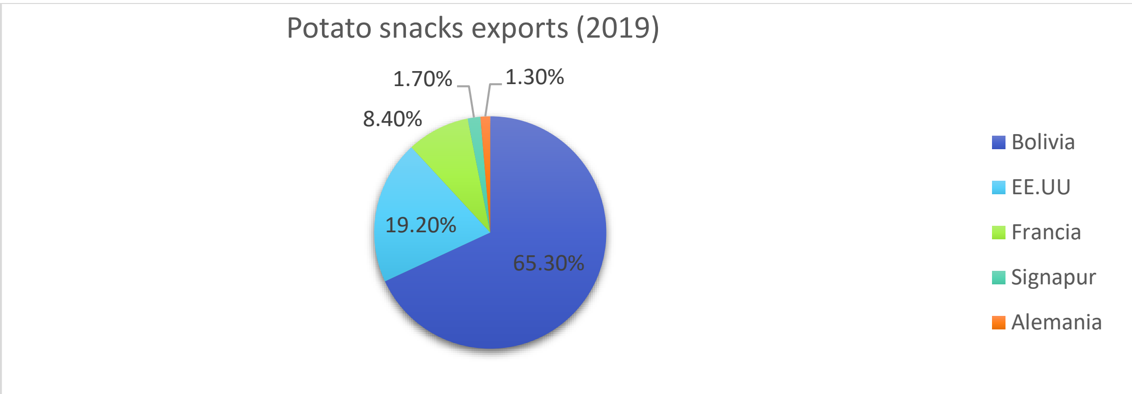
Figure *18*: Potato incomes in the Lima wholesale market. Source: MIDAGRI (Monthly wholesale market entry reports by Department)

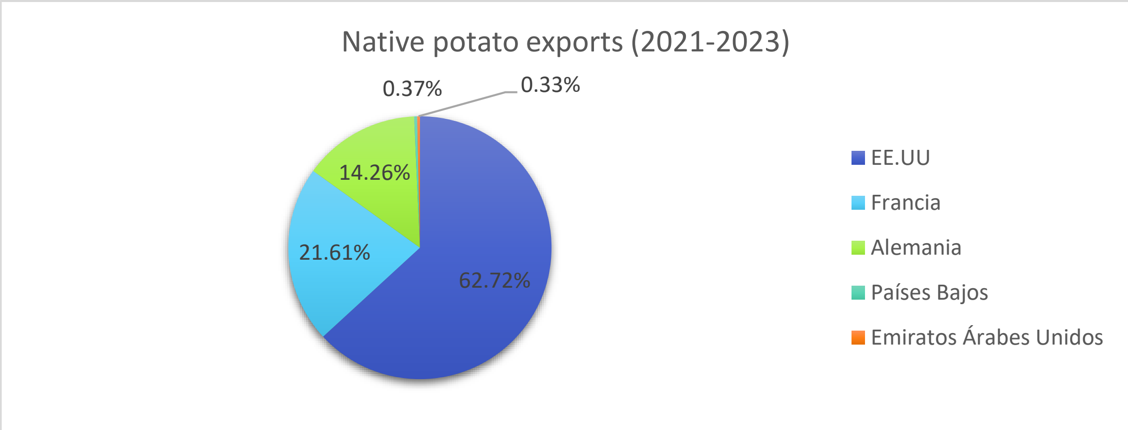


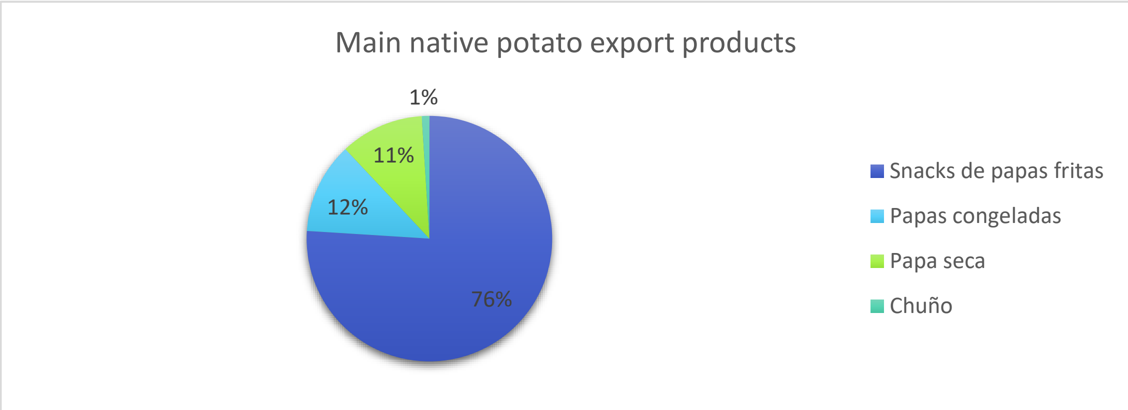
The main international destinations are the USA, France, Germany and the Netherlands (Veritrade. 2023). In the Andean region, the main destinations are: Bolivia, Ecuador, Colombia (Devaux et al., 2021).

In the MIDAGRI potato market study (2022a), the great export potential of native potatoes is evident. In the snack industry, two companies exporting snacks with native potatoes stand out: Inka Crops, a Peruvian company that has managed to position the native potato snack in many markets around the world, the main market being the United States, under the name Peruvian Potato Chips, with significant growth in 2019, with a share of 23%, and Cooperativa Agraria Agropía Ltda, an organization of small producers from Huancavelica, marketing organic native potato chips, destined for the European market. This company has a share of almost 11% of total snack exports. The main export countries for processed potatoes in 2019 were Bolivia (USD 1.3 million) and the United States (USD 1 million), and to a lesser extent, France (USD 0.143 million), Chile (USD 0.082 million) and Spain (USD 0.074 million).

Figure *19*: Potato snacks exports, Native potato exports and Main native potato export products (2019-2023). Source: MIDAGRI - Sierra y Selva exportadora (2020) and Veritrade (2023)



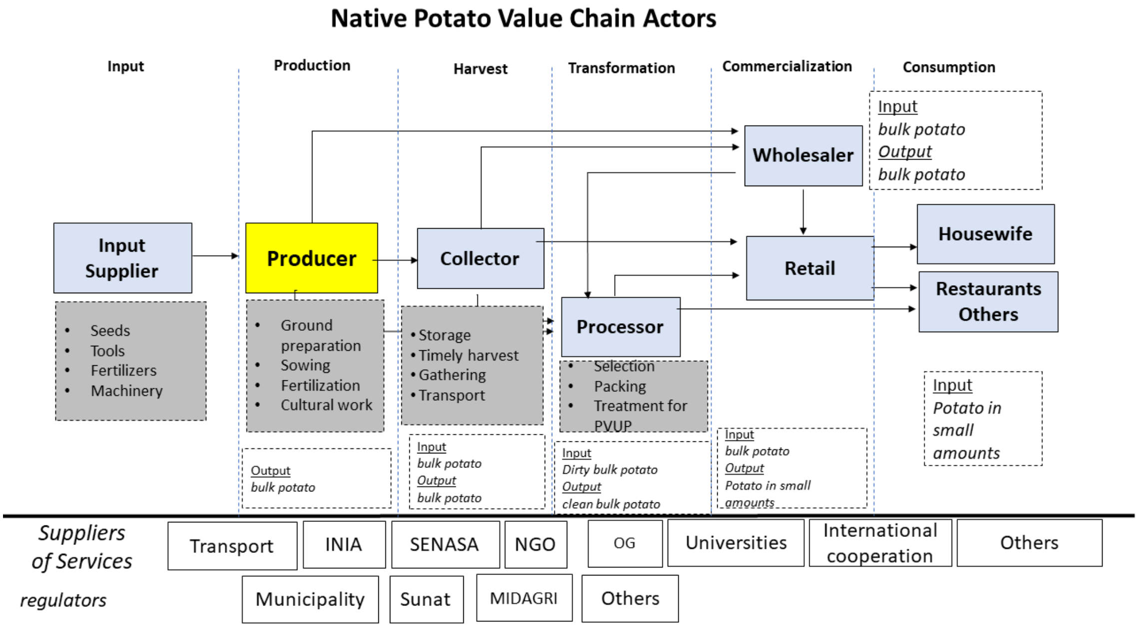




The competitive advantages in the world market are very great (nutritional and protein properties, linked to human health and which could position the crop in a totally different segment and existing varieties, with harvests throughout the year and which can be used for various industrial purposes. The challenges are associated with seasonality, development of high-quality seeds, seed treatment, productive diversification, management of good agricultural practices, technological level, degree of associativity between producers, among others).

- Value chain actors

Figure *20*: Native Potato Value chain actors



The value chain of native potatoes in the SHAP is composed of three sub-chains. Each sub-chain (fresh, tunta/chuño and chips) involves a set of direct actors who interact to bring the product from the place of cultivation and harvest to the consumer. There are also indirect actors that intervene in the chain as regulators or service providers.

Tunta and chuño are made from native potatoes. The main market is the southern part of the country, especially the cities of Puno, Juliaca and Arequipa. In third place, the city of Cusco. The tunta produced in the south of the country is also exported in significant quantities to Bolivia. Regional differences in the preparation of black and white chuño are largely determined by tradition, environmental conditions and market demand. The differences are particularly noticeable in the case of the regional variants of white chuño and involve the sequence and duration of each step in the processing pipeline.

The lack of (running) water sources in Huancavelica strongly influences the final quality of chuño blanco. Chuño in Huancavelica is predominantly produced for home consumption and little attention is paid to commercial quality control, e.g., sorting or grading. Commercial demand in Puno, particularly for chuño blanco, has stimulated innovations such as the use of floating tanks, net bags and rubber boots for treading in order to obtain the highest possible quality (De Haan et al., 2010).

The native potato chips chain is the "industrial" product that has achieved the greatest presence in urban markets, compared to native potato mash or native potato flour, but which does not have a significant supply in the SHAP. Independent and organized producers who sell to collectors or intermediaries who supply the chip processing industry. There are producer organizations that also sell directly to processors. Bags of processed chips are sold through wholesalers or distributors who sell to retailers (convenience stores, bodegas, supermarkets, kiosks) who in turn sell to end consumers.

- Economic analysis

Supply-side analysis

The potato is part of the world food system, it is the fourth most important product after maize, rice and wheat and is consumed by billions of people around the world. Peru is ranked 16th in the world ranking of potato producing countries, and is the second most important product in our agriculture (MIDAGRI, 2020), with more than 4,000 varieties, which are mostly found in the Andes (CIP, n.d).

Potatoes occupy an important place in Peru's agricultural economy, being the second most important crop at the national level, with a 10.7% share in the gross value of production of the agricultural sub-sector in 2019, surpassed only by rice with 11.5%.

Its importance lies in the fact that potatoes are the main source of income for more than 710,000 families living mainly in the Andean areas of our country, considering also the rest of the actors involved in the marketing chain. For family farming, it is a highly important component due to its contribution to diversity and variability as a nutritional source for consumers. In addition to being a livelihood in productive Andean ecosystems, due to its plasticity in adapting to adverse climatic conditions. In the 2018 results of the "Encuesta Nacional Agropecuaria", the main transitional crop harvested was potato, representing 4.6% of the total area.

The native potato is one of the main crops grown in the SHAP, especially above 3,600 masl. The traditional practices of native potato cultivation date back to pre-Columbian times with different management practices in order to be able to grow the crop in a way that suits the environmental conditions and minimises the use of external resources.

Andean agriculture is governed by traditional ancestral knowledge, which is revealed in a set of practices in production (soil preparation and management, consideration of dry or rainy years, crop rotation, use of different techniques in crop management, livestock and community organisation) and conservation (management of great genetic biodiversity. The local knowledge of farming families has played an essential role in the conservation of native potato biodiversity in Peru. For example, in Apurímac, a family may have up to 50 varieties of native potatoes that they inherited from their parents and in turn from their ancestors (Quispe, 2013). The conservation of this diversity is mainly due to the cultural tradition of the people who grow them and to the survival strategy of the families themselves.

Also, according to information obtained from interviews with the GEF-SIPAM project specialists in Peru, it was mentioned that a lesson learnt from the implementation of the project is that having diversified (with many potatoes varieties) plots at different altitudinal levels increases climate resilience.[9]

The terms "native potatoes" and "native varieties" are used to denote local breeds or varieties of potato that have been developed through domestication and selection of very diverse local genotypes that are highly valued by Andean farmers. Tubers of native varieties are visually attractive and come in all shapes, colours and sizes. They are a relatively good source of vitamin C, antioxidants, iron and zinc, and offer a new world of possibilities for combating poverty and malnutrition while securing the food supply in the Andes (de Haan et al., 2019).

Cusco is the department with the greatest diversity of native potatoes according to a study by INIA (2019). Evidence of the promotion of native potatoes in the Cusco market, such as the In Situ Conservation of Native Crops Project, where they evaluated the commercial articulation of the sale of native potato crops with hotels and restaurants in Cusco and the results were positive (UNDP, 2006).

[9] The information on the SIPAM project was obtained by interviewing one of the specialists attached to the project (Javier Llacsa).

The most important native potato varieties are the following:

Table *11*:Native Potato Varieties in Resilient Puna departments. Source: MIDAGRI, Sierra y Selva exportadora (2020)

Native Potato Varieties in Resilient Puna departments				
Group	**Apurímac**	**Arequipa**	**Cusco**	**Puno**
Commercial Potato	Huayro, Ccompis,Sani Imilla, Peruanita	Yama Imilla	Ccompis, Yama Imilla, Sani Imilla	Ccompis, Yama Imilla, Sani Imilla
Yellow Potato	Runtush			
Bitter Potato				Shiri and Piñaza (frost tolerant)

Pricing and value added

The prices of the different potato varieties vary, with the Yungay potato variety receiving the lowest price on average (PEN 0.90 per kg) and the Amarilla Tumbay variety receiving the highest average price (PEN 1.78 per kg). Prices vary according to the months of the year and prices are highest between December and March, and lowest between April and November, with variations due to market dynamics and supply problems. The following table shows the average prices over the last 5 years:

Table *12*:Potato varieties / Average prices over the last 5 years. Source: SIEA (MIDAGRI, 2023).

Department	Average farm gate price for the last 5 years (PEN per kg)	Average price for the last 5 years on the wholesale market (PEN per kg)
Apurímac	1.39	1.32
Arequipa	1.06	
Cusco	1.17	
Lima	1.16	
Puno	1.63	
Total	1.28	1.32

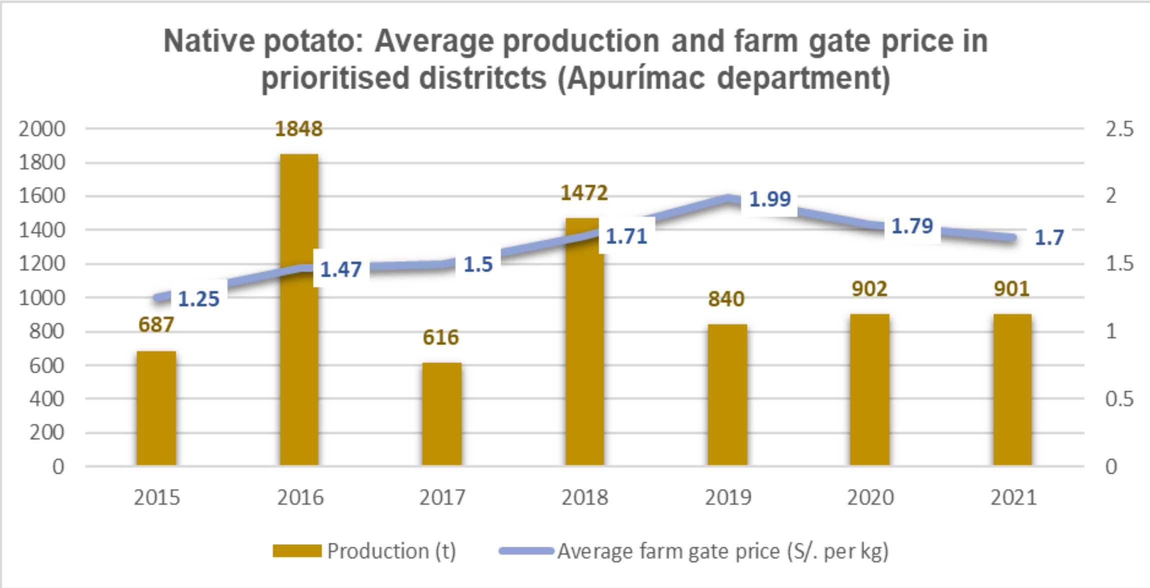
Depending on the potato variety, the price also varies, and an important aspect to highlight is that the prices of native potatoes, such as yellow potatoes, are less dependent on imported fertilizers (MIDAGRI, 2022) which determined the price increase at world level due to the Russia-Ukraine conflict:

Table *13*: Average price of native potato by time interval (7 days). Source: MIDAGRI (2023)

Average price of native potato by time interval (MIDAGRI) - 7 days								
Potato (2022)	**Potato (2023)**	Yellow Potato	Peruvian Potato	Papa Huayro	Huamantanga Potato	Andean Black Potato	Papa Color	Papa Blanca
1,36	**2,10**	3,35	3,23	2,92	2,67	2,10	2,09	1,99

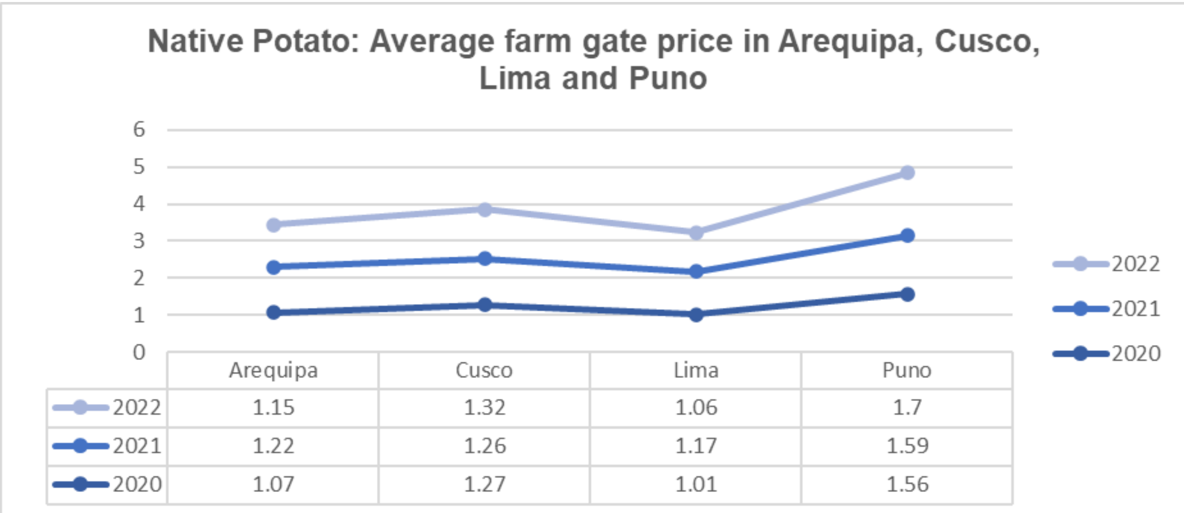
According to MIDAGRI's production profile data (2023), potato production and the price obtained by farmers in the prioritized districts in Apurímac department was as follows:

Figure *21*: Native potato: Average production and farm-gate price in prioritised districts (Apurimac). Source: SIEA - MIDAGRI (2023)



There is only systematised information at district level available for the department of Apurímac regarding the price and production of native potato. However, it is known that there is significant production in the other departments of Arequipa, Cusco, Puno and Lima (Yauyos). Unfortunately, the systematisation of information is not updated in the official databases of MIDAGRI at district level, but it is updated at departmental level. In this sense, the following figure emerges in the project's intervention departments.

Figure *22*: Native potato: Average farm-gate price in Arequipa, Cusco, Lima and Puno. Source: SIEA - MIDAGRI (2023)



- Average prices at departmental level in Arequipa, Cusco, Lima and Puno remain in the range of prices obtained at district level (Apurimac).Climate change

The effects of climate change on crop production are complex, as plant growth and yield are related to temperature. Potatoes can grow in various environments but are adapted to temperate climates. For example, if the temperature is above 17 °C, tuberization decreases, while if it is below 0 °C, crop damage can be quite severe. This said, the effect of global warming in environments where low temperatures limited potato production could now benefit potato cultivation but would be extremely adverse in environments where potato growth is currently optimal.

In the agro-ecological zones of the Puna, in addition to the increase in temperature, there are currently other climatic events that put agricultural production at risk, such as frosts, droughts and hailstorms that generate risks of production losses and loss of genetic diversity of native potatoes (Practical Solutions, 2018). This is compounded by the emergence of new diseases such as rancha, also known as tizón tardío and seca seca.

Increased carbon dioxide in the environment can also produce different responses in potato crop yields. Studies show that a high concentration of carbon dioxide in areas where potato crops are grown reduces the chlorophyll in the plant as well as in the specific leaf area. Another consequence is that when carbon dioxide is high, the rapid ageing of the leaf may be due to increased photosynthesis and increased use of nitrogen for carbohydrate production (Practical Solutions, 2018).

- Agricultural practices

It is usual in potato fields in the highlands to use the system of associated crops, i.e., a single plot of land is used to grow several crops at the same time. The most common associations in this area are maize and potato, and potato is also associated with broad beans and peas (SENASA, 2020).

In terms of food security, oca (Oxalis tuberosa), olluco (Ullucus tuberosus) and mashua (Tropaeolum tuberosum) are the three most important Andean root and tuber crops, in addition to potato. The combined cultivation of potato with oca, olluco and mashua is a tradition dating back thousands of years, and they provide valuable additional nutrients to the basic potato diet (CIP, 2015).

Crop rotation is also a strategy to control pest management in potato cultivation. For example, potato is the main host of the NQP nematode that causes premature plant ageing. This situation allows for rotation with other Andean crop species. For example, planting maize, olluco and broad beans during two seasons prior to planting potatoes allows a good yield, good economic profitability, and a higher marginal rate of return of the crop (Agrobanco - UNALM, 2011).

- Barriers and opportunities

The most important problem currently affecting the supply of native potatoes is the lack of water for the crop due to droughts and sudden changes in rainfall. Another problem is the lack of organization among producers so that they can market collectively and have greater bargaining power with wholesalers. We can also mention the lack of supply of certified seed or quality seed of the most commercial varieties of native potatoes. They have to buy from other producers informally or barter.

Another obstacle that the native potato value chain must face in order to improve its efficiency in the process of adapting to climate change is the diversity of losses that exist throughout the value chain. The main causes of losses found in the study by Ordinola and Triveño (2017) in potato cultivation were lack of rainfall and drought, frost, Andean weevils and frog; problems that will increase with climate change.

Community-based tourism also plays an important role for families involved in potato production, as tourists have the opportunity to visit rural places and have direct contact with the villagers, learn about their lives, cultures and traditions in an authentic way, creating income opportunities at the local level. For example, in the Nor Yauyos Cochas Landscape Reserve (Lima), the cultivation of potatoes in the system of terraces of four types: Wari, Pre-Inca, Inca and Pata Pata, where the cultivation, following and dripping of the soil with the chaquitaclla is carried out, is attractive to visitors. In Ayacucho, the "potato route" has been created, which allows national and foreign tourists to learn about the origin of the potato, from its sowing to its use in local gastronomy. This is complemented by visits to the mountains to learn about wild varieties of potato, oca, mashua and olluco.

Technological / innovation

- The obstacles faced by the agribusiness today are that the production and marketing of potatoes of the requested varieties are irregular, in addition to the issue of seasonality, lack of availability of quality seed and fresh perishability[10] .
- The application of technology is needed for crop development and for processing potatoes into higher value-added products. The use of technology will help the farmer in soil preparation, fertilization, weather risk management, seed treatment, and storage and processing.

- Through the GEF-SIPAM Project, implemented by FAO and the Ministry of Environment, it has been documented that in Andean agricultural production, there is a system of signs and indicators that are applied to conserve agrobiodiversity in each place, and it is made up of many elements such as birds, mammals, clouds, plants, among others. For example, if the howl of the fox is "beautiful", it will be a good year for grain and tuber crops and also heralds the rainy season. Likewise, in Cusco, when the lequecho bird is observed flying from the heights to the village, it means that the time of frost is coming, among others.
- In 2016, ADER's, a private company, was granted the qualification to operate as a private Centre for Technological Innovation in Crafts and Tourism (CITE) for potato and other Andean crops, with the objective to engage in research, training and technology transfer of potato and Andean crops in Peru.

