Quinua in Chile

Didier Bazile, Enrique A. Martinez, Francisco F. Fuentes, Eduardo Chia, Mina Namdar-Irani, Pablo Olguin, Constanza Saa, Max Thomet, Alejandra Vidal

CHAPTER: 5.4

Quinoa in Chile

*Corresponding author: Didier BAZILE didier.bazile@cirad.fr

Authors:

DIDIER BAZILE[a]; ENRIQUE A MARTÍNEZ[b].; FRANCISCO F FUENTES[c]; EDUARDO CHIA[d]; MINA NAMDAR-IRANI[e]; PABLO OLGUÍN[f]; CONSTANZA SAA[e]; MAX THOMET[g]; ALEJANDRA VIDAL B[f].

[a] UPR47, GREEN, CIRAD (Montpellier, Francia) y PUCV, Instituto de Geografía, Av. Brasil 2241, Valparaíso, Chile.
[b] Centro de Estudios Avanzados en Zonas Áridas, Av. Raúl Bitrán s/n, Casilla 599, La Serena, Chile.
[c] Universidad Arturo Prat, Facultad de Recursos Naturales Renovables, Av. Arturo Prat 2120, Iquique, Chile
[d] UMR Innovation, INRA (Montpellier, France).
[e] Qualitas AgroConsultores, Santiago, Chile.
[f] Pontificia Universidad Católica de Valparíaso PUCV, Instituto de Geografía, Av. Brasil 2241, Valparaíso, Chile.
[g] CET Sur, Calle Tres Poniente s/n. Labranza, Temuco, Chile.

Abstract

The biogeography of quinoa (*Chenopodium quinua* Willd.) provides a comprehensive view of a crop that is relatively minor in Chilean agriculture, despite growing in a large geographical area (18°–47°S). Quinoa's genetic diversity illustrates that it is a vital crop in the South American Andes region. It was domesticated in various geographical zones, which generated a wide variety of adaptative morphological and environmental features. Specific adaptations in each macrozone throughout the Andes have created five ecotypes, associated with subcentres of diversity. Two ecotypes are present in Chile – quinoa from the salt flats in the country's extreme north: Salare quinoa, and quinoa from sea-level areas in the central and south central regions: Coastal quinoa. Recently, these ecotypes have been associated with diverse production systems, depending on their biophysical, social and cultural features. Public policies and market relations also play a vital role in determining production system dynamics.

Key words: *Chenopodium quinua* Willd., Chile, biodiversity, geography, agro-ecosystems.

Introduction

In the current context of economic globalization, agriculture is vital to populations around the globe (Harvey, 2001, 2005). A variety of models based on use of natural resources, agriculture (FAO, 2006), social organization and cultural identity (Leff, 2005) may be applied to rural development and food production. Two production models are present in Chile today. One is export-driven and focuses on land concentration (particularly by increasing farm surface area), with resources and production chains highly dependent on external risk factors; the other is dominated by rural, family-run farms, and is limited to food production for local markets. These farms have adapted their practices to ecosystemic features that farmers have understood for generations. Both models have an important role in local development, and exist on a smaller scale in the case of quinoa crops. This chapter aims to use the specific case of quinoa in Chile to underscore the importance of (re)considering agricultural production system diversity in terms of biogeography, for the purpose of optimizing crop potential.

Quinoa was first domesticated over 7 000 years ago in southern Peru and northern Bolivia. It was adapted through a series of agro-ecosystems modelled by ancient civilizations, as it was transported from the north to southern Chile. This generated a high degree of genetic diversity, adapted to a broad ecological spectrum.

There have to date been no studies in Chile to substantiate the importance of traditional crops and farmers' varieties (landraces). Therefore, there is a lack of historical, anthropological, economic, geographical and/or strategic studies able to link quinoa's conservation to the country's development. If quinoa's diversity were considered a phytogenetic resource, the very perception of biodiversity could change from a biological and agricultural productivity standpoint. This in turn would lead to a change in agriculture's relationship with local ecosystems, giving impetus to a redefinition of agrobiodiversity, with globally recognized repercussions, such as agricultural system reproduction, the creation and maintenance of social ties and and the transmission of skills and patrimony from one generation to the next (Chevassus-au-Louis and Bazile, 2008; Kaine and Tozer, 2005). Building sustainability with a focus on agricultural biodiversity is linked to the territorial stakeholders' system. This constant gives meaning to the idea of biodiversity, described in geographical terms as a society's link with the diversity of living things, viewing it in terms of the "problems" (or benefits) it presents to that society. For Leff (2005), "Territory is the place where sustainability is rooted within ecological bases and cultural identities. It is the social space where social actors exercise their power to control environmental degradation and fulfill the peoples' needs, aspirations and desires that economic globalization is unable to satisfy."

At local level, the limitations and positive synergy of growth and agricultural development models are manifested in the spaces created (Zalabata, 2003). Environmental diversity translates to a variety of agrarian practices that do not easily fit into an agrarian systems analysis (Naredo, 1996). To identify sustainability through the ecological pressure or economic potential of crops, it is important to look towards the territory's structural diversity, reflected in the variety of soils, species, ecosystems, landscapes, and their uses and applications. These models describe mechanisms for organizing the territory in question. Additionally, this principle of representation or transcription must contribute to bridging the knowledge gap between rural and scientific cultures, so as to avoid confrontation and antagonism (Serrano, 2005) between traditional and innovative models (Hocde *et al.,* 2008).

The first section of this chapter focuses on the general history of quinoa in the Andes and in Chile, explaining its presence today in Chile's various agricultural contexts, from the far north to the valleys and mountains of the south. The second section presents the agricultural space and its various features: climate, soil and local varieties of quinoa. The third section addresses the characterization of quinoa producers in the Chile of today with respect to farming ecology (Parra, 2007; Rescia *et al.* 2002). The final part analyses the relevance of the features of the "quinoa territories" to explain the crop's high genetic diversity in Chile, and examines the importance of maintaining these features in terms of adaptation to different environments and markets, while offering specific products. In conclusion, despite its status as a minor crop, quinoa in Chile exhibits high ecological and production diversity, occupying a wide range of ecosystems. Quinoa presents new opportunities for agrarian development in Chile, given the potential social, ecological and economic interactions under sustainable development. Quinoa crop management should be planned in line with the dynamics of its broad biodiversity, with twofold vertical management over a wide geographical area extending from the Aymara to the Mapuche region, and horizontal, or local, management when territorial cohesion is required among local stakeholders: farmers and non-farmers; the public and private sector.

General history of quinoa in the Andes and Chile

In the Andean context, the information available indicates that quinoa was probably domesticated by ancient civilizations in different time periods and geographical zones, including the regions of Peru (5000 B.C.), Chile (3000 B.C.) and Bolivia (750 B.C.) (Kadereit *et al.,* 2003). Quinoa's presence in Chile today may be explained by cultural exchanges between ancient peoples, such as the Inca culture and other groups native to Chile, in various agro-ecological contexts from the Chilean Altiplano in the north (17°S) to the island of Chiloe and even further south (47°S, Puerto Rio Tranquilo). During the Spanish Conquest, quinoa was strongly discouraged as a crop, due to its important role in society and the fact that it was sacred to the indigenous peoples' religious beliefs (Ruas *et al.*, 1999).

As a result, quinoa was only retained as a crop in places devoid of agricultural modernization programmes, and it became the particular domain of rural and indigenous women. The current phenomenon of human migration from the rural regions of the Andes to urban centres exposes quinoa to the risk of genetic erosion. This process is consistent with a loss of genetic diversity (preserved *in situ* for thousands of years), caused by the disappearance of traditional farming practices.

