Faculty of bioengineers

Prospective analysis of the degree of food self-sufficiency in the province of Chumbivilcas, Peru

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ANA	National authority of the water (Autoridad Nacional del Agua)
ARPAC	Regional association of agricultural producers
CENAN	National center for alimentation, nutrition, and sane life (Centro Nacional de Alimentación, Nutrición y Viva Sana)
CEPLAN	National Strategic Planning Center (Centro Nacional de Planeamiento Estratégico)
CIRAD	Center for International Cooperation in Agricultural Research for Development
CORSA	Regional counsel of Food Security (Consejo Regional de Seguridad Alimentaria)
CRFS	City Region Food systems
EAP	Economically Active Population
FAO	Food and Agriculture Organization of the United Nations
FD	Food Demand
FS	Food systems
FSS	Food self-sufficiency
FVC	Food value chains
GDP	Gross Domestic Product
GFD	Gross Food Demand
GFS	Gross Food Supply
HLPE	High-Level Panel of Experts
IMA	Institute of Water and Environmental Management (Instituto de Manejo de Agua y Medio Ambiente)
RAAA	Alternative Agriculture Action Network (Red de Acción en Agricultura Alternativa)
INEI	National Institute of Statistics and Informatics (Instituto Nacional de Estadística e Informática)
INIA	National Institute for Agrarian Innovation (Instituto Nacional de Innovación Agraria)
MIDAGRI	Ministry of Agrarian Development and Irrigation (Ministerio de Desarrollo Agrario y Riego)
NFD	Net Food Demand
NFS	Net Food Supply
NGO	Non-Governmental Organization
SSD	Self-sufficiency Degree
UN	United Nations
WFP	World Food Program

Introduction

All nations, in their own way, are concerned with the sustainability of their food systems, whether economically, environmentally, or politically. The concern is also raised by the impact of these dimensions on food security. In South America, the situation of food security is worsening, with more people suffering from hunger, children being overweight, women suffering from undernourishment, and more adults getting obese (FAO, 2023). However, studies have shown that food self-sufficiency is a key to building resilience and sustainability in the face of those challenges (Al-Abdelmalek et al., 2023; Clapp, 2017). Food self-sufficiency excludes the impact of external factors and focuses on local production and consumption.

At the national scale of Peru, the food systems are guided towards agroexportations more than food self-sufficiency (FAO & CIRAD, 2022). Due to the variety of landscapes and climates, very few regions can benefit from the economy of exportation, and other areas are left behind. Additionally, policies focus on a global vision of the systems, which fails to consider the specificities of regions and provinces (FAO & CIRAD, 2022). Since 2002, the government has undertaken a decentralization process, but it has been inefficient ever since (Tirado-Kulieva et al., 2022). The unbalance between regions is strong.

Chumbivilcas is one of these neglected provinces. Because of its isolation and limited access to roads, it is disregarded in more global policies. The province is a significant producer of livestock at the scale of the region and has increasing potential for cultures, especially Andes cultures (Aiqui Kcala, 2024). However, the province has been facing new challenges for about ten years: accentuated homogeneity of water availability with climate change, the emergence of informal and illegal mining businesses, the decrease in the population of family farmers, a lack of voice in the regional decision-making process and political instability.

With all that said, giving more power to local food systems is urgent. Improving provincial and regional policies, identifying the drivers for change, using the right tools, and mitigating climate change are essential to more sustainable production and consumption. Besides, food security shapes the evolution of food systems and vice versa. So, it must be considered to assess food system change outcomes accurately.

This thesis wishes to initiate a reflection on the degree of food self-sufficiency in the province of Chumbivilcas, its evolution by 2050 according to different prospective scenarios, and its impact on a dimension of food security. This thesis offers a scientific base and an external point of view of the local food systems. In this way, it aims at being one of the tools for an improved decision-making process for the local and regional experts in the province.

The thesis is divided into five parts: the state of the art, the objectives, the methodology, the results, and the discussion. On one hand, the state of the art offers insights into the context of the food systems in Chumbivilcas. On the other hand, it provides food for thought for subsequent methodological choices. The objectives' part clarifies the goals and ambitions for evaluating food self-sufficiency in Chumbivilcas. It established a list of questions that the study aims to answer. The third part, the methodology, explains and details the tools for evaluating the degree of food self-sufficiency at the descriptive and prospective scales. The results (or fourth part) present the descriptive and the prospective levels of self-sufficiency degree according to three scenarios up to 2050, as well as their impact on a dimension of food security, the food availability. The last and fifth part discusses the results with previous information and puts them into perspective.

1. State of the art

The state of the art provides the keys to understanding the ground of food systems in Chumbivilcas, in Peru. Firstly, we focus on the national food systems, offering contextual insights into agricultural systems, policies, governance, and the dynamics of the food systems. Secondly, we identify the opportunities and challenges faced by the province of Chumbivilcas, as well as the factors that led to the selection of this location. The second part also lists the components of food supply and the demands of the province that are needed to determine the degree of self-sufficiency. Thirdly, we review the literature to survey food systems evaluation methodologies, self-sufficiency assessment, and food security indicators.

1.1. Context of food systems in Peru

The High-Level Panel of Experts on Food Security and Nutrition (HLPE) defines the food systems (FS) as follows: "a food system gathers all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the output of these activities, including socio-economic and environmental outcomes" (HLPE, 2017). The concept is about linking the different parts of the food chain with its actors within ecological, social, political, cultural, and economic environments at different scales.

A plurality of food systems exists because they depend on the actors considered, the dimensions included, and spatial and temporal scales. The actors of the food chains, along with the scales at which they operate, influence each other. National and international processes and policies regulate local systems. So, it is necessary to understand first the context of food systems at the national level in Peru to further understand its influence on Chumbivilcas.

1.1.1. Peruvian context

Physical and environmental

Located on the Pacific coast of South America, Peru is a Hispanic country covering 1,285,000 square kilometers. It is divided into three main parts: the coast is 3,000km long and covers 11% of the territory, the Andes Mountain range covers 26% and the Amazonian Forest occupies the last 63% of the territory (FAO & CIRAD, 2022).

Food systems in Peru, and particularly production, are influenced by the altitudes and climates (Vera, 2006). The west side, the Andes, has a humid and cold climate, although the coast itself is desertic, while the east side is hot, moist, and tropical and it is majorly composed of the Amazonian Forest (Vera, 2006).

In Peru, there are 38 different types of climates divided into categories of temperature, humidity, and altitude (Midagri et al., 2021). Humidity is dependent on the rain seasons ; there are two main seasons: the rain season from November to March and the drought season from April to October (Midagri et al., 2021). In terms of altitude, the higher the altitude, the less culture and the more livestock there is.

Social

The population of Peru is 33,035,304 inhabitants in 2022, with 79% living in urban areas and 21% living in rural areas; and with a national density of 20 inhabitants per square kilometer (FAO & CIRAD, 2022). On average, the population in Latin America is 20 inhabitants per square kilometer, which is 50% more than the population of Peru (WBOD, 2021). The national population has increased by one percent annually since 2007 (FAO & CIRAD, 2022).

Because of the population spread on the territory, 20% of the population does not have access to sanitation, 10% do not have access to public water services, 5% do not have access to any form of electricity (FAO & CIRAD, 2022). It is also due to a high individual level of poverty, where individuals would rather purchase food than build an electrical system in their households. On average, 40% of the budget of the household is spent on food (Larrea-Gallegos & Vázquez-Rowe, 2020). As for the state's responsibility, it lacks funds to create needed infrastructures to reach isolated populations in the mountains or the forest.

The original language is Quechua or Aymara (depending on the region), but past colonization and migration movements have resulted in the Spanish language dominating. However, recognizing the importance of Indigenous heritage, national laws were imposed in 2020, requiring schools to teach both languages (Spanish/Quechua or Spanish/Aymara) (CEPLAN, 2023). While Indigenous communities still live on the territory, no numbers are enlisted.

Economic

The Peruvian society briefly described above has various economic activities. We need some general information about the country's economy to situate food systems in their economic dimension. Peru's economy is composed mainly of trade, tourism, agriculture and more recently mining. The GDP (Gross Domestic Product) per capita is $15,052 per inhabitant in 2023; it is lower than the majority of countries of Latin America that set the average at $18,560 (OECD, 2022).

Currently, the economically active population (EAP) accounts for 45% of the national population. (FAO & CIRAD, 2022). The share of the EAP of the agricultural sector represents 24% of the total EAP. In turn, the industry contributes to 6% of the national GDP, reflecting a significant disproportion between GDP and EAP (FAO & CIRAD, 2022). Industries and services hold the most significant shares of national GDP, accounting for 37% and 56%, respectively (FAO & CIRAD, 2022). Compared to other countries in South America, Peru's contribution of agriculture to the GDP is low. (Vera, 2006).

The food systems governance has not been able to promote a balanced economic development between regions. Peru has an asymmetric economic policy since the government prioritizes the development of activities that contribute more to the gross domestic product (agroexportations, agro-industry and industrial fishing) over those that generate more employment and food security for the population (family farming and artisanal fishing) (FAO & CIRAD, 2022).

The following section reviews the governance and food policies in the course linked to this context.

1.1.2. Governance system

A. Political instability

The political situation in Peru is unstable. Politics in Peru is very complicated due to a high rate of politicians' corruption at the national level (Paredes & Encinas, 2020). In Peru, the illegal behavior of national representatives and big institutions is frequent, including tax fraud, corruption, embezzling, etc. This has created a lack of trust in political and national organizations from the citizens (Beesley & Hawkins, 2022). However, institutional trust is key to steady economic growth and political progress. Governments do not invest money where citizens would like it. This issue has significantly impacted social and economic development, as shown in part 1.1.1.

B. Decentralization

The territory is divided into 25 administrative regions; these regions represent 194 provinces. Their sub-components are districts and rural communities. The distribution of political power at these different scales was defined in a law called the 'law based on decentralization' in 2002 (Ley de bases de la descentralización, 2002). The reform was prompted by local authorities' limited power to intervene and their failure to maximize local resources and potential. Therefore, there are now three political levels independent from each other: the national level, the regional level, and the local level (which is the provincial level).

The decentralization law sets objectives in a variety of dimensions being: political, social, economic, administrative, and environmental (Ley de bases de la descentralización, 2002). At each level, governments have different responsibilities for their citizens. Its ambition is to further integrate the territorial development dimension (Azpur et al., 2006). Its aim is to promote the development of Peru based on its territories through the proper structuring of space and the sustainable development of resources (Azpur et al., 2006). This decentralization policy reflects the political will to empower local authorities. Given the decentralization, several policies, action plans, and programs have emerged at all levels with different objectives and missions.

However, the reality's experience has shown that most policies are not applied nor respected in rural areas in Peru. The decentralization process is still not optimal. It is still considered to be the most centralized food system in Latin America (Tirado-Kulieva et al., 2022). In times of crisis, for example during COVID-19, Peru has been struggling with a high level of food insecurity due to a lack of proper infrastructures (Tirado-Kulieva et al., 2022). The centralization of the markets in capital provinces, the bad conditions of the roads, and the absence of state intervention (financially and politically) in some regions have led to more health issues in isolated and rural areas.

The next part focuses on food policies from different government scales.

C. *Food policies*

Policies are meant to establish political, social, and economic measures to improve the system. Depending on the government's scale of action, different strategies are implemented.

Since the early 2000s, policies have been trying, for example, to put in place strategies and laws about food security at the national scale. Among those policies are: (1) the National strategies for food security of 2004 and 2013, (2) the declaration of national interest and necessity of food security that created the Multisectoral Commission of Food Security and Nutrition (COSMAN in Spanish) in 2012, (3) the national plan of action for food security of 2015, (4) the law for food security of 2021 (Minagri, 2022). The overarching goals of these various policies were to reduce the rate of undernutrition, decrease the number of households suffering from caloric deficit, reduce the number of people threatened by food insecurity vulnerability, and secure access to rich-nutrient and qualitative food (Minagri, 2022).

Then, the laws and policies are translated into regional strategies and programmes. For example, regarding food security, the regional government has put in place the Regional coordinated plan for health or action plan for the Youth. At the local level, the laws are translated into initiatives like setting informal food chains with only local, ecological, and nutrient-rich food (Ley de bases de la descentralización, 2002).

Regarding agriculture, a national strategy for familial agriculture was elaborated in 2015. Family agriculture is the main form of production in Peru; it accounts for 90% of the agricultural production value (APV), and commercial agriculture accounts for the rest (Midagri, s. d.). The strategy has three main objectives for food production: (1) promote equitable and quality access to services and public goods; (2) strengthen knowledge and capacity management to ensure the sustainability of development opportunities and (3) articulate a national, regional, and local institutional framework (Minagri, 2015). The expected results are increased productivity, improved social integration, and more food security for family farmers. This is then translated into local projects like building artificial water basins to ease agriculture in all seasons (Minagri, 2015).

Given the increasing impact of climate change, governments must act on the topic. in the environmental area, in 2021, a new policy on environmental responsibilities has set 9 new objectives to regulate the current situation (Ministerio del Ambiente, 2021). These objectives concern citizens as well as (inter-)national companies and have been set with specific thresholds for the year 2030. For instance, the policy aims to protect biodiversity, limit greenhouse gas emissions, improve the food value chains' carbon footprint by promoting a circular economy, and reduce air, water, and soil pollution. This will be done through programs and local initiatives that vary in each region, with each region's context and capabilities. For example, in the forest, this law prohibits deforesting some areas in the Amazonian Forest (Ministerio del Ambiente, 2021).

To accompany the national incentives, the World Food Program's (WFP) Country Strategic Plan seeks to expand its support to the Peruvian government to achieve Sustainable Development Goals (Laughton & Castro, 2022). WFP will strengthen its role as the main enabling partner at national and subnational levels in the implementation of food policies and practices to reduce food insecurity and improve the sustainability of food systems (Laughton & Castro, 2022). The plan aligns with the UN's sustainable development priorities for 2022-2026 and sets goals for 2050.

1.1.3. Food systems in Peru

The food production part of FS includes farming systems composed of livestock as well as plant-based production systems for human use (Midagri, s. d.). Food production can also be used to produce energy or feed livestock. Farming systems can be composed of commercial farms or smallholders' farmers, the difference being the agricultural surfaces and agricultural practices. Commercial farms have surfaces five times bigger on average, they are more likely to use chemicals and the products mostly go to the exportations (Vargas Casas, 2019). But, the national population still relies on the consumption of local products (Vargas Casas, 2019). So, food production must consider the supply-demand equilibrium before exporting.

The national repartition of the agricultural surfaces between regions is shown in figure 1.

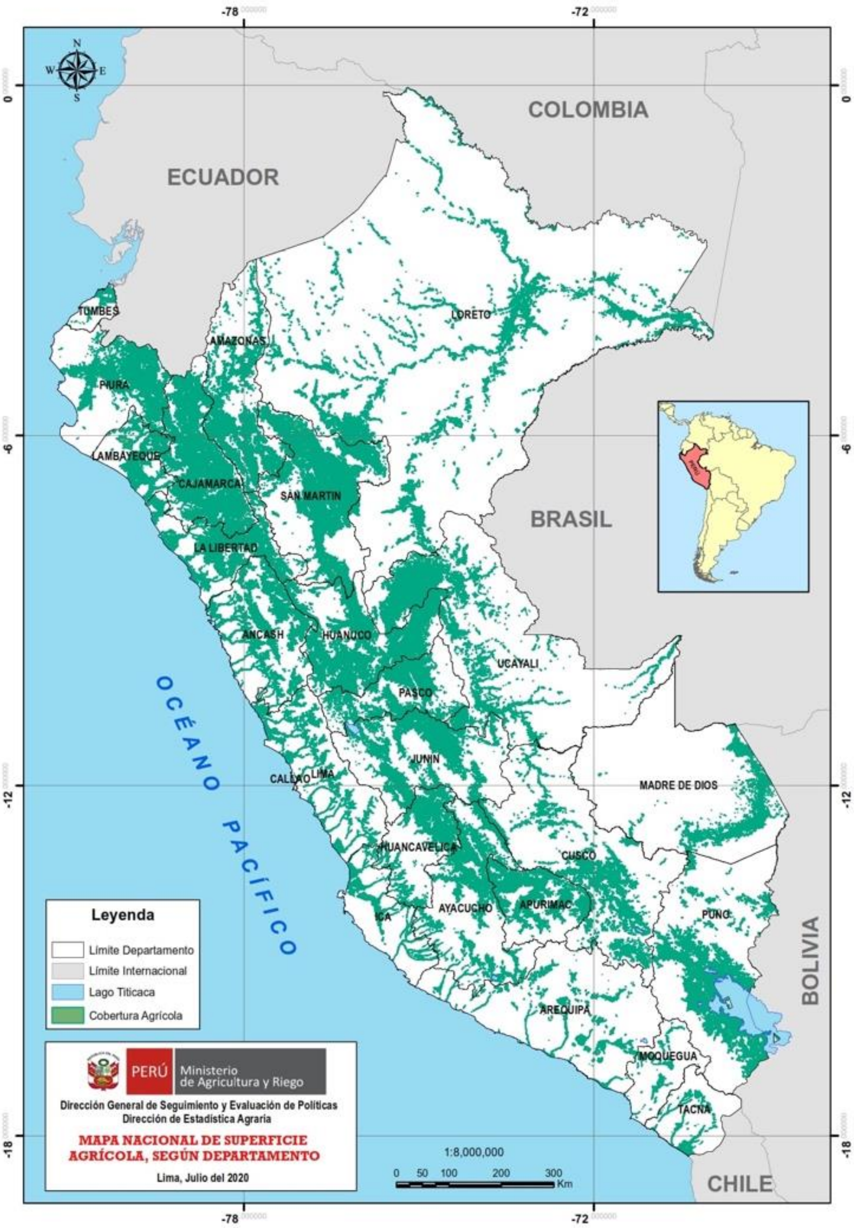


Figure 1. National agricultural surfaces distribution (Midagri et al., 2021)

In the Andean region, agriculture varies depending on the altitudes and topography. At the top of the valley, the slopes are too steep, and native grass is abundant, making it more suitable for cattle and livestock. The breeding is composed of llamas, alpacas, as well as sheep and cattle, depending on the altitude (Aiqui Kcala & Cuevas, 2024). Ice melting and alternating rain seasons create rivers, making water available to produce grains downstream (Vera, 2006).

In the coastal region, where the topography is more ideal, there is increased production of poultry (Vera, 2006). They also produce vegetables and fruits in a more significant amount than in the Andes thanks to the lower altitudes and favorable climate (Aiqui Kcala & Cuevas, 2024).

The climate in the Amazon region is tropical and suitable for the culture of beans, coffee, and tropical fruits, with 80% humidity (Vera, 2006). However, agricultural surfaces are limited for the preservation of the forest. Only 36% of the national agricultural area is irrigated, while the remaining 64% depends on the rainy seasons (FAO & CIRAD, 2022). The natural flow of water in the rivers regulates the irrigation of the cultures, being adapted to the climate and humidity.

The most used method in agriculture is family farming, 95% of the producers in the country are family farmers and they own 48% of the total agricultural surface (Vargas Casas, 2019). Family farming uses extensive production methods; there is a minimum use of mechanization (Vargas Casas, 2019). Subsistence agriculture is cultivated by 86% of the family farmers, the rest is consolidated (cash crop) agriculture (Midagri, s. d.). Family farming produces 70% of the food basket of the inhabitants while the rest is either from commercial farming or imported products (Aiqui Kcala & Cuevas, 2024).

The eight following crops compose 58% of the agricultural superficies in Peru: coffee (10.2%), potato (8.8%), hard yellow corn (6.3%), starchy corn (5.8%), rice (4.3%), banana (3.5%), cocoa (3.5%) and sugar cane (3.4%) (FAO & CIRAD, 2022). Rice and potato account for 42.1% of the GDP and are central to the country's food basket (FAO & CIRAD, 2022).

Over the last two decades, oleaginous cultures and fruits have been increasing in the agriculture GDP with the exportation boom of Peru (FAO & CIRAD, 2022). The exportation boom refers to the increase of agroexportations by 67% between 2011 and 2020 due to the increasing demand for non-traditional agricultural exports[1] (FAO & CIRAD, 2022). The main destinations (accounting for 65% of agroexportations) are the European Union, Chili, China, and the United States (FAO & CIRAD, 2022). In 2022, the agricultural production of the coast represented 84% of the total value of agroexportations (FAO & CIRAD, 2022). The land dedicated to this activity is mainly in the North of the country because of the more favorable topography and climate compared to the mountainous South (Aiqui Kcala & Cuevas, 2024).

To sum up, the context of food systems in Peru is heterogeneous. The agricultural practices show an economic gap between the commercial agriculture in the North and the small-scaled agriculture in the South. This gap is also strengthened by the policies than only envision a national development plan not considering the specificities of local contexts, nor the small-scaled agriculture.

[1] The non-traditional agricultural exports refer to the following products: grapes, blueberries, avocado, mandarin, oranges and pineapple (FAO & CIRAD, 2022).

1.2. Chumbivilcas and its food systems dynamics

1.2.1. Local context: challenges and opportunities

Physical and environmental

Chumbivilcas is a province located in the department of Cusco in Peru (figure 2). The province of Chumbivilcas has an estimated surface area of 5,300 square kilometers (CEPLAN, 2023).

Figure 2. Map of the province of Chumbilvilcas in the region of Cusco in Peru (Andina, 2009)

Chumbivilcas has seven types of climates, but the two major ones are humid with moderate cold (53%) and humid with accentuated cold (13%) (CEPLAN, 2023). The province contains 228 lakes, and 3 main rivers (Santo Tomas, Velile, and Livitaca River) that decomposed into 318 smaller rivers (CEPLAN, 2023). It is between 3,200m and 5,400m altitude. The altitudes are decomposed into three ecological levels: the Interandes valley, the Hillsides, and the Puna (Aiqui Kcala, 2024).

The variety of ecological levels associated with the natural diversity of agricultural species gives to the area a great potential for agriculture. For example, in the region, more than 300 different species of potatoes exist (Aiqui Kcala, 2024). Livestock is found in high altitudes while plants, specifically fruits and vegetables, are found in the lowest altitudes (see section 1.2.3 for more information about food production). Since the temperatures are low and the altitudes high, livestock proportion is more important than cultures.

Over the years, the province has been confronted to three major physical and environmental challenges due to its location (and isolation).