Economic

- Lack of market knowledge, intermediaries, insufficient or no access to finance, high transport costs if production is small).
- Consumers undervalue the different varieties of native potatoes in the local market, not recognizing the differences between native potatoes and conventional potatoes, paying a minimum margin (10 or 20 cents) in favour of native potatoes, which does not represent a profit for the producers.
- Native potato producers are not targeting their production to market segments that recognize the value of native potatoes and pay the corresponding differential. They are selling in mass markets in competition with conventional potatoes. They lack organization for joint marketing and distribution channels that allow producers to reach market segments that are willing to pay a better price.
- One of the problems Peru faces with regard to potatoes is overproduction - especially from the highlands, as mentioned and shown in the preceding paragraphs and tables/graphs - which is often below the cost of planting and harvesting. For this reason, an adequate sowing plan is necessary in order to be

[10] MIDAGRI, Exporting Highlands and Jungle (2020)

able to harvest potatoes in other months of the year. This requires water sources because all depend on rainfall.

- Low crop yields, production costs.
- The farmer's investment per hectare is minimal; he does not invest in the main crop input (seed), which represents between 50% and 60% of production costs.
- The local market for native potatoes in Peru needs to be strengthened. While there are initiatives that support marketing, such as the Kusikuy fairs, or the festival of native potatoes in Lima, these are events that require a high degree of subsidies, which would not be possible without the support of public and private entities.

Social

- Limited educational training is a barrier to technological innovation, weak level of associativity, informality, consumption of high Andean crops (native potato, chocho, etc.) is not widely spread in the country.

Institutional

- Precarious public services, access to roads/roads, limited digital management for data/information retrieval and monitoring, levels of informality.
- There is no single register of potato producers that would allow permanent monitoring of the harvested area as well as the population behind it.
- There are no departmental potato producers' associations to plan, organize and market the planting campaign, as well as to represent the producers in different roundtables with the public and private sector regarding the production and promotion of the tuber.
- Limited use of quality seed standards (certified or meeting certain use requirements), which allow for disease control, improvement of variety types, standardization and certification of purity of production. For example, the United States has in most producing states.[11]

Gender issues

In relation to the management of arable land, in all four regions women manage between 25% and 35% of the irrigated arable land, and in rainfed land (rainfed only) the gap is even wider, with only 15% to 31% of the arable land.

In terms of irrigated area, the gap between women and men in Arequipa is similar to the national level, far exceeding Cusco, Puno and Apurímac. In the rainfed gap, Apurímac and Cusco are well above Arequipa. Puno has the smallest gap.

In all four departments, women have a lower average number of plots than men, below the national average and more markedly so in Apurímac, Puno and Cusco. In Andean family farming, the number of plots is related not only to the total cultivable area per person and the volume of production, but also to risk management: the greater the number of plots located on different ecological levels, the lower the agro-climatic risk (whether from frost, hailstorms, drought and pests or diseases) that the farmer has to face, and the higher the production expectation.

[11] Supreme Decree Nº 010-2018-MINAGRI approves the specific regulation of potato seeds in accordance with Law Nº 27262, General Seed Law, which establishes the rules on activities of production, certification, marketing and supervision of potato seeds, as well as infringements and fines in the sale of seeds. However, it does not focus on the provisions for use by the producer.

Women and men farmers by land tenure status. Although they have fewer plots than men in all regions, women are more often owners than men in Apurímac, Cusco, Arequipa and at the national level, with the exception of Puno. Conversely, there are more male communal landowners than female communal landowners in these same regions, with the exception of Puno. Leasing is in the minority, except in Arequipa, and particularly by men, with a significant gender gap.

According to Cubas (2020), today in the Andean zone of Peru, as well as in many other parts of the developing world, potato cultivation is still labour-intensive. Women farmers provide almost all of the labour in small- and large-scale potato production, from seed saving and selection, to harvesting, storage and marketing. The author mentions that this overload has become more pronounced in recent years due to the migration of men to urban centres for work, which has left women farmers in charge of almost 70% of the agricultural work for their families. Women play a key role in household food security and are almost entirely responsible for potato production. They also possess inimitable knowledge and skills in domesticating native potatoes and adapting new varieties..

In Peru, some state entities have been promoting women's participation in the potato value chain. For instance, the National Agricultural Health Service (SENASA), during 2021, empowered women in Cusco to improve the production of native potatoes in rural areas. To this end, capacities in Good Agricultural Practices were strengthened through the Farmer Field School, with the aim of improving the food chain and the ecosystem with the use of biological agents, organic fertilisers and integrated pest management (SENASA, 2021).

SWOT analysis

Strengths	Weaknesses
In terms of cultivation: ● There is a great diversity of native potatoes of different colours, shapes and sizes. ● The native potato fetches a higher price than the commercial potato and can be produced with agroecological practices. ● Tolerance of native potato to various stresses that characterize the region including drought and frost. ● Low requirement in terms of agricultural inputs (fertilizers, management, pesticides, etc.). ● Its cultivation is part of Peru's cultural heritage. At the gastronomic level: ● It is a nutritious and healthy product highly valued for its natural qualities.	At the production level: ● There is a low level of agricultural yield or productivity. ● Little organization of native potato producers. ● Native potatoes are labour-intensive with very few mechanized operations (especially in the post-harvest phase). ● Lack of availability of good quality seed. ● Susceptibility to diseases such as late blight. In value-added and marketing: ● Basic marketing channels, with reduced price differentiation in local markets. ● Lack of promotion and communication around native potato products.

Strengths	Weaknesses
• The native potato contains vitamin C, anthocyanins and high-quality carbohydrates.	• Poor product quality.
Opportunities	**Threats**
• Willingness of national development agencies to promote soil conservation practices where native potato has potential in the area. • Availability of national and international agricultural fairs for exhibition of native potato products. • Increased interest in healthy food consumption by individual consumers and restaurants. • Growing national and international market for native potato products such as chips, tunta, and dried potato. • Development of promotional events at national level to position the native potato in markets (Kusikuy, Native Potato Festival). • State initiatives that promote agrobiodiversity conservation and food security in the country (MINAM's ReSCA initiative, SERNANP's Aliado por la conservación brand) • The relationship with the gastronomic sector is very important for the promotion of native potatoes. The main Peruvian restaurants, recognised worldwide, have introduced native potatoes in their offer.	• Substitutes are numerous, such as rice, noodles and bread. • Lack of infrastructure for production (irrigation, canals and reservoirs). • There is a lack of local infrastructure to add value to native potatoes. • High cost and slow organic certification process. • Climate variability and negative effects of droughts and heat waves on native potato production. In periods of drought there is more insect attack, which can reduce yields by 10-20%. Excessive rainfall causes fungal damage such as rancha, which can lead to an 80% yield loss. • Loss of genetic yield due to the use of seeds harvested over many years. • The development of promotional events in major cities in Peru requires a high degree of subsidy. • Native potato prices are variable throughout the year.

5.2.2 South American camelids value chain: Alpaca and vicuña value chains

5.2.2.1 Alpaca value chain

- Markets

Alpaca meat is not considered an important meat at the national level, but it is important at the regional level where the production value of alpaca meat has increased from PEN 167 to PEN 224 million per year between 2007 and 2019.

As far as alpaca fibre exports are concerned, the main countries are the USA, China, the UK, Norway, South Korea and Italy.

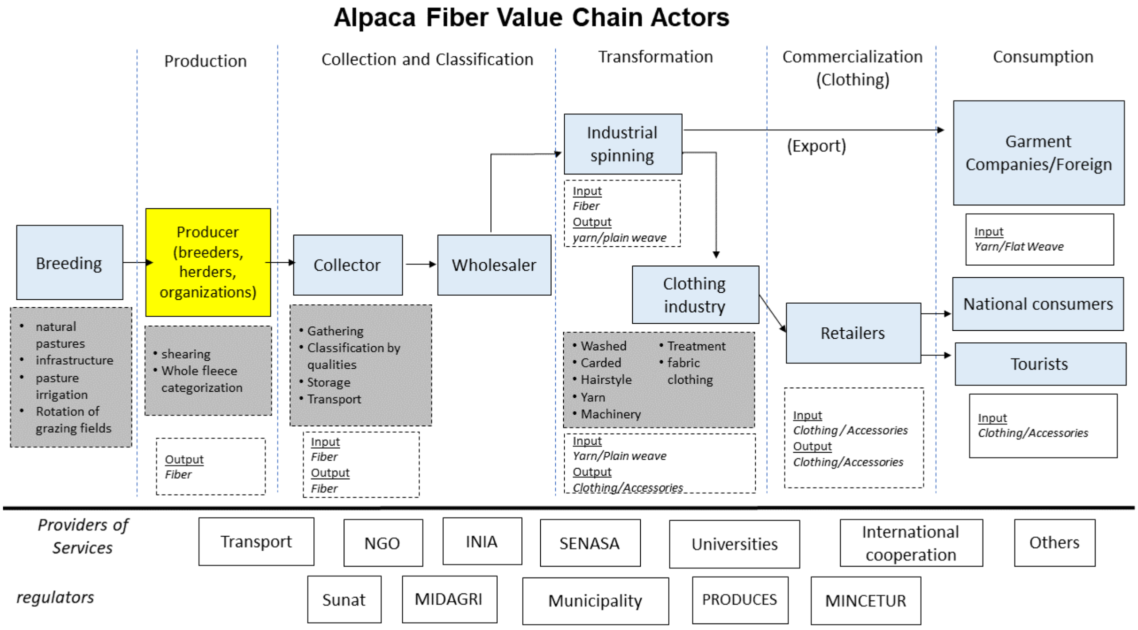
In terms of departmental distribution of alpaca fibre, in 2021 Puno accounted for 61% of alpaca fibre production, Cusco for 15%, Arequipa for 3% and Apurímac for 2%. The prices of both fibre and meat vary according to the producing areas. Apurímac, for example, in addition to having fewer alpaca producers than its neighbours, also has the lowest prices for fibre and meat than the other departments, and on the other hand, the departments with the highest productivity and dependence on alpaca as a livelihood, such as Arequipa and Puno, have the highest prices for both alpaca fibre and meat.

Table *14*: Prices and weight of alpaca fibre. Source: SIEA - MIDAGRI (2023).

YEAR	VALUE IN USD	NET WEIGHT (T)
2015	3547,5	52.788,98
2016	2998,6	36.806,98
2017	5418,2	78.315,36
2018	5108,6	95.123,64
2019	3294,0	61.628,02
2021	4794,3	76.172,14
2022	4057,8	67.096,67

- Value chain actors

Figure *23*: Alpaca fiber Value Chain Actors



The alpaca value chain, like the native potato chain, is divided into sub-chains such as alpaca fibre, fresh alpaca meat, dried alpaca meat and alpaca leather. The best known and most traditional is the sale of alpaca fibre, with alpaca meat in second place. As observed in the field, the alpaqueros/as use alpaca fibre as much as possible in their herds, up to a maximum of 10 years, and then sell the animals standing to meat traders who buy the animals at fairs for slaughtering and marketing. The sale of the fibre and the sale of the animal for meat are businesses that are being carried out by the alpaqueros/as.

The alpaca fibre value chain starts with alpaca rearing by peasant families living in the high Andean areas of Peru. This first link in the chain involves feeding with natural pastures, irrigation in the dry areas and rotation of the grazing fields; a fundamental part of the production of alpaca fibre,

In the second link are the producers, who can be breeders, shepherds or be grouped in organisations. In this part of the chain, the process of shearing (harvesting of the fibre) is carried out, which consists of cutting and separating the fleece or total set of fibre that covers the alpaca. Normally this process takes place between October and April (due to the rainy season in the high Andean regions). Shearing requires space, tools and specialised personnel, as well as compliance with specific steps, in order to guarantee the welfare of the animal and to obtain a quality fibre. After shearing, the fleece is categorised (extra-fine, fine, semi-fine and coarse fibre).

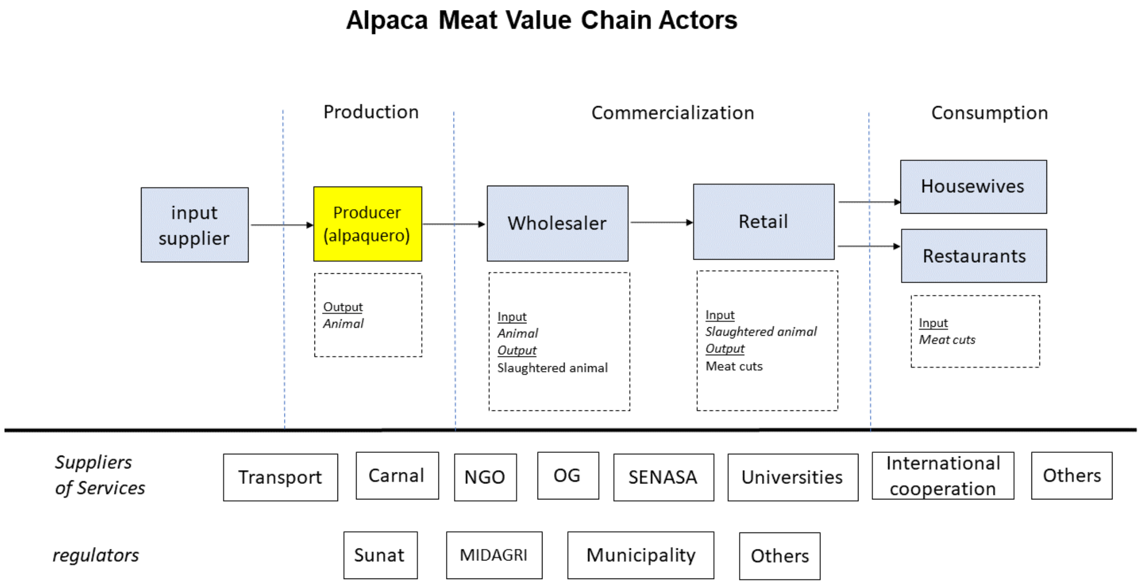
The next link corresponds to the collectors, who form part of the intermediaries along with the rescuers, retailers and wholesalers. Gatherers are in charge of gathering the production, including in many cases the categorisation process. Located in the production zones, they are the ones who sell to wholesalers who in turn supply the alpaca fibre industry located mainly in the city of Arequipa. In this next link, the classification of the fleeces is carried out by specialised people, followed by washing, sifting, combing, spinning and finally weaving. These processes mentioned above include the following (INIA,1996):

- Washing**:** Washing in mechanical vats using water at high temperatures mixed with detergents and sodium carbonate in different concentrations. In this operation, soil, organic impurities and fats are removed. The main purpose of washing is to remove all foreign matter from the skeins, discarding all dirt coming from the raw material storage and other processes.
- Carding**:** This process includes a set of mechanical and successive operations carried out in order to progressively open, individualise, parallelise and clean the fibres to finally produce a roving or ribbon.
- Combing**:** It allows combing and unifying the fibre to obtain a uniform strand by means of combs, which comb the fibre over the whole width of the machine, to later join it into a strand.
- Spinning**:** This process involves steaming of bobbins, resting and drying of yarn, dyeing of yarn, furring of yarn, and twisting of yarn.
- Weaving and knitting: Weaving is the process by which yarns are transformed into finished garments in knitted or woven fabrics; and tailoring is the process involving designing and cutting, sewing, washing, steaming and finishing.

Both the spinning and clothing industries are largely dedicated to the export of alpaca fibre. However, it should be noted that the alpaca industry has expanded into the production of garments; they sell directly to consumers in their own chain shops located in Lima, Arequipa and Cusco. They also sell alpaca yarns to the clothing industry (both handmade and more elaborate garments) which they distribute to the final public through shops or stalls selling to the national and international tourism sector.

Finally, it is important to point out the main institutions that also form part of the chain as regulatory actors and service providers. As can be seen in the graph, there are governmental entities at different levels and sectors, research and technological innovation institutions, non-governmental organisations and professionals who contribute to the sector such as academics, scientists and technicians.

Figure *24*: Alpaca meat Value Chain Actors



On the other hand, the alpaca meat value chain has a smaller number of actors. Producers (breeders, herders, alpaquero organisations) sell the live animals to middlemen who take the animals to slaughterhouses for processing and to sell the meat to final consumers (households) basically through retailers (market stalls, supermarkets). In the alpaca meat value chain, there are also restaurants that prepare various dishes for the final consumers. In this link, high segmentation (gourmet) restaurants can be found as well as restaurants targeting a popular market.

It is important to mention that the alpaca meat value chain shares the breeding link with the alpaca fibre value chain. This implies that the more the alpaca feeds on quality nutritious pasture, the better the meat and the better the fibre.

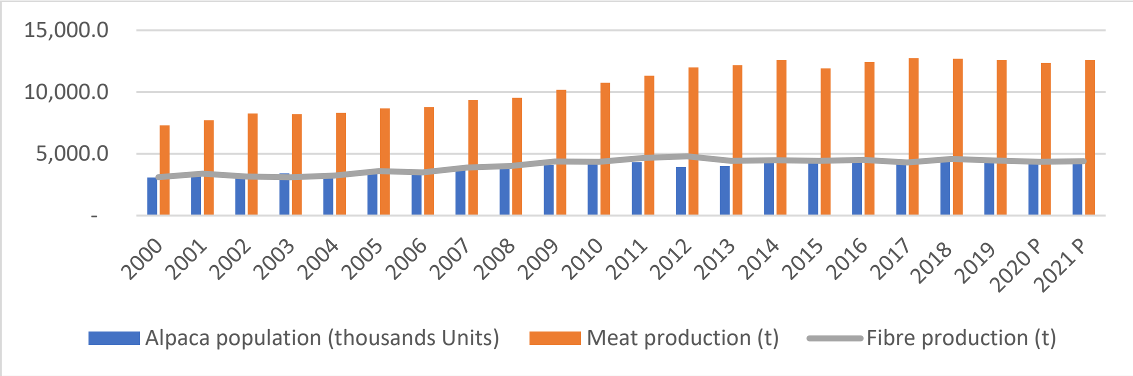
- Economic analysis

The main activity of the High Andean communities settled above 3,800 masl is livestock raising, with South American camelids being the most adapted and developed in this ecological zone. Furthermore, they are the main livelihood and economic activity for the communities living in these arid areas of the Andes.

The main alpaca production area is the department of Puno, with 2,030,525 head of cattle, followed by Cusco (673,731), Arequipa (471,546) and Apurímac (212,220). In Puno, besides having the highest production, they also have the best prices per kg of alpaca meat, higher fibre yield per alpaca than the other 3 departments (between 5 and 9% higher yield), representing 61% of all the fibre produced in the country (4,403 t) and 46% of all the meat produced in Peru (12,583 t).

At the national level, the evolution of alpaca units and production of meat and fibre for the period 2000 and 2021 was as follows:

Figure *25*: Alpaca units and production of meat and fibre at national level (2000-2021). Source: Livestock and poultry production yearbook 2021 of the Ministry of Agriculture (MIDAGRIb, 2022).



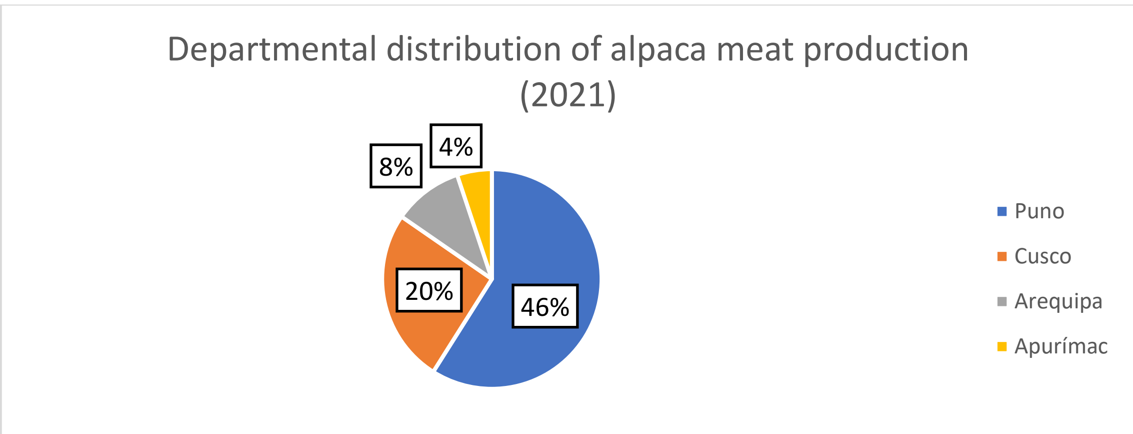
As for the departments within the project area, they have experienced a significant decline over the past 10 years, as outlined below:

Table *15*: Percentage reduction of alpaca fibre production in the Resilient Puna departments 2012-2022 (tonnes). Source: SIEA (2023) - MIDAGRI.

Region	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Avg
Puno	2805	2707	2764	2732	2733	2642	2644	2660	2682	2691	2424	
		-3.5%	**2.1%**	**-1.2%**	**0.0%**	**-3.3%**	**0.1%**	**0.6%**	**0.8%**	**0.3%**	**-9.9%**	-1.4%
Cusco	727	583	598	605	621	569	694	634	659	744	467	
		-19.8%	**2.6%**	**1.2%**	**2.6%**	**-8.4%**	**22.0%**	**-8.6%**	**3.9%**	**12.9%**	**-37.2%**	-2.9%
Arequipa	385	370	415	296	277	209	186	183	148	123	107	
		-3.9%	**12.2%**	**-28.7%**	**-6.4%**	**-24.5%**	**-11.0%**	**-1.6%**	**-19.1%**	**-16.9%**	**-13.0%**	-11.3%
Apurímac	156	154	147	138	122	91	81	80	78	77	60	
		-1.3%	**-4.5%**	**-6.1%**	**-11.6%**	**-25.4%**	**-11.0%**	**-1.2%**	**-2.5%**	**-1.3%**	**-22.1%**	-8.7%
Total		**-28.5%**	**12.3%**	**-34.8%**	**-15.3%**	**-61.7%**	**0.1%**	**-10.9%**	**-16.9%**	**-4.9%**	**-82.2%**	**-6.1%**

However, alpaca meat production increased from 7,300 t in 2000 to 12,580 t in 2021, with meat production stabilising in recent years. The distribution of alpaca meat production in the project area was as follows:

Figure *26*: Departmental distribution of alpaca meat production (2021)



The demand for alpaca fibre is permanent, but the price remains low and does not meet the expectations of the producers. The same is true for meat, but alpaqueros/as have been finding ways to get a better price through sales at fairs or hammer auctions organised by local governments and communities. At these fairs they can sell a live alpaca for PEN 250-300, getting a better price than selling to middlemen.

Average yields for fibre are between 1.8-1.97 kg per bale, while for meat they are between 24.32-27.65 kg per bale.

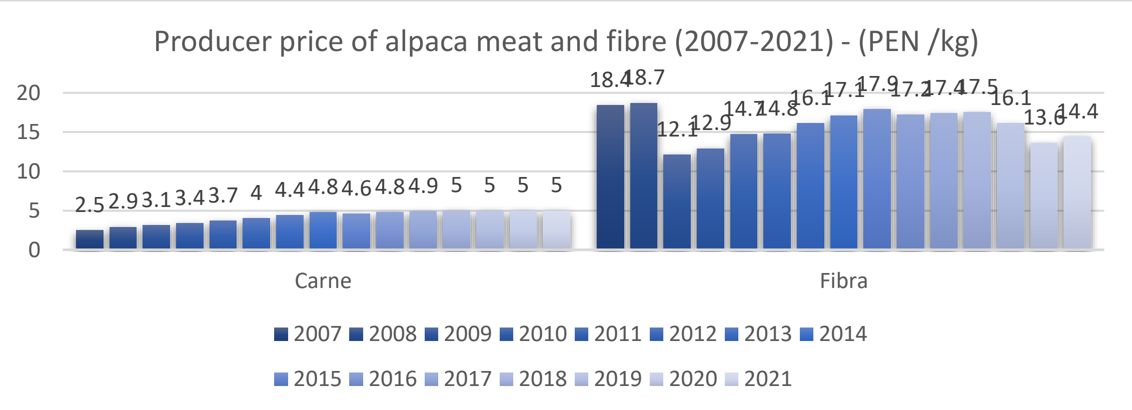
Table *16* Agricultural units and areas of small alpaca producers (with up to 199 alpacas per producer) in the districts prioritised by the Resilient Puna proposal in southern Peru. Sources: (1) National Agricultural Census 2012 and (2) Poultry and Livestock Production Yearbook 2019 (CENAGRO values correspond to districts selected by resilient puna, while yield values correspond to departmental averages from the Yearbook).

Department	AU with less than 199 alpacas	Number of AU alpacas with less than 199 alpacas	Number of ha. Grassland/alpaca*	Average fibre yield (kg/bale)	Average meat yield (kg/bale)
Apurímac	1,006	57,286	4.83	1.977	24.32
Arequipa	3,726	165,844	3.82	1.932	24.64
Lima	385	17,097	5.36	1.571	26.85
Cusco	7,783	265,273	3.20	1.960	26.60
Puno	4,718	185,453	1.87	1.942	27.65
Total	17,618	690,953	3.13	1.876	26.01

* Native grasslands are made up of bofedales, wet puna grasslands and dry puna grasslands and include 100% of the alpacas.

Alpaca meat prices have increased over time, and between 2011 and 2021, the price of alpaca meat has increased by 37% (PEN 3.65-5 per kg), but like alpaca meat production, prices have also stabilised since 2014.