Many historical documents describe quinoa as present in Chile, from the northern regions to the valleys and mountains of the south. The agricultural landscape was described early on by Pedro de Valdivia to King Carlos V during the sixteenth century: "… this land is fertile for livestock like Peru… abundant in the sustenance planted by the indigenous people for their subsistance, such as corn, potatoes, ***quinoa***, madi, chili, beans…"

Later, the French botanist, Claude Gay, travelled to Chile during the nineteenth century and described quinoa as "…a plant native to the Americas and grown for some time in Chile. The Spaniards found it everywhere, from Copiapo to the island of Chiloe, where the inhabitants grew it along with corn and potatoes…" (Molina, 1810).

Juan Ignacio Molina (1810) documented quinoa's production system, with particular reference to the southern variety known as "Dahue", which produced "ashen leaves and white seeds. The black seeds are used to make a pleasant drink that settles the stomach, and the white ones, which swell to look like little worms when cooked, are prepared as a delicious soup; they even eat the leaves, cooked like spinach. Nearly three months before planting, they bring their livestock to sleep there, changing places every three nights; when the field has been well-fertilized, they plant the seeds on top of the grass and on top of the manure."

Quinoa crops had nearly disappeared by the mid-twentieth century, according to Looser (1943). Nonetheless, rural peasants were persistent and continued to grow it in the Andean region in northernmost Chile on the border with Peru and Bolivia (Lanino, 1976), in the central region south of Santiago, at sea level in Concepcion, and in Araucanía, where the Mapuche people knew it as *quinhua* or *kinwa* (Junge, 1978).

Quinoa ecotypes present in Chile

Quinoa grown in Chile retains the same morphological patterns and colours found at other latitudes (Gandarillas 1979; Bhargava *et al.*, 2005; Fuentes and Bhargava, 2011). However, specific adaptations to certain geographical regions throughout the Andes have generated five ecotypes associated with subcentres of diversity (Figure 1).

These subcentres are: (1) the Inter-Andean valleys (Colombia, Ecuador, and Peru); (2) Altiplano (Peru and Bolivia); (3) Yunga (Bolivia); (4) Salare (Bolivia, Chile and Argentina); and (5) Coastal areas at sea level (Chile and Argentina).

Figure 1: Distribution of quinoa ecotypes in subcentres of diversity: A. Inter-Andean valleys, B. Altiplano, C. Yunga, D. Salare, and E. Coastal. Source: By Francisco Fuentes Carmona

Quinoa crop in Chile is based on two quinoa ecotypes: Salare and Coastal (lowlands). The Salare ecotype is found in the regions of Tarapacá and Antofagasta in Chile's far north. Traditionally, these genotypes are grown by indigenous communities in the Chilean Altiplano, in saline soil, with rainfall of 100–200 mm/year occurring between December and February (Fuentes *et al.*, 2012). Several quinoa landraces in the northern region are closely related to varieties of quinoa from the Bolivian salt flats, where there is no natural border between the two countries. There is, however, evidence that some materials have been introduced to Antofagasta from Andean areas of Peru, to which the Atacama Desert acts as a natural barrier. Despite this, in most materials studied hitherto, the dominant morphology corresponds to Salare quinoa (Fuentes *et al.,* 2009a).

In the central and southern regions of Chile (the administrative regions of O'Higgins and Los Lagos) the Coastal quinoa is cultivated. It is suited to cultivation at 0–800 m asl under rainfed conditions (Fuentes *et al.*, 2012). In contrast to the dry conditions of Salare quinoa in northern Chile, the rainy season in the centre and south is concentrated in the winter months, with precipitation fluctuating between 500 and 1 900 mm/year, depending on the geographical zone, which includes the Libertador Bernardo O'Higgins, Los Rios and Los Lagos regions.

There is a marked and well-known difference between these two quinoa ecotypes grown in Chile, in terms of adaptation to altitude, drought and salinity tolerances, and sensitivity to day length. From an agronomic point of view, the Coastal ecotypes may be adapted to high altitudes through natural migration processes between regions as well as by natural or artificial crosses performed by breeders (Fuentes *et al.*, 2009b). Local varieties may also be adapted for other uses, for example forage or raw consumption (Fuentes and Bhargava, 2011).

Current distribution of quinoa in Chile and its associated climates

Distribution of quinoa in Chile may be analysed and understood considering three macrozones of ancestral (or relict) production and associated with subgroups of genetic diversity and agricultural production systems (Fuentes *et al.*, 2009b, c, 2012) (Figure 2): the northern zone (administrative regions XV, I, II), the central zone (administrative regions VI, VII) and the southern zone (mainly in region IX, but also present in regions VIII, XIV, X, XI).

Figure 2: The three relict macrozones of quinoa production in Chile. Source: IMAS (ANR), 2009 (http://imas.agropolis.fr/ and http://www.quinua-chile.cl)

Northern macrozone

In northern Chile, the climate is influenced by the tropics, and quinoa growing is limited to higher altitudes (*puna*, as defined in terms of climate by Di Castri [1968]). Bioclimate differences are linked to summer rainfall typical of the region, which is influenced by low pressure from the eastern Andes (Lanino, 1976). Because of the high altitude, the temperature here is lower than in other tropical regions, and is heavily regulated by landscape microstructures. In Chile's northern region, quinoa is found exclusively in the Altiplano, in zones with an altitude between 3 000 and 4 500 m asl. The elevation of this high steppe climate (or "high marginal desert", according to the older classification – Köppen, 1931) has a direct influence on average temperatures, which are no higher than 5°C and vary significantly between day and night (Figure 3a). On average, there are 9–10 months per year with

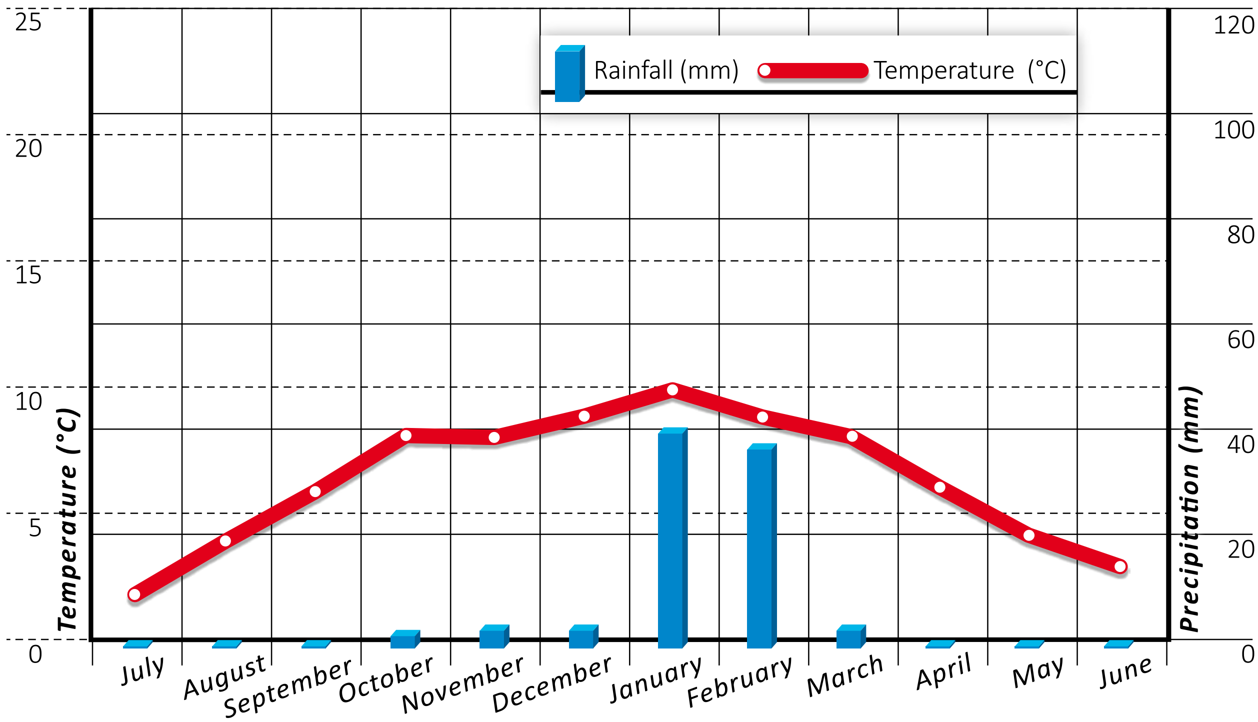

Figure 3a: General Climate Graph for Northern Macrozone using example of Ollagüe, *High Steppe Climate*