› Topography: the irregularity of the surfaces of the mountains makes it difficult to create more than 1 hectare superficies for agriculture (Aiqui Kcala & Cuevas, 2024). Agriculture is mostly manual and not mechanized since the machines are not adapted to such soil irregularities (Aiqui Kcala, 2024). The mountains also complicate physical access; roads and infrastructures are essential.
› The installation of illegal mining: for the last 5 years, mining business has been emerging in the area (informal mining, illegal mining) and has been emitting GHG emissions from its activity mostly transportation (Castro Segura & Cárdenas Farfán, 2023). It also pollutes the water and the soil in alarming amounts since no norms or local policies regulate them.

- Climate change: the region is mostly affected by the availability of water (Hasegawa et al., 2018). Because of climate change, the rain season has become more unpredictable, and the area is more likely to face drought episodes than before (Abhilash et al., 2021). Peru is also impacted by El-Nino in the whole country, happening every eight years and disrupting the weather with massive rains, sometimes destroying crop production (up to 70% of the concerned crop). The strong water flows also create soil and agricultural erosion (FAO & CIRAD, 2022).

Social context

The total population in the province of Chumbivilcas is 71,265 (representing 0.21 % of Peru's population) with 51% of men and 49% of women (CEPLAN, 2023). Half of the population is younger than 30 years old (CEPLAN, 2023). The province of Chumbivilcas has 12.36 inhabitants per square kilometer, with 76% of the population living in rural areas (CEPLAN, 2023). Compared to the national level, it is nearly half the country's population density, indicating a more dispersed population in the province. The main languages of the province are Spanish and Quechua, most of the people from the agricultural field practice Quechua daily rather than Spanish.

In 2021, food production in Chumbivilcas employed 15,000 inhabitants (73% of men) (Midagri, s. d.). The farmers have more than 200,000 hectares of land for culture and livestock production which is 40% of the territory of Chumbivilcas (Midagri, s. d.). Most of the population works in agriculture (CEPLAN, 2023). 96% of the surface for production is cultivated through family farming (Aiqui Kcala, 2024).

Since the early 2010s, the population has decreased yearly due to the social migration of the young to the cities looking for better education. However, it has been balanced by the migration, mostly men, coming to work in informal and illegal mines in the area (Castro Segura & Cárdenas Farfán, 2023). The population decreases by 1% per year (INEI, 2023).

Economic

The economy of the region is based either on agriculture or mining (more recently) (Castro Segura & Cárdenas Farfán, 2023). The region does not benefit from any form of tourism, and trade is very difficult given the lack of roads or railways to transport products. People live from agriculture, craftmanship, or mining.

36% of the population is part of the EAP and only 32% is considered active while the other 4% is inactive CEPLAN, 2023). The other 74% of the population that is not considered in EAP is family farmers who are not registered or included in the EAP because of legal issues.

Over the years, the fragmentation of the territory has been emphasized with the increase of surfaces in production because the number of families is increasing, and they all need a piece of land (FAO & CIRAD, 2022). The need for land is not monitored by the state, they are no laws on private properties in the province. The increase of reduced surfaces for agriculture led to the multiplication of smaller farms and the reduction of intermediate farms (FAO & CIRAD, 2022). The fragmentation process is more present in the Andes because the topography does not allow the agricultural surface to be homogeneously bigger. The increasing competition between farmers and extensive use of the territory have increased poverty among the farmers. In 2023, 34% of the inhabitants of the province were considered poor (CEPLAN, 2023).

Nutritional

The high level of poverty and low percentage of EAP implies that most inhabitants have limited financial possibilities, and leads to food insecurity (CEPLAN, 2023). "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (HLPE, 2017). According to the national food systems profile established by the FAO and CIRAD, Chumbivilcas, along with all other Peruvian provinces, suffer from the triple burden of malnutrition: the undernutrition of children, the prevalence of anemia (lacking nutrients and minerals like iron), and the increasing prevalence of obesity (FAO & CIRAD, 2022).

The population of Chumbivilcas suffers from different forms of food insecurity. In 2023, 13% of children suffered from undernutrition, 35% of children and 30% of women suffered from anemia (CEPLAN, 2023). This information reveals that the population is lacking safe and nutritious food. Also, the region is isolated from the central province of Cusco; the importations are limited and, as a consequence, food options too. The reduced diversity is strongly linked to the undernourishment of the population. Besides, financially accessible food is also an issue for 20% of the families; it is often the case for those who do not live from agriculture or/and live in rural areas (CEPLAN, 2023).

1.2.2. Food self-sufficiency as a sustainable solution for local food systems

The FAO (2013) defines food self-sufficiency (FSS) as follows: ''the extent to which a country can satisfy its food needs from its own domestic production". In other words, it is the capacity of the territory to feed the inhabitants with only the production of the defined territory. It also means that all the processes of the food value chains are domestic. By definition, it excludes exportations and importations.

FSS frees FS from the restrictions of international trade and external dependencies. In consequence, it also strengthens the FS resilience in times of food crisis and geopolitical conflicts. Food self-sufficiency, with the support of a national strategy, can improve the resilience of global supply chains, food security, and the environmental impact of FS (Clapp, 2017b). FSS has been proven to be a tool that empowers local communities in the decision-making process and, financially benefits local producers (Al-Abdelmalek et al., 2023).

Chumbivilcas, due to its isolation and absence of political power could benefit from more food self-sufficiency. FSS would help to address the challenges associated with its local food systems that were outlined in the previous section.

1.2.3. Agricultural systems in Chumbivilcas

Various cultures and livestock are produced depending on the ecological level because water resources, temperatures, and altitudes vary. In high altitudes, the temperatures are too extreme to grow fruits or vegetables, so the land is mainly dedicated to livestock. In the lowest altitudes, producers take advantage of the high availability of water to produce fruits and water-needed cultures like maize. Below is a list of productions according to their ecological level (Aiqui Kcala, 2024).

1. Inter Andes valley: Family farmers produce Andean fruits (avocados, prickly pears, apples, peaches, pacay and capuli), starchy corn (more than 30 varieties), pastures and forages (Alfalfa, Ray Grass, Dactiles, Forage Oats) and breed small animals (guinea pigs, chickens, pigs, and sheep).

2. The Hillsides: Producers cultivate Andes tubercules (native potatoes, oca, añu, olluco), Andes grains (quinoa, tarwi, oat, barley, wheat), pastures and forages. Producers breed small and big animals (guinea pigs, pigs, chickens, sheep, and cattle)

3. The Puna: Family farmers produce native potato (Bitterroot var.), maintain nature, and breed sheep and camelids (alpacas, llamas).

Livestock system

At the altitude of Chumbivilcas, cultures are not easy due to the slopes and the climate, and the livestock is therefore more suitable (Vera, 2006). There are nine types of animal production (figure 3). In Chumbivilcas, the main production is the cow, which produces beef meat or dairy products. Farmers also raise chicken, sheep, alpacas, and pigs (figure 3). Alpacas are part of the cultural history and are pastured on the grass of the puna (Vera, 2006). Sheep and cattle are necessary for maintaining soil fertility, but are of minor economic importance (Vera, 2006).

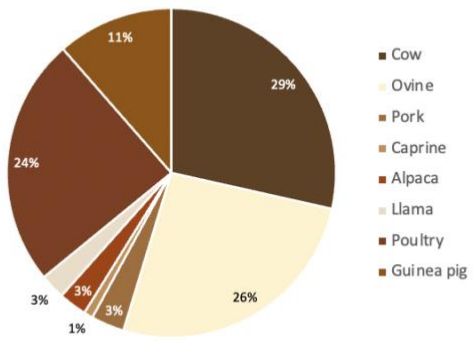


Figure 3. Proportions (in surface) of animal production types in the province of Chumbivilcas (OPMI, 2023)

Family farmers often rely on livestock production for their revenues. Chumbivilcas has high altitudes and the higher the altitudes, the less sheep or cattle can be raised on sown and irrigated pastures. Therefore, family farmers raise traditional animals like alpacas and llamas (Vera, 2006). The main method of feeding is natural grazing with no additional concentrates. Dairy cattle is an exception, it benefits from intensively-manages irrigated ray grass and lucerne (Vera, 2006).

Recently, the breeding of guinea pigs has emerged as a sustainable production, environmentally and financially, for the local communities of producers (Westmont, 2021). The breeding of guinea pigs increases revenues and helps develop a sustainable form of tourism in the Cusco region (Westmont, 2021). The evolution of the breeding since 2017 has not been monitored in the province of Chumbivilcas. Still locals estimate that it might become the most valuable production in the next ten years. It easily adapts to climate change and does not require massive infrastructures or investments to start a production (Aiqui Kcala, 2024).

Fishing system

In the region, trout production has always been part of the agricultural activities since they are naturally present in the rivers (Aiqui Kcala, 2024). However, for 20 years, fishing in the river has been prohibited for production purposes. The production takes place in artificial basins but no ciphers or documents exist on their importance for revenues, sustainability of FS or sustainable tourism. Only 5% of the communities of family farmers benefit from the provincial project of trout (Aiqui Kcala, 2024).

Cropping system

In Chumbivilicas, there are five types of cultures (figure 4). Producers are gathered into family farmers. They use extensive methods of production. They manually disperse the seeds and harvest their production. Most of them do not use chemicals and cannot use mechanized tools because of the topography (Aiqui Kcala, 2024).

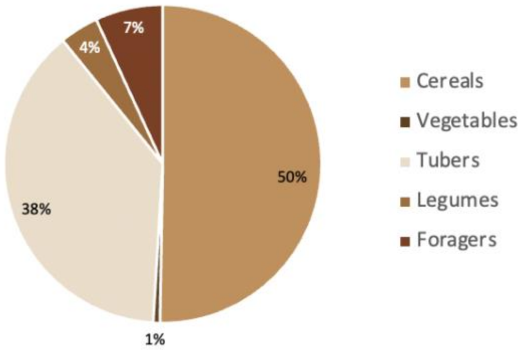


Figure 4. Proportions (in surface) of culture types in the province of Chumbivilcas (OPMI, 2023)

The agricultural production system is rain-fed farming. They rely on the rainy season (from November to April). 10% of the communities has recently benefited from the creation of artificial water basins that harvest the rain from the right season and make it available either for water irregularities or during the drought season (Aiqui Kcala, 2024). No irrigation techniques using technologies like pipes or sprayer tractors are available for the communities.

The main culture in the province is the "papa" (i.e. native potatoes). The potato cultures are ancestral; they are cultivated with traditional methods of family farming (Aiqui Kcala, 2024). Other important cultures in terms of agricultural production value are maize, beans, quinoa, barley, and oats (CEPLAN, 2023). Oat and barley were introduced with the colonization and use more conventional methods (Vera, 2006). The introduction of barley has majorly impacted the food production systems because of the change in land and resource use (Aiqui Kcala, 2024).

1.2.4. Food processing

The food value chains (FVC) aim to process the production and answer the consumer demand through the transformation and distribution of food production (HLPE, 2017). In the province, most of the food chains is informal and small-scale

Transformation

FVC transforms raw materials to gain economic and nutritional value through various operations (involving physical and chemical transformation and the input of multiple producers) (HLPE, 2017). Through this process, part of the food material is lost. The food in the process can be domestic and imported (Loza & Wilder, 2022).

Economically, the transformation is interesting for the local farmers since products can gain up to 50% in value (*Cooperativa de Chumbivilcas*, 2024). The idea of transformation is to preserve the product in time. However, purchasing transformed food is not part of the local traditions, so it does not account for an important part of the local economic activity.

Chumbivilcas accounts for a tiny but unregistered part of the transformation. Most of the products are sold in the district or through local markets without being processed (Aiqui Kcala, 2024). Fruits and vegetables are sold as they are. Meat is being cut out into pieces of eatable parts (brains, liver, muscles) and the rest is thrown out. Products that are part of the transformation (Andes grains, native potatoes) are being processed in a local cooperative that takes in charge the operation for all districts (Cooperative of Chumbivilcas, 2024). The processed food, like snacks and beverages, is imported. A few local industries transform the milk into yogurt, ice creams, and pasteurized milk, but no official information exists.

Distribution

Distribution is the part between production or transformation and consumption; it includes storage and transportation to retailers and vendors (HLPE, 2017). The food in Chumbivilcas is only transported by road since there are no railways. However, the road conditions combined with the province's isolation do not favor the distribution outside the province. Thus, the consumption of local products is high (Aiqui Kcala, 2024). Only very valuable productions like original varieties of potatoes and vegetables are distributed to Cusco because it benefits financially to the family farmers (Aiqui Kcala & Cuevas, 2024).

Distribution happens through both conventional supermarkets and traditional/informal markets (Loza & Wilder, 2022). But the most successful form of distribution in the province still are local or informal markets (Aiqui Kcala, 2024). In these markets, they mainly sell raw products from the province's family farmers. Indeed, the families themselves go to the capital of the province, Santo Tomas, to sell their products twice a week. Imported products are less sold or consumed.

During the COVID-19 crisis, this informal distribution in local markets was prohibited for sanitary purposes (Tirado-Kulieva et al., 2022). During this time, the family suffered from a lack of revenue (Aday & Aday, 2020). Producers were not able to sell their products or purchase other products. Diversity of products was therefore reduced for consumption since it was the main way of purchasing diverse and affordable food (Aday & Aday, 2020). The province did not rely on importations, and the state did not intervene because of the difficulty of access. Food supplies were lacking in the province.

1.2.5. Food consumption

Larrea-Gallegos & Vázquez-Rowe has recently done a food consumption survey (2020). It took place at the national level over 36,000 households. The study included the department of Cusco and estimated the consumption of more than 80 food products divided into 15 food categories (e.g., fruits, vegetables, staples, etc.). The survey excluded products with minimal caloric significance like spices (Larrea-Gallegos & Vázquez-Rowe, 2020).

In Cusco, the study revealed that the population suffers from food insecurity and that households spend, on average, 40% of their budget on food (mainly impacting food access).

A local association, Arariwa, estimates that 80% of the food baskets are composed of local products (Aiqui Kcala, 2024). The disproportion between the average intake and ideal intake in figure 5 is due to the low production of fruits and vegetables in the province associated with their exportation for increasing revenues. Therefore, inhabitants mainly feed on non-exported cheap products such as Andes grains, meat, and native potatoes.

Regarding meat, there has been a change over the last three years that started during the pandemic according to Arariwa. Before, meat was only consumed on special social occasions like communities gatherings, birthdays, or weddings, but now the population is starting to consume it on a more daily basis. The meat concerned is mostly guinea pigs and cows.

During the Covid-19, the informal distribution stopped, and the population suffered more from forms of food insecurity (Tirado-Kulieva et al., 2022). Their choice of food was very limited, and diet diversity was reduced during this period. Since then, the consequential diseases are still strong health problems in the province (see section 1.2.1 for nutritional context).

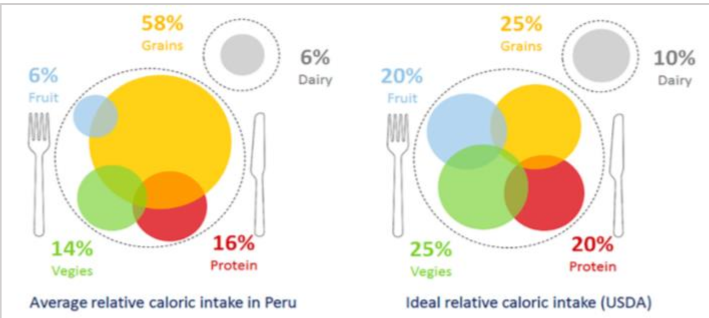


Figure 5. Comparison between the average household caloric intake in Peru to the recommendation of the United States Department of Agriculture. Percentages refer to the relative contribution of each of the five food groups to total caloric intake (Larrea-Gallegos & Vázquez-Rowe, 2020).

1.3. Targeted review of the methodological literature

The methodological literature survey is a first approach to identify tools for the evaluation of FS. More specifically, this section reviews methodologies, their goals, their procedures, and parameters to evaluate the FSS and its impact on food security (the intentions of this study). The first focuses on tools that help determine the temporal and spatial scale of the territorial diagnosis and explains the criteria of selection for the province choice. The second part looks at two existing methodologies for FSS territorial diagnosis, i.e. the procedures and parameters needed for the model. The last part examines methodologies linked to studies on food habits (information currently unavailable at the scale of Chumbivilcas).

1.3.1. Scale of the study

The complexity of FS has become the center of attention in trying to better them for human, animal, and environmental health. Methods and tools for evaluating FS are emerging and depend on the scale, the desired results, and the study's use. The challenge is therefore to identify the scale and scope to bridge the gaps between models developed at different temporal and spatial scales (Geiser, 2015). The existing spatial scale can vary from micro to macro (villages, communities, provincial, regional, national, continental, global, etc.). Whatever the chosen scale, it is always influenced by a smaller or larger scale. It is necessary to acknowledge these interactions between the scales even though they can be outside of the study framework.

Different factors must be analyzed to select the appropriate spatial scale given the challenges. A toolkit, created by the FAO and called the City Region Food System Toolkit (CRFS) gives indicators for the selection of the spatial scale (FAO, 2018). The boundary choices are governed by toolkit objective, which is to develop a sustainable food system in urban-rural areas. The idea is to aim towards a diversification of supply resources and to build resilience in food systems in economic, political, and environmental dimensions (FAO, 2018).

The criteria to select the spatial boundaries can be: (1) administrative borders, (2) natural borders, (3) food supply chains, (4) mutual influences between the urban and rural areas, and (5) density of the territory (FAO, 2018). Food supply chains can occur at local, regional, or national levels. Understanding the dynamic of the scale of both food supply and food demand in the region can enlarge or reduce the scale. Also, the influence between urban and rural areas can impact the scale in the sense that it might be necessary to widen the scale to include an important city. For example, Chumbivilcas is conditioned, in a way, by the city of Cusco. As for the density of the territory, the presence and absence of population can change the scale for the representativeness of a whole.

A second factor of the toolkit is the implications of actors influencing the food systems like NGOs, local governments, producers, industries, distributors, vendors, and consumers (FAO, 2018). Actors who play important roles in the FS must be considered in the choice of the spatial scale, as it can broaden or shorten it. In this case, the objective is the establishment of a self-sufficiency degree. This study was framed by a regional association called Arariwa. This association works on the theme of sustainable agricultural and rural development at the provincial and regional levels in Cusco.

Considering all actors implicated in the FS and the study, the context of the area, and the spatial boundaries mentioned above, this study is to focus on the whole province of Chumbivilcas (see section 3.1.1 for more explanation).

The study is divided into the descriptive (present) and prospective (future) parts that constitute the temporal scale. The descriptive part happens in 2023. The prospective dimension must be selected depending on the objectives of international, national, and regional policies and local planning. Local programs and action plans are often short-termed, giving a vision of the FS five years ahead and not considering the change of agriculture as a long-term process. So, to have a more long-term vision, the prospective temporal scale is aligned with a more long-term plan. For example, the mission of the WFP set objectives for 2050 (Laughton & Castro, 2022).

1.3.2. Tools to assess food systems, their self-sufficiency and food diversity

A. Choosing the factors for the assessment of FS

In this study, local FS is analyzed with the evaluation of the food self-sufficiency degree (see why in section 1.2.2). Many studies try to evaluate food systems. Because every country has different food production systems, food environments, food habits, it is difficult to develop a general method. Besides, the factors considered differ depending on the scale and the objectives.

One approach for the evaluation of FS can be actors driven. The CFRS gives indicators to identify the key actors in the FS (FAO, 2018). Key actors include both direct stakeholders in food value chains and indirect stakeholders, such as NGOs, local organizations, universities, etc. (FAO, 2018). Indirect stakeholders are the actors that influence the FS without being part of it. For example, the regional government regulates the food flows and prices but does not participate in the food chains. The tool helps to understand the dynamics at the chosen scale (FAO, 2018). The model must consider the actors and their dynamics.

A second approach to assess the sustainability of FS is to focus on potential hazards and, more specifically, the health and environmental impacts of current FS. The study suggests evaluating these hazards regarding exposure, vulnerability, and resilience capacities. After the identification of these drivers, the last step of the process (post-study) is to gather the identified actors of FS so they can discuss policy decision-making and adjust to the needs and recent challenges (FAO, 2018). This methodology identifies the main actors and drivers for change.

Another example of factors to consider is given by the Grdr, an international solidarity association that has created a guide for territorialised food systems. Territorialized FS is “a set of agri-food chains that meet sustainable development criteria, located in a regional geographical area and coordinated by regional governance” (Grdr, 2016). In this case, the tool to evaluate FS based its choice on the actors’ pertinence (and their dynamics), food supply chains, and an analysis of territorial strengths and weaknesses (Grdr, 2016).

Another study, led in 2024, showed that five types of factors must be included to evaluate the FS and their sustainability fully. These indicators are: (1) nutritional (diets, health), (2) environmental (natural resources, productions), (3) social and economic (poverty, equity), (4) political (governance) and (5) conceptual (resilience) (Turrini & Ridoutt, 2024).

To sum up, indicators can vary between studies based on the ambitions, scale of action, and resources. Choosing them depends on the context, the physical and financial possibilities, the goals, and the expected outcomes of the study.

B. Establishment of the FSS degree

Riera et al. (2020) developed a methodology to analyze the potential of food supply to meet the food demand of a defined territory. The methodology considers urban-rural food flows and external food flows. The goal is to assess the territory's capacity for more food autonomy (Riera et al., 2020). This study focuses on two parts: production and consumption. The production is estimated with the domestic production, importations, exportations, and losses in the transformation processes (figure 6) (Riera et al., 2020). The result is the food supply. Then consumption is evaluated with the regimes and the population, which allows to characterize the food demand (figure 6) (Riera et al., 2020). Figure 6 shows the relationships between the included parameters for calculating food demand and supply.

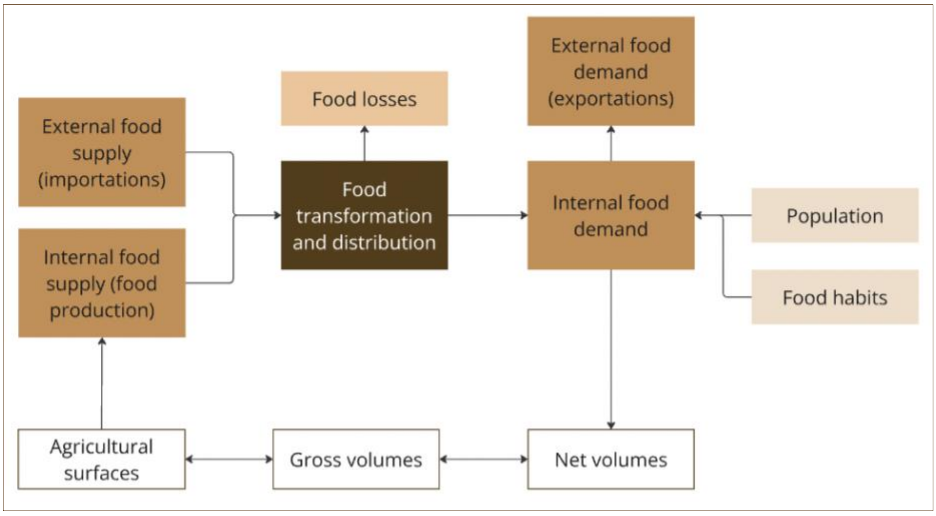


Figure 6. The Riera method: Component's interactions, food supply and demand concepts for calculation of the self-sufficiency degree (Riera et al., 2020)

This methodology was used to develop a new method for calculating the degree of self-sufficiency. With the consideration of only territorial food supply and demand (excluding trade by definition: see section 1.2.2), it is possible to calculate a food self-sufficiency degree (Schreiber et al., 2021). This new method has been used by Montois (2022) in her thesis, and the results were precise enough to address the conclusion about the sustainability of FS in Senegal.