Figure *27* Evolution of alpaca meat and alpaca fibre prices between 2000 and 2021.



Source: Livestock and poultry production yearbook 2021 of the Ministry of Agriculture (MIDAGRI, 2022b).

Currently, alpaca fibre prices are low, having reached PEN 13.6 per kg in 2020, which is 24% lower than the highest average price recorded in 2015. Even back in 2008, the price reached as high as PEN 18.7 per kg. In some regions, bartering is still practiced, however, some middlemen take advantage of this system by undervaluing the fibre and overvaluing items like sugar, rice, or noodles, while also manipulating the weights. Consequently, the sales of alpaca fibre for an average producer generate only about PEN 1,800 per year at the current prices, which translates to about PEN 150 per month for a producer with 50 alpacas (according to MIDAGRI). This amount is considered to be very low.

Alpaca fibre production peaked in 2012, reaching almost 4800 t, but then stabilised between 4,400 and 4,500 t on average since then, with a drop in production to 4,312 t in 2017 and 4,352 t in 2020, the latter probably due to the effect of the pandemic. The price of alpaca fibre has decreased by 7% between 2011 and 2021, but had a price peak between 2014 and 2018, which reached prices of PEN 17.9 per kg.

Table *17* Price (S/ x kg) to the producer of alpaca fibre in the Resilient Puna departments (2019-2022). Source: SIEA - MIDAGRI (2023).

Department	2019	2020	2021	2022	Average
Apurímac	12,55	12,90	12,57	12,84	12,71
Arequipa	17,03	13,96	16,57	16,54	16,02
Cusco	14,44	14,37	14,78	14,82	14,60
Lima	14,06	14,00	13,03	13,77	13,71
Puno	17,03	13,42	14,54	14,86	14,96
Total average	15,02	13,73	14,30	14,57	**14,41**

Prices per kg of meat also vary between departments, with Puno receiving the highest price (PEN 5.36 per kg), 40% more than Apurímac which receives the lowest price (PEN 3.78 per kg).

Table *18* Producer price (S/ x kg) for alpaca meat in the Puna Resiliente departments (2019-2022). Source: SIEA - MIDAGRI (2023).

Department	2019	2020	2021	2022	Average
Apurímac	3,87	3,85	3,78	3,71	3,80
Arequipa	4,98	4,90	4,77	4,67	4,83
Cusco	4,46	4,48	4,51	4,53	4.50
Lima	4,21	4,23	4,20	4,13	4.19
Puno	5,38	5,54	5,36	5,25	5.38
Total average	4,58	4,60	4,52	4.46	**4.54**

The income of the producers depends on the sale of fibre (50%), live animals for consumption (45%) and 5% from other sources (breeding stock, leather and manure). The estimated production of alpaca fibre for the year 2020 is 5,072 t, with an estimated Gross Value for the same year of PEN 91.296 million. More than 80% of the national fibre is exported to cover the demand of European, Asian and North American countries (MIDAGRI, 2022c).

There are innovative initiatives by some alpaqueros/as who are engaging in handicrafts, making hats and garments for sale in the cities. They sell an alpaca hat for PEN 80 or 100 , depending on whether they sell to local people or tourists; and jumpers for 180 or PEN 200 a piece, which can go up to PEN 400 in tourist markets. The alpaqueros interviewed indicated that it is more economical for them because they use about 30 PEN's worth of fibre investment for a hat. To obtain the necessary fibre, they purchase from their neighbours in the production area at a better price (they can pay up to 1-3 PER more per pound), select the fibre they are going to use and take it to their workshop in the city.

The large alpaca fibre weaving industries have not had good practices for fair trade with the producers, generating unfair losses that can reach 40% when the average is 10%. As these companies have excess stock of fibre, this allows them to buy when prices are low.

VARIABLES	PRODUCER	RETAILER	DOMESTIC MARKET	INTERNATIONAL MARKET
Sale Price Kg – Fibre	PEN 13.60			
Sale Price Kg - Meat	PEN 3.78 – 5.36		PEN 6.00 – 7.50	

- Climate change

Climate change in the Andes has brought about shifts in weather patterns that impact every aspect of the alpaca's life, including the diminishing pastures for their herds to graze on. Sudden changes in rainfall and the melting of glaciers are causing disruption among both alpaca communities and the communities that rear them. A primary challenge currently faced by alpaca producers is the scarcity of water due to reduced rainfall, directly affecting pasture and fodder production for feeding the herd. Consequently, they are incurring additional expenses that were not present before for the animals' breeding. Furthermore, the extreme temperature conditions render the herd more susceptible to diseases and contribute to higher mortality rates among newborns.

- Complementary practices

Recently, alpaca herders have become increasingly aware of the tourism business due to its consistent growth and its positive impact on the local economy, leading to improved income and quality of life. Moreover, tourism has strengthened the alpaca production chain as it has resulted in higher consumption of alpaca meat and increased sales of alpaca fibre to artisans, allowing them to highlight and preserve their local culture (Llerena & Carbajal, 2021).

The demand for handicrafts made from alpaca fibre has significantly risen in the worldwide textile and fashion industry, owing to its unique ability to provide warmth in low temperatures while being light in warmer climates (Proinnovate, 2022). Women predominantly engage in crafting these items, being responsible for hand-weaving or using machinery, as well as promotion and marketing.

In addition, guinea pigs play a complementary role in the value chain, particularly in high Andean regions, where they serve as a source of meat for both family consumption and commercial purposes. During periods of high alpaca mortality caused by extreme weather changes, such as frosts or droughts, guinea pig meat becomes a crucial protein source for rural families, significantly contributing to their food security.[12]

- Barriers and opportunities

Alpaca breeding holds significant importance for the people in the High Andean zone, particularly above 3,500 masl, where breeding other species like cattle faces challenges in achieving high production levels due to the adverse climatic conditions of the Puna. Alpaca breeding comes with several benefits, including the production of valuable fibre for both national and international markets. However, a critical issue arises from the low

[12] Information obtained by interviewing guinea pig specialists at MIDAGRI.

price received for the alpaca fibre they sell, which is currently priced at PEN 12 or 13 per kg, leading to losses in their investment. To make the most of alpaca rearing, producers strategically shear the animals once a year to obtain the fibre for commercial purposes. Once the alpacas complete their lifecycle, which can last an average of 10 or 12 years, they are sold to meat brokers for slaughter and further commercialization.

Moreover, alpacas only give birth during the first three months of the year, coinciding with the rainy season. Unfortunately, this previously reliable season, which helped moderate temperatures, has become erratic. Compounding the challenges, alpacas are sensitive to cold, and sudden temperature fluctuations, including cold snaps, have resulted in the death of thousands of these animals.

Economic:

- Price oscillation (unstable price)
- High competition with other markets (Chinese fibres)
- Low demand in the global and domestic market
- Oligopsony

Social:

- Restriction of women's time to participate in fairs and internships/non-attendance at trainings.

Institutional/Regulatory:

- Little promotion of product consumption
- Regulation and enforcement of health measures
- Poor dissemination of technical standards
- Affect data monitoring

Management:

- Organisational capacity
- Lack of market knowledge
- Lack of value added and product innovation

The primary diseases encountered in alpaca rearing are (AVSF, n.d.):

- Enterotoxaemia, which mainly affects young alpacas at 3-4 weeks of age, causing mortality rates between 40% to 60%. Although there is currently no cure, it can be prevented through good grazing practices and avoiding drinking from standing water and hillside roosts.
- Alpaca fever, caused by feed deficiencies.
- Scabies - mites (Caracha) that result in dermatitis and skin destruction. It is caused by Sarcoptes scabiei and Psoroptes var. aucheniae. These mites are commonly found in areas without much fibre, such as the face, armpits, crotches, around the anus, vulva, and ears. In chronic cases, the infestation can spread all over the body, leading to dry, cracked, and painful crusts.
- Verminous gastroenteritis, a parasitic disease caused by parasites residing in the gastrointestinal tract. The most important parasites affecting alpacas are Ostertagia, trichostrongylos, Graphinema, Camelostrongylus in the small intestine, and Trichuris and Oesophagostomum in the large intestine. Alpacas become contaminated by ingesting grass that carries infective larvae. The infestation in most species occurs through oral transmission.

Gender issues

The availability of irrigation water all year round is a key factor to increase the productivity of family farming, particularly for families in the Puna who raise animals such as camelids and small animals (guinea pigs, poultry), an activity mostly carried out by women and who require fodder in the dry season (from June to October or November) to maintain the size of their herds, their productivity and their income.

The harsh climate (strong winds, low temperatures) as well as the scarcity of water sources do not allow them to grow agricultural crops or high nutritional quality pastures for livestock. Due to this precarious livelihood situation, young and middle-aged women and men travel frequently to the cities and other urban centres to earn supplementary income. Due to an increase in migration, due to limited job options and education centres in the rural areas, there is an increasing absence of husbands and young people (Urruti et al, 2019), and household chores and child rearing fall more heavily on women in rural households, who may also wish to migrate permanently to the cities, if their husbands can find income opportunities to make and sustain such a decision.

Women are crucially involved in alpaca rearing and fibre processing, often taking charge while men temporarily migrate to seek alternative sources of income. Unlike vicuña shearing, which involves both genders and occurs on specific dates, alpaca-related tasks predominantly fall under women's responsibility. However, the yield they achieve is not as high as expected, leading to low productivity. This situation arises due to gender inequalities in accessing and controlling natural and productive resources. Moreover, limited adoption of modern technologies further constrains productivity (Manos Unidas, 2019).

Recognizing these challenges, the Ministry of Development and Social Inclusion initiated the "PAIS" Program, which provided workshops in Arequipa to enhance women's capacities in alpaca breeding. The workshops covered genetic improvement, proper nutrition, and alpaca care during 2019 (Peru 21, 2022). Additionally, Sierra y Selva exportadora facilitated the integration of 12 women from Puno into the social economy of alpaca farmers. This was achieved through training and certification for the alpaca fiber classification process, equipping them with the knowledge to work in the Consorcio Alpaquero Perú Export (CALPEX) as quality control masters and seat masters (Andina, 2015). Furthermore, the Regional Government of Huancavelica organized three "Regional Meetings of Alpaqueras Women" between 2020-2023. These meetings aimed to develop joint proposals to address camelid breeding, including initiatives such as creating water reserves for dry seasons, installing irrigation systems, reforestation, and qochas (ancient Andean water reservoirs). Capacity-building programs for alpaca women were also included (COPROFAM, 2021).

Beyond their role in breeding, women also contribute significantly to the classification of alpaca fibre. As part of this effort, MIDAGRI, through AgroRural, issues official certificates for "master sorters of alpaca fibre." This certification, bestowed in the name of the Nation, attests to the ability to plan, organize, and provide alpaca fibre management services in line with market requirements, generating competitive advantages (MIDAGRI, 2018a).

SWOT analysis

Given that the main business lines or sub-chains of the alpaca value chain are fibre and fresh meat, the following SWOTs can be established:

Strengths	Weaknesses
<u>From alpaca fibre</u>: ● Alpaca fibre is a product of recognised quality in the national and international market. ● Sustainable use of native grasslands that conserves many ecosystem services and generates economic income for vulnerable populations of alpaqueros. ● High quality products made from well managed alpaca fibre. ● Products with alpaca fibre have thermal properties. ● Artisans trained in the production process of alpaca garments. <u>From alpaca meat:</u> ● It is a healthy product due to its nutritional qualities and low-fat content. ● The price is affordable to various market segments. ● It represents a source of protein for the local population. ● There are sales channels (local fairs) for the sale of alpacas for meat.	<u>From alpaca fibre:</u> ● Producers sell alpaca fibre without selection or quality classification. ● The price of alpaca fibre is unstable on the international market. *Small production units that do not exceed the break-even point in production. ● Weak and weak organisation of alpaca producers with low representativeness. ● Producers receive a low price that does not meet their expectations. ● There is no good organisation of alpaca producers. ● Repetitive and non-innovative local designs for local garment production. ● Lack of good shearing practices ● Limited access to the maquila service ● The product is positioned in a market of high commercial segmentation, it does not spread to other market segments. <u>From alpaca meat</u>: ● There are health problems in alpaca meat production (sacorsistiosis). ● It is a product that is undervalued in local markets in relation to substitute products (beef, sheep meat, etc.). ● In exclusive or highly segmented markets, demand is limited.
Opportunities	**Threats**

Strengths	Weaknesses
From alpaca fibre: ● Alpaca fibre has commercial attributes that make it a superior value fibre compared to other fine hair fibres, such as a wide range of natural colours and softness to the touch, characteristics that are unmatched by others. ● Value can be added to reach different market segments. ● There is a potential market at national and international level for products made from alpaca fibre. ● There are governmental organisations and NGOs interested in supporting alpaca fibre producers. ● Positioning in the international market through the Alpaca sectoral brand, promoted by MINCETUR.	From alpaca fibre: ● European crisis reduces demand for this type of fibre ● The marketing of alpaca fibre is bought by a few companies (oligopsony). ● There is an increase in climatic variation (frost, drought, hailstorms/snowfall) that affects alpaca production. ● Scarcity of water resources for alpaca rearing. ● There is a lack of greater organisation of producers for the commercialisation of alpaca fibre. ● Alpacas are exposed to parasitic diseases such as mange, which is a risk mainly for the fibre.
From alpaca meat: ● There is an opportunity for the development of gourmet and healthy markets with a better commercial presentation of the product in tourist restaurants. ● There are non-governmental organisations interested in promoting the development of the alpaca meat market.	From alpaca meat: ● Lack of infrastructure for the processing of alpaca meat (camales). ● Climatic variations exist for the production of alpacas for meat production. ● Alpacas are sensitive to cold snaps, which have caused the death of thousands of animals.

5.2.2.2 Vicuña value chain

- Markets

Peru is the country with the highest volume of vicuña fibre obtained from live sheared animals, with 14,830 kg recorded for the year 2021, making it the world leader (MIDAGRI, 2021). Of the volume obtained in 2021, approximately 80% goes abroad in the following presentations: pre-dehorned fibre, dirty fibre and dehorned fibre. The demand for vicuña fibre is derived from the production of high quality and high-priced garments. The domestic market lines are fibre, yarn, felt, garments and handicrafts. The main international destinations include the USA, China, the Netherlands, South Korea and Italy.

At the national level, the export of vicuña fibre (kg) in recent years has been as follows:

Table *19*: Vicuña fibre (kg) exports. Source: Directorate for the Sustainable Management of Wildlife Heritage - SERFOR

Type of fibre	2017	2018	2019	2020	2021
Total (kg)	**4858.681**	**5179.700**	**6756.653**	**6941.666**	**5503.094**
Pre-decomposed fibre	3725.165	4621.854	4982.190	4688.953	3612.987
Washed fibre	100.000	0.000	0.000	227.604	
De-zippered fibre	169.292	143.960	316.742	319.968	925.091
Staple fibre, panties and bristles	0.000	0.000	0.000		55.850
Dirty Fibre	864.224	413.886	1457.721	1705.141	909.166

- Value chain actors

The vicuña fibre value chain is characterised by the participation of few actors.

In this chain, the first link is access to rights, as producers need to belong to management holders in order to capture, handle and shear the vicuña (wild animal). In this sense, once they have the permit and carry out both capture and shearing, primary processing is carried out through the collectors or exporting company. The capture and shearing workers only work between June and November inclusive, or, in general, the period of the year that corresponds to the capture and shearing.

The dehairing is done by the women and the payment is based on yield: USD 0.05 per gram of fibre processed. The dehairers work on a piecework basis: a dehairer in a daily working day can dehair between 22 and 60 grams of clean dehairing fibre. An average of 45 grams of clean dehairing fibre per dehairer is considered to be 45 grams of clean dehairing fibre.

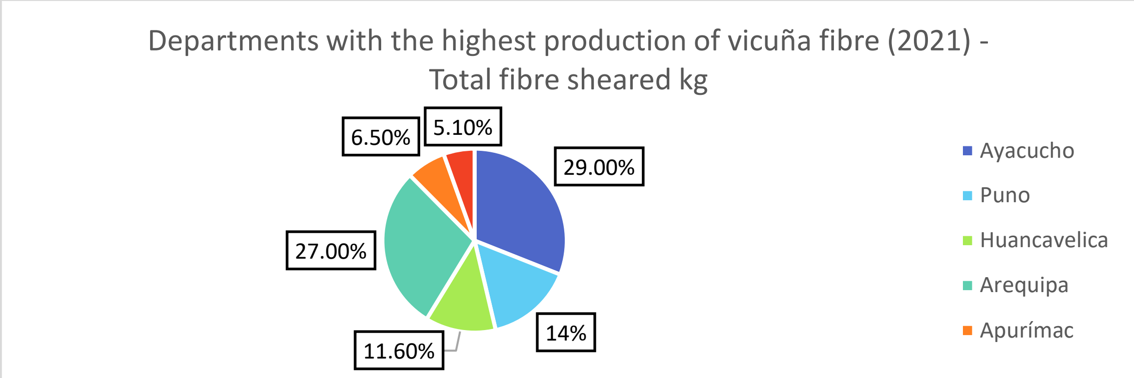
Organised producers sell (mostly) vicuña fibre to the export industry, which sells it on the foreign market. Secondary processing is largely carried out by export companies; however, some producers produce shawls, jumpers, shawls, etc. and sell them to tourists.

The industry that is in the alpaca fibre business is practically the same as the one that markets vicuña fibre. It is worth noting that some peasant communities have exported vicuña fibre directly, with the support of public organisations such as the Sierra Exportadora programme of MIDAGRI. Due to the high price of vicuña fibre, commercialisation and therefore the value chain is basically focused on the international market.

- Economic analysis

It is important to highlight that the departments within the scope of the project produced approximately 54% of vicuña fibre in the last campaign in 2021:

Figure *28*: Vicuña fibre production, total fibre shered in kg (2021). Source: DIR - SERFOR (2022).



Within the districts prioritised by department, the minimum values range from 10.19 kg in Macusani (Puno) to 1030.6 in Chachas (Arequipa) in Chachas:

Table *20*: Vicuñas fibre production and units sheared in prioritised districts. Source: MIDAGRI, DGPA, DEEIA, GORE, SERFOR (2019), SERFOR (2022).

Department	Weight per fleece (grams x vicuña)	Vicuñas sheared (units)	Fibre production (kg)	Fibre weight (kg) 2021 (SERFOR 2023)
APURIMAC	131-161	610	89.7	166.7
AREQUIPA	176-198	6672	1253.1	2566.8
CUSCO	158 -243	1463	272.3	414.1
LIMA	157-209	1283	0	0
PUNO	131-161	610	220.5	178.3
Total	**155-2020**	**1028**	**1835.6**	**3326**

As for prices, they have fluctuated over time. According to Briceño (2013), the prices paid to the producer (management holder) have decreased considerably during the period 2008 to 2012, affecting profitability:

Table *21*: Price variation at vicuña fibre handling headline. Source: Panel A, Survey of 10 Headlines, November 2012. Working Table, Panel B, DGFFS of MINAG.Prepared by Arturo Briceño, "Análisis Económico de la Vicuña" (MINAG,2013).

Price variation at vicuña fibre handling headline (USD per kg)

A) Period 2010-2012			
	Maximum	Minimum	Average
Dirty	400	120	279
Predeclared	520	390	455
Unlocked	670	380	525
Cut	100	70	85
B) Period 2006-2007			
	Maximum	Minimum	Average
Dirty	437	380	409
Pre-decorated	507	475	491
Unlocked	650	625	638
Cut			70

The price fluctuation generates great uncertainty for the producer, who opts for other activities in order to obtain income. In 2022, the price for dirty fibre fell to USD 280 per kg, and for pre-dressed fibre to USD 380 per kg.

The added value given to the vicuña fibre is the factor that determines a higher price; unfortunately, it is the foreign companies that obtain that additional income and not the producers, as they do not have the level of technology that the medium and large companies have (existing intermediary chain). The price difference is as follows:

Gathering company pays producer **USD 280-330** per kg of soiled fibre

It is sold to the foreign company as de-waxed fibre at **USD 760** per kg.

Domestic company pays producer for de-husked fibre **USD 650** per kg.

They add value and sell at **USD 1600** per metre of fabric.

Source: Action Plan for sectoral intervention to strengthen the chains associated with South American camelids 2023-2027 (MIDAGRI). The prices shown in the paragraph are averages of the last 10 years. SERFOR database. The price of USD 760 per kg refers to manual dehairing, which is the most commonly used; in cases of mechanical dehairing, as it includes pre-washing, it can be quoted at more than USD 1,000 per kg.

In recent years, the Free on Board (FOB) value in USD per type of vicuña fibre exported has been as follows:

Table *22*: Free on Board (FOB) value in USD per type of vicuña fibre exported. Source: Directorate for the Sustainable Management of Wildlife Heritage - SERFOR

Type of fibre	2017	2018	2019	2020	2021
Total FOB value (USD)	**2,299,762.090**	**2,194,989.255**	**2,732,877.230**	**3,087,483.270**	**2,331,254.295**
Pre-decomposed fibre	1,598,976.660	1,888,378.455	1,891,446.620	1,771,683.120	1298133.275
Washed fibre	135,000.000			330,025.800	
De-zippered fibre	235,551.200	197,427.000	426,263.400	440,058.600	693,866.800
Staple fibre, panties and bristles					34,085.000
Dirty Fibre	330,234.230	109,183.800	415,167.210	545,715.750	305,169.220

Although the largest percentage of exports (91%) corresponds to the presentation of fibre (mainly pre-dressed and dirty), it is important to highlight the export of finished products (9%):

Table *23*: Vicuña products exports 2017-2021.

Exports 2017-2021	
Product	**Invoicing**
1558 garments (coats, cloaks, jackets, shawls, jumpers, stoles and jackets), mostly shawls.	USD 1,659,760.88
42.8 m of fabric	USD 56,250

- Climate change

Climate change has had adverse effects on the ecosystems and biodiversity of the Andean Altiplano. Increasing temperatures and reduced rainfall have resulted in diminished pastures and a higher incidence of pests and diseases. This situation is likely to negatively impact vicuña populations (Kasterine and Lichstenstein, 2018). Furthermore, climate change has influenced the spatial dynamics of pastures, grazing areas, and vicuña habitat. As grazing areas degrade, vicuñas are forced to cover larger areas with lower-quality pastures and migrate to higher elevations where better pastures can be found (Korswagen, 2015).

Apart from the challenges posed by climate change, vicuñas also face other health issues like dandruff and potentially fatal mange. When afflicted by mange, a vicuña cannot be utilized due to the harm to its skin, and it can also infect other individuals (Tranca, 2020).

- Barriers and opportunities

Various state entities have been promoting the strengthening of the vicuña value chain. For example, MIDAGRI, through Agrobanco, earmarked around PEN 2 million in 2020 for the "Special camelid financing programme" to provide credit facilities to small producers of alpaca and vicuña fibre (MIDAGRI, 2020c). Likewise, during 2023, multisectoral actions have been carried out to combat scabies in vicuñas and to avoid losses of specimens and the impact on harvesting activities (SERFOR, 2023).

Economic:

- Sheared, heterogeneous and atomised fibre.
- Few niche markets identified.
- Poor access to funding for vicuña management holders.
- Little technological development to provide added value at the artisanal level.
- In all transactions the management holder obtains a very low price. It is evident that there is no economic incentive provided by the market, no added value is provided and the supply is heterogeneous and dispersed.

Social:

- Low levels of associativity.
- Organisational weaknesses in producer associations

Institutional and Regulatory:

- Regulation and enforcement of health measures
- Difficult access to media and communication channels
- Affect data monitoring

Management:

- Limited market knowledge.
- Lack of value added and product innovation.
- Process monitoring.
- Cumbersome procedures in the transformation processes.
- Little development of financial inclusion.

Gender issues

Vicuña farming has significantly contributed to improving rural livelihoods in the high Andean regions of Peru, particularly for women who play a vital role in capturing the animals and processing their fibre.

The production process starts in farming communities where they capture, shear, and process the fibre, which comes in different qualities. The transformation of the fibre is a lengthy and delicate manual process involving cleaning, dehairing, and sorting. Women, often working in challenging conditions, hand-clean the fibres before sending them to national or international buyers. In return for their work, the communities receive between 2% to 6% of the total value of the final products (Kasterine and Lichstenstein, 2018).

Twenty years ago, women in Andean societies had submissive and disempowered roles, including in the management of vicuñas. They had little say in communal assemblies where important decisions were made, unless they were the heads of their families (IIED, 2002). However, in recent times, women have taken on more prominent roles in the vicuña value chain by forming productive associations. Additionally, institutions like SERFOR have been providing technical advice to women's associations for the primary processing of vicuña fibre (SERFOR, 2022).