temperatures below 10°C, including four very cold months with an average annual temperature of only 4.5°C, an average high of 11.5°C and an average low of < 0°C.

Average annual rainfall is 120 mm. Most precipitation occurs during the summer and is convective in nature, stemming from clouds produced by rising air masses charged with moisture along the eastern hillsides of the Andes, originating from the Amazon Basin and the Atlantic. In some zones, rainfall may be greater than 400 mm/year, but these areas become progressively less common towards the south. Relative humidity tends to be low. Data collected by the weather station located in Vilacollo in the commune of Colchane (Tarapacá Region) for the 2005–06 season indicate maximum and minimum temperatures of 23.2° and -8°C, respectively, wind speeds of > 54 km/h, maximum solar radiation recorded of 1 218 W/m and annual rainfall of 147 mm (Arenas and Lanino, 2008; Delatorre *et al.*, 2008).

Central macrozone

Central Chile has a Mediterranean climate, with humidity progressively increasing from north to south (Di Castri, 1968). Quinoa production is concentrated in the so-called sub-humid Mediterranean climate region. Topographical orientation also influences the precipitation distribution, with higher rainfall in the western hillsides of the Andes mountain range and the coast than in the contiguous zones. In regions VI and VII there are two types of "warm temperate climate with prolonged dry season" – with or without heavy cloud cover. In addition, Köppen (1931) proposes "warm temperate climate with winter rainfall and heavy cloud cover" and "warm temperate climate with winter rainfall".

The climate with cloud cover is found in the coastal area of the northern part of this macrozone, including coastal plains and the western side of the Coastal Range. The ocean influences the climate, moderating temperatures and creating high humidity, which results in a higher number of cloudy days. Precipitation is frontal and concentrated in the winter, although the dry season may last 7–8 months, due to the influence of the Pacific anticyclone. Annual precipitation varies between 500 mm (region VI) in the north (Figure 3b) and almost 800 mm in the south (region VII). Approximately 80% of the annual rainfall occurs between the months of May and August.
The dry season lasts 7 months, with less than 40 mm

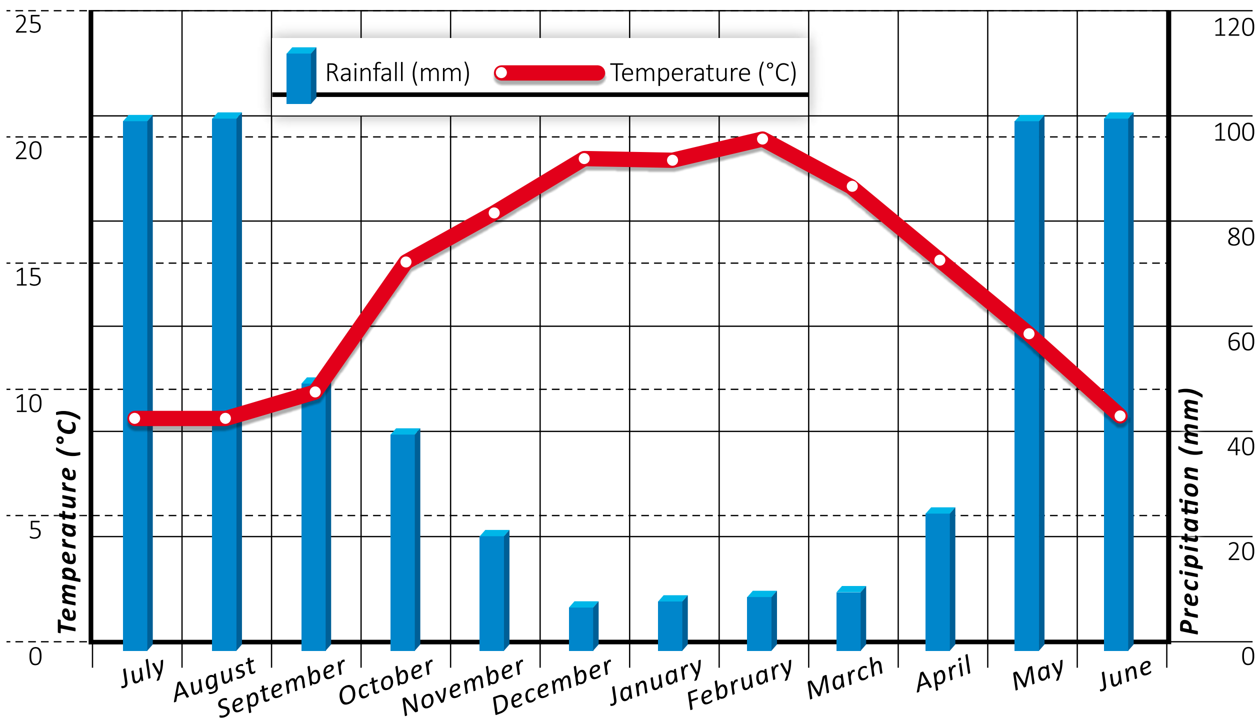

Figure 3b: General Climate Graph for Central Macrozone, using example of Paredones, Warm Temperate Sub-humid Mediterranean Climate with Prolonged Dry Season.

of precipitation occuring from October to April. Most quinoa crops from the central macrozone are cultivated near the coast, between the towns of Pichilemu and Iloca, in an area stretching 25 km inland, and influenced by the same climate (Olguin, 2011).
On the other hand, growing regions furthest from the coast, beyond the city of Santa Cruz and moving towards the mountains, have the same climate, but without the cloud cover. The regions located in the intermediate pressure zone or in the longitudinal valley of this region present Mediterranean climate conditions – hot, dry summers, and cool, damp, rainy winters. Rainfall is somewhat lower than on the coast, but average daily and annual temperatures are higher. The temperature difference between the warmest and coldest months is about 13°C in Rancagua, and only 8°C along the coast. From October to April, rainfall is less than 40 mm. The Chilean Coastal Range limits the maritime influence, and consequently there are more cloudy days than on the coast (Olguin, 2011).

General climate data for the central macrozone are as follows: average annual temperature 14.5°C, average maximum temperature 21.5°C, average minimum temperature 7.5°C; relative humidity 73%; rainfall 700 mm.