Food self-sufficiency can be measured in terms of a country's dietary energy production (DEP in kcal) per capita or through the diagnosis of the regime of the concerned population (Clapp, 2017c). The former does not focus on food items or their nutritional quality but on the general intake of food per inhabitants, and it is the one used in this study.

The methodology works on two temporal scales. The descriptive scale allows to assess the current situation of the food flows. The prospective scale simulates possible evolutions of these flows, the results being theoretical.

C. Evaluation in terms of food security

"Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (World Food Summit, 1996). The FAO identified four components of food security (table 1).

Table 1. Definitions of the four components of food security (FAO, 2006)

Component	Definition
Food Availability	"The availability of sufficient quantities of food of appropriate quality, supplied through domestic production or imports."
Food Accessibility	"Access by individuals to adequate resources for acquiring appropriate foods for a nutritious diet."
Food Stability	"Utilization of food through adequate diet, clean water, sanitation and health care to reach a state of nutritional well-being where all physiological needs are met."
Food Utilization	"To be food secure, a population, household or individual must have access to adequate food at all times. They should not risk losing access to food as a consequence of sudden shocks (e.g. an economic or climatic crisis) or cyclical events (e.g. seasonal food insecurity)."

To assess food security, the FAO has developed a list of indicators (annex 1) to evaluate the four components. These indicators are multi-parameters and need detailed information in various dimensions. For instance, food availability can be evaluated in terms of dietary energy supply adequacy. For the evaluation of this indicator, the information needed is the exact regime (proteins, hydrocarbons, etc.), physical activity, weight, and size of the individual.

Other studies have developed their own set of indicators based on the feasibility and the context of the studied region. For example, the HFIAS or Household food insecurity access scale score, is an indicator to evaluate the tendency of a household to suffer from a lack of physical and financial access to food. It is based on a series of questions such as: "Have you or any member of your household eaten fewer meals per day because there wasn't enough food? " and its occurrence in the week. Many other indicators to measure coping mechanisms to face food accessibility also exist (Mutea et al., 2019).

Another one, focused on food diversity (an aspect of food availability), measures the intake of groups of food compared to recommendations at a broader scale (Swindale & Bilinksy, s. d.). More straightforward indicators like the food price index, household expenditure, GDP can give an idea of the financial accessibility (FAO, 2013).

The choice of the indicator must be based on the scale, objectives, feasibility, and available information. For instance, Chumbivilcas is mostly affected by issues of food availability and accessibility, and the indicator must include these dimensions.

1.3.3. Studies on food habits

Consumption survey methodologies will inspire the methodology of the descriptive part. A study on food habits at the national scale took place in 2019 (Larrea-Gallegos & Vázquez-Rowe, 2020). However, the Covid-19 crisis hugely impacted the food habits of the population, which is highly dependent on international trade (FAO, 2021). A more recent survey of food habits would lead to a more accurate conclusion regarding the degree of self-sufficiency. The methodology used by the study includes the interview of more than 30,000 households in the whole country, taking into account the distribution of the population across the regions, and between urban and rural areas (Larrea-Gallegos & Vázquez-Rowe, 2020).

For the prospective part, food supply and demand evolution needs to be compared to national recommendations. Peru has a guide with food recommendations. One part is qualitative and recommended by experts. It includes recommendations such as eating more natural food, cooking at home instead of take-away, and having a healthy lifestyle by drinking water instead of soda for example. For the quantitative part, the CENAN recommends intake values for a group of foods like cereals, fruits, dairy products, etc. (table 2) (Lázaro & Mirko, 2019). The recommendations are thought to be sustainable, respect the traditional food culture, and bring the minimum caloric intake for a healthy life (Lázaro & Mirko, 2019).

Table 2. Food intake recommendations set by the Peruvian National Dietary Guidelines (Larrea-Gallegos & Vázquez-Rowe, 2020)

Food group	Food group name	Recommended intake value (all minimum except for groups 5 and 10)	Food products
1	Cereals	325 g/day	Wheat, rice, barley...
2	Tubers	310 g/day	Potatoes, pasta...
3	Vegetables	430 g/day	Tomatoes, peppers...
4	Fruits	180 g/day	Bananas, mangoes, oranges...
5	Oils	50 g/day	Unspecified
6	Dairy	250 cc/day	Milk, yogurt, cheese...
7	Meat-based products	500 g/week	Fish, poultry, beef, offal, lamb, pork...
8	Eggs	125 g/week	Eggs
9	Legumes	225 g/week	Peas, beans, lentils...
10	Added-sugar products	60 g/day	Soft drinks, sugar, cakes...

2. OBJECTIVES

The introduction and state of the art highlighted food security problems in the Peruvian context. It also demonstrated the differences between the local reality and the national scale. This gap can be attested in Chumbivilcas province. Besides, this province faces new incoming challenges and opportunities for its FS. This study wants to help local actors reflect on the direction FS can take from a scientific and external perspective.

2.1. Research questions

The general objective of this thesis is to analyze the food self-sufficiency of the province of Chumbivilcas. This objective has both a descriptive and a prospective dimension.

The first descriptive question (DQ1) that occupies the research is: "What is the capacity of the Chumbivilcas province to feed its population?" Given the food security issues, the expansion of mining, and productions' variability with climate change, the population is at risk. Calculating the self-sufficiency of the territory will help us understand if their productions are enough for their population and what could be done to better the situation in case it is not.

The second descriptive question (DQ2) complements the first is: "What are the main drivers influencing Chumbivilcas' ability to feed its population?" The aim here is to identify the drivers for the change, the very ones that drive the possible futures of the FS. This question bridges the gap between the descriptive and prospective sections. It will help us understand what factors need to be included to prospect the future of the province's self-sufficiency degree.

Then, the prospective question (PQ) to answer is: "How might this capacity evolve considering the drivers?". The ambition here is to draw up several scenarios for changes in supply and demand and determine their impact on the degree of self-sufficiency.

Finally, a secondary question (SQ) concludes the research: "What is the impact of a change in the degree of food self-sufficiency on food diversity?" To this end, an indicator of food diversity will be evaluated in each scenario.

2.2. Expectations of the partners

The study is being conducted in partnership with two organizations external to UCLouvain: Humundi and Arariwa. The expectations of partners fit their objectives as organizations.

Humundi is an NGO with an international network. The organization works towards supporting the local FS actors for an optimal agroecological transition while ensuring the food rights of the communities' access to sustainable food. Humundi has been working with Arariwa in Cusco for 6 years.

Arariwa is a leading association in the Cusco region that contributes to regional development; specialized and committed to the challenges of rural development intervention. They work with local authorities and food systems actors through advocacy and technical support. The association is looking into how these communities, which are still relatively uninvolved, can support themselves financially and socially with their agricultural activities.

For these reasons, this report is intended as a decision-making tool, written with a neutral view to assess the states of the local FS. Indeed, because of the food security issues and policies overlooking environmental and human impacts on Chumbivilcas' FS, today the province must act on the sustainability of the FS.

2.3. Scientific, social, and political contribution

The province of Chumbivilcas, because of its isolation, does not benefit from state intervention nor university studies and lacks scientific documentation to make more well-thought and documented decisions. The thesis proposes a grouping of scientific data and qualitative information at the provincial scale to understand the challenges of the food systems of the area. It also assesses the opportunities for the future and how they will impact the food systems.

This thesis is also based on a participatory approach with interviews at all scales and with all types of stakeholders from the value chains, directly or indirectly impacting the evolution of food systems. Participatory approaches have been proven to help develop the systems sustainably since they are discussed with every stakeholder. The idea is to empower the actors who were not yet part of the decision-making and sensibilize the powerful actors to consider other less powerful actors' points of view.

This thesis proposes a neutral evaluation of the food systems so that the discussions are based on data, information, and knowledge from a multiscale approach. This evaluation has the ambition to be a tool, for the local governments and population, to accompany decision-making processes.

3. Methodology

3.1. Methodological framework

3.1.1. General overview

A synthetic framework is shown in figure 7 to resume this study's methodology and expected results. The research combines quantitative and qualitative analysis. The qualitative part allows for the completion and verification of the quantitative data and helps establish future scenarios. This methodology has been used in a thesis on Fatick in Senegal and has proven useful to local experts (Montois & Baret, 2022).

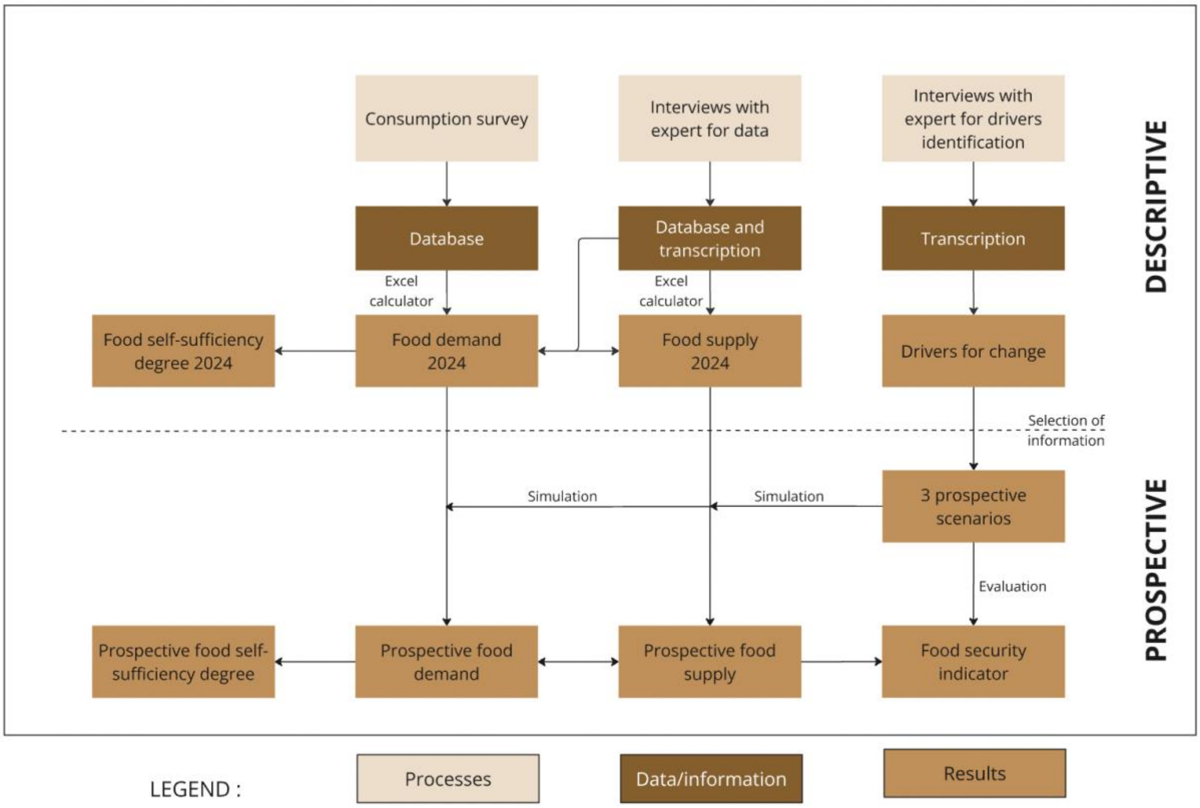


Figure 7. Methodology and expected results

The methodology is divided into two parts (color differences): (1) interviews and field surveys, corresponding to the processes and upper part in figure 7, and (2) a model simulation with selected drivers, corresponding to the results and lower part.

This methodology's results are descriptive and prospective food supply, demand, and SSD (as seen on the right of figure 7). Quantitative results will be analyzed using the qualitative information from the interviews to be more accurate in the discussion.

Before digging into these two parts of the methodology, the following section explains the limits of the framework.

3.1.2. Spatial and temporal scales

The spatial scale of the study was based on three different characteristics:

1. The actors involved: this thesis relies on a partnership between the university and Humundi and a collaboration between Humundi and Arariwa—the former works at the scale of the region of Cusco, in the different provinces and districts.
2. The territory of Cusco, 72,000 square kilometers, was too big to consider investigating for 4-month fieldwork. The size of the territory of Chumbivilcas is more realistic given the time constraint of the thesis. Besides, Arariwa mentioned lacking scientific studies in Chumbivilcas and the need to make more accurate decisions and develop strategies based on numbers, not only informal conversations.
3. The CRFS tool (see section 1.3.1). This toolkit considers the actors of the FS, the challenges, the interaction between rural and urban areas, and a set of borders (administrative, natural, etc.). In the case of Chumbivilcas, the province has consistent urban-rural interactions respecting the criteria of the CRFS. However, the interaction between Cusco and the province is neglected since self-sufficiency excludes the external food flows by definition. Finally, the province's borders respect the constraints of the CRFS toolkit.

These reasons led to the choice of the province of Chumbivilcas meeting both the criteria of the FAO tool as well as the expectations of the experts involved.

The temporal scope of the study is different for the prospective and descriptive parts even though both cases analyze the SSD on a one-year time-lapse. The descriptive part takes place in 2023 and gives an SSD for the current situation of the province. In the prospective part, results will be provided for 2050. Most action plans are short-term (three to six years), and a broader horizon will help to have a long-term perspective of the impacts of the identified drivers. It should help make better decisions for the sustainable development of the province. The year 2050 was chosen based on the UN plan of action for food security in Peru (see section 1.1.2.C).

3.2. The fieldwork: information and data collection

The fieldwork took place for three months. It allowed us to collect data and information to calculate the degree of self-sufficiency (SSD). It was executed with the help of Humundi and Arariwa. The fieldwork allows us to familiarize ourselves with the traditions, and the context of the province, and collect data for the consumption and production of food locally.

3.2.1. Methods for the collection of data

The collection of data took place through three different methods:

1. A consumption survey to collect local data about food intake and integrate changes from the national survey of 2019.
2. Interviews with 7 experts to gather data and information on the food supply.
3. Interviews with 20 experts to identify key drivers of change and establish hypothetical scenarios for the evolution of food self-sufficiency degree.

The first phase consists of visiting households in all the districts to assess the inhabitants' average consumption of food. The survey was conducted with the help of the team of Arariwa in Chumbivilcas since initiating contact with local communities can be difficult.

The second and third phases are dedicated to interviewing different experts. The experts' interviews for data come to validate and complete the numbers obtained through the literature review and the consumption survey. The experts' interview for drivers for change was led through a guided set of questions to identify drivers for change. The information was translated into a set of quantitative variables by selecting the most mentioned drivers for change. Then, these variables are included in the simulation for the calculation of the prospective SSD (figure 11, section 3.3.3). Depending on the expertise, one, the other, or both types of interviews were conducted.

3.2.2. The selection of the experts

The experts are selected based on a conversation with the partner of this thesis, Arariwa. The selection criteria are the following: it must cover all the scales; all the parts of the food supply chains and at least 3 external experts of the food supply chain. Based on that, Arariwa listed all their contacts, and we chose the most relevant to the local context (figure 8).

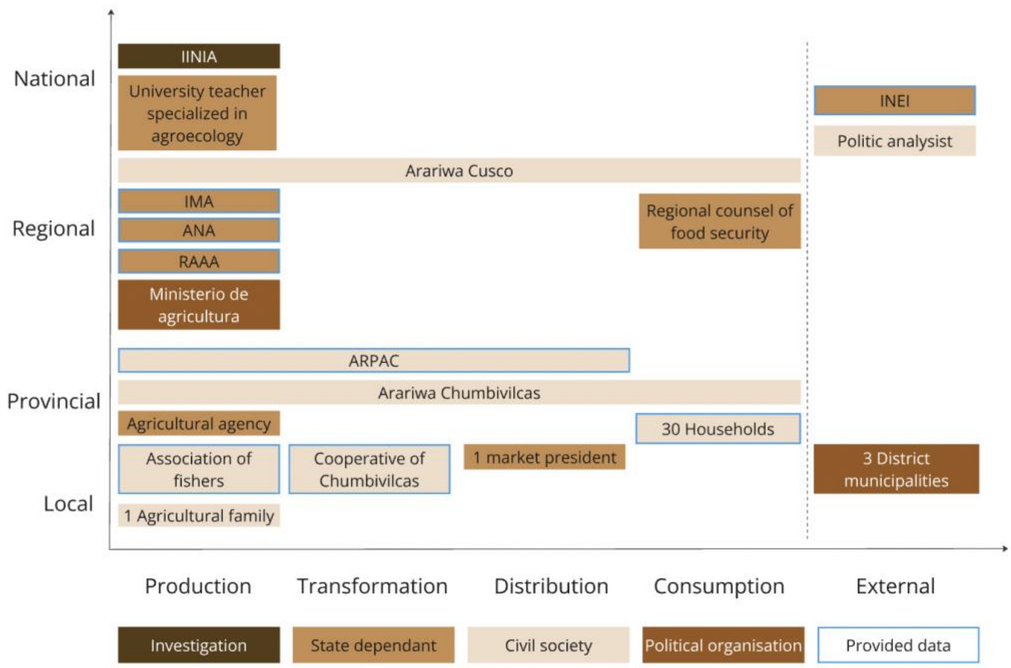


Figure 8. Mapping of the interviewed experts

20 experts are interviewed (figure 9), either in the province or the region's capital, Cusco. Actors on the left of figure 9 are stakeholders participating in the food chains and on the right, the ones that do not. The map reveals that actors from all dimensions, all parts of the value chain, and all scales are considered in this investigation.

In total, 8 state-dependent actors are interviewed. At the provincial level, the agricultural agency is responsible for implementing the national policies and adapting them to the conditions and climate of the province. The market director of Santo Tomas overviews all the food flows between production and consumption. The state's institutions are also interviewed including the Institution of Water and Environment Management (IMA), the National Authority of Water (ANA), the Action Network for Alternative Agriculture (RAAA), and the Regional Counsel of Food Security. At the national level, the INEI or National Institute of Information and Data is interviewed to collect statistics at the provincial and regional levels. Finally, a university teacher is interviewed to understand the scientific dimension of local FS.

Two types of political organizations are interviewed: three district municipalities and the Agricultural Minister.

A research institute, INIA (National Institute of Agricultural Innovation), is included to acknowledge the perspective of researchers working on projects for alternative solutions in agriculture. Interviewing them allows us to discuss the feasibility of technological solutions.

Finally, seven experts from civil society are included in the survey: the family of farmers, one association of fishers, one political analyst, and two members of Arariwa at different levels: provincial and regional. Besides, Chumbivilcas' cooperative is interviewed. It is responsible for transforming Andes cereals, the main transformed product in the province. The ARPAC is a gathering of women working in the agricultural field in production, transformation, and consumption that unites women at the regional level.

3.3. The SSD Model

3.3.1. Parameters for the simulation

The methodology to estimate food self-sufficiency is based on Riera's method, which states that the analysis of food systems is divided into 4 dimensions: territory, products, supply, and demand (table 3). Since the self-sufficiency definition excludes parameters like exportations and importations, not all the parameters of the Riera methodology will be used. Table 3 synthesizes the parameters included in the SSD methodology, selected based on the Montois thesis (Montois & Baret, 2022). Parameters are detailed in the following sections.

Table 3. Chosen parameters for the SSD model

Dimension	**Parameters**
Territory	Production: Cultures surfaces, livestock, and fish production surfaces Consumption: Population of the province Division: Urban and rural
Products	Cultures: Tubers, cereals, vegetables, fruits Livestock: Meat, milk, eggs Fishery: Fish
Food demand (FD)	Descriptive: Consumption survey Prospective: CENAN[2] recommendations
Food supply (FS)	Agricultural practices: Traditional, intensified, agroecology
(FD) and (FS)	Production yields, transformation yield

A calculator is created using Excel software. The data collected is processed using this calculator. Figure 9 shows the parameters used in the calculator and the data sources. In beige are the sources that provide quantifiable information (either discussing numbers or with guidance to access reports online). Because most of the information collected by the governmental organizations is not available online, the interviews with experts for data had an important role in the study. The parameters of the model are listed in brown, they are deducted from the information source. The model's output is shown in dark brown and consists of food demand and supply. These two outputs are used to calculate the SSD.

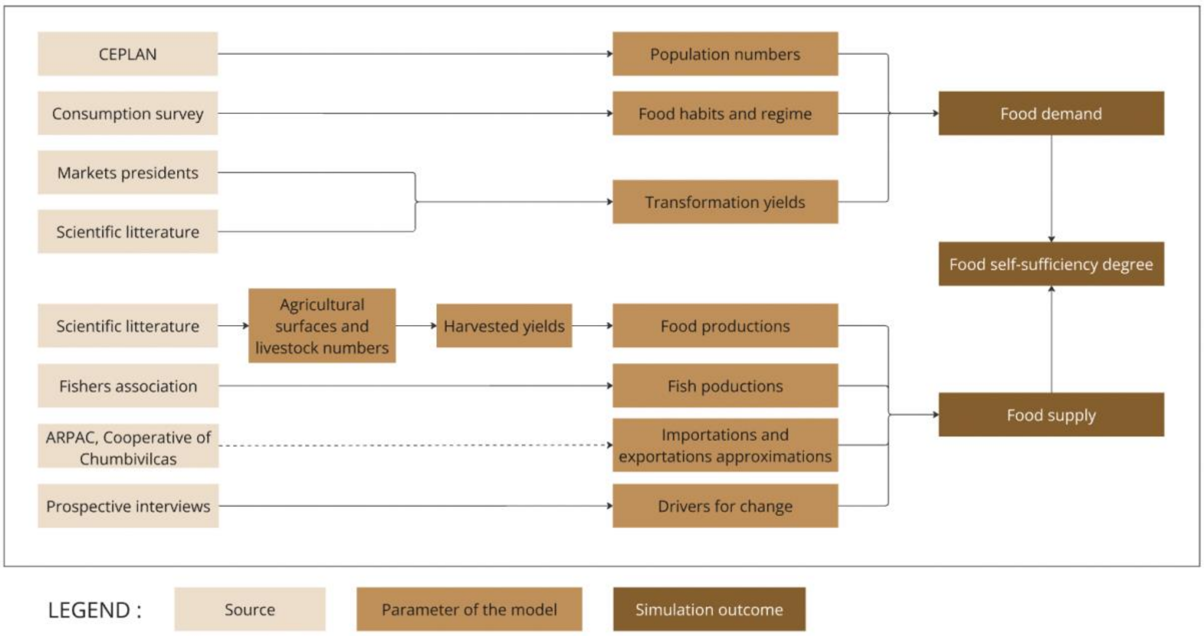


Figure 9. Factors of the simulation of the descriptive self-sufficiency degree

[2] CENAN is a governmental organization responsible for proposing policies and standards, and developing research, innovation, specialized surveillance, technologies, and services in the field of food, nutrition, and other actions for a healthy life for people. It stands for National Center for alimentation, nutrition, and sane life.