SWOT analysis

Strengths	Weaknesses
● South American camelids are well adapted to the ecological conditions of the high Andes. They withstand low temperatures and water scarcity and have other adaptations to the radical climate and altitude. ● Vicuña fibre is a product of recognised quality in the national and international market. ● Sustainable use of a wild species that generates economic income for vulnerable high Andean populations. ● High quality garments made with vicuña fibre, with characteristics of fineness, softness, lightness, thermal and natural colour. ● SERFOR: records the entire process of using vicuña fibre from shearing. ● Peru has the largest vicuña population in the Andean countries and in the world. ● Promotional events for the positioning of vicuña fibre, such as the "Festival Internacional de Camélidos Sudamericanos" (International Festival of South American Camelids).	● Scarce and weak organisation of vicuña handlers with low representativeness. ● Fibre processing has its own know-how and is costly. ● Limited access to the transformation service ● Limited bargaining power of communities ● Limited application of the technical standard (NTP) on shearing ● Despite the obvious economic potential of South American camelids and their undisputed ecological advantages, most of the punas continue to raise cattle and sheep, with very low profitability and great environmental damage (Dourojeanni, 2014). ● Community members who work directly with vicuñas, most of whom are extremely poor, receive little return.

Opportunities	**Threat**
• Value addition (pre-spun fibre, clean, felted, de-waxed, spun, garment/craft) is possible. • There is a potential international market for products made from vicuña fibre. • Implementation of good shearing practices for a better management of the resource. • Opening of new markets (Germany, Italy, UK) • Product is positioned in established market niches • Updated national protocols are in place for the control of parasitic diseases (scabies).	• There is increased climatic variability (frost, drought, hailstorms/snowfall) affecting vicuña habitat and populations. • Scarcity of water resources for the pastures that feed the vicuñas. • Poaching and informal sectors. • There are few incentives for practicing sustainable methods of vicuña farming. • Increase in highly contagious diseases (scabies)

5.2.3 Complementary value chains

5.2.3.1 Kiwicha

Kiwicha (Amaranthus caudatus) is one of the four most important Andean grains produced in Peru, with the largest production areas being Cusco, Apurímac, Ancash, Arequipa, Cajamarca, Huancavelica and Ayacucho. In 2017, the highest production of kiwicha was achieved in the Apurímac region with 1,249 t, which represented 46.4% of the national production (MIDAGRI, 2020).

Kiwicha can be grown from sea level up to 3,000 masl. It is highly susceptible to frost, which limits its expansion to the altitudinal levels at which it thrives. However, due to its high tolerance to drought and soil salinity, it is a viable crop for land with low water availability. It is also an important food alternative, considering its prices and those of quinoa (Miñano, 2015).

Kiwicha grains have a high content of essential amino acids, including lysine, ethionine and tryptophan. They also contain large amounts of calcium, phosphorus, iron, potassium, zinc, vitamin E, vitamin B complex, niacin and folic acid. It is considered a nutraceutical or functional food due to the enormous benefits it brings to humans (MIDAGRI, 2018b).

Markets

In Peru, kiwicha is cultivated in various ways, including traditional, associated, or monoculture farming, often on small plots. The majority of the kiwicha produced (74.3%) is directly sold, while 6.7% is used for subsistence consumption, 3.5% for seeds, and 2.8% for derivative production (MIDAGRI, 2018b). In terms of sales, the primary buyers are retail traders (45.5%), followed by bulk buyers (43.1%), and wholesalers (32.3%). Most kiwicha producers (69%) primarily target the local market, with the regional market being the second main market (31%).

Regarding kiwicha exports, there has been a variable trend between 2011 and 2020. In 2020, the main destinations were the USA (26%), Japan (25%), Germany (8%), and Brazil (8%). The farm-gate price per kilogram ranged from USD 1.2 to USD 1.5, while the export price per kilogram ranged from USD 2.13 to USD 3.11 (Miranda, 2021). Notably, in 2022, Peruvian kiwicha exports experienced exponential growth until September, with 994 t exported, generating USD 1.7 million in revenue. This represents an increase of 188% in volume and 112% in value compared to the same period in 2021.

Barriers and opportunities

Kiwicha is one of the Andean cereals with the greatest potential for growth at national and international level due to its high nutritional value and gluten-free nature, but it still has a low share in non-traditional exports. Similar to quinoa, the world supply of kiwicha is composed not only of the ancestral production of the Andean countries, but also of the production of kiwicha from Canada, China, India, Korea and South Africa. World demand is made up of Japan, the USA, Germany, France, Austria and other European countries.

One of the main importers of Peruvian kiwicha is Germany, a country with a great interest in vegetarian and vegan nutrition. According to the German Vegetarian Association (VEBU), some 7 million Germans are vegetarians (8% and 9% of the country's total population), while approximately 700,000 Germans are vegans (MIDAGRI, 2018b).

5.2.3.2 Cañihua

Cañihua (Chenopodium pallidicaule), similar to quinoa, is a cereal known for its exceptional nutritional value, containing twice as much protein as common staples like wheat, rice, or oats (MIDAGRI, n.d.). This native Andean crop boasts over 200 varieties and has been cultivated for millennia in the Andean altiplano, particularly in Peru and Bolivia, at altitudes ranging from 3,800 to 4,000 masl.

Cañihua is a crop that successfully copes with external climatic events such as frost, drought, and low temperatures. A study that quantified the impacts of climate change on cañihua production from 1997 to 2017 shows that cañihua maintained its yield throughout that period, whereas rice, maize, wheat and other food grains were negatively affected, tolerating critical anomalies of agro-climatic variables in the Puno region (Benique, 2019).

Markets

According to ENAPREF 2008-2009, the average per capita consumption of Andean grains at the national level is 0.6 kg per year, which includes quinoa, cañihua, kiwicha and others (Mayta, 2019). Given this, the potential market for cañihua and its derivatives is constituted by the population of the cities of Puno, Arequipa and Lima. This population is made up of the domestic market that already has consumption habits in the regions of Arequipa and Puno, and Lima is considered because the consumer of natural and nutritious products is willing to buy cañihua and its derivatives.

Although the main market for cañihua is domestic, as it represents only 0.05% of total exports of Peruvian Andean grains, exports of this grain as of May 2016 reached USD 924,895, at an average price of USD 4.28 per kg, a little higher than that of other similar grains such as kiwicha (which reached USD 3.42 per kg). In 2017, cañihua stood out in the export of Andean grains due to a 50% increase in FOB value, with the main destinations for Andean cereals being the US, the Netherlands, Spain, Italy, China and the UK (Garvan, 2018).

Barriers and opportunities

In Peru, the production of Andean grains has experienced significant growth, presenting lucrative market opportunities. However, the problem with cañihua is becoming more complex and diverse as it remains a neglected crop with limited cultivation areas, low-income levels, weak integration into the value chain, low associativity, low production, productivity, and quality levels, and limited per capita consumption. Additionally, there is a lack of technological development to enhance production and transformation with high added value, and limited coordination and public-private collaboration to promote the competitiveness of the production chain (Mayta, 2019).

Despite being consumed to a limited extent, there is a pressing need to improve the productivity of cañihua cultivation, which is currently done in an artisanal manner. Technological advancements and investments are required to modernize and industrialize its production, according to the National Institute for Agrarian Research (INIA). The FAO has highlighted certain grains, including cañihua, as being more resilient to climate change. It is considered climate-smart due to its remarkable capacity to adapt to adverse weather conditions and contribute to mitigating its effects. Like quinoa, cañihua is believed to possess antioxidant properties that can aid in treating and preventing conditions such as diabetes, controlling cholesterol, hypertension, and blood sugar levels, thereby reducing the risk of cardiovascular disease.

5.2.3.3 Tarwi

Tarwi is a legume native to the Andes, known for its high nutritional properties, making it an excellent candidate for combating malnutrition effectively. It holds great potential as a species for commercialization in markets that value nutraceutical foods with high nutritional value (Reyes & Ramirez, 2020).

Furthermore, tarwi is recognized for its beneficial impact on the soil in which it is cultivated. It requires minimal water and can withstand high temperatures, making it particularly advantageous for the altiplano production system. Its roots fix atmospheric nitrogen, thereby contributing to improved soil fertility. Consequently, it is a vital component of traditional crop rotation systems in the Altiplano, such as quinoa-tarwi-potato or quinoa-tarwi-barley, without the need for additional fertilizers (Sierra y Selva Exportadora, 2021).

Sowing typically takes place under rainfed conditions in a traditional manner, on small and isolated plots. In some cases, it is used as a border crop to protect potato and quinoa fields from livestock since it is not consumed directly due to its bitter taste and somewhat repellent smell (Tapia, 2015).

Markets

Over the last 5 years, tarwi cultivation has been steadily increasing at an annual rate of 2.3%. During the period from 2015 to 2020, the production indicators have shown positive trends, with the highest production levels recorded in 2018 and 2019. Notably, the farm-gate price for 2020 was better than all previous prices analysed.

Based on MIDAGRI statistics, 85% of tarwi cultivation is concentrated in the regions of La Libertad, Cusco, Apurímac, Puno, and Huánuco (Sierra y Selva Exportadora, 2021).

However, tarwi exports have shown a declining trend during the period from 2015 to 2020, with an average annual decrease of 5% in volume and 2% in value. The primary exported segment is tarwi beans, accounting for 97% of exports, followed by tarwi flour

(1.9%) and tarwi in brine (1.1%). The main destination country for tarwi exports is Ecuador (86%), followed by Spain (6%) and the United States (6%).

Barriers and opportunities

The Peruvian agricultural sector still faces challenges in competitiveness compared to other countries that produce tarwi, like Australia. This is largely attributed to limitations in planning and execution, partially stemming from the lack of sufficient promotion and support from the state and local governments. As a result, farmers continue to work in precarious conditions, opting to cultivate other, more profitable grains instead (Reyes & Ramirez, 2020).

However, tarwi holds significant potential for agro-exports in the superfoods segment. To fully capitalize on this opportunity, both the public and private sectors need to collaborate and undertake various actions to enhance its production, processing, and yield. This involves developing commercial varieties, promoting certified seeds, improving crop management systems, and implementing strategies to encourage consumption. Such efforts will have a positive impact on current and future producers in this chain. Additionally, tarwi's resilience to climate challenges and its ability to thrive in various soil conditions make it a promising crop in the Andean region. Moreover, its nutritional properties make it a valuable resource in the fight against malnutrition.

5.2.3.4 Oca

Oca (Oxalis tuberosa) is a traditional Andean crop, native to southern Peru, cultivated between 3200 and 3900 meters above sea level. It is a valuable source of proteins, carbohydrates, and primarily vitamin C. Typically, it is grown in small plots alongside potatoes, mashua, and olluco, forming an essential part of farmers' diet (Yenque et al., 2007). While oca takes longer to mature and yields less compared to potatoes, it displays greater resistance to pests, ensuring a stable production.

As the second most cultivated and harvested tuber in the Andes, oca is highly regarded among the Andean population for its resilience, productivity, and delightful taste. During the 2 to 3 weeks of sunny weather in the Andes, oca experiences an increase in sugar content, enhancing its flavour. This makes it a popular ingredient in various dishes, from parboiled tubers accompanying breakfasts and lunches (alongside potatoes) to mazamorras mixed with milk, similar to the famous "Apis" in Puno. Oca is also used to prepare khaya, similar to tokosh (or rotten potato). Additionally, it is commonly used in soups and sautéed dishes, further contributing to its widespread popularity.

Cultivating oca is quite similar to growing potatoes and is known for its resilience to challenging climates. Under regular conditions, it yields around 5 tons per hectare, but with improved practices, this can increase to 7 tons per hectare. In experimental settings, yields have reached as high as 40 tons per hectare. To manage potential issues like fungi-related root rot (e.g., Fusarium sp and Rhizoctonia solani), farmers adopt strategies such as crop rotation, good cultivation practices, soil drainage, and careful control of planting density (Esquivel, 2019).

Markets

A study conducted in the community of Vicos (Ancash) revealed that farmers engage in different agricultural practices during the oca harvest. Approximately 75% of the farmers select oca for self-consumption and as seeds for future planting. Another 17% use oca for self-consumption, as seeds, and for selling purposes. Some producers, however, have ceased oca cultivation and now focus solely on planting improved varieties of potatoes for commercial sale (Caycho, 2019).

Over the past few years, there has been a noticeable increase in consumer demand for oca at the local and regional levels. For instance, in the Huancavelica region, there is an unsatisfied demand for oca, despite only about 50% of the population currently consuming it (Ore, 2018). Surprisingly, there is little to no demand from processing companies, and oca exports are almost non-existent, despite efforts to promote the product for its nutritional richness in energy, minerals, and vitamins.

Barriers and opportunities

The cultivation of oca in Peru is facing significant challenges, mainly attributed to the small plot sizes, the use of low technologies, limited access to credit from state institutions, and the lack of communication routes. These factors adversely affect the production process, resulting in oca being primarily grown for domestic consumption (Hinostroza, 2019).

Gallardo (2018) warns about the risk of genetic erosion facing the oca crop, as is the case with many other crops worldwide. The decline and loss of local oca varieties are attributed to various factors, including the impact of extreme climatic events, especially frost occurrences, the rise in pests and diseases, and changes in the farming community's productive and social dynamics. The introduction of improved potato varieties has led to the displacement of oca cultivation, while the incorporation of external food products like rice, noodles, and tuna has further contributed to this shift.

Despite these challenges, there are initiatives undertaken by Peruvian entities to support oca cultivation and production. For example, INIA implemented the project "Conservation and analysis of the genetic diversity of oca in Peru" to generate knowledge about oca's genetic diversity. This initiative aims to inform conservation efforts and identify future research needs, thereby contributing to meeting the food needs of Andean families (MIDAGRI, 2018).

Moreover, oca offers ample potential for transformation and value addition. Products like flour, starch, jams, nectar, liqueurs, and oils can be derived from oca, presenting attractive opportunities for specialized markets.

5.2.3.5 Mashua

Mashua (Tropaelum tuberosum) is an ancient tuber of great significance in the Andean region due to its nutritional and cultural value. This food offers numerous health benefits, particularly noteworthy for its antioxidant activity and high content of anthocyanins. In fact, mashua contains a substantial amount of vitamins A and C, four times more than that found in potatoes (Gualoto, 2021).

Mashua is remarkably resilient and can be cultivated in poor soils without the need for fertilizers or pesticides. Even under such conditions, its yield can surpass that of potatoes by double. Another notable feature of mashua is its exceptional frost resistance. When faced with hail, frost, and cold, potatoes may be lost, but mashua and ocas can still be harvested, with mashua proving to be the most resilient among the tubers. Additionally, mashua is easy to grow and has a natural repellent effect against nematodes, making it suitable for association with other crops like olluco, oca, and native potatoes. Its presence acts as a protective barrier against nematodes and insects (Chacón, 2019).

In Peru, the primary mashua-producing regions include Cusco, Puno, Apurímac, Ayacucho, Junín, Huánuco, and Huancavelica, which collectively account for approximately 88% of the national production. In 2018 and 2019, the annual production reached around 41,000 t. Peru boasts over 100 mashua varieties, with an average yield ranging from 4 to 12 t per ha, although experimental conditions have shown yields of up to 70 t per ha. Many Andean farmers preserve mashua varieties by cultivating them in small plots. However, due to pests, diseases, and certain agronomic limitations, it is not extensively cultivated over large areas (Yepez & Tumpay, 2023).

Markets

Despite being cultivated in smaller areas compared to other tubers like potato, oca, and olluco, mashua plays a crucial role in ensuring food security for thousands of peasant families through self-consumption and the emerging commercialization that generates economic income. The growing acceptance of mashua (alongside oca and olluco) from Huancavelica in important domestic markets has allowed more farmers to achieve greater profitability by selling their products, thanks to their involvement in the Andean Tubers Project of the Regional Government of Huancavelica (GORE Huancavelica, 2021). The significant nutritional value of mashua, attributed to its proteins, carbohydrates, fibre, and calorie content, along with its health-promoting properties, has attracted the attention of multinational agribusiness, food, and pharmaceutical companies. The primary market for this product is the Netherlands, followed by Sweden, France, the United Arab Emirates, and Canada.

Mashua exports have been mainly directed to companies in the naturist sector and pharmaceutical laboratories that utilize the diverse properties of mashua for food improvements in capsule form. Exports include fresh mashua, mashua flour, nectar, and mashua extract. Different mashua varieties, such as black and yellow mashua, are exported, with mashua capsules fetching prices of up to USD 42 per kg, particularly for the French market, which remains the primary destination for mashua capsules and flour exports (Ordoñez, 2020).

Barriers and opportunities

Despite possessing special characteristics such as functional foods, nutraceuticals (with antioxidant and other capacities), and even medicinal potential, mashua remains an underutilized crop in its native production areas, as well as in national and international markets. Its cultivation is primarily for self-consumption, often used as feed for pigs.

In Puno, mashua cultivation is not widely promoted because it is not considered a staple product. Despite its beneficial health properties, mashua's cultivation lags behind other tubers like potatoes (Chacón, 2019). In recent years, there has been an increase in annual national production and productivity per hectare. Research studies on this tuber have also seen significant advancements. Considering its rusticity and potential, mashua deserves special attention from public policies in Peru to promote its cultivation in the high Andean regions, taking advantage of its beneficial health properties (Chacón, 2019).

5.2.3.6 Guinea pigs

According to FONCODES (2014), climate change will have an impact on the food security of the poorest, including families living in rural areas. In response to this situation, guinea pig rearing has been practiced in rural areas for generations, providing an alternative source of regular protein consumption while also contributing to environmental preservation compared to other forms of livestock.

In Peru, guinea pig rearing is viewed as a complementary activity typically managed traditionally by families, closely linked to agriculture. In recent years, the rearing of guinea pigs has gained recognition not only for its high nutritional value but also for its potential to generate additional income for families through surplus production sales. It is crucial to improve guinea pig management, as the outcomes of various field-validated projects indicate that implementing technical breeding practices can triple production in the medium term, allowing meat availability in just three months. Moreover, guinea pig rearing is a straightforward and cost-effective approach.

Markets

The main guinea pig-producing regions in Peru include Cajamarca, Ancash, Cusco, Apurímac, Junín, Lima, La Libertad, and Huánuco. A study conducted by APCI (2014) revealed that at the local technological level, guinea pig rearing is primarily carried out by school-age children and housewives (in 73% of cases), with husbands contributing to a lesser extent (9% of cases). Other family members occasionally participate in this activity when sharing household responsibilities.

In Apurimac, local marketing is exclusively focused on live animals, as there is no demand for guinea pig meat or other by-products. Guinea pig is considered a luxury food, consumed during celebratory occasions such as patron saint festivals, birthdays, marriages, baptisms, house building, and more. Therefore, it plays a significant role in the local economy and is intertwined with various aspects of people's lives. At the regional level, the demand is also primarily for live animals, while at the national level, especially in Lima, commercialization mainly involves freshly processed guinea pigs, with live animals being sold to a lesser extent (APCI, 2014). Furthermore, MIDAGRI highlights that guinea pig consumption is consistently growing at the national level. As part of its promotion, the sale of live guinea pigs has been exempted from the general sales tax since 2019 to increase guinea pig meat consumption in both domestic and foreign markets (El Peruano, 2020).

On the international front, Peru has been exporting guinea pig meat since 1994, and the growth has been steady since then. For example, during the period 2010-2019, the increase represented an average of 50%, and in 2019, Peru remained the world's main exporter with a 77.6% share. The US is the primary market for guinea pig meat exports, accounting for 99.9% of purchases. The consumers of guinea pig meat in the US are Peruvians, Ecuadorians, and Bolivians living in the country, who not only appreciate the nutritional characteristics of this meat but also have a longing to consume a product that is familiar to their culture. This demographic represents the potential market for this product, and there is potential to further expand the market by promoting and highlighting the special qualities of this traditional product. Remaining exports are destined for markets such as Japan, Canada, South Korea, Italy, and Aruba (0.01%) (MIDAGRI, 2020b).

Barriers and opportunities

Peru is the largest producer of guinea pig meat in the world. According to the latest National Agricultural Survey (ENA) conducted by the National Institute of Statistics and Informatics (INEI), the guinea pig population in 2017 reached 17.4 million, an increase of 213,000 from 2016. The ENA 2017 results also indicate that the average national selling price of live guinea pigs stands at PEN 16.6 per unit, while the carcass price is PEN 21.18 per unit (MIDAGRI, 2019).

MIDAGRI, in partnership with AGROIDEAS, plays a crucial role in supporting sustainable rural businesses at the national level. They promote associativity, improved management, and technology adoption by providing non-reimbursable financing for sustainable business plans, including those for guinea pig breeding. AGROIDEAS has approved a total of 78 business plans in the guinea pig production chain until 2020, investing S/23.8 million across 13 regions of the country. As a result, 1,959 families engaged in guinea pig breeding have benefited from co-financing for their projects, enabling them to strengthen and enhance the profitability of their businesses (Agraria, 2020).

Despite significant achievements, there are some barriers that guinea pig breeders face. One of them is the scarcity of pasture for feed, leading producers to rely on alternative food supplements, which can affect the nutritional value, quality, and taste of the final guinea pig meat product (Aparicio, Bocángel & Espinal, 2017). Additionally, guinea pigs are susceptible to various bacterial, viral, and parasitic diseases. Factors such as sudden changes in the environment, temperature variations, high humidity, exposure to air currents, high animal density, lack of hygiene in facilities, and poor feeding can contribute to disease susceptibility (INIA, 2019b).

5.2.3.7 Textile handicrafts

The Peruvian textile cluster is primarily concentrated in the cities of Arequipa, Lima, Cusco, and Puno, where a highly competitive, vertically integrated, and internationally recognized processing and garment industry has flourished.

The Peruvian flagship product, which encompasses the entire value chain, involves over 150,000 families engaged in various aspects, including alpaca breeding, processing, clothing production, and textile handicrafts. Notably, the breeding and handicraft activities are concentrated in some of the country's poorest regions, and they are crucial for the subsistence of these communities. This underscores the significant social and economic impact of alpaca livestock farming and the textile cluster that has evolved around it (Agroperú, 2022).

Many alpaca-raising families strive to enhance the transformation of alpaca fibre into yarns, felts, and handicrafts to add value to this resource and improve their economic prospects. For instance, amid the pandemic, an association of craftswomen from Sibayo, Arequipa, dedicated to producing clothing made from 100% alpaca fibre, received support from UNDP to learn about digital tools and management techniques to enhance the quality of their products (El Peruano, 2021). Similarly, the Association of Artisans of Pucapaqocha, located within the Salinas y Aguada Blanca National Reserve in Arequipa, creates clothing and stuffed animals from vicuña fibre, paying tribute to emblematic species of the region like the Andean fox and Andean cat. Their garments bear the "Aliado por la Conservación" seal from SERNANP, recognizing their contribution to the conservation of protected natural areas.

Markets

Alpaca fibre is renowned for its softness, durability, luxurious feel, and silky texture. It is hypoallergenic and serves as the basis for various wool products, ranging from simple and affordable garments to sophisticated and high-end ones. However, despite the significant national production of alpaca fibre (95% of which is oriented towards exports), there is limited focus on adding value within the local Peruvian market. The majority of exports consist of raw fibre rather than finished garments, with Tops accounting for 81%, Yarns for 17%, and dresses for 1% (Sierra y Selva Exportadora, 2021).

According to MIDAGRI (2021), the export of alpaca fibre, the most crucial product within the Andean camelid textiles sector, exceeded USD 35.3 million in 2020, cementing Peru as the world's leading supplier of this fibre. The main export markets were China (43.8%), Italy (39.9%), and Korea (4.34%), among others. In 2022, alpaca fibre knitted jumpers ranked as the top product. Additionally, toys, hosiery, knitted cardigans, shawls, handkerchiefs, scarves, blankets, coats, and chullos (a traditional Andean insulating hat), among others, also performed well in the market.

Barriers and opportunities

Peru holds a prominent position as the primary supplier of alpaca fibre on the international stage and is widely recognized as an export hub for high-quality alpaca garments and accessories, known for their diverse shapes, colours, and textures. The Peruvian textile market comprises 338 exporting companies from 10 regions dedicated to alpaca product production, emphasizing the importance of public and private sector support to bolster the alpaca value chain (Sierra y Selva Exportadora, 2021).

Alpaca stands as a flagship product for Peru, leading to the development of the Sectoral Brand "Alpaca Peru" by MINCETUR in 2014, aimed at positioning alpaca fibre and products in the luxury market abroad. While a study by Tito (2019) revealed that the sectoral brand did not significantly influence exports in 2020, interviews with company representatives indicate that with continued and thorough promotion, the brand has the potential to benefit all sector companies. It could lead to increased sales of alpaca products, international market recognition, and support for company exports. Therefore, effective coordination among relevant public and private institutions is crucial to promote a comprehensive value chain, focusing not only on tops and yarns but also on garments made from alpaca fibre. Moreover, ensuring the participation of alpaca producers' organizations in this process is essential to enhance competitiveness.

5.2.3.8 Community-based tourism

Community-based tourism is an activity that has an impact on the families living in the community, the development of the region and their way of life. It also contributes to preserving ethnic identity, as well as valuing and transmitting cultural heritage. For this reason, its development in a transversal way to the cultivation of high Andean products, as well as in the breeding of South American camelids, is of great importance, as the control lies with the community, which is the one that interacts with the market, empowers itself and has authority over all decisions regarding the development of this type of tourism.