Southern macrozone

The southern quinoa production macrozone presents two types of climate. First, “warm and rainy temperate climate with Mediterranean influence”, is found from primarily the intermediate zone (38°S) to near Castro, on the Greater Island of Chiloe (region X, Los Lagos) (42°S). Average rainfall can reach 2 000 mm, with the monthly distribution highest in winter and decreasing in summer (Di Castri, 1968). Temperatures are characteristically moderate along the coast, rising in the mountainous area. Second, “warm temperate climate without a dry season”, is characteristic of the southernmost region. Rainfall is nearly continuous throughout the year, with an annual average of > 2 000 mm and significant monthly distribution from March to November. Temperature variation between night and day is moderate (≤ 5°C), with a recorded annual average of almost 12°C.

The temperate rainy climate with Mediterranean influence is present in the macrozone; it is influenced

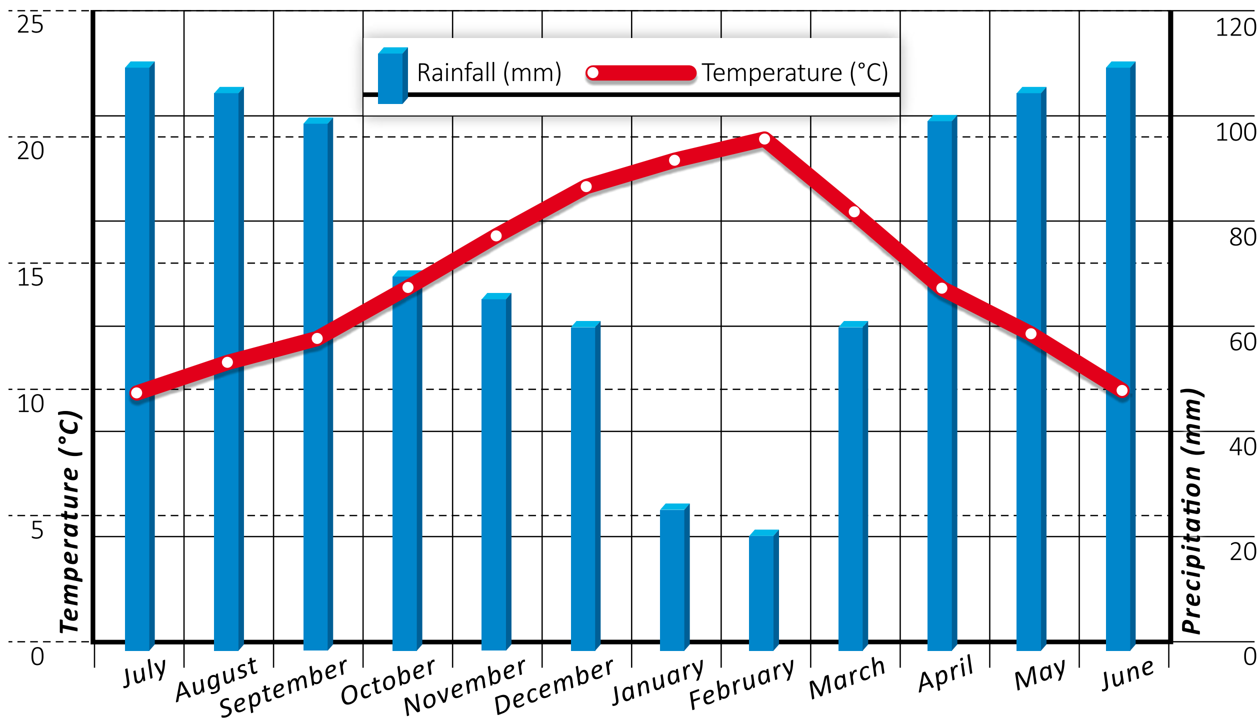

Figure 3c: General Climate Graph for Southern Macrozone, using example of Lebu (Coast), Rainy Temperate Climate with Mediterranean Influence.

by the ocean and there is moderate temperature variation in coastal zones (Figure 3c). In the longitudinal valleys and foothill regions, annual temperature variation is significant due to the distance from the coast, with stronger continental features. The average temperatrure is 11.5°C in the centre (12.5°C on the coast and 8.5°C in the foothills), with an average high of 17°C (16.5° and 16.5°C) and an average low of 6°C (9.2° and 1.0°C). Relative humidity varies between 75% and 85% in the foothills. Rainfall is distributed thoughtout the year, with a slight drop in monthly precipitation during the summer; annual rainfall is > 1 000 mm.

A warm temperate climate with a short dry season of < 4 months is found in the region's intermediate zone, located in the north and extending to around 39°. Moving southwards, temperatures progressively decrease. Precipitation is high and uniform throughout the year, with a slight decrease in the spring. Absolute precipitation values reach 2 050 mm and rainfall is never below 140 mm. The average annual temperature is 8.5°C, with a variation of 5°C. The coldest month (July) has an average temperature of 6°C and a maximum temperature of 12°C.

The state of quinoa production in Chile based on census analysis.

Evolution, 1997–2007

Over the last 15 years, quinoa crops have experienced immense growth in Chile's three macrozones. According to official data from the 1997 and 2007 agricultural censuses, the national cultivation area grew by 736%, from 175 ha in 1997 to 1 470 ha in 2007 (INE, 1997, 2007). Most of this increase occurred in the Region of Tarapacá, where over 92% of cultivation land is located. More specifically, the communes of Colchane and Pica have been at the centre of this increase: 749 ha in 2007 (compared to 163 ha in 1997), and 600 ha in 2007 (no planting was recorded in 1997). To a lesser degree, there was an increase in region VI during the same period: from 11 to 60 ha. Additionally, albeit with very small growing areas, regions such as Atacama, Coquimbo (north central zone), and Araucanía (southern zone) now appear in the census (Table 1 and Figure 4).
Furthermore, the number of quinoa producers doubled during the same period: from 119 in 1997 to

246 in 2007 (Table 1). This increase is proportionally smaller than the increase in area, and is due to the larger average farm size. In 1997 farms averaged 1.5 ha, compared with 6.0 ha in 2007, with a maximum of 46.2 ha per farm in the commune of Pica (northern zone).

In the methodology for data collection adopted, Chilean national agricultural statistics only refer to surface areas and farmers for whom quinoa is a major crop (farmers usually only declare areas of > 1 ha). It should, therefore, be mentioned that quinoa is traditionally grown in the central and southern zones of Chile, particularly Araucanía, by small producers (central) and small-scale Mapuche farmers (southern).

Given the small size of these holdings, they are not recorded in national statistics. Nonetheless, small-scale agriculture plays a vital role in the rural areas of these zones, motivating many farmers to preserve cultural features and implement seed exchange (Fuentes *et al.*, 2012).

Characterization of quinoa producers in Chile today.

A total of 868.5 tonnes of quinoa are produced at national level, 91% of which comes from the communes of Pica (59%) and Colchane (32%). The average national yield is 0.6 tonnes/ha. Although the highest yield is found in the regions of Araucanía (IX) and Libertador B. O'Higgins (VI), these averages are not representative, as they involve very small surface areas (recorded in the census). The highest yields are found in the region of Libertador B. O'Higgins, with an average of 1.2 tonnes/ha in the commune of Pichilemu; the lowest yields in Chile are found in the commune of Colchane, with an average recorded yield of 0.370 tonnes/ha (0.6 tonnes/ha at regional level) (Table 1) (INE, 1997, 2007).