The next section explains the steps for calculating the SSD in the descriptive and prospective dimensions, as well as the impact of the prospective SSD on the food diversity indicator.

3.3.2. The descriptive approach

3.3.2.1. Territory and products

A. Territory

The same territory is considered for consumption and production. The consumption territory corresponds to the population of the province of the Chumbivilcas, which is divided between rural and urban populations. This characteristic was included by Larrea-Gallegos in the Peruvian consumption survey, by Raïssa in her thesis, by Riera in his method, and by many studies on food security (2020b; 2022; 2019; 2020; s. d.). The CEPLAN analyzed the distribution; 76% of the local population lives in rural areas and 24% in urban areas (2023). This thesis aims to create a tool to help communities and governments make decisions. The consideration of only their own territory allows them to be aware of their productions' values.

B. The products

The selected products have been chosen according to the list of productions the Minister of Peru gave. There are eight categories of food products:

1. The tubers: native potatoes (more than 3,500 existing varieties) and local tubers (añu, olloco, and oca)[3].
2. The cereals: maize amilaceo, maize choclo[4], rice, wheat, barley, oat, and local cereals.
3. The vegetables: onions, carrots, tomatoes, cabbages, salad, peppers, beans.
4. The fruits: mangoes, grapes, bananas, apples, pears, peaches, local peaches, and local Andes fruits (tunas, duraznos, pacay and capulli)[5].
5. The meat: alpaca[6], guinea pig, pig, beef, chicken, lamb, sheep, caprine and ovine.
6. The fish: trout.
7. The milk: powder or cow milk.
8. The eggs.

3.3.2.2. The food supply

The food supply expressed in gross volumes considers the production and transformation yields. Before getting the net volumes, the losses between the production and the distribution are deducted from the gross volumes. The supply gross volume calculation differs depending on the products and available information. This is explained in the following sections.

[3] Informal names (in spanish) of native tubers
[4] A variety of maize (corn) native to the Andean region of South America
[5] Informal names (in spanish) of Andes fruits
[6] Alpaca are mainly produced for wool and in rare social occasion, it is consumed as meat.

A. Cultures productions

Cultures' gross food supply (GFS) is given in yielded surfaces. The MIDAGRI has a database registering all the cultivated surfaces, harvested surfaces, and the harvest yields for each culture in the categories of cereals, maize, and starches of the province in 2023 (Midagri, s. d.). The food supply can be calculated as follows for each product:

$$GFS_p = SSu_p * HY_p * 10^3$$

GFSp = Gross food supply of the product p [T/year]

SSup = Supply surfaces of the product p [ha]

HYp = Harvested yield of the product p [kg/ha.year]

The Midagri database provides data on fruits and vegetables but is only available at the regional level (Midagri, s. d.). Only a few exceptions exist: the carrots, the onions, and the beans which are available at the provincial level. Based on this information, a fruit and vegetable production estimate has been made, knowing that the province is responsible for 15% of the regional production. Therefore, the numbers of these food groups should not be regarded as exact, but rather as a basis for showing its variations in the prospective section (Uncertainty 1).

B. Livestock productions

GFS of livestock is given in mass of available meat. The MIDAGRI has a database that registers all the production of animals at the regional level and their transformation ratio (Midagri, s. d.). Chumbivilcas is responsible for producing 15% of the region's total production. Livestock production should be more than 15% because Chumbivilcas is a livestock production area. But, since it is impossible to quantify it, the hypothesis of the 15% is used (Uncertainty 2). The food supply of the livestock can be calculated as follows:

$$GFS_L = LP_L *0.15* TY_L * 10^3$$

GFS_L = Gross food supply of the livestock animal L [T/year]

LP = Livestock production at the regional level of animal L [unity/year]

TYL_L= Transformation yields of the livestock animal L [kg/unity]

In livestock production, the proportion dedicated to producing wool of alpacas, llamas, and sheep is disregarded (Uncertainty 3). Also, according to Arariwa, the province of Chumbivilcas is known to produce dairy products such as Andes cheese. However, no information exists, and no experts could estimate the proportions of cows dedicated to this activity. Besides, no numbers on the transformation ratio exist for the conversion of milk into dairy products. The hypothesis being unverifiable, no hypothesis was made on the dairy products (Uncertainty 4).

The municipalities told us that around 400 guinea pigs are produced yearly in each 'stable'. In the province of Llusco, the biggest producer, the chief of economic development estimated the production to be around 250,000 units yearly. Considering it is one of the most producing provinces but also the smallest in the territory, this number is multiplied by eight, the number of provinces. The yield of this animal is estimated at 0,6kg per unit. However, this number might not be accurate (Uncertainty 5). A study was done in 2017 by the local governments. But ever since, no scientific studies have taken place in this area to monitor the progress of this production even though it is known to gain importance (Westmont, 2021).

C. Fish production

Only trout is produced in the province of Chumbivilcas. The GFS of fish refers to fresh products. Data were collected in the municipality of Santo Tomas since they are responsible for the province's trout project. As it was the case for guinea pigs, no official recent documents exist to gather data for this production. The municipality of Santo Tomas estimates that 500,000 trout are produced each year and dedicated for human consumption. One trout weighs 0,7kg on average (Uncertainty 6). It is estimated that 30% of the fish is lost in the form of skeletons and scales. The food supply for trout is calculated as follows:

$$GFS_F = FP_F * W_F * 10^3$$

GFS_F = Gross food supply of the fish F [T/year]

FP = Fish production at the provincial level of fish F [unity/year]

W_F = Average weight of the fish F [kg/unity]

The data from this part will not be accurate since it is an estimation of one person, this should be considered in the discussion of the results. A monitoring of this activity in the province might be planned for the year 2025 according to the trout project chief.

After these calculations, the losses from the transport and distribution could be deducted from the GFS to determine the net food supply (NFS). However, experts estimated no losses in the transport or distribution process.

3.3.2.3. The food demand

The food demand is expressed in net volumes, like the food supply. The food demand considers the net consumption of food by the inhabitants, the transformation yields, and the territory's total population. These three elements are necessary to estimate the food demand of the population precisely.

Currently, no specific numbers exist on food consumption in the province of Chumbivilcas. A national survey took place in 2019 including the region of Cusco. But particularities exist in the province of Chumbivilcas given the local traditions and informal food chains. For example, until very recently, guinea pig production has been increasing as an alternative form of revenue for farmers and has become important in daily consumption. Besides, COVID-19 has strongly impacted South America by temporarily increasing the triple burden of malnutrition. Verifying the data is interesting and necessary to determine the precise provincial food demand.

The sample of the consumption survey included 30 households, respecting rural and urban areas, districts' population proportions, gender, and age (figure 10). The team randomly chose each household based on these criteria. In 2022, 76% of the population lives in rural areas in the province (CEPLAN, 2023). In total, 23 communities were visited to survey all the districts.

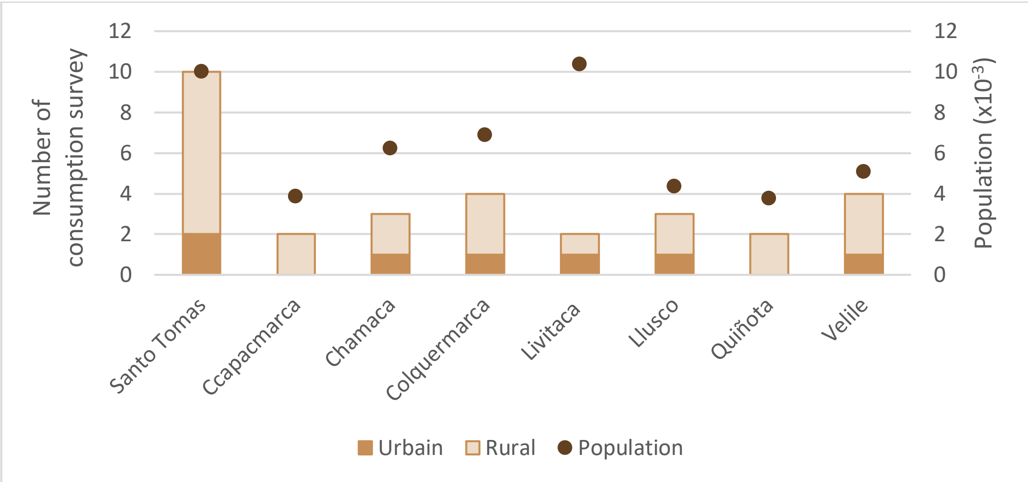


Figure 10. Population repartition in the eight districts of the province for the consumption survey

As seen in figure 10, there is a disequilibrium between the number of interviews and the actual population in Santo Tomas and Livitaca compared to other provinces. Most surveys that should have happened in Livitaca (the most populated area) were moved to the Santo Tomas district for logistic reasons. The association does not have many relations with the inhabitants or politics. They also wanted to minimize the trip to this district because it is the furthest from the office. Santo Tomas and Livitaca being similar in terms of rural/urban dynamic, and territory size, the impact of this decision is negligible for the analysis of the results.

Before surveying, a discussion took place with the representative of agricultural projects in each district town hall. This discussion asked for permission and suggested collaboration in case of needed information or missing numbers on agricultural and breeding matters.

The survey took place in all eight districts of the province. Each province is constituted of one big city and the rest of the area is rural with villages and communities. All the districts have different agricultural dynamics depending on the altitude levels and water availability from the rivers. For example, Santo Tomas has access to the river, allowing trout production that is not possible in other districts.

During the consumption survey, the communication could be either in Spanish or Quechua. The information given in Quechua was translated into Spanish afterward. In each household, the interviewee was responsible for feeding the family. The consumption survey can be found in annex 2. There are eight categories of food. The data for each product could be given by day, week, or month according to the household's preferences. Data about the households were collected, including address, household size, age, and gender.

The data is processed in an Excel calculator, using the consumption of a product for one day for one person. The means between households for each product is calculated. The food demand is calculated separately for the urban and rural areas since the consumption can vary. This method was used by Montois in her thesis and is applied identically in this thesis (2022). This assumption is based on the context of Peru where rural areas tend to suffer more from food insecurity than urban ones. The formula for the mean food demand is the following:

$$DFD_p = \frac{1}{N}\sum_{h=1}^{N}\frac{x_h}{n_h}$$

With $DFD_{p,d} = \mathit{Daily\ food\ demand}$ of product p per day d per person [kg.d^{-1}.pers^{-1}]

N = Number of consumption surveys [-]

x_h = Daily consumption of the household h [kg.d^{-1}]

n_h = Number of people in the household h [pers]

The daily food demand is converted into annual food demand.

$$AFD_P = DFD_p * 365$$

With $AFD_p =$ Annual food demand of product p per year per person [kg.year^{-1}.pers^{-1}]

With the population statistics from the CEPLAN (confirmed with the INEI), the annual food demand is adjusted to the province's total population distribution between rural and urban areas and then combined. This allows us to obtain the annual net food demand which is the actual food demand of the province.

$$NFD_P = \ AFD_P * Pop \ * 10^{-3}$$

With $TAFD_p =$ The net food demand of product p per year [T.year^{-1}]

Pop = Total population of the province [pers]

It is always lower than the gr oss food demand because it does not consider the transformation yield of the food. Gross food demand indicates the total production needed to meet the net food demand of the population. This gross food demand will be compared with the gross food supply through the SSD.

$$GFD_P = \frac{NFD_P}{TY_P}$$

With $NFD_p =$ Gross food demand [T.year^{-1}]

TY_P = Transformation yield of product p [-]

The gross food supply for cereals is given in tons of grains and considers the losses from harvest to threshing (harvesting, drying, transport, threshing). However, some cereals and maize productions are transformed for consumption. Cereals are transformed into flour, pasta, or bread while maize can be broken down into grains and dried out to be consumed in this form. Beans and potatoes can be dried into dry beans and 'chuño'. The transformation ratio is shown in table 4.

Table 4. Transformation yields

Product transformation	*Transformation yield*
Wheat-> flour	0.85 (Chumbivilcas cooperative)
Wheat -> pasta	0.6 (Chumbivilcas cooperative)
Flour (wheat) -> bread	1.2 (ARPAC)
Maize -> husked corn	0.95 (Chumbivilcas cooperative)
Maize -> corn milling	0.95 (Chumbivilcas cooperative)
Bean -> dry bean	0.9 (Chumbivilcas cooperative)
Potato -> chuño	0.99 (ARPAC)

3.3.2.4. The self-sufficiency degree

The SSD is inspired by the Riera method and is the ratio between the gross food supply and the gross food demand. It is the capacity of a territory to feed its own population with its agricultural surfaces. However, the SSD is theoretical since it does not consider the percentages of the food production dedicated to animal feeding or energy production. The theoretical SSD is the following:

$$SSD_P = \frac{GFS_P}{GFD_P}$$

With $SSD_p =$ The food self-sufficiency degree of product p
With $GFS_p =$ Gross food supply of product p [T.year^{-1}]
With $GFD_p =$ Gross food demand of product p [T.year^{-1}]

The formula considers the gross food supply and demand because they consider the losses in the transformation process in their calculation. If the net food supply and demand were compared, the SSD would not be comparing the food production with what is required for the inhabitants.

3.3.2.5. The identification of the drivers for change

The drivers for change are the key external and internal factors that impact the FS in the province of Chumbivilcas. They influence the different scenarios for the prospective FS. After their identification, they were translated into variables that affect the parameters of the model and the outcomes for food supply and demand. The drivers that do not enter the model quantitatively will be discussed qualitatively.

The drivers are identified through the literature review or mentioned in interviews with local FS experts. The drivers previously identified were discussed during the interview to understand to what extent they could influence the province's GFS and GFD. The interview also asked more general questions; experts were free to mention any issues or potential factors that could impact the future FS. The selected drivers were those most mentioned during the interview.

3.3.3. The prospective approach

The aim of the prospective approach is to see how the province's degree of self-sufficiency will evolve by 2050, based on different scenarios. This is situated in the second part of the overall methodological diagram (figure 7). Supply and demand were recalculated based on three prospective scenarios. Scenarios were based on the selection of the drivers for change. As a reminder, the major drivers of change were identified through expert interviews (see previous section).

Figure 11 shows the relationships between the major drivers for change and the model inputs. The drivers of change are listed here to facilitate understanding of the foresight methodology, but these results will be discussed in greater detail in section 4.1.4.

In the case of this thesis, three drivers for change were selected for establishing scenarios: **the availability of water, the use of agricultural technologies (intensification), and diversification**. The availability of water and the use of technologies impact the harvested yields. A hypothesis is made for the diversification. Because of the absence of information on the impact of the diversification at the parcel scale in Peru (impact on yields if use of intercropping, agroforestry, etc.), the scale considered is territorial. Therefore, diversification only impacts the surfaces available per culture.

The model does not directly explain the remaining drivers. Only their qualitative influence is put into perspective in the discussion.

Then, the impacts of the selected drivers for change will be evaluated regarding food diversity since it is a liability for the province.

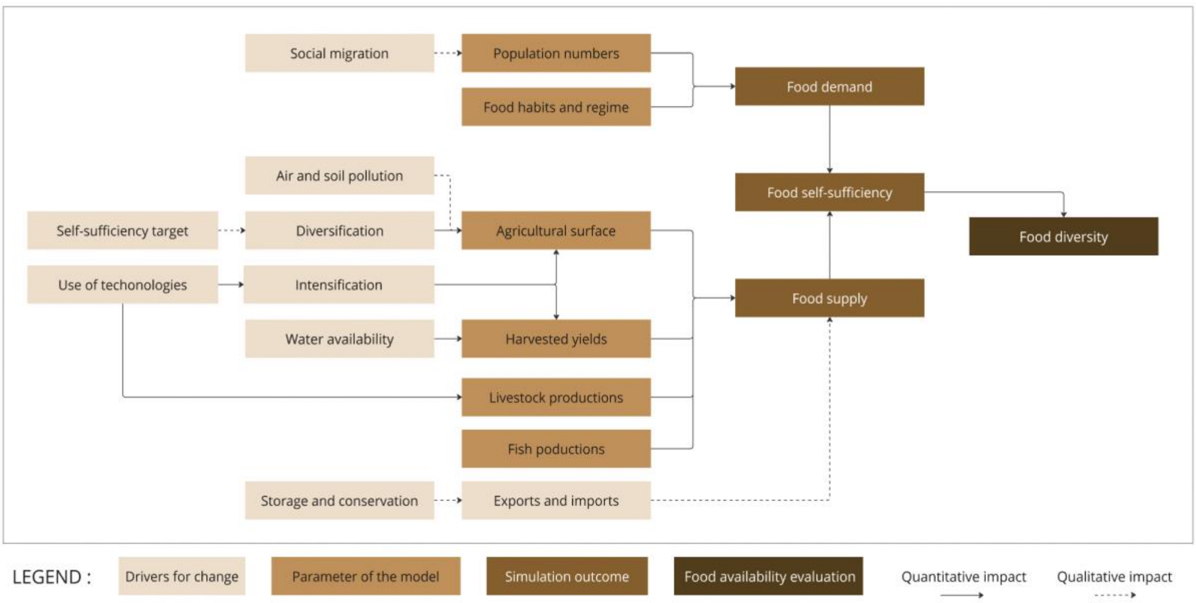


Figure 11. Drivers for change of the model of the prospective SSD

3.3.3.1. Assumptions and scenarios

Three scenarios were created to include best the three selected drivers for change (water availability, diversification, and use of technologies). These scenarios could either include specificities of the context of Chumbivilcas or follow the pattern identified by Raïssa in her thesis. The identified uncertainties and lack of scientific studies on certain drivers led to the choice of following the methodology established by Raïssa. Her methods for creating the scenarios claim to enhance each driver's impact on most model parameters. Therefore, this thesis uses the same scenarios and there are the following.

A. The traditional agriculture scenario.

This scenario follows the current trajectory of FS trends in the province. The loss of agricultural surface is estimated at 1% per year and includes the impact of mine extension and land abandonment by the youngest generations. Farming would remain extensive. Farmers would combine the use of a few chemical inputs, hybrid seeds, and low levels of mechanization. There would be a slow diversification of the production, following the currentx trends of varieties used. Water availability would remain an issue, impacting harvested yields and productions, with the same variability as the latest 10 years. The scale of 10 years was chosen to include the impact of El-Niño and annual inter-variability.

B. The agroecological agriculture scenario.

Transition efforts would increase. More farmers would convert to the agroecological model. They would integrate the main principles of agroecology in their practices. Organic farming would take precedence over traditional (and ancestral) practices. The communities and family farmers would use conservation agriculture, integrated farming, and agroforestry more. For example, terrace farming has been proven to help with the efficiency of resources like water and chemical inputs: rainfall drops from terrace to terrace without being lost as it would be in a normal decreasing slope (J. Sanchez, personal communication, 2024). Water availability would be managed by agroecological practices such as irrigation implementation, crop choice that capture and conserve soil water, etc. In addition, production diversification would be more sustained than in the traditional scenario. Specific and genetic diversity would be ensured while enhancing the production of currently non-self-sufficient cultures.

C. The intensified agriculture scenario or industrial scenario.

The model would switch from traditional practices to intensified practices. Large-scale farms would emerge on the most plane surface in the area. Government-supported mechanization would increase with the use of more tractors. Yields would be improved using more agricultural technologies such as chemical inputs, hybrid seeds, etc. To meet the objectives of industrial potatoes, quinoa, wheat, and guinea pigs, no measures would be taken to diversify production, which would remain predominantly focused on these. These cultures are among the most profitable for the family farmers. In addition, the water availability issue would be enhanced, encouraged by the unsustainable agricultural land management. At the same time, industrial maize and vegetable production would increase.

To create the scenarios, assumptions, and estimations had to be made about how the parameters would evolve. Parameters can be either variable over time and between scenarios, or stable, which means they evolve identically in the three scenarios (table 5). Parameters can also be constant, meaning they would not change between the descriptive and prospective situations. The constant parameters were explained in the methodology of the descriptive section (see section 3.3.1).

Table 5. Categorization of parameters in the prospective SSD simulation

Constant parameters	Steady parameters	Variable parameters
C1: Territory C2: Products C3: Transformation yields C4: Food chain losses	S1: Fish productions S2: Population decrease	V1: Agricultural surfaces V2: Livestock productions V3: Harvested yields

Table 6 below summarizes the variations of parameters for each scenario. The next section on prospective food supply develops these changes in more detail.

The use of technologies refers to the use of pesticides, chemical inputs, mechanization, and transgenic seeds while the practices refer to the type of agriculture (organic, traditional, precision, industrial, etc.). Diversification refers to the proportions of each culture at the scale of the territory (see assumption in 3.3.3).

Table 6. Variations of the parameter according to the three scenarios

Traditional scenario	Agroecological scenario	Intensification scenario
V11B: No diversification	**V11A**: Diversification +	**V11C**: Diversification -
V13B: Use of technologies +	**V13A**: Use of technologies	**V13C**: Use of technologies ++
V2AB: Traditional livestock trends	**V2AB**: Traditional livestock trends	**V2C**: Intensified livestock productions
V31B: Traditional harvested yields	**V31A**: Biological harvested yields	**V31C**: Industrial harvested yields
V32B: Water availability -	**V32A**: Regulation of water availability	**V32C**: Water availability - -
V33B: Traditional practices	**V33A**: Transition towards agroecological practices	**V33C:** Industrial practices

3.3.3.2. The prospective food supply

The prospective food supply is influenced by the use of technologies (V13), water availability (V32), and diversification (V11 and V2). These drivers impact different variable parameters enumerated in table 5.

A. Cultures productions

Culture production depends on the surfaces accorded to each type of culture, the total surfaces, the surfaces dedicated to every kind of practice, and the harvested yields.