Markets

Tourists arriving in Peru and consuming Community-based tourism products come mainly from the cultural (58%), adventure (56%), traditional (46%) and ecotourism (38%) segments.

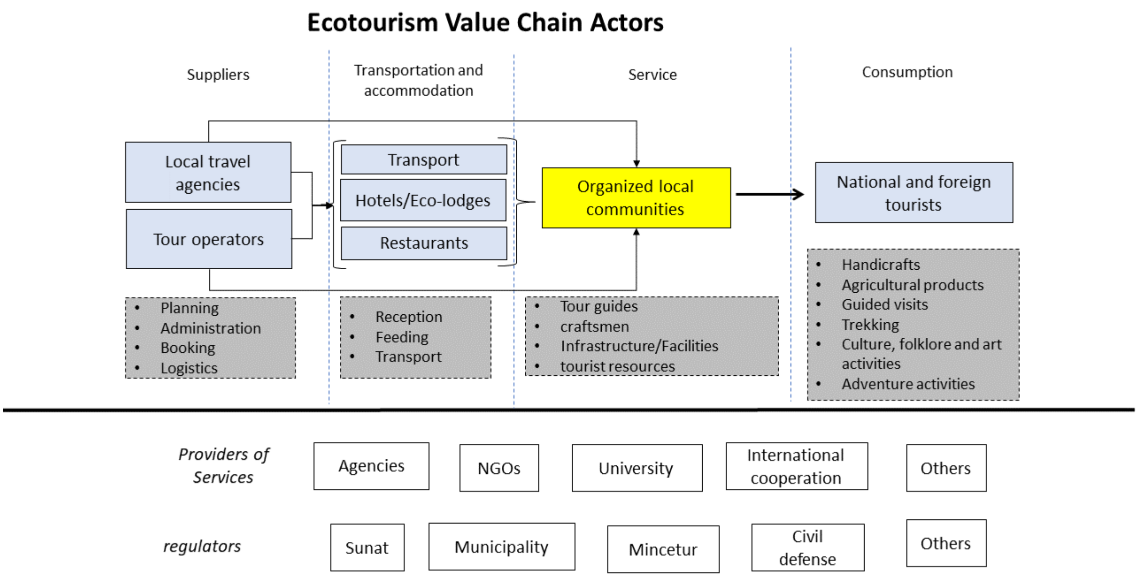
In 2017, international tourist arrivals to Peru showed sustained growth, reaching 4 million, which represented an increase of 8% compared to 2016. Of the total number of arrivals, foreign holidaymakers amounted to 2.64 million, of which 48% visited rural communities. Regarding community-based tourism, the markets with the highest demand are the US and European countries. In a study on the marketing of community-based tourism in Peru, 44% of the operators surveyed mentioned the US as their main market of importance, followed by France (15%) and Germany (10%).

Trends indicate that the use of digital media to purchase tourism services will increase, becoming more important at the time of travel. This creates a challenge for community-based tourism ventures, which must be prepared to meet these needs and also have innovative communication strategies that allow, through content and a powerful brand, to generate travel interest in the various marketing channels.

Furthermore, a study on travel trends shows that 74% of tourists in Latin America are holidaymakers and their main interests are nature activities (25%) and adventure (25%). These travellers value getting close to the reality of the places they visit. In addition, tourists arriving in Peru and consuming Community-based tourism products are mainly from the cultural (58%), adventure (56%), traditional (46%) and ecotourism (38%) segments.

- Value chain actors

Figure *29*: Ecoturism Value Chain Actors



The main actors of a value chain are peasant communities, NPA authorities, MINCETUR, tour operators, suppliers of tourism-related services and products, foreign tourists, and domestic tourists. The community-based tourism chain works through the local production of products and services that help to boost the local economy indirectly and directly.

The culture and tradition of the communities, landscapes, flora and fauna, handicrafts, heritages and local practices make up the necessary resources for community-based tourism. Local travel agencies and tour operators are in charge of all the planning, logistics, administration and booking of products and services to be provided to tourists. Among their responsibilities are the transport, accommodation and food that will be offered within the tourism package. The next link is the most important, as providing the service involves the integration of local resources with communities and tourists.

The consumption of tourists through the various activities offered in tourism packages allows them to gain various value-added benefits such as employment, training, education, capacity building, security and community development by adding values to the local nature and culture. It is worth noting that resources and stakeholders can only work in cohesion when there is greater awareness among the community about the benefits of community-based ecotourism (Gupta & Chandra, 2016).

It is also important to mention that as service providers in the community-based tourism chain, in addition to agencies and operators, there are NGOs, universities and international cooperation agencies. Likewise, the main regulatory bodies are SUNAT, local municipalities, MINCETUR, Civil Defence, among others.

- Economic analysis

According to MINCETUR (2016), formal enterprises in the specific field of rural community-based tourism have increased significantly, with 42 in 2010, rising to 65 in 2011 and 76 in 2016. This notable increase in supply has gone hand in hand with a growing increase in demand, as "in three years (2014-2016) the number of visitors to communities increased from 80,000 to 300,000 per year" (Correo, 2016).

The income generated by community-based tourism can help nature conservation. In particular, employment opportunities are provided for local people as guides, trackers and anti-poaching guards (Leung et al., 2018). Nature conservation, tourism involves the wise use of natural resources and the equitable sharing of benefits, particularly for local communities (Romeo et al., 2021).

Supply-side analysis

According to the guidelines for the development of Community-based (MINCETUR, 2019), in Peru community-based tourism is any tourism activity that takes place in a rural environment,[13] in a planned and sustainable manner, through management models with the active participation and leadership of local populations, represented by community-based organisations. Community-based tourism is harmoniously integrated with traditional local economic activities, in order to contribute to the development of the community,[14] with its culture and natural environment being the key components and differentiators that make up its tourism product.

Community-based tourism, as a strategy, is a line of intervention of the tourism sector, led by MINCETUR, which promotes competitive, sustainable and differentiated tourism development from the communities, through authentic tourism experiences that respond to market trends and demands, contributing to the diversification of the national tourism offer and the socio-economic development of the communities involved, strengthening cultural identity and promoting the conservation and appropriate use of the natural heritage.

[13] The rural environment comprises the extensions of fields and natural areas, as well as rural population centres that maintain a rural way of life and develop traditional activities of production and/or use of the territory and its resources. These may include district capitals that are considered urban only because they are administrative centres, but which, because of their configuration and size, as well as the way of life of their inhabitants, have not ceased to be rural.

[14] Rural culture encompasses not only the cultural manifestations themselves (customs and festivals, oral tradition, built heritage, etc.), but also involves lifestyles and values, patterns of occupation, production and use of the territory, forms of relationship with other communities, etc. Rural culture has been shaped by the incorporation of multiple elements. Some are endogenous, which have to do with the permanent contact of rural inhabitants with nature, with manual activities, with the markedly artisanal and multidimensional nature of the peasant profession, drawing on biology, climatology, chemistry, mechanics, economics, but also, and above all, on experience and common sense. Others of an exogenous type, which are related to the foreign occupation of the territory and to external influences. In short, a culture of synthesis, diverse and rich in its manifestations.

The area of intervention is the communities with a tourist vocation located in rural areas in the main tourist destinations of Peru. These communities have a vast cultural and natural heritage that makes it possible to offer tourism through travel experiences with a high degree of authenticity. These spaces are ideal for the development of community-based tourism ventures.

Community-based tourism ventures are: A set of tourism initiatives established in a territory with a tourist vocation and linked to a tourist route, driven by entrepreneurs and with the participation of managers who, under a collaborative management model, promote the development of Community-based tourism products, in order to generate authentic, quality and meaningful travel experiences that contribute to sustainability and the integral wellbeing of local populations.

The approaches to guide and evaluate the daily work and working methods of the various actors, in order to promote greater coherence and alignment between the various perspectives and to achieve the objectives of Community-based tourism are: a) community-based approach, b) territorial approach, c) intercultural approach, d) market approach, e) experience approach, gender approach, f) governance approach.

Currently, the Community-based tourism Strategy has 66 ventures located in the main tourist destinations of Peru, in 11 regions: Amazonas, Ancash, Arequipa**,** Cajamarca, Cusco, Lambayeque, Lima, Loreto, Madre de Dios, Puno and San Martin. These projects involve 72 communities. Of these, 69% are located in the southern part of the country, 11% in the central part and 19% in the northern part of the country. In all cases, communities with a tourist vocation and settled in rural areas are the main managers of these enterprises. To date, there are 1,663 entrepreneurs registered in the MINCETUR system, of which 774 are men and 889 are women. In order for a community-based tourism enterprise to be approved by MINCETUR, it must meet the following conditions: collective organisation, tourism vocation, demand, heritage, product proposal, and facilitation.

The main product in Community-based tourism is the identification and preparation of tourist circuits around native potatoes, alpacas and guinea pigs, defining special routes for each of these products and taking advantage of the presence of a high flow of tourism in the Cusco-Puno-Arequipa axis, the most touristic in the country. Proposals can be implemented for agronomic, cultural, gastronomic and ecotourism tourism, or a mix. The articulation with tour operators, Civil Society Organisations, or with SERNANP itself is needed to develop these proposals.

Community-based tourism brings many benefits to communities, especially in relation to the conservation of natural and cultural resources, empowerment and increased ownership among local people, improved communication infrastructure, job creation and increased income, and reduced rural migration (Goulding et al., 2014). When tourism services are operated by women, economic empowerment and greater gender equality have also been documented (LaPan et al., 2016).

A business model based on high Andean community-based tourism requires promoting the sustainable socio-economic development of rural communities in marginalised areas. The Community-based tourism strategy has triggered the flourishing of community-based tourism initiatives in the Peruvian Andes and the emergence of many governmental and non-profit institutions seeking to provide technical training and marketing assistance to local communities.

Tourism products have three fundamental elements (Loayza, 2013):

- Attractions**:** comprising tourism resources: nature, culture, history, events, etc.
- Connectivity**:** all land, rail, water and air infrastructure.
- Services**:** comprising accommodation, food, interpretation-guidance, transport, trade, information and security services.

Some initiatives have different management models in terms of tourism organisation and management structure. For example, Amaru and Saccacca operate as part of a consortium known as "La Tierra de los Yachaqs" (8 communities) and "Parque de la Papa" (6 communities), respectively; other initiatives operate independently: Misminay is managed through a tour operator with the support of a non-governmental organisation (NGO), Amaru is managed through an NGO exclusively, Saccacca is a community managed with the support of an NGO, and others such as Raqchi, Hatun Qolla, Llachón, and Amantani are exclusively community managed.

The exceptional diversity of landscapes and cultures in the Andes has rich opportunities for tourism. Ecotourism in particular finds ideal preconditions in the richness and variety of vegetation in the tropical areas, both in the horizontal profiles of the landscape and in areas of vertical elevation. Today there are a large number of national parks and other protected areas that have attracted nature lovers.

Other impressive spheres are the high mountains with monumental peaks, the high volcanic peaks (such as Misti in Arequipa), the high plains of the Puno Altiplano, the imposing glaciers (Quelcaya in Cusco), and the narrow and deep valleys and canyons (e.g., the Colca Canyon and Cotahuasi in Arequipa), which offer visitors unique landscapes.

Demand-side analysis

Community-based tourism satisfies a demand that seeks: cultural exchange and learning, deep contact with local populations, to know and understand the local culture, to be proactive and not passive actors of their journey, to be part of a lifestyle they do not know. Moreover, it represents an experience of abstraction: to get away from the hustle and bustle of modern life, to experience a return to the roots and a contact with nature.

NPAs have a great potential for development. In the case of Natural Protected Areas, there is great potential to promote Community-based tourism, in which there must be prior permission from SERNANP in coordination with MINCETUR. Tourism in ANP in recent years has increased, reaching 2.1 million visitors in 2017 (42% foreigners, 53% nationals and 4% free entry, with 16 ANP5 receiving more than 5 thousand visitors annually in 2017 (SERNANP, 2018). An important fact is that from 2009 to 2017 the average annual growth of visits to ANP was 19%, which implied a total growth of 235%, i.e., in 7 years visits to ANP have tripled (SERNANP, 2018). In this sense, of the 16 ANPs analysed, in 10 ANPs the number of visitors has at least doubled. Two natural protected areas in the intervention area of the project, such as Nor Yauyos Cochas, are among the NPAs with the highest growth in visitors. Vilela et al. (2018), indicate that tourism linked to visits to NPAs has generated, in 2017, direct benefits of PEN 2.3 billion to the local economy, also generating more than 36 thousand jobs in and around the NPAs.

In the Natural Protected Areas of the Resilient Puna project, SERNANP reports the following data on tourist arrivals:

Table *24* Historical series of visitors to NPAs within the area prioritised by the Resilient Puna proposal in Peru. Source: Own elaboration based on information from SERNANP (Unpublished).

Natural Protected Area	2016	2017	2018	2019	2020	2021	2022
SN Ampay	2,729	3,976	3,585	3,494	1,743	4,639	4,112
RP Nor Yauyos Cochas	23,187	26,546	28,660	44,374	5,677	0	0
RP Cotahuasi sub-basin	3,316	3,760	5,909	8,887	1,515	0	0
Salinas and Aguada Blanca NR	1,222	638	2,002	4,210	582	0	0

The COVID pandemic had a negative effect on visits to the protected areas as can be seen in the Table, although data is only available for 2021 and 2022 for Ampay, a significant increase in tourism can be observed in Nor Yauyos Cochas until before the pandemic with a record number of visits of more than 44,000 tourists visiting this protected area. On the other hand, the Cotahuasi sub-basin, the Ampay National Sanctuary, and the Salina and Aguada Blanca Reserve also had record numbers of visitors in 2019. Efforts are still needed to attract tourism from Cusco to areas with tourism potential in Arequipa and Apurimac.

- Tourism handicrafts

Peru is renowned for its rich artisanal heritage, offering a diverse array of products that hold significant cultural value. Handicrafts play a crucial role as an economic activity, benefiting the communities that produce them while also contributing to the growth of inbound tourism, a major source of foreign exchange for the country (UNWTO, 2016).

Handicrafts have emerged as a means of diversifying subsistence agriculture, providing additional income to rural families, and preserving valuable knowledge that might otherwise be forgotten. Although predominantly associated with women, there are also skilled male artisans crafting pieces of great heritage and symbolic significance. Like agricultural products, handicrafts find opportunities for direct marketing through community-based tourism, avoiding intermediaries and ensuring better earnings for the artisans.

In 2007, the Annual National Peruvian Handicraft Amautas Award Competition was established, recognizing the importance of artisanal works and their contribution to preserving this diverse tradition—one of the most varied on the continent—through Law 29073, the Law of the Artisan and the Development of Handicraft Activity.

According to the General Directorate of Handicrafts of the Peruvian Vice-Ministry of Tourism, 91% of tourists purchase handicrafts during their trips. These items include garments like jumpers, hats, and scarves (69%), alpaca fur products (44%), ceramics (40%), jewellery (36%), and tapestries (26%). A significant number of tourists also indicated that learning about handicrafts influenced their choice of visiting Peru, even though it might not be a top priority at the pre-trip planning stage (UNWTO, 2016).

While tourism enhances the symbolic value of handicrafts, it is not the primary marketing channel for authentic crafts. Artisans mainly sustain their craft by selling to specialized decoration establishments, museum shops, and through export strategies.

In various regions, like Cusco and Puno, unique and traditional crafts thrive. Exceptional weavings in alpaca fibres with natural dyes can be found in Cusco, while Puno is celebrated for its pottery, reflecting the fusion of Andean and Spanish cultures. In the Nor Yauyos Cochas Landscape Reserve in Lima and the Salinas y Aguada Blanca National Reserve in Arequipa, women-led organizations transform alpaca fibre into garments that showcase biodiversity and promote cultural traditions through sustainable fashion.

Institutions like the CITEs contribute to artisanal development, focusing on product innovation and craft techniques. Additionally, MINCETUR's "Ruraq Maqui" event not only sells handicrafts but also encourages visitors to experience the places where these crafts are made, contributing to tourism and economic reactivation (Andina, 2021b).

- Climate change

The tourism sector is highly susceptible to the effects of climate change, facing challenges not only due to its sensitivity to climate variability and extreme events but also because it can influence tourists' decisions, leading to potential economic losses (Libélula, 2019). Moreover, tourism itself contributes to greenhouse gas emissions, exacerbating the issue of global warming. Taking prompt climate action in the tourism industry is of utmost importance to ensure the sector's resilience (UNWTO, 2021).

The negative impacts of climate change on tourism are linked to changes in the competitiveness of tourism destinations resulting from the closure of access routes and communication channels. Estimates suggest that cumulative economic losses from 2011 to 2100 could surpass PEN 5 billion, equivalent to 30% of tourism GDP (IABD, 2016).

Numerous studies have analysed the effects of climate change on tourism, examining adaptation and mitigation measures adopted by various economies. The impacts on tourism manifest directly through damages to hotel infrastructure (capital) and significant places of interest such as natural areas or ecotourism ecosystems (environmental services). Indirectly, there are effects on the supply chain of goods and services required for tourism activities, leading to income losses, job reductions, and repercussions on related sectors and the overall economy (Libélula, 2019).

- Barriers and opportunities

Although community-based tourism has significant growth potential, there are still challenges related to quality, marketing, and the development of innovative and distinct offerings. Enterprises in this sector must address these issues to achieve sustainability. A study on the commercialization of community-based tourism identified several limitations (MINCETUR, 2018):**Gender issues**

The tourism sector plays a vital role in the global economy, generating numerous jobs and contributing to poverty reduction and equality in countries with high levels of extreme poverty. However, a closer look at employability figures, as indicated by the World Bank in 2019, reveals that only 39% of employed individuals are women, with a more equitable representation of 54% in the tourism sector. Nevertheless, gender pay disparity remains an issue, with women earning 14.7% less than men in the tourism industry, according to the World Tourism Organization (Ynouye, 2020).

In various interventions, we can observe enterprises led by women. For instance, in Cusco, there is the "Land of the Yachaqs" association, led by a woman who is also the president of the Regional Network of Inca Community-based Tourism in Cusco. In Lima, at an altitude of 3,350 meters above sea level in the Nor Yauyos Cochas Landscape Reserve, there is the small town of Laraos, boasting unique mountain landscapes and terraces covered with vegetation. Here, the tourist association “Sinchimarka Laraos” is led by a woman. Likewise, on the floating islands of Lake Titicaca in Puno, there is the association “Uros Khantati,” led by an indigenous Aymara woman dedicated to the tourism sector in the region.

Tourism has significant potential to drive social change and narrow gender gaps. A study on women community-based tourism leaders in Peru demonstrates that despite patriarchal resistance from communities, these women have experienced empowerment at personal, economic, and political levels. At a personal level, tourism has enabled them to enhance their leadership, self-esteem, and critical awareness. At a political level, it has fostered collective agency, social capital, and increased participation. However, there are still challenges to achieve full economic empowerment (Sánchez, 2022).

SWOT Analysis

Strengths	Weaknesses
● Existence of scenic and cultural tourism resources. ● Profitability produced by these services enables the sustainability of the chain. ● Tourist alternative is not very saturated ● Ownership of the territory allows for control of the space and maintenance of the spaces. ● Local population willing to get involved in a community-based tourism venture ● It allows the complementary development of businesses linked to gastronomy and handicrafts.	● Little development of local tourism outside Cusco. ● Poor organisation of communities to implement businesses. ● Lack of training of the local population to meet tourism demand. ● Lack of promotion and communication around local tourism offers. ● Poor quality of current transport network and tourism infrastructure.
Opportunities	**Threats**
● Tour operators interested in promoting Community-based tourism. ● Availability of national and international fairs to exhibit tourism services. ● Increased interest in environmental care on the part of local and national consumers. ● Great tourism opportunity of protected natural areas as a driving force for rural tourism. ● Great tourist opportunity in the high Andean zone of southern Peru. ● Creation of tourist routes associated with High Andean crops for community based ecoturism	● Increased competition between tourism projects may limit the inflow of tourists to each site. ● Frequent local protests over political and economic issues in the south affect the image of the area as a tourist destination. ● Climate variability and negative effects of droughts affect the scenic beauty of the area. ● Natural events or disasters (rains, landslides).

5.3 Effects of climate change on selected value chains

According to IPCC (2014), risk "is the probability of occurrence of hazardous events or trends multiplied by the impacts should such events or trends occur. Risks result from the interaction of exposure, hazard and vulnerability". In other words, the level of risk is determined by knowing where the population of interest is, what affects them and what capacity they have to adapt or respond.

Exposure is determined by the presence of people, livelihoods, species or ecosystems, environmental functions, services and resources, infrastructure; or economic, social or cultural assets in places and environments that could be negatively affected. Accordingly, in the short term, the areas producing the chains foreseen in the Resilient Puna Project should be prioritised and defined, and analyses should be carried out based on this initial prioritisation.

In the context of climate change, the term hazard generally refers to physical events or trends related to climate or its physical impacts. Based on this definition, the current and future climate and its impacts on some crops that may or may not be grown today must be analysed. This requires a baseline of the current climate, e.g., WorldClim (Hijmans et al., 2005), which consists of a set of climate surfaces of approximately 1 km spatial resolution. It provides data from information accumulated from 1950 to 2000, projected into the future and the scenarios of the IPCC Fifth Assessment Report, which are best suited to the conditions in the high Andean region.

Vulnerability comprises a variety of concepts and elements including sensitivity or susceptibility to damage and lack of response and adaptive capacity. Vulnerability should be related to the response capacity and governance of the project territory, with values of socio-economic indices at district level. In this sense, the biophysical sensitivity of crops and livestock activities should also be analysed (modelling of crops and livestock activities) and the social sensitivity that generates indicators, by type of capital, according to the livelihood analysis of the territory.

Ecosystem-based Adaptation (EbA) is the use of biodiversity and ecosystem services as part of a comprehensive adaptation strategy to help people adapt to the effects of climate change. EbA integrates sustainable management, conservation and restoration of ecosystems to provide environmental functions to maintain and enhance resilience and reduce the vulnerability of ecosystems and people. It also creates opportunities for mitigating greenhouse gas emissions, conserving biodiversity, reducing disaster risk and preventing desertification.

Therefore, the analysis of territorial vulnerability is a key prerequisite for designing adaptation strategies in value chains. Proposing actions from the local level makes it possible to address the risks posed by climate change as the great challenge of mitigation and adaptation. This is why it is important to develop spaces for social construction to understand what climate change is and its associated concepts in order to implement measures that help communities and social groups to prepare themselves to face the possible impacts of future climate change.

5.3.1 Exposure to climate hazards and the impact on value chains

The Andes are the largest and highest mountain range in the tropics and their land mass, glaciers and altitude modify the atmospheric circulation and climate of the region (Vuille et al. 2008a; Rabatel et al. 2013). The Andean region is very sensitive to the significant warming evident in recent years (Schauwecker et al. 2014; Vuille et al. 2015) that is affecting the region's hydrology, land use and agro-ecosystems.

Water availability

The Andes are experiencing delayed rainy seasons and consequently longer dry spells, making water and pasture scarcer. It also changes land preparation and planting of crops that depend on these resources.

In this part of the Andean region, water availability is key to agricultural productivity and depends largely on rainfall and access to irrigation systems. The rainy season varies throughout the Andes (between September and November), lasting until March-April.

Temperature increase (max and min)

Rising temperatures, evapotranspiration and glacial retreat are affecting water regulation and the dynamics of ecosystems such as wetlands that depend on and are directly fed by glacial meltwater (Vuille, 2013).

The average warming of the Andes between 1939 and 2006 was around 0.7 °C (Vuille et al. 2008a) with variations conditioned by altitude and slopes (Vuille et al. 2003). Warming trends are highest at high altitudes reaching values of more than 0.3 °C, despite a cooling due to a recent hiatus in warming, mainly affecting coastal areas (Vuille et al. 2015). The warming trend is projected to continue in the coming decades (Thibeault et al. 2010), but with differences as functions of geographical position and altitude not yet clearly determined.

According to the National Institute for Research on Glaciers and Mountain Ecosystems (INAIGEM), Peru has lost 71% of its glaciers nationwide as a result of global warming. This increase in temperature has caused the extinction of the Barroso and Volcanic mountain ranges and has left the Chila, La Raya, Huanzo, Chonta and La Viuda ranges in danger of extinction (in the last decades they have lost more than 90% of their glacier surface). These phenomena undoubtedly affect agricultural and livestock activities, the main pillars of food security in the most vulnerable areas of the Peruvian Andes.

To a large extent, livestock activities are affected because natural grasslands are also affected and the area that is today covered by grasslands, wetlands and shrublands would reduce its area of coverage from 77.6% to approximately 50%. Grasslands would be reduced from 15.4 to 4.6 million ha, while wetlands would decrease from 0.5 to 0.2 million ha. Shrublands would increase substantially over time, from 2.8 to 7.1 million ha (Flores, 2016). As temperatures rise, animals die from lack of grazing areas and planting is delayed.