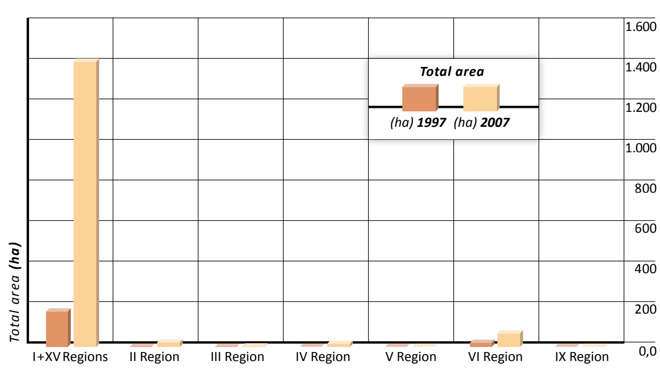

Figure 4: Evolution of total quinoa surface area (ha), 1997–2007.
Source: supplied by Qualitas AgroConsultores, based on *INE, 1997, VI Censo Nacional Agropecuario and INE, 2007, VII Censo Nacional agropecuario y forestal (National agriculture and forest Census, (Tn)*.

When analysing the economic size of farms where quinoa is grown, we note their small size,[1] indication that in Chile, quinoa tends to be grown on family farms, with individual producers operating on a small scale.

In conclusion, the environments in Chile are in contrast to the extremes conditions found in other quinoa-producing countries in the Andean region. Thus, high altitude (3 500–4 000 m asl), arid conditions (100–300 mm per year), salinity and frequent frosts are characteristic only of the northern macrozone of the Chilean Altiplano. Quinoa growers in that region tend to be elderly, as young people abandon agriculture in search of new work and educational opportunities (Fuentes *et al.*, 2012). In the central macrozone (coastal areas and intermediate zones between San Fernando, Curico and Linares), quinoa is not unknown and may provide new economic opportunities for some producers. In the southern macrozone (region of Temuco), quinoa is found in 85% of small gardens grown by women.

Quinoa as part of agricultural systems

The methodology applied in the INE agricultural census did not reveal the true diversity of quinoa production systems throughout the Chilean territory.

These contexts are geographically diverse and generate a wide range of agricultural practices, while traditional selection processes lead to the emergence of landraces (genetically heterogeneous but agronomically stable populations), which explains the low variability (high stability) in annual yields. Field studies were performed over 4 years

[1] Qualitas AC has developed a model for estimating the gross production value for each registered holding, which has been used to categorize and classify holdings according to this variable. For more information, see INDAP, Qualitas AC, 2009, *Estudio de Caracterización de la pequeña agricultura a partir del VII Censo Nacional Agropecuarios y Forestal*.

Table 1: Evolution of quinoa producers, growing area, production and yield by commune and region, 1997–2007

Region	Commune	Number of Producers		Total Area (ha)		Production and Yield by Region 2007	
		1997	2007	1997	2007	PROD (t)	YIELD $(t{\cdot}ha^{-1})$
XV Arica and Parinacota and I Tarapacá	Camiña	2.0	3.0	0.5	7.5		
	Colchane	101.0	153.0	162.7	749.0		
	Pica	-	13.0	-	600.0		
	Pozo Almonte	1.0	1.0	-	13.0		
	Huara	-	1.0	-	18.0		
	Putre	1.0	8.0	0.2	4.0		
	Regional total	105.0	179.0	163.4	1 391.5	800.8	0.6
II Antofagasta	Calama	1.0	2.0	0.1	1.0		
	Ollagüe	1.0	5.0	0.3	1.0		
	San Pedro de Atacama	3.0	13.0	0.7	7.0		
	María Elena	-	1.0	-	1.0		
	Regional total	5.0	21.0	1.1	10.0	6.9	0.9
III Atacama	Alto del Carmen	-	1.0	-	1.0		
	Regional total	-	1.0	-	1.0		
IV Coquimbo	La Serena	-	1.0	-	0.5		
	Paiguano	-	1.0	-	0.5		
	Ovalle	-	1.0	-	0.5		
	Monte Patría	-	1.0	-	1.0		
	Río Hurtado	-	1.0	-	0.5		
	Coquimbo	-	3.0	-	1.0		
	Regional total	-	8.0	-	4.0	12	1.2
V Valparaíso	Quilpue	-	1.0	-	0.1		
	Regional total	-	1.0	-	0.1		
VI O'Higgins	Pichilemu	8.0	15.0	10.6	34.0		
	San Vicente	-	1.0	-	0.5		
	Navidad	-	1.0	-	0.1		
	Chépica	-	1.0	-	2.0		
	San Fernando	1.0		0.5	-		
	Paredones	-	11.0	-	24.0		
	Regional total	9.0	29.0	11.1	60.6	58	1
IX Araucanía	Lautaro	-	2.0	-	1.0		
	Teodoro Schmidt	-	1.0	-	0.5		
	Curacautín	-	1.0	-	0.5		
	Vilcún	-	3.0	-	1.0		
	Regional Total	-	7.0	-	3.0	1.6	1.6
National total		119.0	246.0	175.6	1 470.2	868.5	0.61

Source: *Qualitas AgroConsultores*, from INE, 1997 and 2007.

(2008–2011[2]) in order to understand the reality of the rural context and traditional crop management (described below).

Farmers in each macrozone were interviewed, with the aim of understanding how important quinoa crops are in their holdings and how they manage their landraces. The sample analysed is representative of quinoa's importance in the three macrozones: 31 farmers in the northern macrozone (regions I and II), 26 in the central macrozone (region VI) and 34 in the southern macrozone (region IX). The data (quantitative and qualitative) were handled statistically, so as to describe quinoa producers and create decision trees by macrozone, underscoring the most relevant points of quinoa landrace dynamics.

Quinoa in the northern macrozone: managing diversity through tatas *(men over 60 years of age)*

Quinoa producers in northern Chile are mostly found in the commune of Colchane and in the town of Cancosa in the commune of Pica, and a minority are found in the town of Socaire in the commune of San Pedro de Atacama. The commune of Colchane has the largest area in the northern macrozone, and is home to 75% of the farmers in our study. Colchane is located at 3 800 m asl in the Chilean Altiplano, and is one of the eight rural communes in the first region of Tarapacá, located 262 km from the coastal city of Iquique, Tarapacá's regional capital. A total of 99% of its inhabitants (1 649) are indigenous (Aymara/Quechua), and they are organized into communities of neighbours (*ayllus*), which explains quinoa's traditional presence as a main crop, with potatoes in second place (INE, 2002). Since ancient times, the agricultural system in this zone has involved these two products and camelid livestock (llamas and alpacas) (Arar, 2009). Farming work is performed as part of community labour (*ayne*). Part of the traditional food strategy involves exchanging products with communities from other agro-ecological zones, such as vegetables in the foothills (Vidal, 2012).

Traditional methods are still used in quinoa cultivation, which is characterized by: an absence of chemical fertilization or pest and disease control (though this is not absolute, and products aimed at increasing production are beginning to appear); a low level of mechanization throughout the production process; and no cultivar selection.

Though quinoa is the region's most important agricultural product, the largest average farm measures only 3.6 ha in Colchane, 1 ha in Cancosa, and < 0.25 ha in Socaire. Traditionally, growing quinoa begins with soil preparation (November, December and January during fallow crop rotation, lasting until August or September). Seeds are planted in August/September (especially September, when moisture accumulation in the soil is generally more suited and frosts are less frequent). Crops are harvested earlier in Socaire (Jan-Mar.) compared with zones such as Colchane, where most activity occurs in April-May. Traditionally, seeds are planted manually and deep in the soil (sometimes up to 30 cm), to take advantage of the soil's moisture until seasonal rainfall can sustain the plants' growth (Lanino, 1976).