1. General evolution

The calculation of culture evolution is based on the trends observed over the last 10 years by the MINGARI. A period of 10 years is chosen to include the impact of El-Niño of 2015-2016. Besides, it is assumed that the trends will not reach a threshold regarding surface expansion. Currently, the higher ecological level is mostly occupied by livestock production But, according to numerous experts, the impact of climate change (in temperature) allows the production to climb in altitude and gain independence on ecological levels.

2. The impact of the diversification on the surface of each culture (V11, V2)

Diversification usually refers to practices such as intercropping, agroforestry, etc. However, in this case, the diversification takes place at the territorial scale and refers to the surface dedicated to each culture. This decision was based on the incapacity to collect data at the scale of the parcel. Besides, no data exists, nor can be estimated on the change of yields based on the practices in three-month fieldwork. The RAAA is leading studies on diversification in similar areas but no ciphers, nor reports were exchanged during the interview.

The surfaces dedicated to each culture depend on each family farmer's will to diversify their cultures. Following the scenarios, there are three possibilities (figure 12). Different actors have mentioned the resistance to change from different family farmers, making the possibilities for diversification close to none in the traditional scenario. Respecting the belief, this hypothesis is considered; therefore, the traditional scenario will continue with the same trends and no change in the agricultural surfaces (V11B).

For the two other scenarios, diversification focuses on four types of cultures: the tubers (native potatoes and Andes tubers) cereals (tarwi, quinoa, and wheat), the maize (amilaceo and choclo), and vegetables. Note that vegetables will be considered in the diversification as a food group and not separately by culture as it is done for the other food groups. This is because no data exists for vegetable production at the provincial level (Uncertainty 1).

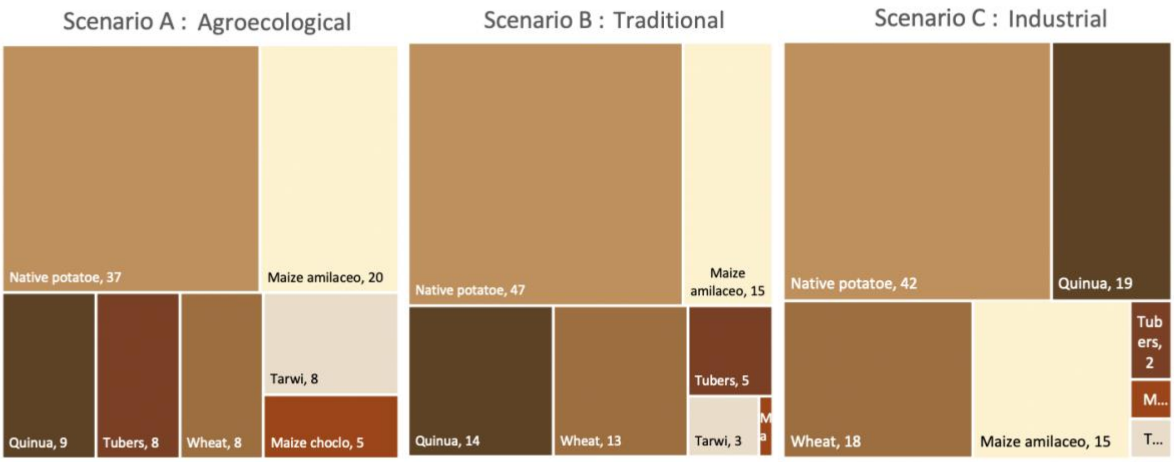


Figure 12. Diversification: Repartition of the cultures (in%) according to the three scenarios

For intensified agriculture, more emphasis will be put on the cultures that are most valued in the economic part of the food systems of the province (V11C)—this concerns mostly cereals. The experts estimate an increase of 25% in the production of quinoa and wheat. The vegetables and maize are following the current trends while the Andes cultures are decreasing in surfaces to make space for the cereals.

In the agroecological scenario, an emphasis is put on the Andes cultures, adapted to the environment even though it is rapidly changing, the diversification would be accelerated (V11A). Overall, the idea is to compensate the surfaces of highly self-sufficient cultures with more currently lacking cultures. Therefore, the agricultural surfaces dedicated to maize and tarwi would increase reducing the surfaces for wheat and quinoa. It is estimated that the production of Andes cultures would increase by 5% on average for every culture. The production of native potatoes, which are excessively present, will be reduced. The vegetables would be given more space too, up to 3%. The agricultural surfaces for vegetables can't expend more since only the lowest ecological level allows their production.

The estimated percentages are based on a mean of the different experts' answers. The methodology could have also been using ranges with all the numbers received by the experts. But, since the answer could vary to extremes, the matter was discussed with Arariwa, and it was decided to select the mean of the less extreme answers. These extreme answers were often given in institutions not dealing with data management like family farmers.

3. The impact of water availability on the harvested yields

Numerous actors mentioned the consequences of climate change as a real driver for the future of agriculture in the province. Climate change led to a disparity of water availability over the years and the areas, longer drought periods, extreme weather events disturbing the plant cycle, the El-Nino event being stronger every time, and destroying from 40% to 100% of crops in different areas of the province.

In the traditional scenario, experts estimate that the yields could lower to 30% (V31B). This is an average number. In the local context, parcels are extremely fragmented. Therefore, if extreme weather events destroy one crop in one place, it can be counterbalanced by another one in another area. In intensified scenario, the cultures would tap more into the soil water, so yields would increase in the short term. However, in three- to five-year plans, the yields would be lower by 40% if water projects are not implemented to counterbalance the intensive productions (V31C). In an agroecological scenario, however, practices like agroforestry or terrace agriculture could increase the yields by up to 20% estimates the RAAA (V31A).

All these data are estimations based on conversations with experts. Midagri database shows that in 2015 (the year of El-Niño), the yields were 25% lower than on average in the traditional scenarios (Midagri, s. d.). The 5% added by the experts must come from the worsening of the climate conditions over the years. Thus, the assumptions made by experts are considered reliable.

4. The impact of the use of technologies (intensification) on total agricultural surfaces

Interviewing the minister of production, it is estimated that the territory is losing 1% of agricultural surfaces yearly due to abandonment of family surfaces by younger generations. Land is lost as young people leave the rural environment and family land is no longer cultivated or taken over by another family. This loss in included in all scenarios.

The traditional scenario is not affected by a change in agricultural practices (V33B). Family farmers are resistant to change and are not in favor of converting their land to other practices or technologies.

In the intensified scenario, they estimated that 20% of the agricultural surfaces could be converted into surfaces dedicated to industrial practices (V33C). The limit to this estimation is due to the province's topography which makes it almost impossible to use tractors and machines to spread pesticides or harvest the crop.

In the case of the agroecological scenarios, the experts estimated that 50% of the total agricultural surface could be converted to parcels for agroecological practices in 2050 (V33A). However, this is considering that the family farmers would be given technical assistance and education on the agroecological practices to adopt these practices.

5. The impact of the use of technologies (intensification) on the harvested yields

Estimating the impact of each scenario on the harvested yields is difficult since it depends on many factors besides practices like climate change, local weather, soil conditions, fertility, water availability, etc.

In traditional scenarios, family farmers will not change their practices, nor will their use of technologies and harvested yields follow the current trends (V31B). According to the different experts, the coast and the Northern regions are dedicated to agroexportations, and this information has been validated during a conversation with the INEI and the minister of production at the regional level. The cultures dedicated to agroexportations are treated with industrialized techniques (mechanization, using hybrid seeds, and applying pesticides). Therefore, the harvested yields from the coast were studied by the INEI and the INIA and revealed that they are on average 30% higher. Hence, the industrialized scenario is assumed to follow this trend (V31C).

Discussing with the university teacher specialized in agroecology and the RAAA, they both reveal that agroecology has the potential to reach the same harvested yields as the traditional scenarios but only with a long-term vision. In 25 years, the yields could reach the current one with agroecological practices but with a risk of uncertainty of 5% (V31A). According to the experts mentioned above, using agroecological practices helps restore degraded soil, improve fertility, and increase parcel biodiversity.

B. Livestock productions

Chumbivilcas is a breeding region, livestock production is an important part of the agricultural systems. Livestock production is assumed to follow two directions: business as usual or intensified. According to the experts, the reduction in these productions is not conceivable. The family farmers depend on these productions for their revenues and food security.

Production follows the evolution of the last five years (V2AB) in traditional and agroecological scenarios. Only five years are considered because of a change in meat management following the COVID-19 crisis. Additionally, the recent introduction of guinea pigs has changed the production dynamics at the local level. It would not be representative to go further in the past.

For the intensified scenario, the evolution of the guinea pig is estimated at 25% more than the current trends (V2C). Poultry would also emerge in the food systems at a rate of 10% more than the current trend. Poultry is underestimated in the region, but experts believe they're economically interesting for family farmers since they could have a double value: chicken meat and eggs.

For all scenarios, water availability will impact the production. Animals, especially cows, require a significant amount of water to build muscle or produce milk. Water availability being a driver for change, the intensified scenario limits the animal subject to the intensification. The cow production, both for milk and beef meat, will be limited by a 10% decrease in current trend considering they are the biggest consumers of water. A greater reduction could not be conceivable knowing it is the most important animal production in the province, in terms of quantity of production and economy (figure 3).

C. Fish productions

Fish production is currently not monitored in the province of Cusco. The different experts do not mention it as either an important part of the food basket or an important part of the economic interests of the family farmers. Therefore, it is assumed that the number of fish will not vary in the next years depending on the scenarios.

Since no data exist, the evolution rate is based on the province's projects. The production will increase by 2% a year in the following years since the water is a constraint. However, since the population will be decreasing and the main target is self-sufficiency, it is assumed that the fish production will never overcome the hypothetical threshold of 650,000 trout a year. The chief of the trout project has given this number.

3.3.3.3. The prospective food demand

The prospective food demand is influenced by the decrease of the population (S2) and the food habits. The INEI has studied the national population, showing the expected reduction of the Chumbivilcas population based on data collected since 1940. The population data were collected in 2017 and prospective evolution was calculated until 2023. The data was extrapolated until 2050 based on the last 15 years' trends.

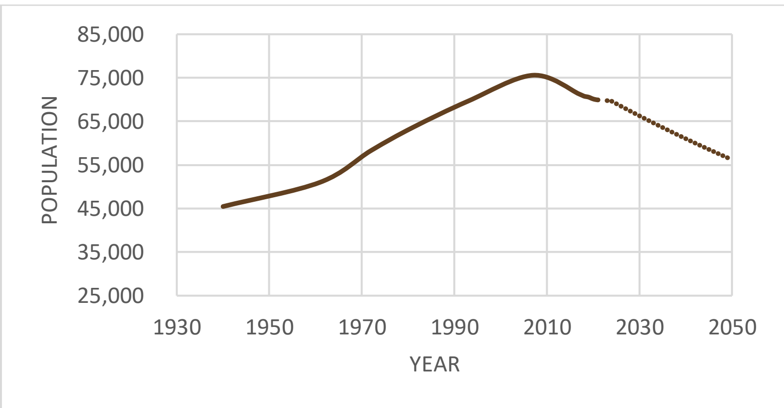


Figure 13. Estimated evolution of the population of Chumbivilcas until 2050 (INEI, 2023)

According to figure 13, a decrease of 22% is estimated between 2021 and 2050, mainly due to the migration of young people to the closest cities for access to education. The population would decrease from 71,265 to 55,748 inhabitants.

Two scenarios were proposed for 2050: one in which current food habits would be maintained, and a second and alternative scenario. For the first scenario, the results of the consumption survey are used. The second scenario uses the recommended food intake given by the CENAN. In 2019, the CENAN developed a food habits recommendations guide showing the proper quantities for a healthier and more sustainable diet. This guide was made for Peruvian citizens and considers the territory's possibilities and limits of food products.

The differences between the current and recommended regimes are seen in specific categories of food groups (see table 2 in 1.3.3). Following the same methodology as in the descriptive approach (see section 3.3.2.3) the daily quantity is translated into an annual amount and then multiplied by the projected population in 2050.

3.3.3.4. The prospective self-sufficiency degree

The prospective SSD is established with the same formula as in the descriptive approach (see section 3.3.2.4).

3.3.4. The evaluation of the food availability

From the field experience, it was found that Chumbivilcas is suffering from food insecurity in two forms: food availability and accessibility. Other dimensions will not be evaluated due to insufficient data and information besides lower interest.

An analysis of various methodologies and tools was done to select the most adequate indicators. The analysis was based on reports from the FAO, the Regional Counsel of Food Security in Cusco, and a study cataloging food security indicators in a Kenya region. This study was selected based on the similarities of the cases: rural areas, three ecological zones, potential in agriculture, and the isolation of important economic cities.

Due to data unavailability and limited resources, only one data entry indicator could be used, and more complex indicators could not be investigated. Given limited information on the consumption of inhabitants and the form of the collected data, it has been decided to select the household dietary diversity index (HDDS). Food diversity is part of the food availability. However, food accessibility could not be estimated due to the complexity of the indicators.

The HDDS or Household Dietary Diversity Score is used to evaluate food availability. It was developed by the United States Agency for International Development (USAID). HDSS assesses a part of food availability: food diversity. It works as follows (Mutea et al., 2019):

1. Regroup the food into 7 groups (table 7). The oils and fats are excluded from the index since no data exists on Chumbivilcas. The households interviewed could not precisely account for the use of these products.

Table 7. HDDS food groups

1	Tubers, roots and cereals
2	Pulses and legumes
3	Vegetables
4	Fruits
4	Meat, fish, seafood, and eggs
6	Dairy products
7	Oils and fats

2. For each group, create a binomial variable where 0 is the absence of the consumption of this food group and 1 is the consumption of the food group. In this case, the binomial value 1 is only given if the consumption meets the food group's CENAN consumption standard per day with a 25% margin.

3. Sum up the binomial values to obtain a score between 0 and 6.

4. The value is disaggregated between rural and urban areas to verify the affirmation that rural areas suffer more from food insecurity. As for the men and women distinction, women normally suffered more from food insecurity, but since the interviews took place mainly with families, the distinction could not be made.

5. The binomial values are classified into three categories
    - Good dietary diversity = 5+
    - Medium dietary diversity = 4-5
    - Low dietary diversity = < 4

For the prospective analysis of the diversity, the value of 1 will be given if the evolution of the SSD follows these trends:

- For over-consumed products: 1 if the increase of SSD is lower than 50% and 0 if higher.
- For under-consumed products: 1 if the increase of SSD is higher than 50% and 0 if lower.
- For products consumed in recommended quantities: 1 if it follows the trends of production and 0 otherwise.

4. Results

4.1. Descriptive dimension

The results of the descriptive approach include the food supply (4.1.1) and food demand in 2023 (4.1.2). From these results derive the theoretical SSD for 2023 (4.1.3). The final section (4.1.4) presents the drivers of change in the 2023 food situation for the forward-looking section of the prospective approach.

4.1.1. Food supply in 2023

The presented results are calculated using the process and assumptions explained in the methodology (3.3.2).

A. Culture production

The results of the cultures' food supply of Chumbivilcas province are the following (table 8).

Table 8. The food supply of the cultures of the Chumbivilcas province

Categories of products	*Products*	*Supply surfaces [ha/year]*	*Harvested yield (mean) [T/ha]*	*Gross Food Supply [T/year]*	*Total GFS[7] (Per categories) [T/year]*
Tubers	Native potato	3,206.0	20.7	34,295.8	37,523.9
	Andes tubers	167.0	19.3	3,228.1	
Cereals	Maize amilaceo	257.5	5.0	1,287.5	14,410.2
	Maize choclo	176.4	8.8	1,552.3	
	Wheat	1 874.3	3.4	6,372.7	
	Oats	471.0	3.5	1,648.5	
	Tarwi	280.0	4.1	1,148.0	
	Quinoa	690.0	3.5	2,401.2	
	Rice	-	-	-	
Vegetables	All confounded	2,253.3	5.3	11,936.0	11,936.0
Fruits	All confounded	380.5	12.1	4,616.4	4,616.4

The native potato occupies most of the agricultural surfaces. Native potato is the main culture in the province of Chumbivilcas. Cereal has the most different product types and is the province's second most important production. The wheat is the most produced and the maize amilaceo is the least produced in the cereals category. Regarding total gross food supplies, tubers weigh more than other cultures' production. Over the last 10 years, the Andes cultures have returned as more sustainable and economically interesting options for the family farmers. For example, the Choclo maize doubled its surface over this period. Vegetables and fruits are third and fourth respectively. See annex 2 for examples of fruits and vegetables included in the calculation.

[7] The GFS is presented and not the NFS for two reasons: (1) experts assumed that are no losses between the productions and distribution and (2) the GFD considers the transformation ration while NFS does not.

B. Livestock productions

In 2023, the livestock productions of Chumbivilcas are composed of more than three million livestock units. It comprises 77% of guinea pigs, 8% of ovine, 7% of poultry, 4% of alpaca, 3% of cows, 1% of llama, and pork and caprine (figure 14). However once converted in the available food supply, the cows predominantly represent 54% of the livestock productions available for consumption and weigh almost 10 tons in meat. It is followed by the ovine (16% or 2.8 tons of beef meat), alpacas, and guinea pigs. The rest of the productions are minor and mostly dedicated to wool production for craftmanship.

In figure 14, the Guinea Pig represents 7% of the livestock's gross food supply. Exchanging with the Agrarian agency, they estimated the production of the Guinea pig to be 8% of the total production of livestock, which validates the estimation made for the guinea pig food supply calculation. As a reminder, this estimation was based on an interview for data with the representative of the district of Llusco, a leading area in the production of Guinea Pig.

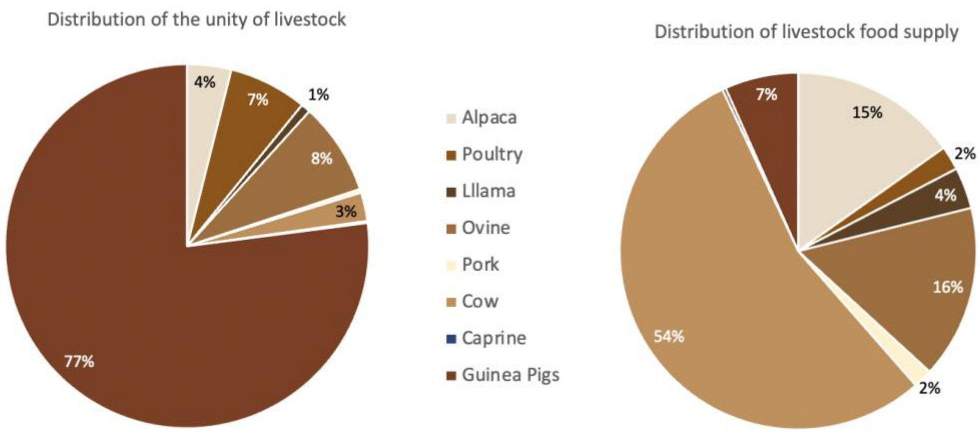


Figure 14. Repartition of livestock production in the province of Chumbivilcas

The egg production is estimated at 113 tons accounting for around 2 million eggs.

The production of milk is estimated at 110,781 tons. There are no numbers on the production of milk in powder and no companies or institutions could estimate the transformation of the milk into dairy products at the provincial scale, nor the regional.

C. Fish productions

Fish productions are only concerned with trout in Chumbivilcas. The production is estimated at 350 tons every year. The estimation was based on an interview with the project chief of the trout in Santo Tomas. Any further interpretation should consider the uncertainty o of this data. No transformation process is applied to the trout, they are sold fresh in the markets. Experts confirmed the absence of other fish production in Chumbivilcas.

4.1.2. Food demand in 2023

The 30 households surveyed account for 120 inhabitants of the province, 58 being women and 62 being men. The average household size is 4 persons, the average age is 33. The results of the consumption survey are shown in table 9. This table shows the difference between the consumption habits in rural and urban areas and the net and gross food demand in 2023. The repartition between men and women was not assessed since the survey occurred within families and the data were collected for the whole family and not per individual. Also, results are evaluated using qualitative information from the families.

Table 9. Results of food consumption survey in Chumbivilcas province

		Urban FD [kg.year^{-1}.pers^{-1}]	**Rural FD** [kg.year^{-1}.pers^{-1}]	**Diff FD** [kg.year^{-1}.pers^{-1}]	**Net FD** [T.year^{-1}]	**Gross FD** [T.year^{-1}]
Starch	Native potato	**162**	**222**	**-60**	**14,930.6**	**23,734.9**
	Andes tubers	2	5	-3	307.4	307.4
Maize	Maize amilaceo	17	28	-11	1,834.1	1,899.5
	Maize choclo	**21**	**41**	**-20**	**2,588.9**	**2,588.9**
Cereals	Rice	55	41	14	3,140.2	3,140.2
	Wheat	39	37	2	2,630.0	4,702.1
	Tarwi	6	14	-8	2,132.3	2,369.2
	Oat	18	16	2	1,192.9	1,192.9
	Quinoa	5	12	-7	774.3	774.3
	Bread	43	19	24	1,705.6	1,672.1
Vegetables	All confounded	**64**	**86**	**-21**	**5,789.2**	**5,789.2**
Fruits	All confounded	**91**	**101**	**-10**	**7,040.5**	**7,040.5**
Fish	Trout	17	7	9	666.4	952.1
	Other	0	0	0	15.5	22.1
Meat	Alpaca	12	7	5	573.8	573.8
	Llama	0	0	0	-	-
	Caprine	0	0	0	-	-
	Ovine	30	21	8	1,645.5	1,645.5
	Cow	0	0	0	23.2	23.2
	Pork	2	0	1	46.4	46.4
	Guinea pig	17	14	3	1,026.6	1,026.6
	Poultry	**40**	**12**	**28**	**1,262.8**	**1,262.8**
Leche	Powder	0	1	-1	81.1	81.1
	Cow milk	**47**	**80**	**-33**	**5,165.5**	**5,165.5**
Eggs	-	14	7	6	10,257.5	615.5

** FD = food demand [kg/year.pers], Diff FD= difference in food demand between urban and rural area [-], NFD=Net food demand [T/year], GFD= Gross food demand [T/year]*

Looking at the data, two surveys were excluded because they were outliers for more than 5 products and were therefore considered too extreme to represent the food demand. The data distribution is very heterogeneous and variable depending on each product. Thus, the chosen criterium for data observation was the rural-urban areas because the context revealed significant differences between them.

The comparison between rural and urban areas reveals specific food habits in both cases. The households in urban areas tend to have more rice, bread, guinea pigs, poultry, and eggs. The population from the rural areas eats more potatoes, maize, milk, vegetables, and quinoa, typical products of the region. More globally, the inhabitants of rural areas tend to eat less food than in rural areas.