In the south of the country, lower temperatures have been recorded compared to other years and periods of frosts lasting more days. In 2020, the Sicuani meteorological station in Cusco recorded frosts with a very strong intensity (-10.6 °C) that had not been recorded since 2006 (SENAMHI, 2020).

Table 25: Agricultural area exposed to low temperatures. Source: CENEPRED (2022) – Low temperature risk scenario forecast for June – August 2022

Prioritised districts by department	Agricultural area (ha) exposed to low temperature (very high risk level)	Agricultural area (ha) exposed to low temperatures (high risk level)
Apurímac	-	370,84.7
Arequipa	4,162.8	6,162.3
Cusco	4,024.9	77,994.1
Puno	-	1,120.4
Yauyos, Lima	17,471.7	7,584.0
Total	**25,659.4**	**129,945.5**

Changes in precipitation patterns and droughts

In contrast to the warming characteristics, there is no clear pattern of decreasing or increasing precipitation in the region (Haylock et al. 2006; Morin 2011). Uncertainty in precipitation patterns is recurrent in scenario projections of climate change and decreasing seasonal precipitation levels, but more intense events are expected during the austral summer (Thibeault et al. 2011).

Significant events such as the South American Monsoon (Carvalho et al. 2012) and El Niño Southern Oscillation (Garreaud et al. 2003; Vuille et al. 2008b) that regulate precipitation in the region will be exacerbated by climate change and fuel its effect (IPCC 2013).

Several studies have reported changes in the rainy season and rainfall distribution in the Andes. The rainy season now arrives later and with shorter but heavier rainfall over a shorter period of time, instead of the prolonged, gentle rains of 20-30 years ago (Keleman Saxena et al., 2016).

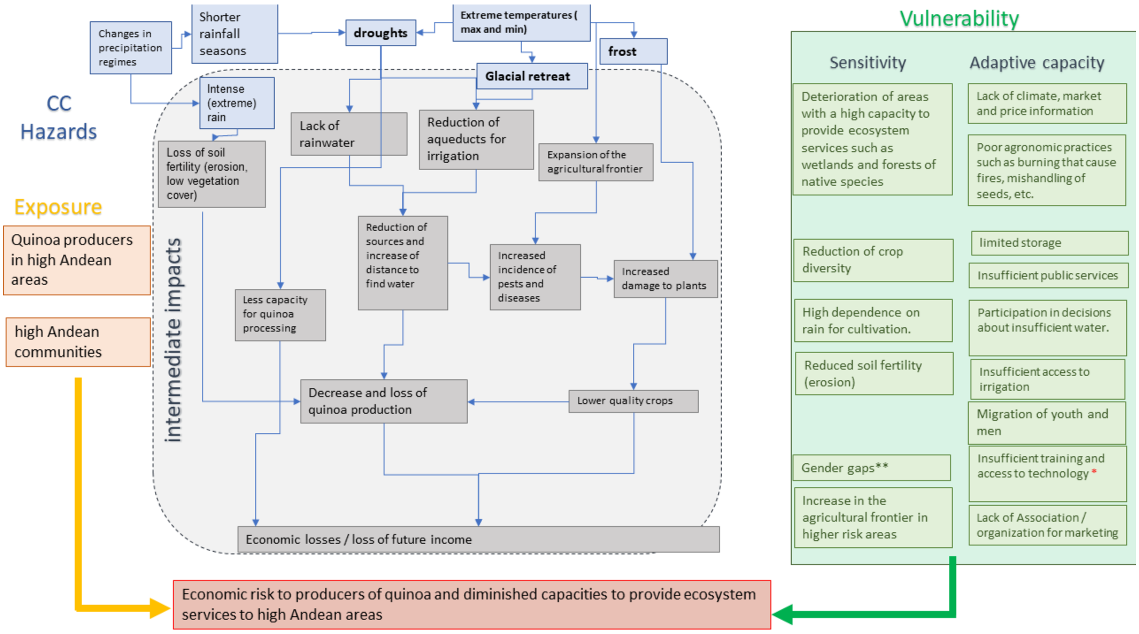
According to Morales et al. (2012) the maximum temperature in summer has a positive impact on benefits, while the maximum temperature in autumn has a negative and greater impact on this variable, and coincides with the periods of tuberization and harvesting of potatoes, which is a predominant crop in Apurímac. In Cusco, on the other hand, the climatic variable that determines the benefits is rainfall; rainfall seems to generate greater vulnerability and more risk for agricultural producers. An increase of 1 mm^3 in minimum precipitation would increase benefits by 0.8%, while an increase of 1 mm^3 in maximum winter precipitation (extreme events) would decrease benefits by 0.5%. If, by 2030, maximum precipitation was to increase by 74.29 mm^3, this would imply a 37% decrease in benefits to farmers.

Similarly, Doughty (2016) found that farmers in the Southern Andes of Peru are already experiencing the problems of climate change. He interviewed farmers in Cusco who explained that hail at the wrong time could severely damage their crops, especially young shoots. The farmers also explained that before they could plant potatoes and it was very fertile land, but now it is degraded, the climate is not as it used to be. Additionally, farmers in the area were extremely concerned about livestock health, specifically related to feed availability and increased diseases/pests.

5.3.2 Climate change effects on High Andean crops

5.3.2.1 Effects on the quinoa value chain

Figure *30*: Effects of climate change in quinoa value chain



In the High Andean crops value chain, drought is affecting crops due to delayed rainfall. Birds have increased and are invading quinoa crops. The cultivation is organic and it is not possible to use products that contaminate, for example, chemicals, or even nets that can generate traces of chemicals in the crops. In Puno, there is individual ownership, 74% of the members are women. There are also women leaders. In Cusco, the majority are communities, women are generally not members, nor are they leaders.

In quinoa, the phenological stages most sensitive to climate change are the flowering stage of the plant and the milky grain stage. The former is affected by frosts and hailstorms, and the latter is affected by the lack of rain (water deficit) on yield and grain quality (Espinoza, 2016).

However, quinoa can, for example, represent an opportunity for farmers in a drier and salt-affected climate, and quinoa varieties can be adapted to cope with high salinity, drought tolerance and grow successfully on poor soils and can be considered a suitable crop to contribute to achieving food security (Ruiz et al., 2015).

The quinoa crop is sensitive to the absence of water and low temperatures; therefore, given the variability of precipitation and air temperature, the variable most affected is the crop yield (SENAMHI, 2019). The stage most sensitive to frost is flowering, when 50% of the inflorescence flowers are open and can only withstand temperatures as low as -2 °C (SENAMHI, 2019).

Quinoa can be cultivated from sea level or coast (0 to 500 masl), the yunga (500 to 2500 masl); middle highlands – Quechua zone or inter-Andean valleys (2500 – 3500 masl) and up to the highlands, Suni or Altiplano (3500 to 4000 masl) (MIDAGRI, 2020).

New climate change patterns, which predict longer droughts in many areas of the Peruvian Andes, pose a major threat to quinoa production. Despite this, climate uncertainty has not prevented the crop from growing at an annual rate of 5.8% in terms of cultivated area (Cancino-Espinoza, 2018). ILO (2023) notes that grain yields can reach 5000 kg per ha in Arequipa, while in the highlands of Puno this value tends to range between 800 kg per ha and 2500 kg per ha; depending on the degree of mechanisation and technical assistance farmers receive (Fairlie, 2016).

Changes in temperature (max-min) is one of the factors affecting quinoa production and yield, and found a negative relationship and that once the optimum temperature threshold of the crop is exceeded, quinoa yield is reduced by 169.1 kg per ha when the temperature rises by 1 °C, and by 127 kg per ha when rainfall rises by 300 mm.

Extreme temperatures (very high and very low) generate pollen sterility and affect the development and growth of the quinoa plant; this results in sterility or immature, shrivelled or underweight grains (depending on the time at which the temperature stress occurs) (MIDAGRI, 2020).

The lack of rainfall and humidity affects the productivity of the crop, since during the periods of germination or emergence, the state of growth and filling of the fruit is impaired (MIDAGRI, 2020).

Frosts, the presence of low temperatures will especially affect the germination and flowering stage, causing low pollen production and consequently, plant sterility (Carrasco, 2016).

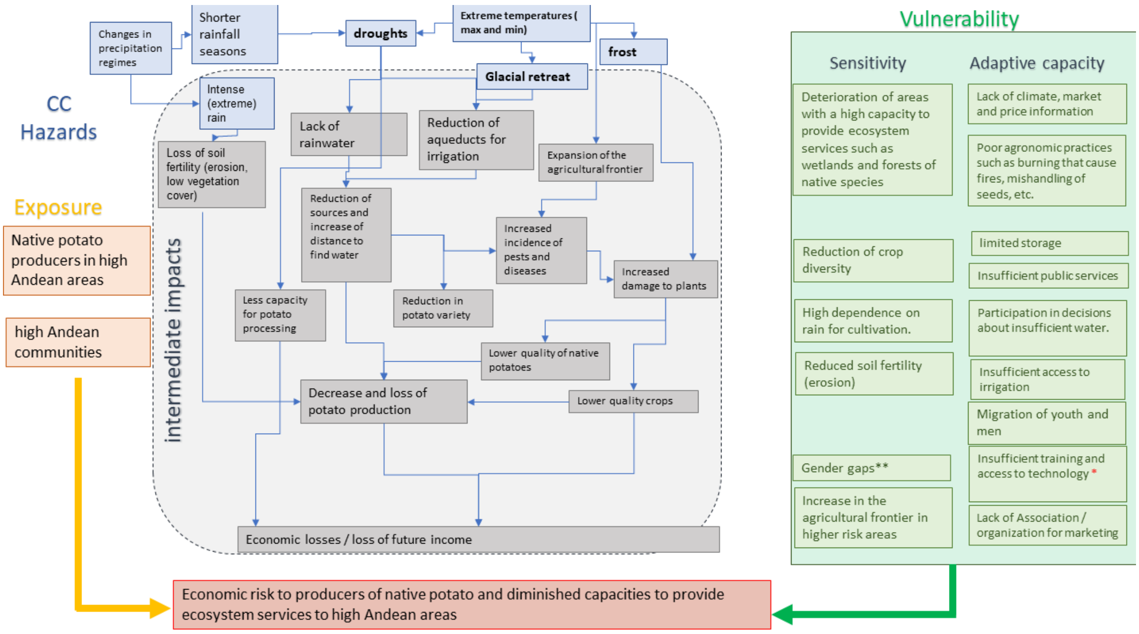
Table *26* Climate change impacts on quinoa value chain. Source: own elaboration.

VALUE CHAIN PHASE / CLIMATE DRIVER	INPUT	HARVEST	LOCAL PROCESSING	LOCAL SALES AND TRADING	LOCAL TRANSFORM. PROCESSES	DOMESTIC MARKET	EXPORT	INT'L MARKET
Temperature extremes	↓ crop growth ↓ production quantity	↑ heat stress for workers ↓ crop yield	↑ heat stress for workers ↓ efficiency of mechanical/automated processes	↑ heat stress for workers ↑ commodity scarcity, increased prices	↑ heat stress for workers ↓ efficiency of mechanical/automated processes ↓ production quality	Minor impacts		
Extreme rainfall	↓ soil fertility ↓ production quantity	↓ crop yield from logistical difficulties	Minor impacts	↓ trade due to logistical difficulties	Minor impacts	↓ trade due to logistical difficulties		Minor impacts
Drought	↓ crop growth ↓ production quantity	↓ crop yield	↓ production quality ↓ production quantity owing to water scarcity	↑ commodity scarcity, increased prices	Minor impacts	↑ commodity scarcity, increased prices	Minor impacts	↑ commodity scarcity, increased prices
Frost	↓ crop growth ↓ production quantity	↓ crop yield	↓ production quality	↑ commodity scarcity, increased prices	Minor impacts	↑ commodity scarcity, increased prices	Minor impacts	↑ commodity scarcity, increased prices
Glacial retreat	↓ crop growth ↓ production quantity	↓ crop yield	↓ production quality	↑ commodity scarcity, increased prices	Minor impacts	↑ commodity scarcity, increased prices	Minor impacts	↑ commodity scarcity, increased prices

Legend: ↑ increase ↓ decrease Minor negative impacts Moderate negative impacts Major negative impacts

5.3.2.2 Effects on the native potato value chain

Figure *31*: Effects of climate change in native potato value chain



The Altiplano is characterised by its high altitude (over 3,500 m), representing an area highly vulnerable to the climatic variability generated by the ENSO phenomenon (Rome-Gaspaldy & Ronchail, 1998) and to the risks of drought and radiative frosts (Alarcón, 1997). The main economic activity in the region is agriculture (crops and livestock) and potato is the most important crop, with a great diversity of species. It is grown under rainfed conditions and is essentially for self-consumption (Sanabria & Lhomme, 2013).

The potato plant is sensitive to water deficit as its roots are unable to overcome the small retention stress at shallower soil depths compared to the roots of other cultivated plants; under mountain conditions the crop needs approximately 600-1000 mm of rainfall per hectare (Egúsquiza et al., 2020).

Potato cultivation, in order to maintain its nutritional properties, requires cold temperatures. Many farmers in the High Andes have moved the agricultural frontier upwards to maintain favourable temperatures for their crops (Giamberso, 2014). Shaw and Kristjanson (2013) found that potato farmers in the region have raised their crops by approximately 150 m in the last 30 years. Arce et al. (2019) found that in Huancavelica, native potatoes rose almost 500 m above those reported 38 years ago. Evidence also indicates that farmers are responding to climate change by increasing areas of potato cultivation in natural grassland areas in Puna areas, due to the increased population and rate of pests and diseases that appear to be occurring at lower altitudes, with the unintended consequence of conversion of native grasslands to cultivated areas, which could potentially lead to reduced carbon sequestration and increased release of carbon into the atmosphere (Quiroz et al., 2018).

Changes in weather patterns increase the exposure of crops to pests and diseases, marginalising the use of native varieties, as commercial potato varieties are more resistant to pests.

Farmers are restricting planting of native varieties to recently fallow land and higher altitudes, where pest loads are lower, while reserving more fertile lowland and accessible plots for commercial varieties (Saxena et al., 2016).

Puno has the highest percentage of exposed agricultural area (672,317 ha), followed by Apurímac with (282,153 ha), Cusco with (271,882 ha), Arequipa with (87,202 ha) and Lima with (70,844 ha) (CENEPRED, 2022). This department, due to severe unfavourable climatic conditions, has had the highest level of potato crop losses compared to the other departments (Mendoza, 2009). This has a direct impact on producers in High Andean communities (Puno, Cusco, Apurímac, and Arequipa) as a large part of their income and food comes from potato cultivation; approximately 45% of the income of the rural poor comes from agricultural labour (World Bank, 2022).

Potato cultivation is thus affected by climate change in different ways, such as reduced potato varietal diversity, increased frequency of frost and drought, and increased frequency of pest and disease attack (Practical Solutions, 2010; de Haan, 2019). The change in rainfall occurrence and intensity, as a result of climate change, affects the cultivation of native potatoes and other Andean grains, causing the growing season to be shortened at both ends (Giamberso, 2014). It is estimated that, in the coming decades, the reduction of the rainy season and the increase of drought periods will have the greatest impact on native potato cultivation (INIA, 2012).

Native potato production is mostly in Suni and Puna areas, with relatively low yields compared to modern improved varieties, and climate change will lead to a reduction in available water and an increase in temperature that will affect tuberization and tunta production. Within climate-adapted agriculture, the literature reviewed and local stakeholders surveyed mention that drought is occurring and is expected to worsen in the south of the country, with less water in the aquifers, shorter and more intense rainfall periods, higher ambient temperatures, however, frost is also reported during the growing season.

Rising maximum and minimum temperatures are a danger to the chain. The southern highlands are increasingly experiencing unusual maximum and minimum temperatures. SENAMHI (2021a) recorded consecutive very hot and extremely hot days in July during the day, while night temperatures were consecutively cold and very cold. In Puno, a record low monthly minimum temperature of -4.64 °C was recorded in 2020; where the area of cropland exposed to the very high danger level of low temperatures is 228,359.200 ha; and to the high level is 24,954.04 ha (GORE Puno, 2021). These temperature changes (maximum and minimum) generate increasingly recurrent pests, which affect the yield of the native potato crop (Quiroz et al., 2018).

On the other hand, according to a study by the International Potato Centre (CIP) (1980), drought in the Andes can cause yield losses of up to 85%. Andean departments such as Puno have the highest percentages of drought-affected potato crops, with districts in which drought has affected between 90%-100% of potato crops (SENAMHI, 2021b).

The droughts have caused a reduction of approximately 12.1% in potato sowings (2022/2023 season) with respect to the average accumulated sowings up to October of the last 5 seasons, i.e., 21,028 ha less (MIDAGRI, 2022e). The area planted at national level for the 2022/2023 crop year (period: August-December) for potato cultivation was 152,775 ha, of which 28,472 ha (18.64%) were affected, representing an approximate of 367,990 t (worth PEN 482,807,190). Puno and Cusco were the main departments with the highest losses and damages (MIDAGRI, 2022e).

Low temperatures (frosts) affect the level of native potato production, especially in the departments of Puno, Apurímac, Cusco (MIDAGRI, 2020). The increasingly aggressive intensity of frosts causes plants/crops to burn. In some Andean departments of southern Peru, the presence of meteorological frosts affects potato plantations in full vegetative growth phase (lateral shoots), during the first month of the year, causing a high risk (SENAMHI, 2022). An unexpected frost or hailstorm can be extremely damaging to the potato crop and, in some cases, can cause the loss of an entire potato farm (Giamberso, 2014). In 2009, potato crop losses due to hailstorms averaged between 50% and 60% (Ensor & Berger, 2009). In 2020, more than 150ha of potato crops were lost to frost in just two districts of Cusco; leaving villagers with even less resources to subsist as agriculture is their only means of income (RPP, 2020).

In the department of Apurímac, approximately 4,272 ha of surface area for potato cultivation was compensated by MIDAGRI due to frost for the period 2011-2022 (MIDAGRI, 2023). Likewise, in the department of Cusco, approximately 1,218 ha were compensated for potato cultivation (2013-2022) due to frost, and in the department of Puno, 775 ha (2013-2022). In 2021, more than PEN 4 million was compensated to farmers affected by the frosts in the southern part of the country, however, the losses represented more than PEN 10 million (RPP, 2021).

Condori et al. (2014) in their study of potato biodiversity management in the face of frost risk in the Andes found that, generally, the greatest losses were evident in early frosts, with average yield reductions ranging from 70-100% when they occurred at 30 and 60 DAE (days after planting); while at 90 DAE, the average reduction was around 50%.

Table *27* Climate change impacts on native potato value chain. Source: own elaboration

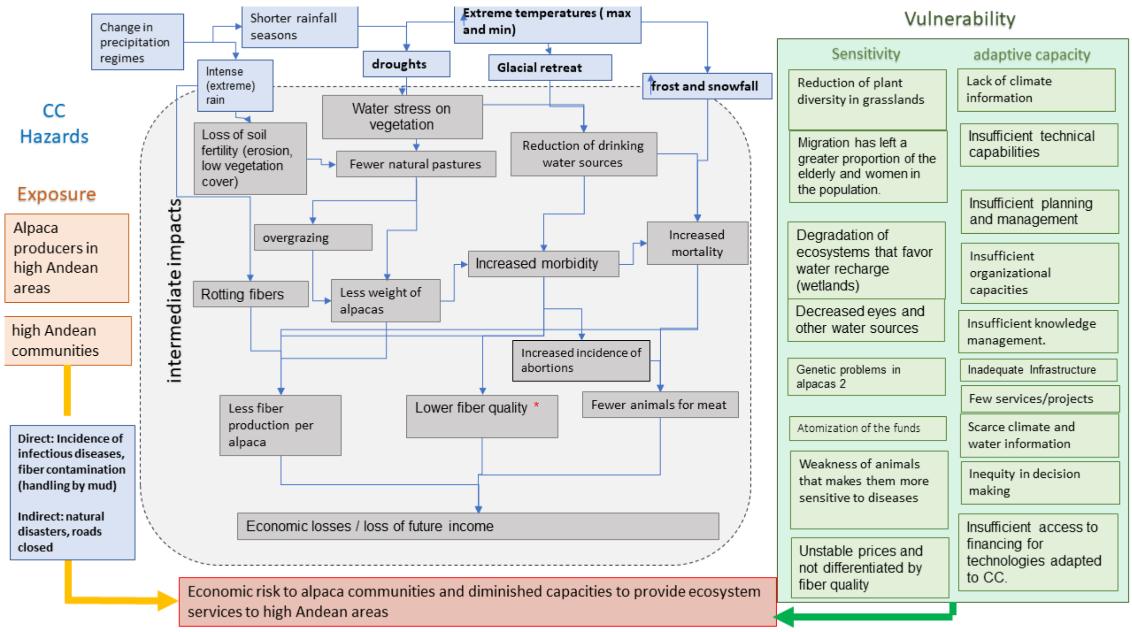
VALUE CHAIN PHASE / CLIMATE DRIVER	INPUT	HARVEST	LOCAL PROCESSING	LOCAL SALES AND TRADING	LOCAL TRANSFORM. PROCESSES	DOMESTIC MARKET	EXPORT	INT'L MARKET
Temperature extremes	↓ crop growth ↓ production quantity	↑ heat stress for workers ↓ crop yield	↑ heat stress for workers ↓ efficiency of mechanical/automated processes	↑ heat stress for workers ↑ commodity scarcity, increased prices	↑ heat stress for workers ↓ efficiency of mechanical/automated processes ↓ production quality	Minor impacts		
Extreme rainfall	↓ soil fertility ↓ production quantity	↓ crop yield from logistical difficulties	Minor impacts	↓ trade due to logistical difficulties	Minor impacts	↓ trade due to logistical difficulties		Minor impacts
Drought	↓ crop growth ↓ production quantity	↓ crop yield	↓ production quality ↓ production quantity owing to water scarcity	↑ commodity scarcity, increased prices	Minor impacts	↑ commodity scarcity, increased prices	Minor impacts	↑ commodity scarcity, increased prices
Frost	↓ crop growth ↓ production quantity	↓ crop yield	↓ production quality	↑ commodity scarcity, increased prices	Minor impacts	↑ commodity scarcity, increased prices	Minor impacts	↑ commodity scarcity, increased prices
Glacial retreat	↓ crop growth ↓ production quantity	↓ crop yield	↓ production quality	↑ commodity scarcity, increased prices	Minor impacts	↑ commodity scarcity, increased prices	Minor impacts	↑ commodity scarcity, increased prices
Pests and diseases	↓ crop growth ↓ production quantity ↓ native varieties	↓ crop yield as epidemic diseases impact local communities	↓ production quantity as epidemic diseases impact local communities	↑ commodity scarcity, increased prices ↓ trade quantity as epidemic diseases impact local communities	↓ production quantity as epidemic diseases impact local communities ↓ production quality	↓ trade quantity as epidemic diseases impact local communities	Minor impacts	↑ commodity scarcity, increased prices

Legend: ↑ increase ↓ decrease Minor negative impacts Moderate negative impacts Major negative impacts

5.3.3 Climate change effects on South American camelids

5.3.3.1 Effects on the alpaca value chain

Figure *32*: Effect of climate change in alpaca value chain



In the face of different climatic events, alpacas die of hunger or cold, as they are not animals that are raised in stables; this constitutes a great economic loss for rural producers as alpacas not only provide them with wool and meat, but also when sold in markets they represent an income for the family and reduce the temporary migration of part of the family to the cities (Valdivia et al., 1996; Valdivia, 2001; Baigorria, G., 2021).

The study by Desco (2011) found a high mortality rate of alpacas due to extreme events, with 30% in calves, 10% in adults and 20% in abortions. Torres and Gómez (2008) found, with respect to livestock production, that the sprouting and growth of pastures is retarded by drought, and that these problems were exacerbated by the lack of climate risk management for alpaca rearing.

Levels of damage to natural pastures due to snowfall-frost can be as high as 60% in alpaca communities (Desco, 2011).

The general habitat of alpacas is above 3,800 masl, being exposed to delayed rainfall (drought), especially in the final third of gestation periods (for a total period of 11.5 months), which is where abortions occur due to the high incidence of drought (MIDAGRI, 2022d).

In the department of Puno, approximately 1,348,275 alpacas are exposed to a very high danger level of low temperatures and 1,400,500 alpacas to a high level (GORE Puno, 2021). The area of land with natural pasture that is exposed to a very high level of danger due to low temperatures in the department of Puno is approximately 2,873,668.300 ha; and at a high level, 3,247,943.34 are exposed this year (GORE Puno, 2021).

Climate change, especially drought and frost, influences the alpaca value chain by affecting the pastures where alpacas feed, as well as alpaca offspring, increasing disease and mortality.

Changes in temperature (max-min). Severe nocturnal temperature drops cause pneumonia in South American camelids (SENAMHI, 2022b).