Soil recovers its fertility through crop rotation and the complementary raising of llamas. Llamas eat vegetable residue from the plant and provide organic fertilizer during fallow years (Arar, 2009). One of the most common practices is planting several types of quinoa, on the basis of the land parcels' relative exposure to the cold and frost (preferably red or pink varieties). These types of quinoa are recognizable by the colour of their seeds, and there is a secondary classification based on plant and inflorescence size. The most common types are: red (*lirio* in Aymara), pink (*canche*), white (*janku*), yellow (*churi*), brown (*chullpe*), dark red (*pandela*) and orange (*pera*).

All the subjects interviewed stated that they regularly consume quinoa as part of their diet, prepared in various ways. Quinoa plays an important role in the traditional cuisine of the Chilean Altiplano, as illustrated by its many culinary uses. Each type of quinoa has features that make it ideal for a specific dish: some varieties are better for stews or soups, others for grains, bread or toasted flour (*pito*), and some for desserts.

In 2008, each producer grew an average of 2.4 varieties of quinoa, out of the nine varieties found at the commune level. This means that most rural producers may plant varieties with the best features for their production, consumption or sales goals.

[2] Proyecto IMAS, ANR-Francia.
http://imas.agropolis.fr/ y http://www.quinua-chile.cl

Of the farmers interviewed, 70% grew more than one type of quinoa – further evidence that quinoa is a potentially important tool for limiting environmental risk. Nearly all farmers who grew only one type of quinoa planted white quinoa, for its colour and culinary features. For those farmers who grew two or more types, white quinoa was always one of the varieties grown.

The interview results made it possible to study quinoa's agricultural biodiversity in the Chilean Altiplano in greater depth (Table 2). It was possible to identify producers growing more than three varieties, and of these, 17% grew four or more varieties. These producers are considered a resource – because of theirknowledge of the local varieties they manage, and because of the seed dissemination they carry out within the territory via their social and professional networks.

To conclude, although producers have a broad knowledge of different types of quinoa, none of them grow or know every type available. Promoting the creation of mechanisms or spaces for the exchange of traditional knowledge is necessary to avoid later risk of genetic erosion and loss of quinoa germplasm conserved *in situ*. Additionally, growing quinoa may be further compromised by the advanced age of the farmers who operate in the region: the *tatas*, who use household labour (planting and harvesting). Quinoa's agricultural system undergoes continuous change in terms of management, especially considering that approximately 25% of young people remain in the rural zones of the Altiplano, with large numbers migrating to the

Table 2: Quinoa diversity management criteria according to production macrozones

	North	Central	South
Number of local varieties per holding	3-5	1	1-3
General characteristics of types grown	less or no photoperiod sensitivity in number of grains	photoperiod sensitivity	photoperiod sensitivity
Seed origin	passed down in families for generations within communities, and at Aymara fairs with Bolivia or Peru	passed down in families for generations, traded with neighbours, disseminated via the *Cooperativa Paredones* [Paredones Cooperative]	passed down in families for generations, *Trafkintu* (seed exchanges; trade), and agricultural modernization programs
Improvement	selection of red and yellow populations with a broad genetic base (UNAP)	Search for improved varieties by the *Cooperativa Agricola Las Nieves* [Las Nieves Agricultural Cooperative]	only registered improved variety in Chile: *Regalona* from private company *Semillas Von Baer*
Links between producers	strong communities, but competing over power, territorial conflicts	isolated	strong communities with links between regional sectors, conflict over numerous issues (forest management, water)
Public rural extension institutions (Prodesal/INDAP)	subsidies for livestock	basic technical support and fertilizer subsidies	dissemination of varieties, including *Regalona*
Producer organization	two cooperatives which are able to guide sales based on specific seeds: orientation according to market demand. New organizations are limited in their ability to offer producers a good price (now less than in Bolivia)	one cooperative which has conflicts of interest with some producers, as few are partners and the price varies between members and non-members. Solely export-driven (less biodiversity) with organic certificate bringing added value.	DAWE Project (with CET-Sur) for rural certification that retains the value of diverse seeds. Local market promotion and added value for seed diversity in restaurants.

Source: Proyecto IMAS (ANR), 2010

nearby cities of Iquique and Arica. This panorama endangers the workforce available for quinoa management. The exodus from rural communities influences the evolution of local customs and affects the traditional indigenous community structures that underpin traditional farming practices and landraces today.

Quinoa in the central macrozone: a product of ancestral and isolated rural growers

Quinoa is still grown in some areas of the coastal dry lands in region VI in B. O'Higgins and region VII in Maule. Despite a major reduction in cultivated land in the area – due to land use changes over the past decade with areas now dedicated to forest plantations (conifers) – some producers have maintained quinoa crops as a family tradition, in a region where the major crops grown are wheat, potatoes and legumes. The quinoa-growing area is often small and may measure just a few rows or be in a land parcel measuring 1–4 ha (Alfonso, 2008). Producers who plant large areas (around 10 ha) are landowners, while other producers rent most of their growing land, or have agreements in which they pay a percentage of their production (sharecropping). These producers may have another job, not on the holding (companies, agricultural industries etc.) in order to supplement their farming income. Most farmers are also elderly (average 65 years), and they only grow white quinoa. In 38% of cases, they acquire quinoa seeds through family members, while 46% obtain seeds from neighbouring farmers.

Chile's coastal dry lands in regions VI and VII have the country's highest poverty rates. Natural conditions limit agricultural development – rainfall is only 650 mm/year over a 5-month period, and those areas in the vicinity of estuaries are characterized by saline soil. As a consequence, farmers select landraces adapted to the challenging conditions, and a group of farmers in the communes of Paredones, Pumanque and Pichilemu (region VI) now have increased income from quinoa sales, thanks to the organization of an agricultural cooperative, *Cooperativa Agrícola Las Nieves.*

When describing the various crops planted in the region, it should be noted that wheat, corn, barley and oats are important to farmers, and take up a significant portion of individual farms. Quinoa crops represent the smallest share of farmland in the commune of Paredones, accounting for an average of only 34%, while in Pichilemu this figure is 61%, and in Pumanque 49%. Figures from the commune of Paredones indicate that farmers give greater importance to products yielding higher sales volume. Quinoa, on the other hand, is historically destined for family consumption, or for sale in small volumes to individual buyers. In the commune of Pichilemu, producers place greater importance on quinoa crops, despite having a smaller average growing area per farmer (3.03 ha).

The various tasks performed by quinoa producers in these regions take place as follows: soil preparation from August to November; seed planting in October and November; harvest between February and April.

Farmers for whom the most important crop in terms of area is quinoa (28% of producers) have an average area of 6.3 ha per farmer. Quinoa takes priority over other products grown, accounting for almsot 60% of the growing area. These farmers have close ties to the *Cooperativa Agrícola Las Nieves*, and also created the company *Agrícola Las Nieves Limitada*, with the aim of strengthening sales for export. The company may also acquire additional quinoa supplied by small-scale farmers in the region. For a second group (representing almost 21% of the producers interviewed), quinoa is an important crop and takes up half of their growing area. This group alternates quinoa on a biannual basis with grains (wheat or oats) or potatoes. Of this group, however, only 11% claim to have links with the *Cooperativa Agrícola Las Nieves*; this is in part due to the fact that they can obtain higher prices by selling privately.

A total of 51% of farmers dedicate less than 1 ha of their land to quinoa crops. These producers are usually landowners who inherited their farms. They produce primarily for their own family's consumption and occasionally sell their quinoa to tourists or neighbours, and therefore do not have ties to the *Cooperativa Agrícola Las Nieves*.