In both areas, potatoes, maize, and rice are consumed daily. Vegetables are consumed daily but in tiny portions. Fruits are consumed weekly. Milk consumption is variable given the districts but is more consumed in districts where cow milk production is more important. Most households consume meat, fish, and eggs in minimal quantities and frequencies. Meat is consumed weekly or monthly, while eggs are consumed a few units a week. The less consumed foods are other types of fish and powder milk which were included in only 10% of the households. Llama and caprine are not consumed as meat.

At the national level, a consumption survey was conducted in 2019 in Cusco. The data reveals that more cereals and tubers are eaten in the province of Chumbivilcas, but the magnitude is similar. For example, rice consumption was estimated at 34,7 kg/year per capita in 2019, and the data collected in this study reveals an average consumption of 44,1 kg/year per capita. The same can be assessed for the bananas estimated at 16,9 kg/year in 2019 and the consumption survey of Chumbivilcas shows an average consumption of 17,9 kg/year. As for the meat, the example of pork reveals that the population was consuming on average 1,4 kg per year and this study estimates the consumption to be 0,7 kg per year. The order of magnitude is the same and experts explain the difference with the change in meat consumption following the COVID-19 crisis and the emergence of the Guinea Pigs in the food basket. No data for comparison exists for milk or eggs.

The consumption of potatoes is 3 times more important in the province in 2023 than in the region in 2019. The consumption of vegetables was 2 times lower in the province in 2019 than in the area in 2023. This difference comes from family farmers mainly feeding on what is produced in the regions and that is tubers. Vegetables are exported more for their economic value and are consumed less. They are also less part of the traditional and ancestral diet. Knowing this qualitative information, the differences are considered negligible for interpreting the results.

4.1.3. Food self-sufficiency in 2023

Table 10 synthesizes the information collected in the province in 2023 regarding the SSD of the cultures. As a reminder, the SSD considers the gross food demand and supply for two reasons. First, experts estimated that there are close to no losses between the production and the distribution of the food on the markets. Second, the gross food demand considers the transformation yields whereas the net food demand does not. The idea is to compare two similar data so for these reasons, the SSD is calculated with gross volumes.

Table 10. Food self-sufficiency degree for cultures

Culture	GFS	GFD	SSD
Potato	34,295	23,734	144 %
Other tubers	**3,228**	**307**	**1,050 %**
Maize amilaceo	1,288	1,899	68 %
Maize choclo	1,552	2,588	60 %
Wheat	6,373	4,702	136 %
Oat	1,649	1,193	137 %
Quinoa	2,401	774	310 %
Tarwi (dry grain)	1,148	2,369	49 %
Rice	-	3,140	ND
Vegetables	11,936	5,789	206 %
Fruits	4,616	7,040	66 %

** GFS=Gross food supply [T/year], GFD= Gross food demand [T/year], SSD=self-sufficiency degree [-, ND = no data]*

The province of Chumbivilcas is self-sufficient in native potatoes (144%), Andes tubers (1,050%), wheat (136%), oat (137%), and quinoa (310%). The high SSD of the tubers is because they are part of ancestral traditions in production. Many family farmers rely on them for the stability of their income. All varieties are adapted to the climate. The high SSD of the cereals is due to the introduction of these cultures during the colonization. They were cultivated in massive quantities during this period and stayed in the production systems afterwards.

The province is not self-sufficient in maize production. The SSD of the maize amilaceo is 68% and the maize choclo is 60%. The rice is not produced in Chumbivilcas and has an SSD of 0. The province of Chumbivilcas relies 100% on rice importation to meet local food demand.

The province is self-sufficient in vegetables and not self-sufficient in fruits. Originally, fruits and vegetables were not part of the culture. And, though the topography is not ideal, these productions have been increasing over the years with climate change and increased temperatures in the Andes mountains. The fruits particularly need water and warmer temperatures so the production of local fruits like Tuna, Pacay, etc explains the 66%. Discussing with the municipality officers, they confirmed these results but added that the avocado was produced mainly to be exported (about 80%) to other provinces or regions.

The province of Chumbivilcas being in high altitudes, the agricultural system is majorly composed of livestock. The results of the food demand reveal that the population does not consume llama, and caprine (table 11). According to experts, the first is used to produce wool, and the latter is used to produce milk. However, no data are available on the production of milk by caprine; it is not known to be part of the food basket locally. However, the degree of self-sufficiency in cow milk is very high at 369%. The province exports all this production to increase the producers' revenues as explained by the market president of Santo Tomas. Regarding the powder milk, no data exist on the production and the transformation process at the regional or local level, and it is impossible to estimate the SSD.

Table 11. Food self-sufficiency degree for livestock

Livestock	GFS	GFD	SSD
Alpaca	2,730	573	475 %
Poultry	393	1,262	31 %
Llama	674	-	ND
Ovine	2,827	1,645	171 %
Pork	311	23	1,342 %
Cow	**9,804**	**46**	**21,107 %**
Caprine	56	-	ND
Guinea pig	1,200	1,026	116 %
Egg	113	615	18 %
Trout	350	952	36 %
Other fish	-	22	0 %
Powder milk	-	81	0 %
Cow milk	19,099	5,165	369 %

** GFS=Gross food supply [T/year], GFD= Gross food demand [T/year], SSD=self-sufficiency degree [-, ND = no data]*

The highest level of self-sufficiency is for the cow, estimated at 21,107%. This is because most cows are used for milk production, not meat consumption. As mentioned in the methodology, no hypothesis on the proportions of cows dedicated to production or the transformation ratio for dairy products could be made. Being on the field, I also learned that the meat demand is high in the province of Arequipa, and most beef is exported there. The province is self-sufficient in all livestock that is produced in the province: alpaca, ovine, pork, and guinea pig.

The SSD of the trout is at 36%, showing that the offer does not satisfy the demand. This production has been recently introduced in artificial basins, official data is lacking in the area and therefore this result must be discussed cautiously. The production is prohibited in rivers, limiting the SSD (Proyecto truchas, personal communication, mars 2024).

The lowest levels of SSD are for poultry and eggs (table 9). Poultry and eggs are mainly imported from the coast and local conditions are not optimal for their production.

4.1.4. Drivers for change

4.1.4.1. General overview

The experts interviewed have cited 10 main drivers for change in the dynamics of local food systems (table 12). The drivers for change were either identified in the state of the art and experts were asked for their opinions or brought up by experts themselves.

Table 12. Drivers for change in the food systems of the province of Chumbivilcas

	Cooperative of Chumbivilcas	*Santo Tomas market (president)*	*Arariwa Chumbivilcas*	*Family farmers*	*Municipality of Santo Tomas*	*Municipality of Velille*	*Municipality of Llusco*	*Arariwa Cusco*	*IMA*	*RAAA*	*Agricultural minister*	*Counsel of Food Security (CORSA)*	*Political analysist*	*Univerisity teacher in agroecology*	*INIA*	**TOTAL**
Water availability			1	1	1		1	1	1	1	1	1		1		**10**
Agricultural practices	1		1	1		1	1		1	1			1	1		**9**
Use of technologies		1		1	1		1		1	1			1		1	**8**
Diversification			1		1		1	1		1			1	1		**7**
Self-sufficiency targets		1	1			1						1	1	1		**6**
Territory management	1			1					1		1			1		**5**
Financial resources					1			1		1			1		1	**5**
Water and soil contamination					1				1			1		1		**4**
Women organizations			1									1				**2**
Storage and conservation	1															**1**

**In brown = drivers for change identified in the state of the art, in black = drivers mentioned spontaneously by the experts*

Arariwa has been interviewed at the provincial and regional levels. The goal is to see the different points of view according to the scale of intervention. Within the same institution, the same drivers were mentioned except for very local aspects like women’s organizations and self-sufficiency targets acknowledged only by the local point of view. Therefore, it is understood that interviewing different scales was necessary to understand the broader issues.

The distribution of answers is heterogeneous. No pattern can be drawn from which type of actor (NGOs, governments, etc.) mentioned what kind of issue (dimension, scale, etc.).

4.1.4.2. The drivers for change

Water availability is the most mentioned driver. The ANA (National Authority of Water) has revealed that the main issue with water is the accentuated variability of rainfall. Rainfalls are currently strongly heterogeneous on the territory. Some areas are impacted while others are not at all. The second and third most mentioned drivers are agricultural practices (traditional, biological, etc.) and the use of technologies (transgenic seeds, mechanization, etc.).

The self-sufficiency degree targets have been mentioned as much as the diversification, and most actors revealed that both are linked. During interviews, it was specified to the experts that only the diversification at the scale of the territory was part of the driver's definition. The CORSA believes that food diversification is crucial to food diversity. CORSA also suggested that the agroecological scenario (explained as a scenario that would allow more food diversification) is more interesting for human health. The food would not contain as many chemical residues as the industrial scenario using chemical inputs. Diversification is also necessary to strengthen the SSD.

Experts have mentioned that the local agricultural objectives mainly focus on self-sufficiency in the province and that external food flows play a minor role in the economic activities and food baskets except for a few products. The products mentioned were cow products (beef meat and dairy products), guinea pigs, and vegetables. The ARPAC also revealed that Chumbivilcas is specifically dependent on importing fruits and processed products like oils.

Territory management is the sixth most mentioned challenge. In this thesis, the territory management is decomposed into three dimensions. First, it refers to the lack of infrastructures like roads for example, and more globally to the lack of plans for a global development of infrastructures in the province. Experts have mentioned that physical access is challenging for state intervention and scientific studies. Second, it refers to the topography issue that creates a difficulty to arrange the land for agricultural production, the parcels are very heterogeneous in the province because of the slopes. Third and finally, it refers to the absence of private property. In Chumbivilcas, experts explained that family farmers can claim a piece of land as theirs without government authorization and the same can be said for the mining businesses. Because there are no regulations, experts have attested that it is the source of social conflict between farmers and miners.

Financial resources are more politically and economically driven. It refers to the lack of budget allocated to the province to implement the strategies established by the regional and national governments. Experts are certain that corruption, added to an ineffective decentralization process, is responsible for low financial resources in the province and lack of budget for their projects. These low budgets are influencing the possibilities of projects to create more technological and practical infrastructures in the province such as water reservoirs.

Experts assumed that soil and water degradation is due to mining activities. According to experts, these activities are not regulated by norms or thresholds. The GHGs and residues they issue are not monitored. It is concerning for human and environmental heaths. The CORSA revealed that it might become one of the major sources of food insecurity, products and people could be contaminated by these forms of pollution.

The less-mentioned drivers are the women's organizations and storage. Women's organizations include both local and regional organizations. Women's organizations impact the social aspect of the FS. According to Arariwa, the producers are mainly women, and working with them on the decision-making process could have major influences on the implementation of new agricultural practices, yields, and the change in the use of agricultural surfaces. However, Arariwa stated that women are still left out of decision-making processes.

The cooperative of Chumbivilcas mentioned the potential of evolving in the transformation and storage processes to reduce the dependency on the rain season for food supply.

4.1.4.3. Political concerns of experts

Many experts have expressed concerns about the inefficiency of the governments and the absence of political will to transform FS into sustainable FS. Most experts mentioned that politicians are not acting on current issues which could lead to disastrous consequences. This aspect is not mentioned as a driver since it could not enter the simulation with any selected variables. This issue is purely political while this thesis focused on drivers that directly impacted food systems. But it is still crucial for FS's future.

4.1.4.4. Selection of the drivers for change for the model

Based on these observations, three drivers for change were selected (based on the criteria of 'most mentioned') for the establishment of future scenarios:

- The **availability of water** affects the yields of the cultures.
- The **use of technologies** improves the yields and the revenues of the local farmers and affects the use of agricultural surfaces for extensive and intensive practices.
- The **diversification** impacts the agricultural surface per culture.

Agricultural practices are excluded from the selected drivers since the scenarios themselves include the driver. As a reminder agricultural practice refers to organic farming, agroecology, industrial farming, etc. and these are the three scenarios elaborated.

As explained in the methodology, these drivers are translated into variables that enter the model. The variables influence parameters, and their impacts on each parameter are evaluated through three scenarios in the prospective approach. The variables and their assumed quantitative effects on the three scenarios can be consulted in annex 3.

4.2. Prospective approach

This section presents the prospective results for territorial food supplies, food demand, and the SSD associated with each scenario for the 2050 perspective. The scenarios considered are (1) a traditional scenario, (2) an agroecological transition scenario, and (3) an intensification scenario (section 3.3.3.1). The prospective results are based on the situation in 2023 and the tendencies over the five previous years. Finally, food diversity is evaluated in each scenario to assess how they can improve Chumbivilcas' nutrition situation.

4.2.1. Food supply

4.2.1.1. Cereals and tubers food supplies in 2050

The results for cereals and tubers supply are shown in table 13. Unlike the other products, they have been presented separately from the overall results because they vary according to the three drivers of change. Fruit and vegetables have not been modeled similarly, because the data was insufficient and could only be modeled as food groups (Uncertainty 1).

Globally, the total surfaces dedicated to agriculture are reducing by 1% every year with the loss of agricultural surfaces either deserted by family farmers or taken by the mining businesses. Nevertheless, the current trends show an increase in food supplies for these products even with this loss of agricultural surfaces. Therefore, all cereals and tubers production will still increase between 2023 and 2050 (table 7 and table 13).

The traditional scenario has the largest agricultural surfaces for tubers and cereals production, followed closely by the industrial scenario (difference of 0.5%) while the agroecological scenario has the smallest surfaces. Because of the diversification process and assumptions, the agroecological scenario will reduce the surfaces for cereals and tubers and substitute them with vegetable production. The difference between the two extremes is 4%.

Looking at the gross food supply, the agroecological scenario has the largest quantities of cereals and tubers while the industrial scenario has the least. Because agroecology practices deal better with water management, the yields are higher than other scenarios that will be impacted by the accentuated homogeneity of water availability. The use of technologies for more productivity will not palliate this issue. There is a 25% difference between the most and least productive. The difference is almost six times bigger than the surface difference.

With that information, the agroecological scenario has the optimum ratio of agricultural surfaces to quantity of production. The agroecological practices allow for a bigger quantity of production with less agricultural surfaces.

Table 13. Prospective gross food supply in tubers and cereals in Chumbivilcas in 2050

		Traditional		Agroecological		Industrial	
Native potato	HY	SO [ha]	GFS [T.an^{-1}]	SO [ha]	GFS [T.an^{-1}]	SO [ha]	GFS [T.an^{-1}]
HY traditional	14	21,578	312,665	8,472	122,759	15,387	222,957
HY agroecological	24	0	0	8,472	201,718	0	0
HY industrial	19	0	0	0	0	3,847	71,665
	2050 total	21,578	**312,665**	16,944	**324,477**	19,234	**294,621**
Andes tubercules							
HY traditional	14	2,296	31,074	1,832	24,784	733	9,914
HY agroecological	22	0	0	1,832	40,720	0	0
HY industrial	19	0	0	0	0	183	3,413
	2050 total	2,296	**31,074**	3,664	**65,504**	916	**13,326**
Maize choclo							
HY traditional	6	261	1,600	1,145	7,028	366	2,249
HY agroecological	10	0	0	1,145	11,546	0	0
HY industrial	8	0	0	0	0	92	723
	2050 total	261	**1,600**	2,290	**18,575**	458	**2,972**
Maize amilaceo							
HY traditional	4	7,055	24,693	4,579	16,028	5,495	19,234
HY agroecological	6	0	0	4,579	26,332	0	0
HY industrial	5	0	0	0	0	1,374	6,182
	2050 total	7,055	**24,693**	9,159	**42,360**	6,869	**25,416**
Wheat							
HY traditional	2	6,040	14,291	1,832	4,334	6,594	15,602
HY agroecological	4	0	0	1,832	7,120	0	0
HY industrial	3	0	0	0	0	1,649	5,015
	2050 total	6,040	**14,291**	3,664	**11,454**	8,243	**20,617**
Quinoa							
HY traditional	2	6,523	15,891	2,061	5,020	6,961	16,956
HY agroecological	4	0	0	2,061	8,247	0	0
HY industrial	3	0	0	0	0	1,740	5,450
	2050 total	6,523	**15,891**	4,122	**13,267**	8,701	**22,407**
Tarwi							
HY traditional	3	1,273	3,690	1,832	5,308	366	1,062
HY agroecological	5	0	0	1,832	8,721	0	0
HY industrial	4	0	0	0	0	92	341
	2050 total	1,273	**3,690**	3,664	**14,030**	458	**1,403**
	2050 total	45,027	**403,904**	43,505	**489,666**	44,879	**380,762**

** HY= Harvested yields [T.ha-1.an-1], SO = Surfaces offer [ha], GFS = Gross food supply [T.an-1], Traditional harvested yields, agroecological harvested yields and industrial harvested yields.*

To understand more specifically the impact of each driver on this result, here is an example with the native potato. The native potato is the most important production in the province in terms of surfaces and gross food supplies. It is also one of the most contrasted examples.

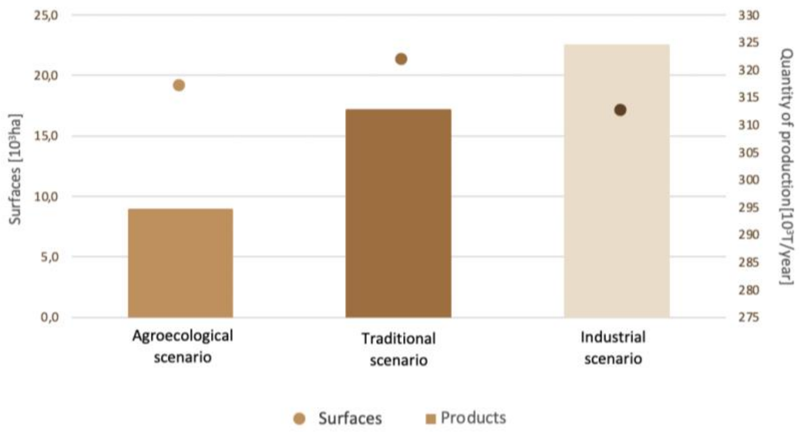


Figure 15. Estimated surfaces and quantity of production of native potatoes according to three scenarios in Chumbivilcas in 2050

Regarding the quantity of product, the ultimate 5-years trend have shown an increase in potato yields from 16.5 to 19.8 T/ha. This accounts for an increase of 17%. According to the family farmers, the increase is mostly due to the apparition of water reservoirs created by Arariwa and the introduction of technologies that are more improve productivity (e.g. tractors). However, seeing the long term, technological improvements are not as fast as the drastic consequences of climate change (specifically the consequences of accentuated homogeneity of water availability in the region) or degradation of the soil. Therefore, the yields will be impacted. Figure 15 allows us to acknowledge the difference in yields in the three scenarios by showing the agricultural surfaces and the quantity of products associated with these surfaces in the case of the native potato.

First, the surfaces dedicated to the potato are bigger for the traditional scenario, intermediate for the industrial scenario, and smaller for the agroecological scenario (figure 15). This is because of the diversification process. The industrial scenario emphasized the more valuable productions. Quinoa and wheat are worth more, financially than potatoes. The agroecological scenario reduces the surfaces even more because it tends to an equilibrium in agricultural surfaces and substitutes surfaces dedicated for potatoes for surfaces for Andes cultures or other food groups like vegetables.

The yields for the industrial scenarios are estimated to be 10% lower than the traditional yields in 2023 because water availability will be reduced, and no strategies will be put in place to manage it. The yields for the agroecological scenarios are 15% higher thanks to adequate practices for topography and water management. The yields of the traditional scenarios are constant for the impact of practices but will reduce by 30% due to water variability.

Therefore, there is a shift between the agricultural surfaces and the quantity of production. The agroecological scenario, though it has fewer surfaces, produces the biggest quantity of native potatoes. On the contrary, the industrial scenario, with the second largest surfaces dedicated for production, has the lowest quantity of production. So, the agroecological scenario is more interesting in the long run.

4.2.1.2. Global food supply for 2050

In 2050, the global food supply will be higher for wheat, quinoa, milk and eggs in the industrial scenario (Table 14). The gross food supplies for tarwi, Andes tubers, maize choclo, and maize amilaceo are higher in the agroecological scenario. The evolution of native potatoes, oat, fruits, and fish is similar in all three scenarios (Table 14). The rice remains absent in all scenarios.

The vegetable diversification as a food group is very contrasted between the scenarios. The vegetables are only increasing in quantity of production in the agroecological scenario, the vegetables are in less quantity in the traditional scenario and still reduced (but less) in the industrial scenario. Moreover, the INIA expert has revealed that they are working on new projects to implement more vegetable products in the province of Chumbivilcas. These projects mainly focus on the genetic transformations of seeds so they can adapt to the local climate and water variability.

Table 14. Global gross food supplies according to the three scenarios

	Ref. (R)	Traditional (B)		Agroecological (A)		Industrial (C)	
Offer	**GFS [T.an-1]**	**GFS [T.an-1]**	**B - R**	**GFS [T.an-1]**	**A - R**	**GFS [T.an-1]**	**C - R**
Native potato	34,296	312,665	**89%**	324,434	**89%**	294,621	**88%**
Andes tubers	3,228	31,074	**90%**	65,505	**95%**	13,101	**75%**
Maize amilaceo	1,288	24,693	**95%**	42,360	**97%**	25,416	**95%**
Maize choclo	1,552	1,600	**3%**	18,575	**92%**	2,972	**48%**
Wheat	6,373	14,291	**55%**	11,454	**44%**	20,617	**69%**
Oat	1,649	33,062	**99%**	43,690	**99%**	34,952	**99%**
Quinoa	2,401	15,891	**85%**	13,267	**82%**	22,407	**89%**
Tarwi	1,148	3,690	**48%**	14,030	**86%**	1,403	**-38%**
Rice	-	-	**ND**	-	**ND**	-	**ND**
Vegetables	11,936	5,928	**-101%**	19,021	**37%**	6,936	**-72%**
Fruits	4,616	7,055	**35%**	7,584	**39%**	6,914	**33%**
Meat	17,518	18,841	**7%**	18,841	**7%**	19,283	**9%**
Egg	113	585	**81%**	585	**81%**	643	**82%**
Milk	19,099	56,913	**66%**	56,913	**66%**	62,604	**69%**
Fish	350	455	**23%**	455	**23%**	455	**23%**

**GFS = Gross food supply [T.an-1], B-R/A-R/C-R=difference ratio between the GFS of the reference and the scenario considered (e.g. (B-R/R) *100)*

The overall expansion of cultures and intensification of livestock means that more surfaces will be covered by agricultural activities. It also means that family farmers will have more land to produce and harvest. Physically, the expansion is possible. The territory size of Chumbivilcas allows this expansion (if mining is not included). However, without the social immigration of farmers or technological help, the agricultural agency of Chumbivilcas expressed that it would be too much work for the farmers and that the global expansion could reach a threshold in terms of surfaces.