In 2019, PEN 38.5 million was allocated under the Multisectoral Plan against Frosts and Cold Weather 2019 – 2021, to protect 226,500 head of livestock, including alpacas and sheep, against low temperatures with the implementation of 2,265 sheds in the High Andean areas of Apurímac, Arequipa, Ayacucho, Cusco, Huancavelica, Moquegua, Pasco, Puno and Tacna (MIDAGRI, 2019).

The atypical period of droughts between October and December has affected the productive and reproductive performance of all livestock species; however, the most affected species has been the alpaca (MIDAGRI, 2022c). In 2022, MIDAGRI declared an emergency in the High Andean zone due to severe droughts. At the national level, that year, 293,286 alpaca abortions occurred due to droughts, affecting a total of 80,509 families of producers due to the reduction of their livestock capital (MIDAGRI, 2022d).

In the irregular rainy season (delay and/or drought) the birth of alpaca calves is affected by 20% due to an increase in the rate of abortions, so MIDAGRI estimated that there would be 116,758 abortions in Puno; 43,622 in Cusco; 37,458 in Arequipa and 17,514 in Apurímac (MIDAGRI, 2022c). The death of more than 5,000 alpaca calves was recorded in the province of Carabaya in Puno; figures outside the normal range (RPP, 2021). It also estimated that the total value of alpacas affected by drought was PEN 61,133,163 (MIDAGRI, 2022e).

During the frost season, alpacas contract diseases such as pneumonia and fever; in addition, the frost burns the grasses that are in the process of sprouting and influences the decrease in their supply in the following months (Desco, 2011). In the province of Caylloma (Arequipa), mortality of calves was 25%, mainly due to pneumonia and enterotoxaemia, while adult mortality was 5% due to fever and accidents (Desco, 2011). In the department of Pasco, approximately 200 ha of pasture were lost due to frost, leaving farmers with large economic losses (Diario Correo, 2018).

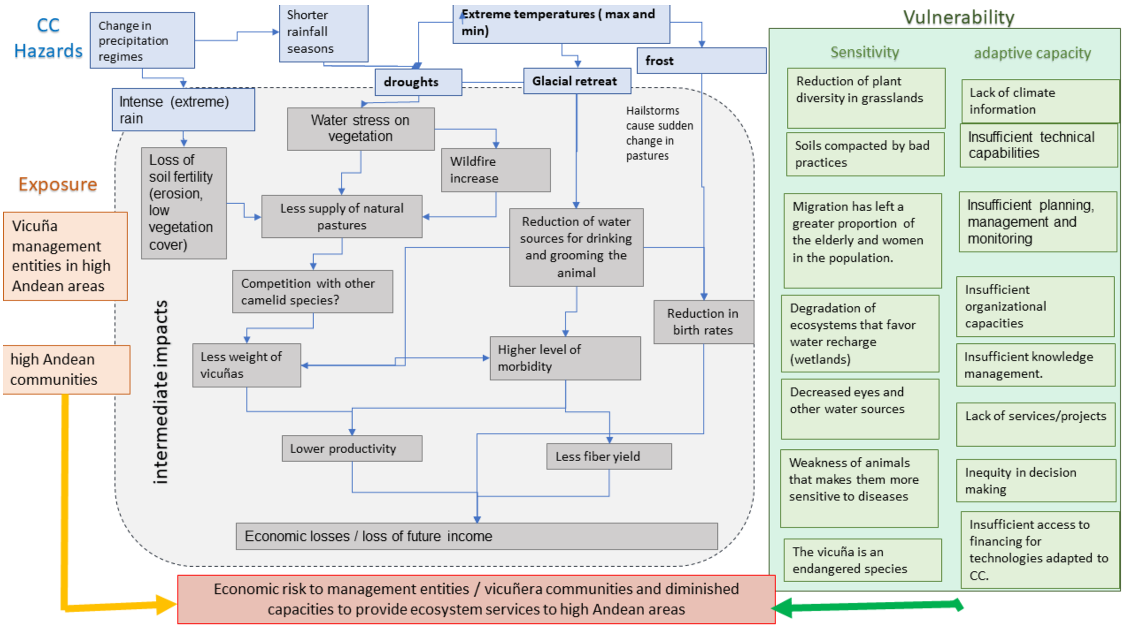
Table *28* Climate change impacts on the alpaca value chain. Source: own elaboration.

CLIMATE DRIVER \ VALUE CHAIN PHASE	INPUT	HARVEST (meat/fiber)	LOCAL PROCESSING (washing, combing etc.)	LOCAL SALES AND TRADING	LOCAL TRANSFORM. PROCESSES (weaving, knitting etc.)	DOMESTIC MARKET	EXPORT	INT'L MARKET
Temperature extremes	↓ carrying capacity ↑ herd morbidity and mortality ↓ herd size	↓ meat/fiber yield ↓ fiber quality	↑ heat stress for workers ↓ efficiency of mechanical/automated processes	↑ commodity scarcity, increased prices	↑ heat stress for workers ↓ efficiency of mechanical/automated processes ↓ production quality	↑ commodity scarcity, increased prices	Minor impacts	
Extreme rainfall	↓ vegetation quality ↓ carrying capacity	↓ fiber quality	Minor impacts	↓ trade due to logistical difficulties	Minor impacts	↓ trade due to logistical difficulties		Minor impacts
Drought	↓ carrying capacity ↓ herd size	↓ meat/fiber yield	↓ production quality ↓ production quantity	↑ commodity scarcity, increased prices	Minor impacts	↑ commodity scarcity, increased prices	Minor impacts	↑ commodity scarcity, increased prices
Frost	↑ herd mortality ↓ herd size	↓ meat/fiber yield ↓ fiber quality	↓ production quality ↓ production quantity	↑ commodity scarcity, increased prices	Minor impacts	↑ commodity scarcity, increased prices	Minor impacts	↑ commodity scarcity, increased prices
Glacial retreat	↓ sources of drinking water ↓ herd size	↓ meat/fiber yield	Minor impacts	↑ commodity scarcity, increased prices	Minor impacts	↑ commodity scarcity, increased prices	Minor impacts	↑ commodity scarcity, increased prices
Pests and diseases	↑ herd morbidity and mortality ↓ herd size	↓ meat/fiber yield ↓ fiber quality	↓ production quantity as epidemic diseases impact local communities	↑ commodity scarcity, increased prices	↓ production quantity as epidemic diseases impact local communities	↑ commodity scarcity, increased prices	Minor impacts	↑ commodity scarcity, increased prices

Legend: ↑ increase ↓ decrease Minor negative impacts Moderate negative impacts Major negative impacts

5.3.3.2 Effects on the vicuña value chain

Figure *33*: Effects of climate change on vicuña value chain



Extreme weather events such as frosts and droughts negatively affect the availability and quality of pastures, endangering not only alpacas but also wild animals such as vicuñas (Vicugna vicugna).

The vicuña belongs to the group of wild South American camelids, characterised by the fact that it adapts to the climate of the high Andean zones between 3,800 and 4,800 masl and lives for an average of 12 to 13 years.

They feed on natural grasses and have a gestation period of 11.5 months, of which, at the beginning of the second half of gestation, droughts occur (MIDAGRI, 2022c).

Due to glacial retreat, changes in hydrological regimes are expected to impact livelihoods, ecosystems and wildlife in mountain regions. Changing rainfall patterns and unpredictable seasons in addition to the challenges for farming communities in the Andes, and the household economy, also impact endangered wildlife species such as the vicuña.

The activity patterns and daily movements of vicuñas are strongly influenced by water availability as they are obligate drinkers (Franklin, 2011).

The vicuña forms part of the characteristic fauna of the dry Puna and humid Puna ecosystems, which are considered to be exposed to fires and overgrazing (Kometter, 2022).

Animals are also exposed to higher levels of radiation during the dry season, which has consequences for their health.

Changes in temperature (max-min) and severe night-time temperature drops cause pneumonia in South American camelids (SENAMHI, 2022b).

Droughts and lack of rainfall is a favourable condition for the occurrence of fires on vegetation cover in the humid Puna ecosystem (up to 93.73% of the territory) (Kometter, 2022). The highest frequency of fires has occurred in the years 2000, 2005, 2010 and 2016, which could be explained by the decrease and/or absence of rainfall, as these years historically correspond with dry periods (MINAM, 2019). Due to lack of resources to prevent diseases in vicuñas, the fibre harvested by small farmers is more likely to be of lower quality due to problems of mange and dandruff in the animals, which affects the quality of the fibre (Briceño, 2012). Only in times of extreme drought do they eat tola or other thorny shrubs of low nutritional value (Baldo et al., 2013).

Heavy frosts burn the natural grasses on which the vicuñas feed, as well as those that are in the process of sprouting and influence the decrease in their supply in the following months (Desco, 2011). The forage species for the vicuña is Calamagrostis vicunarum and is found at an altitude of 3797 to 4144 masl (Kometter, 2022).

Table *29* Climate change impacts on the vicuña value chain. Source: own elaboration.

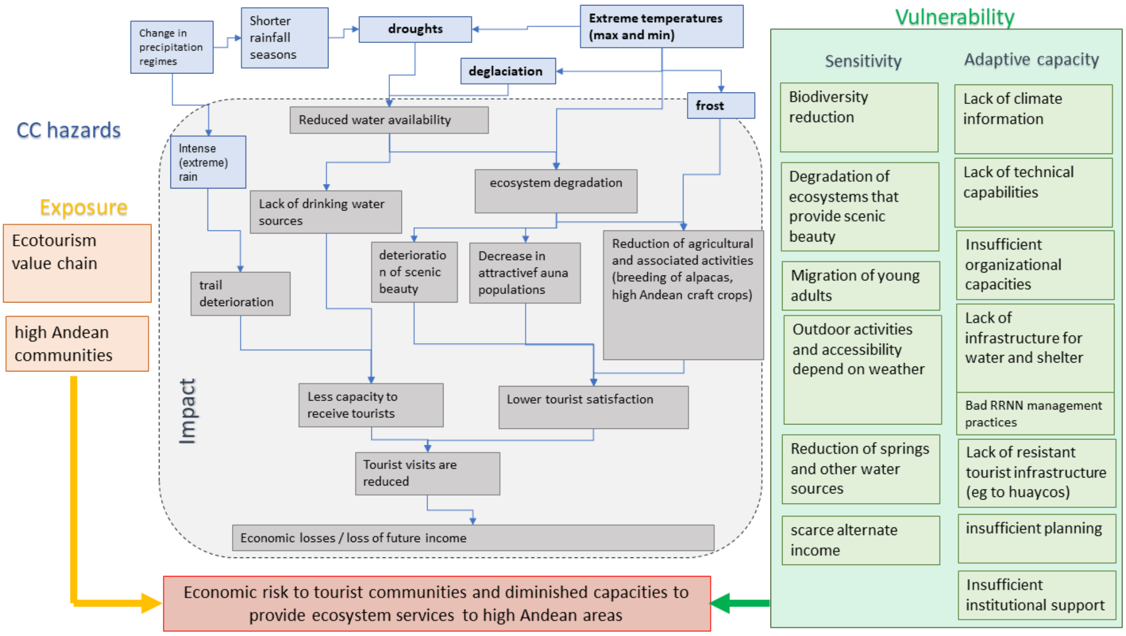
VALUE CHAIN PHASE / CLIMATE DRIVER	INPUT	HARVEST (fiber)	LOCAL PROCESSING (washing, combing etc.)	LOCAL SALES AND TRADING	LOCAL TRANSFORM. PROCESSES (weaving, knitting etc.)	DOMESTIC MARKET	EXPORT	INT'L MARKET
Temperature extremes	↓ carrying capacity ↑ herd morbidity and mortality ↓ herd size	↓ fiber yield ↓ fiber quality	↑ heat stress for workers ↓ efficiency of mechanical/automated processes	↑ commodity scarcity, increased prices	↑ heat stress for workers ↓ efficiency of mechanical/automated processes ↓ production quality	↑ commodity scarcity, increased prices	Minor impacts	
Extreme rainfall	↓ vegetation quality ↓ carrying capacity	↓ fiber quality	Minor impacts	↓ trade due to logistical difficulties	Minor impacts	↓ trade due to logistical difficulties		Minor impacts
Drought	↓ carrying capacity ↓ herd size	↓ fiber yield	↓ production quality ↓ production quantity	↑ commodity scarcity, increased prices	Minor impacts	↑ commodity scarcity, increased prices	Minor impacts	↑ commodity scarcity, increased prices
Frost	↑ herd mortality ↓ herd size	↓ fiber yield ↓ fiber quality	↓ production quality ↓ production quantity	↑ commodity scarcity, increased prices	Minor impacts	↑ commodity scarcity, increased prices	Minor impacts	↑ commodity scarcity, increased prices
Glacial retreat	↓ sources of drinking water ↓ herd size	↓ fiber yield	Minor impacts	↑ commodity scarcity, increased prices	Minor impacts	↑ commodity scarcity, increased prices	Minor impacts	↑ commodity scarcity, increased prices
Pests and diseases	↑ herd morbidity and mortality ↓ herd size	↓ fiber yield ↓ fiber quality	↓ production quantity as epidemic diseases impact local communities	↑ commodity scarcity, increased prices	↓ production quantity as epidemic diseases impact local communities	↑ commodity scarcity, increased prices	Minor impacts	↑ commodity scarcity, increased prices

Legend: ↑ increase ↓ decrease Minor negative impacts Moderate negative impacts Major negative impacts

5.3.4 Climate change effects on complementary value chains

5.3.4.1 Effects on the community-based tourism value chain

Figure *34*: Effects of climate change on community-based tourism value chain



As indicated by Valdivia et al (2014), community-based tourism in the High Andean zone is presented as an adaptation strategy to climate change, it uses and conserves natural heritage for tourism and is able to complement agricultural income and sustain rural livelihoods of high Andean populations impacted by droughts, frosts, floods and diseases.

Community-based tourism depends on ecosystems, nature, biodiversity, etc. and needs to provide a healthy natural landscape to be attractive to tourists (Valdivia and Barbieri, 2014). Tourism is a sector sensitive to the effects of climate change; as extreme events are related to the likelihood of road breaks, landslides, floods, forest fires, loss of biodiversity and scenic beauty (ECLAC, 2014; WWF, 2001). It is estimated that by 2100, accumulated losses of PEN 5 million could be generated (ECLAC, 2014).

Increases in daytime temperatures and decreases in nighttime temperatures, changes in the intensity and frequency of short-term rainfall, with potential risk scenarios for floods and landslides, prolonged summers, droughts and seasonal frosts significantly affect the health and agricultural and tourism activities of the people of Anacash (GORE Anacash, 2016).

The natural environment is very important in determining the attractiveness of a region for tourism. This is especially true for nature-based tourism, which is one of the fastest growing segments of the tourism market worldwide. A study of the nature-based tourism market (HLA & ARA, 1995) found that the natural environment was the most critical factor in determining the quality of a tourism product. Consequently, if climate change negatively affects the natural environment of mountain destinations (loss of glaciers, special flora or fauna, fires and diseases affecting forest landscapes), the quality of the tourism product would be diminished, with implications for visitation and local economies.

In addition, heavy rains and avalanches can put tourists who travel to these mountainous areas at risk, endangering the lives of the people who live in the communities, as well as the road and tourist infrastructure. In the case of droughts, the canoeing activity that takes place in the rivers surrounding the communities is affected, as well as the scenic beauty of the areas and the scarcity of water for the different activities. In the SHAP region, glaciers are a major tourist attraction and play an important role in the relationship between communities and nature, facilitate economic activities such as tourism, and use glacial meltwater for agriculture. NPAs also depend on tourism activities, especially the rural community-based tourism that takes place in these areas.

If the effects of climate change continue to progress, experts warn the market for nature-based tourists will decline, and jobs in hotels and businesses would consequently be lost. In the case of mountain communities, tourism is part of their livelihood. The UN World Tourism Organization considers them as areas particularly sensitive to climate-induced environmental changes by targeting nature-based tourism niches.

Peru has lost 71% of its glaciers nationwide, according to the National Institute for Research on Glaciers and Mountain Ecosystems (INAIGEM). The increase in maximum temperatures leads to the disappearance of glaciers and snow-capped mountains, and in some cases, such as the Ampay glacier, they may even disappear faster than expected (Serrano, 2018).

In the case of Cusco, the melting of the glaciers is threatening the sacred ancestral festivals and rituals that the indigenous Quechua communities perform. An example is the Qoyllur Riti, a ritual performed on the Colque Punko (Ausangate) Mountain. Communities perceive that their rituals and beliefs may be affected by climate change as it is changing cultural practices. Devotees can no longer climb to the top of the glaciers to collect ice (an important practice in the ritual). They must take ice from the foot of the glacier, as higher up they have no stability to sustain them. The Qoyllur Riti normally attracts 100,000 visitors (tourists and devotees) each year.

According to SENAMHI (2023), the departments of the south-western and eastern highlands will have above-normal and below-normal rainfall conditions in July (43%). Droughts cause crop losses and as a consequence there is less variety and higher prices in the products offered in the local market and specifically for tourists.

In places where there is no potable water, inhabitants and tourism stakeholders depend on rainfall to be able to receive and serve tourists.

According to the Peruvian Geophysical Institute, the regions most prone to the negative effects of frost, owing to their proximity to the inter-Andean valleys of the altiplano, are Cusco, Puno, Junín, Huancavelica, and Ayacucho (RPP, 2021). Frosts cause crop losses, and, as a result, there is less variety and higher prices in the products offered in the local market, specifically for tourists.

Table *30* Climate change impacts on the ecotourism value chain. Source: own elaboration.

VALUE CHAIN PHASE / CLIMATE DRIVER	INPUT (environment)	SUPPLIERS (travel agencies, tour operators)	TRANSPORT & ACOMMODATION	LOCAL COMMUNITY SERVICE PROVISION (tour guides, recreational activities, handicrafts etc.)
Temperature extremes	↓ ecosystem degradation ↓ natural beauty	↓ income reduction from lack of tourists	↓ income reduction from lack of tourists	↑ heat stress tourists and local community ↓ income reduction from lack of tourists ↓ crop losses ↓ tourist satisfaction ↓ impact on cultural practices
Extreme rainfall	↓ trail deterioration ↑ risk of landslides	Minor impacts	↓ visits due to logistical difficulties	↓ reduced tourist capacity
Drought	↓ reduction in drinking water ↓ ecosystem degradation ↓ natural beauty	↓ income reduction from lack of tourists	↓ lack of drinking water ↓ income reduction from lack of tourists	↓ crop losses ↓ reduced tourist capacity ↓ income reduction from lack of tourists ↓ tourist satisfaction ↑ commodity scarcity, increased prices
Frost	↓ ecosystem degradation	↓ revenue reduction from lack of tourists	↓ income reduction from lack of tourists	↓ crop losses ↓ reduced tourist capacity ↓ reduction in agricultural activities ↑ commodity scarcity, increased prices
Glacial retreat	↓ ecosystem degradation ↓ natural beauty	↓ revenue reduction from lack of tourists	↓ income reduction from lack of tourists	↓ income reduction from lack of tourists ↓ reduced tourist capacity ↓ impact on cultural practices

Legend: ↑ increase ↓ decrease Minor negative impacts Moderate negative impacts Major negative impacts

5.4 Recommended measures and strategies for climate-resilient value chains

5.4.1 Developing interventions

Upon analysing the economic activities related to rural communities in the Puna region, it becomes evident that there is a significant heterogeneity in production systems, organizational development, and market integration. Various initiatives exist, requiring coordination to bring about transformative changes, address climate change, and enhance the resilience of local communities. Additionally, initiatives are needed to conserve and restore fragile ecosystems and biodiversity.

To design an intervention strategy for this complex scenario, an examination of the relationships between communities, the biophysical landscape, and their livelihood strategies for sustenance and services is essential. Over the last decade, Peru has undergone transitions that support sustainable agriculture and a resilient agricultural sector. Mitigation measures and ecosystem-based adaptation have gained success. Although climate change and mitigation have received substantial funding, agricultural initiatives remain inadequately integrated across sectors and regions. Measures such as Ecosystem-based Adaptation (EbA) have demonstrated their ability to enhance and restore ecosystem services, including water, grasslands, and soil fertility. Adaptive practices like efficient irrigation systems and crop rotation have also proven effective in increasing resilience within the value chain and for farmers' livelihoods. There is an opportunity to integrate both approaches to ensure resilience within the complexity of the Puna Region.

Economic activities should be oriented towards three objectives based on their functionality: (1) Strengthening organizations and catalysing climate adaptation while preserving ecosystems, biodiversity, and services to ensure household food supply. (2) Providing reimbursable resources to established organizations, catalysing transformational change towards climate resilience, and ensuring sustainability through market participation. (3) Catalysing transformational change, including promoting EbA and adaptation measures in existing productive programs supported by the Peruvian government (AgroIdeas).

Understanding the needs at these three levels will be vital to facilitate a sustainable and resilient promotion of value chains in the territory. Considering climate change scenarios for the Peruvian Puna, aspects such as the organization of productive activities within households, community decisions on land and resource use, access to land use, use of family labor, and property rights over land, water, fauna, and flora will be decisive in designing intervention strategies that align with the socio-ecological conditions of the territory. Knowledge of the rationalities behind the use and combination of physical, human, natural, financial, and social capital of rural households can provide options for proposing and agreeing on measures for sustainable development and adaptation to climate change.

Diversified systems on farms result in a livelihood strategy for a high percentage of rural families. According to INEI (2012), almost 85% of rural producers in the high Andean zone practice polyculture as part of the production of their wage-goods, some within self-subsistence economies, and others realising surpluses in local and regional markets. This means that approximately 15% of the rural producers in the Puna actively participate in the markets, have specialised their productive offer and have become part of the global chains of products such as quinoa, alpaca and vicuña fibre, with different standards of quality and commercial articulation. These include consolidated producers' cooperatives and associations that persist despite price fluctuations, often with the support of government bodies or international cooperation agencies.

An element to be taken into account at any level of intervention in these landscapes should not overlook the fact that many of the crop and livestock management activities are supported by a diversity of species that are part of long processes of adaptation of the inhabitants of the puna to climate variations and that constitute the most important source of their natural capital and ecosystem adaptation processes. On the other hand, the persistence of institutional rules of the game to face labour demands, scarcity of credit capital, community (ayllu, mita) and cultural institutions and links, and ancestral knowledge, represent another strength of the social capital of the inhabitants of the territory.

Over the past few decades, public interventions and certain market trends have spurred the development of productive activities linked to international and national markets. This has led to the emergence of specialized value chains, with medium-sized rural enterprises benefiting from technology access, credit resources, and improved management and market capabilities. These four regions have seen a growing export supply that was sustained until before the pandemic. Public funds and cooperation resources have played a significant role in promoting the production of raw materials like quinoa grain, alpaca, vicuña fibre, and native potatoes. Private industrial processing sectors have actively engaged with producer associations, although the introduction of environmental and social standards, such as Organic Production Certificates, Fair Market, and RAS standard for textile fibres, has started changing the dynamics in recent years.

However, these strategies often lack an integrated and holistic vision that considers the diversity of ecosystems and production systems. In Peru, food insecurity affects almost half of the population, surpassing the pre-pandemic figure of eight million. This is primarily due to increasing poverty and barriers to accessing a healthy diet. To ensure sustainability and the conservation of increasingly scarce resources and services, a sustainable strategy should not solely focus on external markets but also prioritize food security as an integral part.

In the case of quinoa and alpaca fibre, there are potential threats of future competition in the markets from countries like China, Australia, and the USA, where capital- and technology-intensive companies are establishing themselves. To address this, it is crucial for regional and national institutions to be proactive in facing these challenges. Exploring local and national markets can offer an opportunity for these products, including their derived products, to be included in national programs such as Qali Warma. The Qali Warma program ensures food provision to students in public schools throughout the school year based on their characteristics and residential areas, which can further enhance local market opportunities.

As mentioned above, in order to guarantee impacts on the different dimensions of development, the value chain approach must be complemented with other territorial, gender, intercultural, climate change, biodiversity green economy and ecosystem services approaches. These topics have been considered in the respective chain diagnoses and, in any case, respond to the interest of serving as a reference framework for the design of a chain strategy for the Puna ecosystems affected by the impacts of climate change.

5.4.2 Strategies for selected value chains

According to the arguments presented above, the strategy options for the development of a value chain are multiple and will depend on the visions determined in a concerted manner by the direct actors in the chain, against the backdrop of resilience to climate change.

The classification of farmers in the project intervention zones is presented in the following table:

Table *31*: Classification of farmers in the project intervention areas. Source: Grade (2015)

Department	Subsistence family farming	Intermediate Family Farming	Consolidated Family Farming
Apurímac	87%	11%	2%
Arequipa	55%	21%	24%
Cusco	82%	16%	2%
Puno	79%	19%	2%
Lima (Yauyos)	73%	21%	6%

The analysis reveals a high concentration of the population engaged in subsistence family farming. Based on SWOT analyses of the selected value chains, various options are oriented towards different objectives. These include enhancing the value chain and fostering innovation, addressing market failures for small producers through associativity and increased bargaining power, adopting measures to tackle climate change impacts such as drought, and promoting the efficient use of natural resources like water and soil. Additionally, the identification of business models that benefit vulnerable groups, including young people and women, is of paramount importance.