The information gathered was used to determine how the farmers identify their seeds, and it was noted that some of them only grow "white" quinoa. Several synonyms (white, golden, yellow) were used for what is, according to the farmers, the same type of quinoa. The perception among the farmers was that there was only one quinoa crop seed in the study area, and it was called by different names depending on the location. Agricultural practices were then analysed – from the planting period through to harvest – and it was demonstrated that there are several paths to selection among isolated groups of quinoa producers in the region. The dates of various agricultural tasks related to growing quinoa were identified for each producer in the three communes in the study area. The results revealed that the harvest period is concentrated in the period from February to April. In Pichilemu, 80% of farmers planted in August to harvest in January. The uniform nature of the agricultural practices adopted suggests that the farmers are growing the same type of quinoa. In the commune of Paredones, most planting is only done in November, although there are two major harvest periods. Approximately 33% of the crop is harvested in February and 50% in April. This suggests that there are at least two types of quinoa, early and late. On the other hand, in Pumanque, planting often lasts 4 months (July–Oct.), with homogenous distribution among the farmers (25% each month), although crops are usually harvested in April (80%). This suggests that there is one type of quinoa with a high photoperiod coefficient. In addition to considerations relative to crop management practices, it was also noted that some farmers select types of quinoa with higher tolerance for saline stress, as they cultivate land that is naturally penetrated by salty coastal waters near river mouths (Ruiz-Carrasco *et al.*, 2011). Therefore, management of farmer production systems and the dynamics of crop management in the central zone have led to a high level of quinoa type biodiversity, as revealed by molecular genetic analysis (Fuentes *et al.*, 2012). Nevertheless, recent high sales of seeds in the zone may have negative repercussions in terms of potential loss of genetic diversity, as seeds may become homogenized throughout the region to respond to potential market demands.

Quinoa in the southern macrozone: a tradition in Mapuche women's gardens.

Quinoa growing in southern Chile is currently practised on a small scale, performed mainly by Mapuche women, who grow it in small gardens near their homes, together with vegetables, as is the tradition in this region. Growing areas are usually less than 100 m2, and may reach 0.5 ha (Aleman, 2009). Such small growing areas are not generally registered in the Chilean National Agricultural Census (Table 1), which explains the fact that quinoa cultivation in the south is relatively unknown. Mapuche quinoa is always sown in animal pens or with large amounts of manure. This feature is uncommon in other regions, where quinoa is considered a crop requiring few or no inputs (fertilizers, pesticides etc.) for its development. Quinoa is often sown in gardens alongside corn, bean and potato crops to protect the latter from strong summer sun (Alfonso, 2008). The major difference between quinoa in the Altiplano and *kinwa* or *dawe* in the Mapuche language is that the latter is produced in regions with higher precipitation and lower altitude. It differs from quinoa from the central macrozone, in particular with regard to its adaptation to arid conditions, seed type (colour, size), higher productivity and photoperiod (Anabalon and Thomet, 2009). These contrasts are also the result of different management practices (crop density and planting depth) due to the low fertility and moisture. In the south, quinoa seeds are sown densely at a shallow depth via broadcast seeding (Thomet *et al.*, 2003).

The various types of quinoa found in this zone have been handed down in families for generations, and have been spared most agricultural modernization programmes (Thomet and Bazile, 2013). The traditional peasant/indigenous system in this region is characterized by highly diverse crops and landraces, and the wide range of uses for quinoa within families or communities – for example, it is used for human consumption, poultry feed, or preparing *mudai* (a traditional drink for Mapuche celebrations, recommended for pregnant women and medicinal purposes) (Aleman, 2009).

Descriptors have been developed to characterize landraces of quinoa, including the following features: inflorescence colour, seed colour, number of days between planting and harvest, size of seed and number of seeds per gram, inflorescence density, nutritional value and usability (Sepulveda *et al.*, 2003). According to the phenotype of quinoa in the southern macrozone, quinoa in the south can be classified as "early", with a period of 68–80 days between sowing and flowering (130–150 to harvest) (Figure 5).

Sowing dates depend on the features of the location and on theagricultural techniques adopted (mechanized or manual seeding). When this task is performed also depends on the depth at which seeds are sown, which in turn is associated with the moisture conditions (1–3 cm). In moist soil, seeds are sown later and at reduced depth. Given that yield decreases significantly with later sowings, this technique should only be adopted to avoid a late frost.

Interestingly, quinoa grown in the southern macrozone has reached a yield potential of 6 500 kg/ha in garden conditions, with organic fertilizer. This contrasts with the growing conditions of quinoa in the northern macrozone, where yield averages 180–640 kg/ha.

Genetic diversity in Chilean quinoa: *a treasure in farmers' hands*

The varied morphology presented by this crop in the major production macrozones has meant that the Andean farmers (Aymaras) on the arid coastline of the central zone and the Mapuches in the south have taken advantage of quinoa's many forms, using it as a food and for other purposes. For example, a range of plant and seed colours can be seen in quinoa fields, as well as differences in branching and/or plant architecture. Varied seed productivity and major phenological differences can also be observed (Fuentes and Bhargava, 2011; Fuentes *et al.*, 2012). Quinoa is an important genetic resource representing a challenge, as the genetic variables may influence features, such as seed production, seed saponin content, nutritional elements, tolerance to cold and disease resistance. It is necessary to understand these variables in order to increase opportunities for potential new uses.

Combined research has demonstrated evidence of quinoa's ancestral movement from southern Bolivia to the northern Chilean Altiplano, and then southwards. Analysis of various quinoa populations originating from the Andes and low altitude regions of southern Chile reveals that there are two different types of quinoa in the country: the Salare ecotype (found in the Altiplano) and the Coastal ecotype (found in the central-southern region) (Figure 1) (Fuentes *et al.*, 2009b; Miranda *et al.*, 2012; Fuentes *et al.*, 2012). Characterization of wild relatives has also demonstrated that there is a mixed system of self-pollination/cross-pollination in the Coastal ecotype, as well as an active complex crop weed (Fuentes and Zurita, 2013).

Recent investigations using molecular genetic approximations support hypotheses regarding quinoa's genetic relations in the South American Andes (Christensen *et al.*, 2007; Fuentes *et al.*, 2009b, 2012). One such hypothesis is that of Wilson, who points to quinoa's ancestral colonization of southern Chile, and suggests that Chilean quinoa populations came to the region via the Bolivian Altiplano. Our study confirms these hypotheses, revealing that quinoas from Chile's northern macrozone are closely related to Bolivian quinoa varieties (Salare ecotype) (Christensen *et al.*, 2007; Fuentes *et al.*, 2009b). There is also evidence that material from the Peruvian Andean zone was introduced to the Altiplano in the region of Antofagasta (north). Despite this, the dominant morphology in most materials studied in Chile's far north corresponds to

Figure 5: General characteristics of quinoa growing cycles in Chile's different production macrozones

	June	July	August	September	October	November	December	January	February	March	April	May
North macrozone			planting	planting	plant growth	plant growth	plant growth	plant growth	plant growth	plant growth	harvest	harvest
Center macrozone				planting	planting	plant growth	plant growth	plant growth	harvest	harvest	harvest	
Southern macrozone					planting	planting	plant growth	plant growth	harvest	harvest		

planting · plant growth · harvest

Source: *Prepared by authors Bazile* et al.

Salare quinoa (Fuentes *et al.*, 2009b; Fuentes and Bhargava, 2011).

These genetic relations correspond to the concept of germplasm exchange – a practice that must have existed among pre-Hispanic people from the Altiplano in the north, extending to the central and southern lowlands in modern-day Chile, i.e. the Aymaras, Quechuas (Altiplano 18°–24°S), Diaguitas (30°S), Picunches (32°–34°S), Pehuenches (35°–39°S), Mapuches and Huilliches (40°S). This theory supports a north-south genetic relations model (Fuentes *et al.*, 2012).