4.2.2. Food demand

Prospective demand is calculated based on diet and demographic trends. The population is projected to decrease by 22% between now and 2050. As demographic trends are considered constant in both scenarios, the gross volume demand of the scenarios varies only as a function of diet. This is compared in figure 16, with the current diet in brown and the recommended diet for more food security in beige. As a reminder, the current diet is taken from the consumption survey led in 2024, and the recommended diet from the CENAN in 2019.

The comparison reveals that the population is globally overeating. The population eats 3 times more tubers than recommended and almost 2 times more cereals. The population should reduce this intake to avoid food security issues and linked diseases. The intake of vegetables is half of what is recommended. In the future, the population should consume more vegetables and legumes to avoid anemia in minerals. Fruits, milk, and eggs are consumed in significantly close quantities compared to what the CENAN recommends and should therefore remain constant in the future. Finally, meat is also overconsumed by the population and should be reduced to a third of the current regime.

However, the CORSA attests to a resistance to change from the population to change their diets, and most households have confirmed that during the consumption survey.

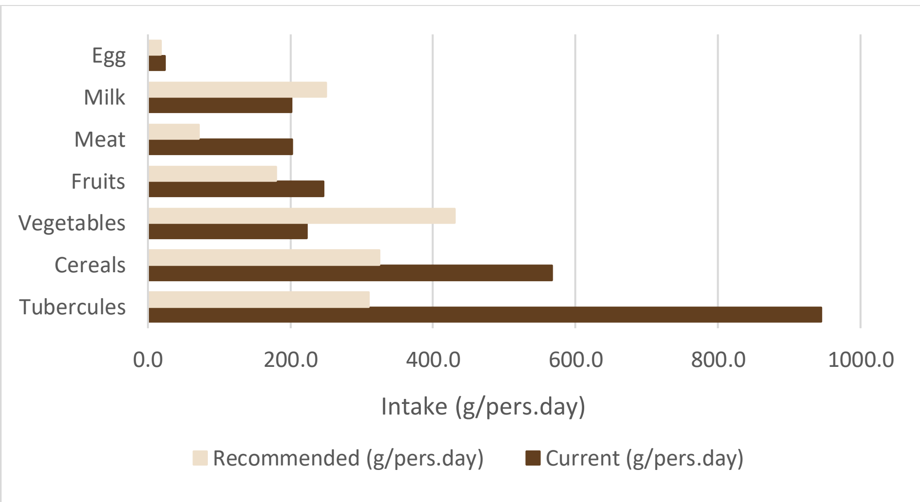


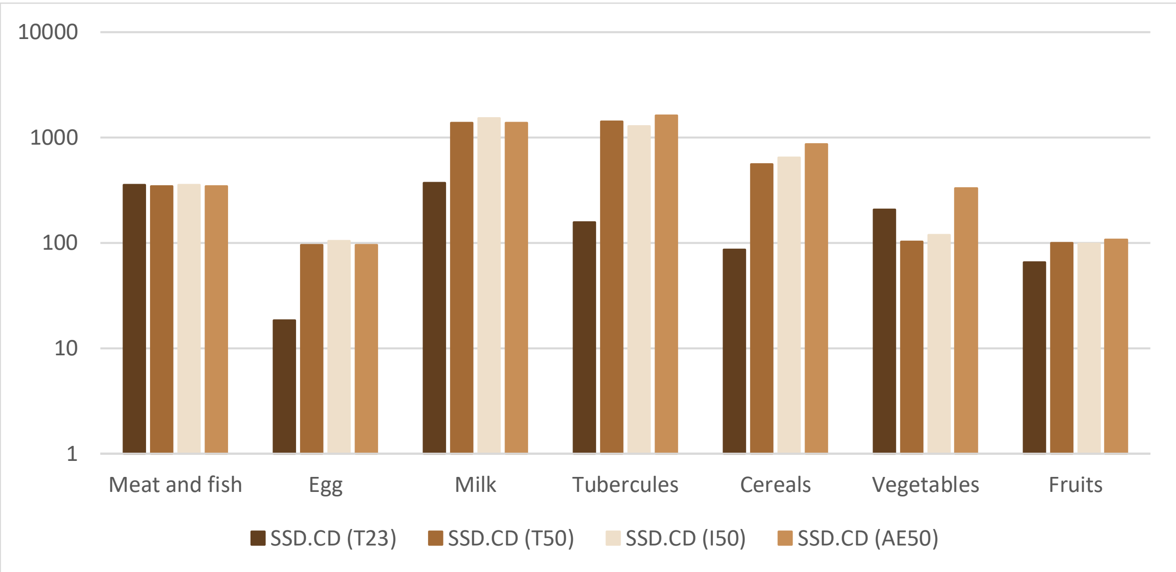
Figure 16. Comparison of the recommended intake of food categories and the current regime of the population of Chumbivilcas

4.2.3. Food self-sufficiency degree

The prospective SSD can be presented on a constant diet basis for the three scenarios, or on the assumption of a paradigm shift in diet. In the latter case, the change in production methods would be accompanied by a change in eating habits. Demand would then be determined by the CENAN-recommended diet (table 2). Both scenarios will be explored in this section.

4.2.3.1. The SSD under the current regime

The prospective SSD is represented in figure 17 for 7 food groups. The representations of the SSD are shown on a **logarithmic scale**. SDD only varies according to the gross food supplies in the three scenarios. The SSD is calculated with the current demand adapted to the prospective population of 2050. The data and the calculation of the SSD for each product (extracted from the model) can be consulted in annex 4.



** SSD = Self-sufficiency degree, CD = current dirt, T23 = traditional scenario in 2023, T50 = traditional scenario in 2050, I50= industrial scenario in 2050, AE50 =agroecological scenario in 2050*

Figure 17. SSD of the food groups according to the three scenarios in 2050 compared to the reference SSD in 2023

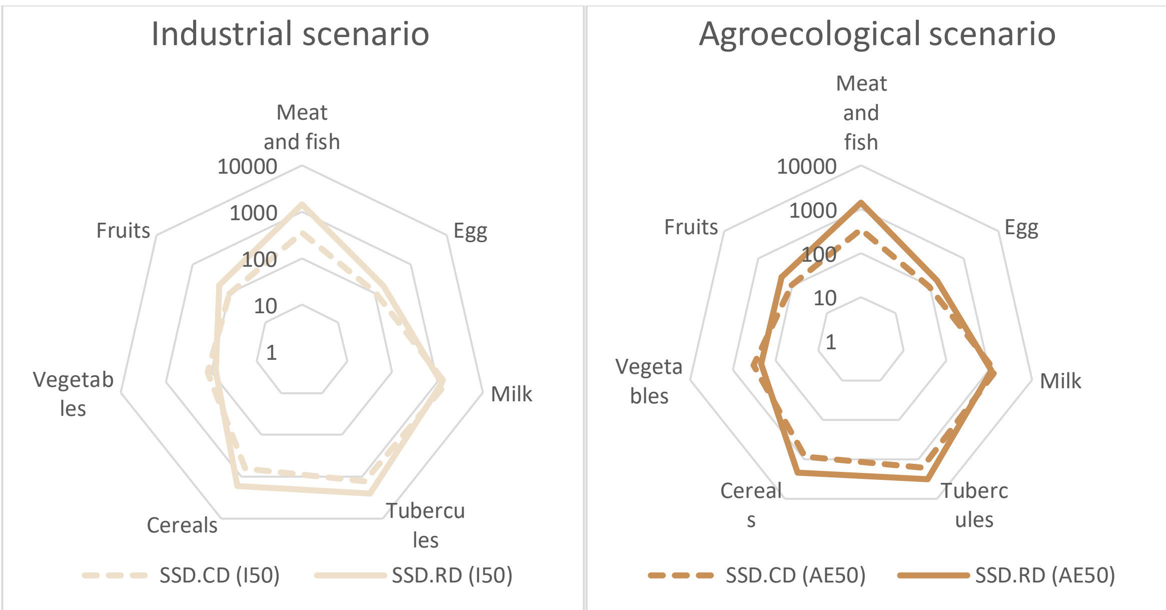
The SSD of the meat does not evolve. The production has been decreasing over the last 5 years and following this tendency, with a decrease of the population, it will not change the SSD. The production of eggs and milk (derived livestock products) is increasing. But eggs are not going to reach self-sufficiency. The milk production, still in augmentation nowadays, will remain at the same rate in the industrial scenario and lower by 10% in other scenarios but the population decrease makes the SSD higher in 2050 than in 2023. This decrease comes from the impact of the water availability on livestock production, especially cows which are the biggest consumer of water (section 3.3.3.2).

Following the gross food supply tendencies, the total surface dedicated to culture production increases in all scenarios. Therefore, the SSD is rising in almost all food groups except vegetables. The exception of vegetables lies in the fact they are dependent on water availability for their growth and are under the diversification process, therefore the SSD varies accordingly to the drive for change. It is not the case for the fruits because they do not vary with diversification and thus only the increase of the last 5 years has been considered. Fruits almost reach the self-sufficiency target in all scenarios, at 98% in the industrial scenario, 100% in the traditional one, and 108% in the agroecological one.

Regarding tubers and cereals, as analyzed in more detail in section 4.2.1, SSD increased in both cases. The tubers are slightly less increased in the industrial scenario because the diversification hypothesis supposes that it is not the focus (the revenues are not interesting enough). The industrial scenario also remains with a lower SSD in the cereals categories than the agroecological one. This is because the industrial scenario does not deal with water management issues and the yields are lowered even though more surfaces are dedicated to their production.

4.2.3.2. The SSD in case of a change in diet

A radical scenario involves changing eating habits simultaneously with changing production methods. Demand would then be based on the CENAN-recommended diet (figure 18).



** SSD = Self-sufficiency degree, CD = current diet, Rec = recommended diet, I50= industrial scenario in 2050, AE50 =agroecological scenario in 2050*

Figure 18. Comparison of the SSD calculated with the recommended intake of food categories and the current regime of the population of Chumbivilcas in 2050

In both scenarios, the SSD increases with the CENAN-recommended diets compared to the current diet. Looking back on figure 16, the population tends to overeat, so the gross food demand is higher.

Nonetheless, a few differences can be acknowledged. Comparing the industrial and agroecological scenarios, the vegetables reach a higher SSD in the agroecological scenario. The diversification process increases the SSD in the agroecological scenario while decreases in the industrial scenario. There is a difference of 63% in the vegetable SSD between the two scenarios. The tubers SSD with the CENAN recommended diet is 20% higher in the case of the agroecological scenario and 25% for the cereals compared to the current diet. Eggs, and fruits evolve similarly while meat and milk have an SSD of almost 5% higher in the industrial scenario than the agroecological scenario.

4.2.4. Evaluation of food diversity

Food diversity is evaluated, and the results are shown in table 15. The hypothesis made for calculation is based on the food habits of the population. The population's consumption is mostly based on tubers and cereals for cultural production. Therefore, they are still thought to be overconsumed.

Table 15. Evaluation of HDDS according to the three scenarios in 2050

HDDS (in 2050)	Traditional	Intensified	Agroecological
Tubers	0	0	0
Cereals	0	0	0
Vegetables	0	0	1
Fruits	1	1	1
Animal products	1	0	1
Dairy products	1	1	1
TOT	**3**	**2**	**4**

No scenario can achieve good dietary diversity. According to the CORSA, the way to avoid overconsumption is to drive a nutrition campaign in remote areas so that families can understand the health risks of overconsuming food categories. Therefore, without this campaign, it is close to impossible to reach more than 5 points or a good dietary diversity.

The agroecological scenario allows the HDDS to reach 4 points, meaning that the population could have a medium dietary diversity. The agroecological HDSS shows that the SSD evolutions of vegetables, fruits, dairy products, and animal products favor reaching more food diversity for the local population. The traditional and intensified scenarios have low dietary diversity. They both scored for the fruits and the dairy products. The traditional scenario also scores for animal products.

5. Discussion

The discussion is the part where opinion and knowledge converge with practical results. The discussion answers the study's questions and evaluates if the research has fulfilled the partners' expectations. It also sets the study's boundaries so that further researchers can dig into the loopholes and evaluate the pertinence of the potential perspectives. Finally, the discussion allows us to give a personal interpretation and critique of the results.

5.1. The territorial capacity of Chumbivilcas to feed its population

This section aims to answer the research questions. It aims to assess the capacity of the territory to feed its population and evaluate it in a descriptive and prospective dimension.

5.1.1. "What is the capacity of the Chumbivilcas province to feed its population?"

In the state of the art, two scales of food systems have been studied: the national and the provincial. These two levels of production condition the food supply and the food demand in the province of Chumbivilcas. The national scale influences the local scale through imports and exports between regions. The methodology assumed that external food flows were excluded because it is not part of the definition of food self-sufficiency (section 1.2.2). The interview results revealed that the production of Chumbivilcas is mainly dedicated to local consumption. Therefore, the exclusion of exportations and importations in the descriptive model was confirmed (section 4.1.4).

The descriptive dimension results have enabled the calculation of the food supply and demand in 2023. But the results remain theoretical. They give the maximum capacity to meet demand since what is produced is not necessarily available for local human consumption. For instance, this is the case with cow production (both for meat and milk). It is produced in high quantities, reaching an SSD of more than 21,000% but most of it is dedicated to the meat production for the population of Arequipa (section 4.1.1). Arequipa is the neighboring region closer to the Chumbivilcas province than Cusco's center province. Therefore, doing business with Arequipa is more interesting for the family farmers. It is also because beef meat is not part of the food habits in Chumbivilcas.

Moreover, the results show that vegetables, specifically avocados, are exported for economic reasons (section 4.1.1). This culture has emerged over the last few years thanks to climate change, which creates a better environment for its production. Both of these results (vegetables and cows) confirmed the emergence and importance of the exportation boom in Peru in every region (FAO & CIRAD, 2022).

Other cultures such as rice, poultry, eggs, and fruits are imported. Vera explained that these products are difficult to produce in the Andes region since the climate does not favor their growth and expansion (2006).

Moreover, the context has revealed a failing decentralization process in the country (Tirado-Kulieva et al., 2022). The political instability is strong, and the disparity between regions and provinces is marked. Experts have confirmed the government's inefficiency to decentralize the FS and have expressed their frustration about the lack of power over their own FS (section 4.1.4). Moreover, large-scale institutions do not intervene nor monitor agricultural activities or food flows in the province of Chumbivilcas. It makes it harder to act on the FS sustainability when no help is given. It is mostly because of the province’s isolation in the Andes mountains and the difficult physical access. Current FS are suffering from this issue: exportations are more difficult, food insecurity is increasing, and national policies are not applied.

5.1.2. "What are the main drivers influencing Chumbivilcas' ability to feed its population?”

This section discusses the challenges and opportunities known as drivers for change. Drivers for change were included in the model either quantitatively or qualitatively.

Water availability is one of the province’s biggest challenges for food production (Aiqui Kcala & Cuevas, 2024). This driver was the most mentioned by experts (table 12). It can either evolve towards more drought and disparities in water availability or management of the water through reservoirs and agricultural techniques (Abhilash et al., 2021). Currently, the ANA has confirmed that the water availability is very heterogeneous in the territory, some areas are more affected than others because of micro-climate within the province. As for the state responsibility, experts have revealed lacking financial aid to support family farmers facing this water crisis (section 4.1.4).

Talking with experts, they also revealed that they are given little room for maneuvering over their food systems (section 4.1.4). Besides the isolated province, the family farmers and inhabitants are relying on food self-sufficiency for their FS. Chumbivilcas receives few financial resources to implement national strategies or strategies given in the decentralization law (section 4.1.4). Beesley & Hawkins had already identified the problem: the corrupted system (2022). The financial resources are not coming into the province. Therefore, agricultural progress is slow and family farmers have little trust in political institutions to create change (Beesley & Hawkins, 2022). This is a strong issue in the current local FS.

The qualitative driver of territory management is divided into three aspects: physical infrastructures, land use, and the right to private property.

In the context, it was stated that the topography is the main barrier to optimal physical access to the cities and the communities (CEPLAN, 2023). Physical access infrastructures are conditioning food flows in the province and reducing the potential of exchanges between rural and urban areas, creating a disparity. This issue of physical access is strongly linked to financial resource issues. Depending on where the money is allocated, projects for public infrastructures could take place, or action plans for sustainable agricultural systems. Nevertheless, it depends on how the money is distributed within the decentralization process. Tirado-Kulieva and al. have attested that this process is currently inefficient and making the province FS more and more vulnerable (Tirado-Kulieva and al., 2022). Experts have expressed the fear that political institutions are a major obstacle to FS's sustainability (section 4.1.4).

Because of the topography, land use is a challenge. The agricultural surfaces are spread in small parcels in the territory. In the fieldwork, it was observed that municipalities do not have strategic plans for land use.

Additionally, no laws exist on private property in the province. Therefore, family farmers can claim a piece of land as their own without any authorization, making territory management harder. Consequently, family farmers (women) have been losing their territories for production and therefore their source of revenues because of the installation of the mining businesses (section 4.1.4). Moreover, the expansion of mining businesses on the territory could seriously reduce the available surface for agriculture. So, family farmers and miners are often in social conflict over territory and resources. Castro Segura and Cárdenas Farfán led a study in the region to examine the issue closely (2023). The study revealed that family farmers are losing their agricultural potential, and the extraction activities make the environment more polluted (Castro Segura & Cárdenas Farfán, 2023). The conditions to produce near these activities are hazardous for the health and are causing perturbations in local FS dynamics. Moreover, the expansion of mining businesses on the territory could seriously reduce the available surface for agriculture.

These forms of environmental contamination could have been evaluated in terms of yields and surfaces and the existence of policies to deal with the issue. However, this study did not aim to assess the environmental impact of mining on agriculture. Governments have not implemented policies for these informal and illegal mines, nor any ecological thresholds to limit these negative impacts (Castro Segura & Cárdenas Farfán, 2023). However mining does impact the environment and human health in the region. This driver is a concern and should not be disregarded in future studies on the province or region's food systems. This study offers a methodology for addressing this driver in the scenarios by suggesting a pool of potential variables to estimate its impact.

Other qualitative drivers were mentioned and seem essential for a sustainable change. This is the case for the women's movements (section 4.1.4). Arariwa mentioned that women are the center of the food systems they are the producers, processors, sellers, and cooks of the food products. Disproportionately, they are less implicated in decision-making (section 4.1.4). The GRDR has led a study for sustainable food systems and stated that sustainability can be maintained only if the concerned actors are implicated in transforming their FS (2016). Change needs to happen in a participative manner to be sustainable in time.

5.1.3. "How might this capacity evolve considering the selected drivers?"

This section discusses the potential impacts of drivers for change. It focuses on quantitative drivers included in the industrial and agroecological models and gives a cross-section of these.

In its prospective dimension, the study attempted to initiate a reflection on the trajectory that the agricultural model could take. Two contrasting models have been created: agroecology and agriculture based on intensification. Agroecology is promoted in the province by associations and NGOs that support women's organizations in their training in agroecological practices. The intensification is not currently observed but its practices are being promoted in national policies: the use of pesticides, tractors, and genetically transformed seeds. This demonstrates a clear difference between strategies implemented at the national level and those that local governments and communities want.

According to Arariwa, the agroecological transition has been happening for at least the last ten years (Aiqui Kcala, 2024). The transition could lead to the development of new lines of products: fruits, and vegetables. The emergence of these new lines would require putting in place water management techniques such as water reservoirs, agroforestry, and agriculture in terraces. However, water availability is a current concern that is not addressed by the governments as much as it should be (section 4.1.4). The FAO and CIRAD have witnessed political organizations focusing on the valuable production of vegetables, especially avocadoes, for exportation rather than the diversification or investment into alternative practices (2022).

Following the assumption of the methodology, the industrial shift, as opposed to the agroecological scenario, supports the productions that are valuable and already cultivated in the biggest proportions. In the industrial scenario, even if the harvested yields are higher than in the traditional scenario, the absence of water management will result in drastic consequences for the production in the province. According to Abhilash et al., lacking water for production could lead to lower yields and more poverty amongst the family farmers (2021).

Moreover, the industrial scenario is the only one considering a change in livestock production, specifically the Guinea pigs. Westmont believes that Guinea pigs have the potential to be highly profitable for the family farmers (2021). It is not only a fixed source of revenue but also a new form of sustainable tourism (Westmont, 2021).

In all scenarios, the province will remain dependent on certain importations: rice, poultry, and eggs. The mountains and the climatic conditions are not optimal for their development and Vera confirmed it in his study of country pastures (2006). Besides, the population is not planning on reducing the consumption of these products or changing their intakes (section 4.2.2). These products will remain not self-sufficient.

Regarding milk and cows, they are over-produced to meet the food demand of the population (table 10). It was acknowledged previously that most of the cows dedicated to meat were exported to Arequipa (section 4.1.1). Regarding the milk, the high SSD comes from the fact that Chumbivilcas is ancestrally a region for animal products (Aiqui Kcala, 2024). However, this study could not gather data on exact milk production, the transformation into cheese or yogurt, or its proportion to exportations. It is known that there are actual and current processes, but they were not modeled due to the high level of uncertainty. Both scenarios would benefit from a more complete understanding of how their productions could evolve for the sustainability of FS. The governments could benefit from an insight into how a slight change in these major productions could affect their economy and agricultural systems.

The prospective scenarios have revealed that the ratio of agricultural surface and product quantities is more optimal for the agroecological scenario than the industrial scenario (section 4.2.1). Proceeding with the traditional scenario is not conceivable looking at average yields that will decrease by 30%. However, knowing family farmers' resistance to change makes it unimaginable to consider a complete transition towards one model. The compromise would be to convert only a part of the traditional agricultural surfaces to agroecological and/or industrial practices such as 40/40/20 % respectively.

However, this trajectory is only possible if family farmers can maintain the current growth trends. For that, they need support from younger generations and technological support from governments for seeding and harvesting activities. These two last elements are currently lacking in the province and must be considered as essential for a successful transition towards a more balanced model.

Finally, surfaces are expanding for crops and livestock and thus, production quantities. Figure 13 shows a high level of self-sufficiency in all food groups and scenarios except vegetables. The FAO and CIRAD mentioned an exportation boom that has been happening over the last decade (2022). Combining these two pieces of information, Chumbivilcas will be playing an increasing part in this trade system at the national level with its productions' surpluses.

5.1.4. “What is the impact of prospective SSD of the scenarios on food diversity?”