In this regard, a single strategy cannot be applied to the development of the analysed chains. Instead, a diversified approach is needed, taking into account the vulnerability of ecosystems to climate change, the design of ecosystem-based adaptation (EbA) measures at the local level, and the analysis of livelihoods and productive strategies of rural producers and communities. Below are some climate change mitigation strategies based on priority value chains:

In countries where agriculture is central to economic development (World Bank, 2008), transforming smallholder systems into more resilient ones is not only important for food security, but also for poverty reduction, as well as increasing value addition and structural change. According to FAO (2010), the efficiency, resilience and adaptive capacity of agricultural systems improve when their various components are addressed:

1. **Soil and nutrient management:** the availability of nitrogen and other nutrients is essential to increase yields. This can be done through composting of manure and crop residues, more precise, targeted matching of nutrients to plant needs, controlled release and deep placement technologies or use of legumes for natural nitrogen fixation. Use methods and practices that increase organics. Thus, nutrient inputs, retention and use are critical and reduce the need for fertilisers which, due to cost and access, are often unintentional.

2. **Harvesting and water use:** Improved water harvesting and retention (such as qochas, dams, pits, micro reservoirs, retention ponds, etc.) and water use efficiency (irrigation systems) are key to increasing production and addressing the increasing irregularity of rainfall patterns. Today, irrigation is practised on 20% of agricultural land in developing countries, but can generate 130% higher yields than rainfed systems. The expansion of efficient management technologies and methods, especially those relevant to smallholder farmers, is essential.
3. **Pest and disease control**: There is evidence that climate change is altering the distribution, incidence and intensity of animal and plant pests and diseases, as well as invasive and alien species. The recent emergence in several regions of aggressive, multi-virulent strains of wheat yellow rust adapted to high temperatures is a good indication of the risks associated with pathogen adaptation to climate change. These new aggressive strains have spread at an unprecedented speed across five continents, resulting in epidemics in new growing areas, previously unfavourable for stripe rust and where they were well adapted.
4. **Resilient ecosystems**: Improving ecosystem and biodiversity management can provide a number of ecosystem services, which can lead to more resilient, productive and sustainable systems that can also contribute to reducing or eliminating greenhouse gases. Services include pest and disease control, microclimate regulation, waste decomposition, regulation of nutrient cycles and crop pollination. Enabling and enhancing the provision of such services can be achieved through the adoption of different natural resource management and production practices.
5. **Genetic resources:** Genetic make-up determines the tolerance of plants and animals to shocks such as temperature extremes, droughts, floods and pests and diseases. It also regulates the length of the growing season/production cycle and the response to inputs such as fertiliser, water and feed. Therefore, preserving genetic resources of crops and breeds and their wild relatives is fundamental to building resilience to shocks, improving resource use efficiency, shortening production cycles and generating higher yields (and quality and nutritional content) per hectare of land. Generating varieties and breeds that are adapted to ecosystems and farmers' needs is crucial.
6. **Harvesting, processing and supply chains:** Efficient harvesting and early processing of agricultural products can reduce post-harvest losses (PHL) and preserve the quantity, quality and quality of food and the nutritional value of the product. It also ensures better use of co-products and by-products, whether for livestock, to produce renewable energy in integrated systems or to improve soil fertility. As supply chains become longer and more complex, it becomes more important to increase the efficiency of processing, packaging, storage, transport, etc. to ensure longer shelf life, preserve quality and reduce carbon footprint. Food processing allows surplus food to be stored during low production years or allows for staggered sales. This ensures greater food availability and income throughout the season and in low production years. Food processing creates jobs and income opportunities, especially for women.
7. **Climate resilient/smart practices useful in small-scale agricultural production:** Climate resilient agriculture-based value chains refer to the set of actors that interact for the production, transformation and commercialisation of products under a sustainable model, employing technologies that allow the efficient use of natural resources and value concepts that enable the positioning in the markets of products differentiated by their socio-environmental attributes such as environmental conservation and increased income for populations vulnerable to climate change .

Over the years, due to the harsh nature of the Andean climate and as part of adaptation strategies, producers have diversified their production and rotated crops of tubers, grasses, and legumes to reduce their dependence on fertilisers. Such crop rotation has also lowered pest and disease loads (which are more likely with higher temperatures and humidity) (Ponce, 2018).

Different adaptation strategies to climate change have been observed in the SHAP by different authors and methodologies. For example, Ponce's (2018) study on the SHAP found that farmers, faced with an increase in intra-seasonal climate variability, change their production strategies towards more tolerant crops, decreasing the area allocated to mixed cropping. Lennox (2015) found that, in some areas of the SHAP, farmers have replaced native quinoa and potatoes with improved pastures (such as forage oats) for livestock.

Ponce (2018) found that Andean farmers use crop diversification strategies and mentions two possible reasons:

1. farmers allocate more land to more tolerant crops that were already in their portfolio, but keep the same set of crops; or
2. farmers introduce new, more tolerant crops into the portfolio and allocate larger portions of land to them than those allocated to previous crops.

Other options for farmers to adapt to climate change in agriculture are:

1. extensification (i.e., cultivating more land or increasing herd size) (Villar, 2019),
2. diversification or commercialisation, i.e., shifting to higher-value market-oriented production (Lennox, 2015);
3. adaptation of climate-resilient production practices (Sanabria & Lhomme, 2013).

However, the decision on which strategy to adopt will depend on the education and gender of the household head, number of household members, diversification into livestock, use of extension services and access to credit (Ponce, 2018).

In some communities in Cusco, the qochas are being used as a mechanism for planting water, an ancient practice that consists of storing water in natural lagoons in the highlands so that they serve as a watering place, but indirectly this water is infiltrating the soil and providing water flow to the springs or puquios.

Some coping strategies of farming families have been income diversification due to loss of earnings from agriculture, including handicraft making, and teaching and capacity building jobs for farmers with more education, but there are also opportunities for nutrition improvements by replacing foreign foods such as rice and noodles with potato and quinoa.

77% of the department of Puno lies above 3,812 masl, and it is here that one of the poorest rural populations in the world is located with a high climatic risk, especially besieged by droughts and extreme thermal events. The population has mainly engaged in agriculture and livestock farming.

The crops and livestock used have adapted to these ecological conditions. For example, native cultivated potatoes are able to tolerate temperatures as low as -4 °C in some of their phenological phases, and have higher protein content than varieties grown at lower altitudes (Baigorria, 2021).

The main adaptation measures could be strengthened with the promotion of some Local initiative per chain, such as, for example, measures presented in the following table:

5.4.2.1 Strategies for the High Andean crops value chain

Based on the literature review and workshop considerations, the prioritized ecosystem-based adaptation (EbA) measures in the value chain of high Andean crops in the intervention areas include: restoration and conservation of wetlands, qochas (traditional Andean ponds), integrated soil fertility management, restoration of terraces/andenes, construction of infiltration ditches, contour agriculture, agroforestry, conservation agriculture, and forest restoration with native species. Among the departments, Cusco has the highest number of hectares classified as "very favourable" (i.e., with three or more measures of medium and/or high suitability) with 107,765 ha, followed by Puno with 45,172 ha, Apurimac with 44,826 ha, Arequipa with 15,167 ha, and Lima with 2,579 ha.

It is also important to mention other measures that will be taken into account to make the value chain resilient to climate change:

Technified irrigation: Technified irrigation plays a crucial role in addressing water scarcity by optimizing water usage. It involves implementing efficient irrigation systems that provide the right quantity and quality of water needed for crops, thus improving production. In the SHAP, technified irrigation has been promoted for years. For instance, the "My Irrigation" project (implemented by MINAM between 2013 to 2018) invested PEN 1 billion to improve water resource services and infrastructure in High Andean communities (MEF, 2019). Various smaller-scale initiatives, such as a solar-powered pressurized irrigation system implemented in Puno in 2017 by AgroRural, have also been successful in addressing water stress in rural areas (Agraria, 2023).

Geotanks: Geotanks are durable structures made of geomembranes that effectively store water. They provide farmers with access to water during droughts, ensuring the continuity of their crops. Geotanks have become increasingly common in Peru's rural areas due to the advantages they offer in water management, storage, and distribution in agriculture. In 2018, geotanks were installed in ten rural communities in Cusco to provide water for irrigation during periods of insufficient rainfall (Andina, 2018).

Solar pumping: Solar photovoltaic water pumping systems convert solar energy into electrical energy to power water pumps, offering a cost-effective and eco-friendly alternative to traditional systems. In Puno, a pre-investment study for an irrigation project using a solar-powered pumping system began in 2021, aiming to improve farmers' yields (GORE Puno, 2021b). A pilot project with a similar system was developed in Cusco in 2022, benefiting 47 families by providing water for irrigation through solar panels (La República, 2022).

Improved seeds: The recent increase in productivity of high Andean crops can be attributed to the use of quality seeds and improved varieties. Research efforts have been made to conserve existing varieties of crops like potato and quinoa, resulting in technologies and innovations such as improved and certified seeds and the establishment of germplasm banks. Utilizing these seeds is a mitigation measure that addresses issues related to productivity, quality, climate risks, and overall production improvement (Fairle-Reinoso, 2016). INIA has a research program on genetic resources and biotechnology at the Illpa-Puno Agrarian Experimental Station, which includes a germplasm bank that conserves genetic resources of quinoa with around 1,720 ecotypes preserved (35% of the 4,400 accessions of different species in the region's Germplasm Bank). Additionally, this station produces seeds of 7 quinoa varieties, and in situ conservation is carried out by producers in the system of aynokas, laymes, and suyos.

Seed banks

5.4.2.2 Strategies for the South American camelid value chain.

According to the literature review and workshops, the prioritized Ecosystem-based Adaptation (EbA) measures for the South American camelid value chain in the intervention areas include: restoration and conservation of wetlands; qochas; infiltration ditches; sustainable management of natural pastures; forest restoration with native species; and terraces/andenes restoration. Among the departments, Puno has the highest number of "very favourable" hectares, with 2 or more measures of medium and/or high suitability, totalling 59,821 ha. Cusco follows with 57,665 ha, then Apurimac with 26,697 ha, Arequipa with 21,408 ha, and Lima with 3,310 ha.

In addition to the above-mentioned measures, there are other mitigation strategies to enhance the resilience of the South American camelid value chain to climate change:

Protection modules (hutches): This activity aims to address the challenges posed by low temperatures, especially in high Andean areas. It involves constructing modules to protect livestock, reducing animal mortality and morbidity rates. Peru has already undertaken this activity, with Agro Rural building 2,417 protection modules through the Multisectoral Plan against Frosts and Cold Weather 2021. These modules were implemented in 213 high Andean districts, successfully safeguarding over 241,700 South American camelids (Andina, 2021c).

Vicuña watering troughs: Extreme climate events like droughts and frosts adversely affect the availability and quality of pastures for wild animals, such as vicuñas. Regions with significant vicuña populations in the central and southern highlands, including Ayacucho, Puno, Huancavelica, Apurímac, Cusco, and Arequipa, have a high drought risk potential (SERFOR, 2019). To address the risk of drought, water troughs can be established to provide water for animal consumption. These facilities can be made of different materials like cement or plastic and are placed strategically to ensure water availability for the animals (SERFOR, 2019).

Integrated animal health management: In 2021, SERFOR, SENASA, and SERNANP jointly developed the National Protocol for the Treatment of Scabies in vicuñas (SERFOR, 2021). This protocol aims to standardize technical and operational criteria to reduce the incidence of scabies, a contagious disease primarily transmitted through wallows and coexistence with infected animals. Mitigation measures will involve monitoring the health status and movement of managed vicuña populations, evaluating animal health to rule out infectious and parasitic diseases, and implementing the protocol as a reference (SERFOR, 2021).

Green houses

5.4.2.3 Conclusions

To this end, some guidelines should be proposed for the development of value chains in sustainable and climate-resilient landscapes, in harmony with the EbA measures identified as priorities for the different ecosystems of the territory.

1. Identification of landscape units including information on climate, soils, land use dynamics, land cover, technology used by producers, etc.

2. This implies processes of planning and use of the resources foreseen in the EbA measures (water infrastructure, soil management) that correspond to the existing production systems to enable governance and social appropriation of the territory. The assumption in a sustainable value chain perspective is the configuration of scenarios directed towards the generation of agricultural and ecosystem goods and services that favour biodiversity, social well-being, economic profitability, food security and socio-ecological resilience in the face of extreme events (climatic, economic, social, etc.).

3. The comparison of these conditions at the sociological level of the landscape with the market trends of the chains should lead to the construction of a strategic vision of the chains, aiming both to improve the position of producers in the international market, as in the case of quinoa and alpaca fibre, and to meet local and national demand with products of higher added value and quality.

   In this regard, the development strategy, and measures for the two aforementioned chains should be oriented towards product differentiation in the market, based on sustainable technological innovation, improvement of regional and local governance of the chains and the enhancement of the ecosystem services derived from the origin of the biodiversity resource and ancestral culture. The same is valid in the case of the Vicuña, which, given its status as a species covered by the CITES convention, must comply with a special regulatory framework of protection that should of course be included in the criteria of standards such as RAS and as part of the agreements of the COP15 on Biodiversity.

4. Value chains such as high Andean crops and camelids should also be projected in relation to the territories where they are produced and with an understanding of their function as livelihoods (food security) and/or market goods. They should even be assumed under a multi-chain (cluster) approach due to their complementarities and the value of short marketing circuits with the direct participation of the producers' communities. There is a technological innovation gap in these local and regional chains that has to do with self-sustaining food conservation, for example, where food losses occur for the family and farm animals; or in the possibilities of adding value to transformed products for regional consumption, through the development of small agro-industry business models (for example for the production of chuños, corn starch with regional varieties, for cold chains based on renewable energy from livestock species, etc.).

   A "From the Puna to the Table" approach, for example, could promote in the territory the articulation of food chains with agrobiodiversity products with the tourism sector established in regions such as Cusco, Puno or Arequipa, or with community projects of rural experiential tourism. The model of the Park of the 9 communities around the Potato Park in Cusco can be taken as a valid reference for the integration of the ecological, cultural and social components of the inhabitants of the Puna. At this point, it is important to highlight the necessary public investment in the improvement of public infrastructure (drinking water, drainage, renewable energy, connectivity) in the territories, and the capacity building of the communities in the self-management of their projects.

5. In all cases of value chains, those linked to global chains as well as to national and local circuits, there is a need for a “motor” of knowledge in situ, linked to the communities and as a support for the needs of technological innovation, information management and real-time attention to the contingencies imposed by climatic variations, the consequent phytosanitary problems, capacity building and the valuation of traditional knowledge in adaptation practices. An applied research hub model, adequately equipped, located in key activities in the territory, and with the permanent presence of researchers from CIP, INIA, NGOs, regional or international universities, would fill the knowledge gap on Andean ecosystems and their species, in order to strengthen communication and care for Andean communities.

6. The strategy of sustainable, climate-resilient value chains for the Puna requires a major effort in terms of relations and governance structures in the territory. The revision of the overlapping of plans and projects oriented towards the aforementioned activities, coming from the public sector and cooperation, is necessary to channel common objectives of sustainability and efficiency in the use of resources. Inter-institutional coordination mechanisms, digital platforms for monitoring and tracking indicators of the impacts of value chains and landscape management, and the creation of early warning climate networks, equipped with adequate technological resources, are part of the medium-term measures necessary for a resilient and sustainable Puna.

   At the central level, a coalition of institutions such as MINAM, MIDAGRI, PROMPERU, MINCETUR is required to design a country strategy in the face of global markets that compete with Peruvian biodiversity products through different mechanisms, some of them illegal. Support for the positioning of a certified country brand for Andean products and the economic potential of camelid RRGs, for example, for the global pharmaceutical sector, should from now on suggest a concerted strategy at institutional and benefit-sharing level (ABS in terms of CBD), for compensation via ecosystem services.

7. Finally, strategies of the kind described here, i.e., with economic, social and environmental objectives, resilient to CC, require a detailed economic analysis of both the distribution of profits and the distribution of value along the value chain in order to establish the competitiveness of the respective chains. This is necessary in order to assess the scope of investment measures in the production and processing links and their impact on the well-being of companies and/or producer associations in the Puna.

Value chain	Climate change impacts	EbA measures	Other adaptation measures	Benefits
High Andean crops: Quinoa, potato	Reduced water availability and changes in rainfall patterns lead to water stress affecting productivity and quality. Potato is a crop highly sensitive to water deficit, as its roots cannot tolerate water stress; drought can cause yield losses of up to 85% and frost causes crop burn, which can lead to losses of entire farms. Changes in maximum and minimum temperatures lead to crop losses and damage. As the temperature rises, exceeding the optimum threshold for the crop, the production and yield of quinoa is reduced, for example, when the maximum temperature rises by 1 °C in Puno, production is reduced by 112. 2 Mt and yield by 169.1 kg/ha and by raising rainfall by 300 mm, production is reduced by 75.78 Mt and yield by 127 kg/ha (Carrasco, 2016). Climatic events that put agricultural production at risk,	Restoration and conservation of bofedales Qochas Infiltration ditches Integrated soil fertility management Contour farming Conservation agriculture Agroforestry Restoration of andenes and terraces	Technified irrigation. Geotank Water bags Hyperlocalised Weather Alert Integrated pest management techniques. Crop rotation Solar pumping Productive diversification (guinea pigs) Seed bank (native potatoes). Acquisition of improved seed.	EbA measures ensure the provision of ecosystem services. • The water regulation functions of wetlands towards the basins in times of low water levels represent an important measure to make a significant contribution to the challenges of water security, integrated water resources management, and ensuring adequate water availability for human supply (SDG06). • Qochas contribute to both "water seeding", associated with infiltration and aquifer recharge, and "water harvesting" or rainwater harvesting. Previous experiences (PACC-PERU, MINAM) have shown how the implementation of qochas are effective in storing and infiltrating rainwater, recovering depleted springs and maintaining the humidity of the natural grassland, making water available during the period of scarcity (June-August), helping to guarantee crops. • Improved soil fertility would increase resilience to climate change, underpinning plant growth and optimising crop yields. This would promote food security and environmental sustainability of agricultural systems.

Value chain	Climate change impacts	EbA measures	Other adaptation measures	Benefits
	such as frosts, droughts and hailstorms that generate risks of production losses and loss of genetic diversity of native potatoes (Practical Solutions, 2018). Studies show that a high concentration of carbon dioxide in areas where potato crops are grown reduces the chlorophyll in the plant as well as in the specific leaf area. Another consequence is that when carbon dioxide is high, the rapid ageing of the leaf may be due to increased photosynthesis and increased use of nitrogen for carbohydrate production (Practical Solutions, 2018). Heavy rainfall erodes the soil and reduces its productive capacity. Changes in temperature and humidity generate a higher incidence of pests and diseases.			• Infiltration trenches contribute to capture surface runoff, reducing surface runoff, as well as soil losses partially or totally through erosion and degradation, and helping to recharge the groundwater table. • Contour farming is a sustainable tool for water and erosion management: it helps to intercept and reduce runoff, while allowing more water to infiltrate into the subsoil. This retention of water in the furrows or contours helps to reduce water erosion and increases moisture (Natural Resources Conservation Services, 2020). These benefits will contribute to sustainable crop management, helping to strengthen the resilience of communities. • Agroforestry reduces the vulnerability of communities to climate change by diversifying production and improving crop quality by contributing to both nutrient cycling and soil and water conservation, reducing erosion and intercepting surface runoff, while allowing more water to infiltrate into the ground. • Forest restoration: forests help to intercept, capture, infiltrate and regulate rainwater, mitigating the effects of torrential rains and prolonged droughts; they also protect the soil from water and wind erosion, improving soil quality and

Value chain	Climate change impacts	EbA measures	Other adaptation measures	Benefits
				helping soil regeneration, nutrient fixation and carbon sequestration. Finally, they play a strategic role in climate regulation, stabilising sudden changes in temperature. • Agricultural terraces are of great importance in a context of climate change, reducing soil erosion and optimising water use, thanks to the water retention capacity they generate, which allows crops to be irrigated less often. In a scenario of low provision of water, technologies to increase efficiency within the irrigation systems is crucial. Solar pumping, geotanks and sprinkler and srip irrigation systems are also crucial to water management. Improved soil fertility would increase resilience to climate change, underpinning plant growth and optimising crop yields. This would promote food security and environmental sustainability of agricultural systems. Sustainable pest management and other adaptation practices will maintain and/or increase productivity and product quality in a changing climate context. Diversifying production will increase the resilience of producers in the event of a climatic event affecting economic activity.

Value chain	Climate change impacts	EbA measures	Other adaptation measures	Benefits
South American Camelids: Alpaca, vicuña	Drought reduces the natural productivity of the pastures that feed vicuñas and alpacas, leading to overgrazing and conflict over the use of pastures. The Helvetas study "Water management and climate change: Spatial analysis study of the bofedales in the region of the Aymaras sin Fronteras commonwealth" (2014), indicates how community income has been reduced by up to 50% due to the loss of their livestock, as they have lost bofedales and barley crops, their main sources of food. Abrupt changes in rainfall, as well as melting glaciers are creating chaos in both the alpaca community and the communities that raise them. One of the main problems currently faced by alpaca producers is the lack of water (rainfall), which has a direct impact on the production of pasture and fodder for feeding the herd. This has led them to	Restoration and conservation of bofedales Qochas Infiltration ditches Sustainable management of natural pastures Agroforestry Forest restoration with native species	Protection modules (hutches) Vicuña watering troughs Technified irrigation. Geotanks. Integrated animal health management. Productive diversification	EbA measures will improve water harvesting during the rainy season for distribution in times of drought by supplementing water from rainfall. This, together with efficient irrigation technologies, will improve and make sustainable use of water resources for fodder production: • The restoration and conservation of wetlands and their potential use for Andean camelid livestock would increase the resilience of communities in the face of climate change, helping to recover the necessary balance in the relationship between soil, pasture and livestock. Wetlands are the main source of food for high Andean livestock and a strategic social and economic element for camelid producers. • Qochas contribute to both "water seeding", associated with infiltration and aquifer recharge, and "water harvesting" or rainwater harvesting. In both situations, qochas are a key strategy to increase resilience to climate change in high Andean communities, as an EbA measure associated with other practices such as grassland management, restoration with native species or planting natural grasses, improving water supply by favouring the capture, storage and infiltration of rainwater.

Value chain	Climate change impacts	EbA measures	Other adaptation measures	Benefits
	incur expenses that they did not have before for the breeding of the animals. In addition, extreme temperature conditions are making the herd more vulnerable to disease and contributing to an increase in new-born mortality rates. High mortality in times of drought (30-50% in the worst cases detected). Also, alpacas give birth only during the first three months of the year, during the rainy season. This reliable season, which moderates temperatures, has now become erratic. In addition, alpacas are sensitive to cold; sudden changes in temperature, including cold snaps, have resulted in the death of thousands of animals. Rising temperatures and low rainfall have reduced pastures and led to increased incidence of pests and diseases. This is likely to have a negative impact on vicuña populations (Kasterine and Lichstenstein,			• Infiltration trenches contribute to partially or totally capture surface runoff, reducing surface runoff, as well as soil losses due to erosion and degradation, and helping to recharge the groundwater table. This practice allows the recovery of soils that would otherwise be unproductive, positively impacting communities and reducing their vulnerability to erosion and degradation. Water infiltration contributes not only to groundwater recharge and water supply in the lower part of the basin, but also contributes to the benefit of nearby vegetation, such as grass growth, helping to reduce vulnerability to the effects of climate change on local communities. • Forest restoration: forests help to intercept, capture, infiltrate and regulate rainwater, mitigating the effects of torrential rains and prolonged droughts; they also protect the soil from water and wind erosion, improving soil quality and helping soil regeneration, nutrient fixation and carbon sequestration. Finally, they play a strategic role in climate regulation, stabilising sudden changes in temperature. • Grassland vegetation cover protects soils from the effects of erosion, reduces evaporation as well as runoff. This not

Value chain	Climate change impacts	EbA measures	Other adaptation measures	Benefits
	2018). Climate change also influences the spatial dynamics between pastures, grazing areas and vicuña habitat, since as grazing areas are degraded, vicuñas need to cover a larger area with lower quality pastures and migrate to higher elevations where they find better pastures (Korswagen, 2015). Climate stresses reduces productivity and fibre quality. Changes in temperature and humidity generate a higher incidence of diseases, especially scabies in vicuñas and alpacas. But also other respiratory and stomach diseases.			only improves carbon sequestration, helping to mitigate greenhouse gas emissions from livestock production, but also contributes to improved soil quality by increasing soil porosity and water retention capacity (DDCC, 2019). Its sustainable management contributes to increasing communities' resilience to climate change by buffering the effects of extreme events, and is also a strategic social and economic element for camelid producers, as a source of food and survival for Andean vicuñas and alpacas. Diversifying production will increase the resilience of producers in the event of a climatic event affecting economic activity.

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