An indicator, called HDDS, was used to evaluate the potential food diversity brought by the different scenarios. It was calculated based on changes in the SSD (section 3.3.3.5). The results revealed that the agroecological scenario is bringing the most food diversity. This is because this scenario assumes a balance in food production. The diversification is a key driver for more food security in the population’s diet (section 4.1.4).

Comparing the current diet with the recommended one, the population is generally overconsuming (figure 15). The overconsumption mostly concerns tubers, cereals, and meats. It translated into an overconsumption of hydrocarbons, starches, and proteins at the expense of minerals and vitamins. This disequilibrium in consumption is one reason for the food insecurity in Chumbivilcas. Regional and international institutions confirmed food security issues linked to anemia and lack of minerals and vitamins (CEPLAN, 2023; FAO, 2013).

However, the results have revealed a gap between the political statements and the field reality, they do not converge. The population tends to overconsume and is not undernourished (figure 15). Therefore, looking more closely at local food systems is necessary to understand food security challenges locally. The survey, even though it is not fully representative due to the sample size, was needed to assess the local situation of food consumption properly.

Interviewing the Regional Counsel for Food Security, the experts believe that promoting the consumption of alternative proteins and minerals locally and with a participatory approach is key to reducing food insecurity. Food consumption and food security should be part of the policies and strategies of the decentralization process to dismantle the overhanging logic of the national scale from the local reality. Implementing national strategies in a local context is not sustainable nor effective.

Moreover, food security was only analyzed in the food availability dimension (with food diversity). The physical and economic accesses were not evaluated; the methodology did not consider the collection of this data to deal with this matter because of the complexity of the indicators. However regional authorities have shown that these dimensions are a concern in the Chumbivilcas (CEPLAN, 2023). The results also demonstrated issues with territory management and physical access to the province (section 4.1.4). Therefore, governments should consider an investigation on the subject to be able to act on it. It is one of the limits of this study, but more details about the model and methodological constraint will be explained in the next section.

5.2. The limits of the study

This thesis has been facing a few challenges that led to the creation of constraints. Understanding these limits will help to better appreciate the drawn-out results and discussion.

The first and most concerning limit is the uncertainty of the data. Throughout the study, 6 uncertainties were identified at the base of the food production. It strongly impacts how the data can be interpreted or whether the data is correct. Chumbivilcas is a remote province in Peru that lacks state interventions and scientific research at the local level (Aiqui Kcala & Cuevas, 2024). Consequently, data on food production for fruits, most vegetables, and animal products only exist at the regional level. These results must be seen as estimations of proper magnitude but not exact. Nevertheless, when estimated data could be compared to existing reports or documents, the magnitude was close enough to consider the differences negligible. This study must be perceived as a pilot study to demonstrate the potential of quantitative data and scientific intervention in a more thought-through decision-making process.

Secondly, an undeniable limit of the model (and shared limit with Raïssa's thesis) is that the calculated SSD assumes that all exportations and importations are not part of the food demand and supply. Exportations and importations were excluded based on the definition of self-sufficiency and confirmed as negligible by experts. Experts insisted that the food productions of the province were dedicated to the food consumption of the inhabitants and that few products were part of these external food flows (section 4.1.4). The study also disregards the proportions of the food production dedicated to animal alimentation, energy creation, etc. due to lack of time to investigate these dimensions further. In this study, the SSD is an estimation of the maximal food supply capacity to answer to the local human food demand.

Thirdly, the discussion encourages questioning the importance of the qualitative drivers for change. These drivers for change are the ones that were mentioned in the interviews with the experts but not translated into variables in the model. They are the contamination of the water and the soil, the self-sufficiency targets, territory management, financial resources, women's movements, storage, and conservation (table 12). Without them, the study can be seen as incomplete and as discussed in section 5.1.2, they are as crucial for the sustainability of the FS as the one included in the model. However, looking at the accessible information and the agricultural focus of this study, they could have brought more uncertainties or confusion to this evaluation of the prospective SSD.

Finally, working with NGOs that have their own perspectives and agendas is challenging and requires mutual adaptation. Sometimes, the visions and the ideas are very different, resulting in improvement, adjustment, or abonnement of an idea.

In a nutshell, the study and the model have their limits. Further collaborations and studies to assess the abovementioned elements could help have a more exact overview of FS in Chumbivilcas. The study must be seen as a first approach to FS. It intends to advise the local and regional experts on food supply potential evolutions and changes in food demand.

5.3. Perspectives

This last part of the thesis offers new perspectives on the potential evolution of the food systems in Chumbivilcas. First, all the questions brought up in the section above reveal the importance of working with all actors to build more sustainable food systems. It is also important to consider all dimensions for a complete overview of the FS and their sustainability: political, social, economic, environmental, agricultural, and nutritional.

The importance of the experts interviewed was already acknowledged at the level of the study since they made it possible to verify, add, and assess the quantitative information produced by the model. With the quantitative results collected, this report provides a common knowledge base for a participatory process. For instance, Arariwa aims for territorial development in Cusco and could use it to frame its work with local authorities and farmers communities.

Moreover, one of the main issues underlined is the inefficiency of the decentralization process (section 4.1.4). At the same time, most districts are creating their projects independently from one another instead of having a global vision of the local territory. It is a paradox. However, the results are that their efforts overlap when financial resources are already limited.

Two points must be considered at the province scale for an optimal decentralization process. The first is the importance of a systemic approach, as it reduces the fragmentation of the governance of the food system. It would strengthen the link between the development and implementation of food policies at the national and provincial levels. Secondly, actors need to collaborate and discuss potential plans of action together. Discussion between different types of actors: state-dependent and independent is lacking. With more cooperation, their efforts would merge, resulting in better system management and increasing the impacts of strategies put in place. The GRDR has proved that collaboration is key for the sustainable development of local FS (2016).

For the food supply, the topography and climatic conditions limit the possibilities. The results have shown that agroecological research is promising for agricultural surfaces, harvested yields, water management, and food diversity. The industrial scenario is interesting for the harvested yields and meat production but limited in its impact on agricultural surfaces, water management, and food diversity. The territory authorities should favor a balanced conversion.

This way, water management is improved with agroecological practices, valuable cultures are more productive using technologies in the industrial parcels, the diversification happens to better the food security situations and family farmers (resistant to change) keep a part of their cultures with their traditional practices.

To implement the strategy, it would be useful to establish a set of FS monitoring indicators for each type of product or the food groups and the balance between each other's. That way, the substitution of products can be monitored and analyzed for the future. The multidimensional nature of the set of indicators is essential as it would allow a systemic approach to the sectors. This set of indicators must include food self-sufficiency and food security impacts. Other economic, social, political, and environmental indicators could be added. For example, the income of farmers and the environmental impact of their practices would be economic and environmental indicators respectively.

For the food demand, promoting adequate food consumption and sensibilization to the long-term impact of a bad diet is necessary. This work must be done in coordination with the women's organizations since they are the most responsible of the food chains in the province. Food consumption, overall, must be reduced except the consumption of vegetables which should be increased. This way, the intake of minerals would be enhanced in coordination with reducing hydrocarbon consumption. A change in the food diet will improve food security for the local population. However, without this part of promotion and instruction, the change will likely not happen since women are uninformed about nutrition and food utilization.

This exercise is a prospective analysis based on assumptions against current trends. If one scenario or a combination of scenarios was adopted, it would be interesting to look back on the previsions made 10 years from now to assess the exactitude of the information modeled. If the information is incorrect, verifying what deviated from the assumptions and for what reasons might be necessary. New drivers for change could emerge with climate change and social evolution.

All choices and associated results should be analyzed and exploited by Arariwa and Humundi, in coordination with the local government, and all those concerned with changing the trajectory of the province's FS. As a pilot study, this study offers an overview of the FS and their potential evolution regarding SSD. But remember that this study is one tool among many more and choosing other tools or methodologies could lead to breakthroughs for the FS of Chumbivilcas.

Conclusion

Chumbivilcas is a Peruvian province with many opportunities and challenges in its food system. Located in the mountains, the climate is more favorable for livestock production than the cultures but over the years family farmers have managed to include both in their agricultural systems. More recently, Chumbivilcas has been facing numerous challenges like the accentuation of the homogeneity of water availability, the emergence of mining activities, social conflict, and a global crisis that revealed the vulnerability of its system. Therefore, acting on it is urgent for the sustainability and food security of the local population. Arariwa is asking itself what issues to address first and what tools to use.

Food self-sufficiency stands out as a sustainable alternative to address social, environmental, and economic concerns. It has been proven to bring more resilience to FS when facing a crisis. Thus, this thesis aimed to assess the current and future capacity of Chumbivilcas province to meet the food demand of its inhabitants with its own domestic production. This objective was achieved by using an indicator, the degree of food self-sufficiency.

The results revealed a degree of self-sufficiency that was variable amongst products and food groups. The province is dependent on imports of rice, fruits, poultry, and eggs. Besides, tubers, cereals, and vegetables are facing a major climatic issue: accentuated homogeneity of water availability. Theoretically, they are produced sufficiently but more recently, the productions have been destroyed or impacted by drought, flooding, or variable rain seasons. The production is very dependent on the natural flow of water and the rain season, food harvests have become increasingly indecisive with time. With that comes poverty and food insecurity among the farmers and local communities.

Other emerging challenges await the FS of Chumbivilcas: the degree of crop diversification, the level of production intensification, the territory management, the decentralization process, the social conflict between farmers and miners, etc. Depending on the chosen model, these drivers for change can be translated into different parameters. However, the ultimate question relies on which direction the experts will choose for their FS. This thesis offers a prospective dimension to evaluate the advantages and disadvantages of choosing one of the scenarios. While the industrial scenario improves productivity in the short term, the agroecological scenario is more sustainable and profitable economically and environmentally in the long term.

This pilot study of FS in Chumbivilcas, with its prospective analysis of self-sufficiency, offers a tool to support experts and governments in their decision-making process. It aims to lead them towards more sustainability in the FS with choices based on a scientific and external perspective.

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Annexes

Annex 1 – FAO food security indicators

Table 3.7 FAO: food security indicators

A. Food availability
a. Average dietary energy supply adequacy
b. Average value of food production
c. Share of dietary energy supply derived from cereals, roots and tubers
d. Average protein supply
e. Average supply of protein of animal origin
B. Food accessibility
a. Rail lines density
b. Gross domestic product per capita (in purchasing power equivalent)
c. Prevalence of undernourishment, 3-year averages
d. Prevalence of undernourishment, yearly estimates
e. Prevalence of severe food insecurity in the total population, 3-year averages
f. Prevalence of severe food insecurity in the total population, yearly estimates
g. Prevalence of moderate or severe food insecurity in the total population, 3-year averages
h. Prevalence of moderate or severe food insecurity in the total population, yearly estimates
C. Food stability
a. Cereal import dependency ratio
b. Per cent of arable land equipped for irrigation
c. Value of food imports over total merchandise exports
d. Political stability and absence of violence/terrorism
e. Per capita food production variability
f. Per capita food supply variability
D. Utilization
a. People using at least basic drinking water services
b. People using safely managed drinking water services
c. People using at least basic sanitation services
d. People using safely managed sanitation services
e. Percentage of children under 5 years of age affected by wasting
f. Percentage of children under 5 years of age who are stunted
g. Percentage of children under 5 years of age who are overweight
h. Prevalence of obesity in the adult population (18 years and older)
i. Prevalence of anaemia among women of reproductive age (15–49 years)
j. Prevalence of exclusive breastfeeding among infants 0–5 months of age
k. Prevalence of low birthweight

Source: FAO (2019)

Annex 2 – Consumption survey

<table>
<tr><td colspan="2">District:
Household:</td><td>Day</td><td>Week</td><td>Month</td></tr>
<tr><td>Food type</td><td>Product (kg)</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td rowspan="3">Starch</td><td>Native potato</td><td></td><td></td><td></td></tr>
<tr><td>Chuño</td><td></td><td></td><td></td></tr>
<tr><td>Other tubers</td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">Maize</td><td>Maize amilaceo (raw)</td><td></td><td></td><td></td></tr>
<tr><td>Maize amilaceo (grain)</td><td></td><td></td><td></td></tr>
<tr><td>Maize choclo</td><td></td><td></td><td></td></tr>
<tr><td rowspan="8">Cereal</td><td>Rice</td><td></td><td></td><td></td></tr>
<tr><td>Wheat</td><td></td><td></td><td></td></tr>
<tr><td>Barley</td><td></td><td></td><td></td></tr>
<tr><td>Oat</td><td></td><td></td><td></td></tr>
<tr><td>Quinoa</td><td></td><td></td><td></td></tr>
<tr><td>Tarwi</td><td></td><td></td><td></td></tr>
<tr><td>Other cereals</td><td></td><td></td><td></td></tr>
<tr><td>Bread (unity)</td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">Vegetable</td><td>Carrot</td><td></td><td></td><td></td></tr>
<tr><td>Onion</td><td></td><td></td><td></td></tr>
<tr><td>Other</td><td></td><td></td><td></td></tr>
<tr><td rowspan="6">Fruit</td><td>Mango</td><td></td><td></td><td></td></tr>
<tr><td>Banana</td><td></td><td></td><td></td></tr>
<tr><td>Apple</td><td></td><td></td><td></td></tr>
<tr><td>Orange</td><td></td><td></td><td></td></tr>
<tr><td>Andes fruits</td><td></td><td></td><td></td></tr>
<tr><td>Other</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Fish</td><td>Trout</td><td></td><td></td><td></td></tr>
<tr><td>Other</td><td></td><td></td><td></td></tr>
<tr><td rowspan="8">Meat</td><td>Alpaca</td><td></td><td></td><td></td></tr>
<tr><td>Llama</td><td></td><td></td><td></td></tr>
<tr><td>Caprine</td><td></td><td></td><td></td></tr>
<tr><td>Ovine</td><td></td><td></td><td></td></tr>
<tr><td>Beef</td><td></td><td></td><td></td></tr>
<tr><td>Pork</td><td></td><td></td><td></td></tr>
<tr><td>Guinea pig</td><td></td><td></td><td></td></tr>
<tr><td>Poultry</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Milk</td><td>Powder</td><td></td><td></td><td></td></tr>
<tr><td>Cow milk (L)</td><td></td><td></td><td></td></tr>
<tr><td>Egg</td><td>Unity</td><td></td><td></td><td></td></tr>
</table>

Annex 3 – Impacts of the variables on the three scenarios

<table>
<tr><th>Variables</th><th>Impact</th><th>Impact quantification</th><th>Impacted production</th><th>2050 B</th><th>2050 A</th><th>2050 C</th></tr>
<tr><td rowspan="10">V1: Agricultural surfaces</td><td>V1 (Annual trend)</td><td>% Of annual losses</td><td>All</td><td>-1</td><td>-1</td><td>-1</td></tr>
<tr><td rowspan="9">V11 (Diversification)</td><td rowspan="9">Distribution between production surfaces (%)</td><td>Native potato</td><td>47</td><td>37</td><td>42</td></tr>
<tr><td>Tubers</td><td>5</td><td>8</td><td>2</td></tr>
<tr><td>Maize choclo</td><td>1</td><td>5</td><td>1</td></tr>
<tr><td>Maize amilaceo</td><td>15</td><td>20</td><td>15</td></tr>
<tr><td>Quinoa</td><td>14</td><td>9</td><td>19</td></tr>
<tr><td>Wheat</td><td>13</td><td>8</td><td>18</td></tr>
<tr><td>Tarwi</td><td>3</td><td>8</td><td>1</td></tr>
<tr><td>Vegetables</td><td>2</td><td>5</td><td>2</td></tr>
<tr><td>Tot.</td><td>100</td><td>100</td><td>100</td></tr>
<tr><td rowspan="2">V2: Livestock production</td><td rowspan="2">V2 (Intensification)</td><td rowspan="2">Ratio of the trend + ratio of intensification</td><td>Meat/egg</td><td>1</td><td>1</td><td>1,25</td></tr>
<tr><td>Milk</td><td>0.9</td><td>0.9</td><td>1</td></tr>
<tr><td rowspan="3">V3: Harvested yields</td><td>V31 (Technologies)</td><td rowspan="2">% Of gain/loss</td><td>All</td><td>0</td><td>-5</td><td>30</td></tr>
<tr><td>V32 (Water availability</td><td>All</td><td>-30</td><td>20</td><td>-40</td></tr>
<tr><td>V3 (Sum)</td><td>Ratio of evolution</td><td>All</td><td>1</td><td>1.15</td><td>0.9</td></tr>
</table>

Annex 4 – Quantitative results for the prospective SSD with the current diet (extracted from the model)

	TRADITIONAL 2023			TRADITIONAL 2050		
	GFS [T/year]	GFD [T/year]	SSD [%]	GFS [T/year]	GFD [T/year]	SSD [%]
Livestock						
Alpaca	2,730.9	573.8	476.0	2,885.0	452.5	637.5
Poultry	393.8	0.0	ND	381.5	0.0	ND
Llama	674.0	0.0	ND	573.8	0.0	ND
Ovine	2,827.9	1,645.5	171.9	2,701.5	1297.8	208.2
Pork	311.4	23.2	1,340.8	149.3	36.6	407.6
Cow/beef	9,804.2	46.4	21,107.2	11,213.3	18.3	61,207.9
Caprine	56.1	1,026.6	ND	13.6	0.0	ND
Guinea pig	1,800.0	1,262.8	142.5	923.4	809.7	114.0
Egg	113.4	615.5	18.4	584.5	614.5	94.9
Trout	350.0	952.1	36.7	455.0	525.6	86.6
Other fish	0.0	22.1	0.0	0.0	12.2	0.0
Milk (powder)	0.0	81.1	0.0	0.0	64.0	0.0
Cow milk	19,099.3	5,165.5	369.7	56,913.4	4074.2	1,396.9
Culture						
Native potato	34,295.8	23,734.9	144.5	312,665.2	11,776.2	2,655.1
Other tubers	3,228.1	307.4	1,050.0	31,073.6	466.4	6,662.1
Maize amilaceo	1,287.5	1,899.5	67.8	24,693.4	980.2	2,519.3
Maize choclo	1,552.3	2,588.9	60.0	1,599.9	2,476.8	64.6
Wheat	6,372.7	4,702.1	135.5	14,291.3	2,074.4	689.0
Oat	1,648.5	1,192.9	136.6	33,062.7	940.9	3,514.1
Quinoa	2,401.2	774.3	310.1	15,890.8	610.7	2,602.0
Tarwi	1,148.0	2,369.2	48.5	3,690.1	1,754.5	210.3
Arroz	-	17,549.1	ND	0.0	2,476.8	0.0
Vegetables (all)	11,936.0	5,789.2	206.2	5,928.4	3,642.5	162.8
Fruits (all)	4,616.4	7,040.5	65.6	7,055.0	967.5	729.2

	INDUSTRIAL 2050			AGROECOLOGICAL 2050		
	GFS [T/year]	GFD [T/year]	SSD [%]	GFS [T/year]	GFD [T/year]	SSD [%]
Livestock						
Alpaca	3,029.2	452.5	669.4	2,885.0	452.5	637.5
Poultry	419.7	0.0	ND	381.5	0.0	ND
Llama	602.5	0.0	ND	573.8	0.0	ND
Ovine	2,701.5	1297.8	208.2	2,701.5	1297.8	208.2
Pork	149.3	36.6	407.6	149.3	36.6	407.6
Cow/beef	11,213.3	18.3	61207.9	11,213.3	18.3	61,207.9
Caprine	13.6	0.0	ND	13.6	0.0	ND
Guinea pig	1,154.2	809.7	142.5	923.4	809.7	114.0
Egg	38.6	614.5	104.5	584.5	614.5	94.9
Trout	455.0	525.6	86.6	455.0	525.6	86.6
Other fish	0.0	12.2	0.0	0.0	12.2	0.0
Milk (powder)	0.0	64.0	0.0	0.0	64.0	0.0
Cow milk	62,604.8	4074.2	1525.4	56,913.4	4074.2	1,396.9
Culture						
Native potato	294,621.3	11,776.2	2,501.8	324,434.2	11,776.2	2,755.0
Other tubers	13,101.1	466.4	2,808.8	65,505.3	466.4	14,044.1
Maize amilaceo	25,415.9	980.2	2,593.0	42,359.9	980.2	4,321.7
Maize choclo	2,972.0	2,476.8	120.0	18,574.8	2,476.8	750.0
Wheat	20,617.4	2,074.4	993.9	11,454.1	2,074.4	552.2
Oat	34,952.0	940.9	3,714.9	43,690.0	940.9	4,643.6
Quinoa	22,406.7	610.7	3,668.9	13,267.1	610.7	2,172.4
Tarwi	1,403.0	1,754.5	80.0	14,029.6	1,754.5	799.6
Arroz	0.0	2,476.8	0.0	0.0	2,476.8	0.0
Vegetables (all)	6,936.0	3,642.5	190.4	19,020.9	3,642.5	522.2
Fruits (all)	6,913.9	967.5	714.6	7,584.1	967.5	783.9

Prospective analysis of the degree of food self-sufficiency in the province of Chumbivilcas, Peru

Presented by Justine Joris

RESUME

The question of the sustainability of food systems has been accentuated over the years with many global and local challenges emerging. At the global level, international crisis, climate change, and political inefficiency have led to strong levels of food insecurity. At the scale of Chumbivilcas, social conflict, topography, and inefficient decentralization process have led to a vulnerable food system. Food self-sufficiency is a powerful tool that brings more resilience and strengthens local actors' power (Al-Abdelmalek et al., 2023).

This thesis aims to analyze the capacity of Chumbivilcas province to feed its population with its own domestic productions. The question is answered at the descriptive and prospective scales. The descriptive approach presents the current situation, while the prospective approach provides potential trajectories for the territory's self-sufficiency by 2050. To this end, three prospective scenarios were constructed: traditional, agroecological, and industrial.

The results show contrasting levels of self-sufficiency. On the one hand, the products most subject to external dependence In Chumbivilcas are poultry, eggs, fruits, and rice. On the other hand, self-sufficiency is exceeded in beef meat, milk, cereals, and Andes cultures. Scenarios for the evolution of self-sufficiency showed that three drivers of change would mainly determine food supply: water availability, crop diversification, and intensification in production. In addition, future food demand will be influenced by a 22% decrease in population by 2050, and potentially by raising awareness of what a sustainable diet should be for human and environmental health. Based on these changes, prospective scenarios were explored to understand the extent to which each of them could bring more sustainability to local FS.

From a scientific and external point of view, this thesis aspires to be a tool for experts and governments in the decision-making process. It gives food for thought on which trajectory their FS could go according to different scenarios, challenges, and possibilities.

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