Quinoa germplasm in the northern macrozone has been described using molecular genetic approximations that proved far more diverse than previously believed and reported (Fuentes *et al.*, 2009b). The greater diversity that exists in quinoa from southern Chile compared with quinoa from the northern macrozone may be explained by a cross-pollination system between coastal quinoas and *C. hircinum* weed populations. This hypothesis explains to a certain extent the difficulty faced by quinoa breeders in obtaining new, pure cultivars in Chile's central region (L. von Baer, personal communication).

Analysis of quinoa in northern and southern Chile has revealed the existence of shared microsatellite marker alleles. This confirms the theories of Wilson (1988) and Christensen *et al.* (2007), who both reported greater genetic similarity between quinoas in the southern Andean Altiplano and quinoas in southern Chile. Curiously, using the same molecular approximation, quinoas from northern Chile (Altiplano) present a greater number of unique alleles than quinoas from the south (coastal) (Fuentes *et al.*, 2009b). An analysis of existing genetic relations between *C. quinua* from the southern macrozone and wild relatives from the *Chenopodium* genus originating in southern and northern Chile, reveals similarities between *C. quinua* and *C. hircinum* at the nuclear DNA and chloroplast levels, supporting the hypothesis that under growing conditions in southern Chile, quinoa plants present a system of constant intra- and/or interspecific genetic information exchange. This represents the first natural evidence of an active complex crop weed in southern Chile (Fuentes and Zurita-Silva, 2013).

Recent analyses of intrafarm genetic diversity on farm plots in the different quinoa macrozones also compare the effect of seed selection by farmers (e.g. massal selection, the case of seed company AGROGEN). For the individuals sampled, three microsatellite loci (QAAT78, QAAT74, QCA57 – described by Christensen *et al.*, 2007) were used in order to observe an average allele per locus: 0.56 (values weighted by number of analysed plants) for the northern macrozone, 0.7 in the centre and 1.13 in the south (with just 0.2 in the massal selection group in the southern macrozone). This study confirms the concept of genetic diversity in Chilean quinoa based on molecular genetic approximation. Genetic diversity increases in the north and south of the country, and the seed selection process (as expected) revealed a decrease in populational genetic diversity (Martinez *et al.*, unpublished).

The importance of defining a collective *ex situ* conservation strategy: *Building a Chilean national quinoa collection*

Biodiversity data on Chilean quinoa highlight the national and global interest in defining a collective strategy in order to conserve the species' potential, achieve greater complementarity between *in situ* and *ex situ* conservation and lower the risk of losing the germplasm. However, farmers' rights must also be considered, with regard to long-term access to their ancestral heritage in seed banks. Farmers should be protected from the disadvantages of their seeds being reproduced annually outside their native ecosystems, and a diversity management scheme is required that includes traditional practices.

Ex situ conservation is usually carried out on seeds in germplasm banks at the *Instituto de Investigaciones Agropecuarias* (Institute for Agricultural Research) (INIA). The quinoa collection maintained by INIA's national germplasm bank, *Banco Nacional de Germoplasma*, includes a total of 377 accessions, and comprises material collected in 1994, as well as other materials from different sites collected by various national and international centres and organizations (Table 3) (Salazar *et al*., 2006, 2009).

The Semillas Baer company began collecting and conserving samples representing local landraces and quinoa populations grown in southern Chile in 1968, as part of the company's genetic breeding programme in that period (von Baer *et al.*, 2009). In 2001, as part of a cooperation agreement between INIA, the *Asociación de Municipalidades* (Municipalities Association) and the Semillas Baer company, 85 accessions were duplicated and sent to INIA for long-term conservation. In 2008, Baer Semillas sent 77 more accessions from southern Chile to INIA. The collection of the NGO CET SUR, which was begun in 2000, was added to the quinoa materials grown in southern Chile, for a total of 192 accessions, some of which are also currently stored by INIA's national germplasm bank (Madrid, 2011).

Collections made by institutions, such as the *Centro de Estudios Avanzados en Zonas Aridas* (Centre for Advanced Studies on Arid Zones, CEAZA) and the Arturo PRAT University (UNAP), between 2003 and 2006 have contributed to conserving samples representative of local varieties grown in the northern region of Chile (Altiplano ecotype), which, together with the materials conserved by INIA, add up to a total of 121 accessions (Madrid *et al.*, 2001).

Accessions of quinoa grown in Chile's central coastal areas are represented by samples obtained in two collection expeditions: one by CEAZA between 2005 and 2006, and the other by the same research centre, in cooperation with CIRAD (International Cooperation Centre of Agricultural Research for Development, France) in 2010, as part of an international scientific cooperation project, with a total of 64 quinoa accessions representative of Chile'snorthern, central and macrozones.

Most quinoa collections have been developed within the framework of studying and re-evaluating quinoa crops in Chile. For example, Semillas Baer's collection was created as part of the project "*Recuperación, Revalorización y Difusión del Cultivo y Uso de la quinua en cuatro Comunas de la Precordillera de la IX Región: Cunco, Melipeuco, Padre Las Casas y Vilcún*" (Recovery, Re-evaluation, and Dissemination of Quinoa Crops and uses in the Four Lowlands Communes of Region IX: Cunco, Melipeuco, Padre Las Casas, and Vilcun), financed with local funds from INDAP's PRODESAL and PRODER programmes and Semillas Baer. Collections have been made by Arturo Prat University as part of molecular genetic studies programmes (Fuentes *et al.*, 2009b) and programmes on selection and diversified crop use in the Altiplano and Pampa del Tamarugal (Fuentes *et al.*, 2009c; Fuentes and Bhargava, 2011), financed by national institutions such as the *Centro de Investigaciones del Hombre en el Desierto* (Research Centre of Man in the Desert, CIHDE) and *Fundación para la Inovación Agraria* (Foundation for Agrarian Innovation, FIA), as well as foreign institutions such as Brigham Young University (United States of America). Collections made by the CEAZA in the central zone, specifically in the regions of O'Higgins and Maule, were developed within the framework of the project, "*Cultivo doble propósito de Chenopodium quinua (quinua) para la Región de Coquimbo: Modelo de grano para consumo humano y follaje para ganado caprino"* (Two-purpose *Chenopodium quinua* [quinoa] crop for the Region of Coquimbo: Seed model for human consumption and for goat feed), financed by Innova CORFO (2006–08).

Today, all accessions are maintained at the INIA national bank in Vicuña, and 100% of the materials are kept in long-term conservation chambers. Of the samples, 92% have origin information (passport data); only materials donated by AGROGEN and UNAP have duplicates.

Chile does not have a national body regulating access to genetic resources conserved *ex situ.* Since 1995, following a ministerial mandate, INIA has acted as a national curator of Chile's phytogenetic resources, and can authorize access. However, because the authorization process is not mandatory, few institutions recognize INIA's powers in this area. Whether or not to distribute materials is usually decided by the researcher in charge. There is no common policy or coordinated procedure for access to material conserved *ex situ* between the various institutions that store plant germplasm, or between the various centres performing that task within a single institution (Manzur, 2003; Salazar *et al.*, 2006). In the case of INIA, distribution depends on the type of material requested and who is making the request. The current system of exchange is rather complex. INIA formalizes germplasm distribution through a materials transfer agreement, which defines conditions for access. Generally speaking, a regulatory framework governing access to genetic resources is lacking, which limits the possibility of research cooperation between institutions that possess germplasm and those that do not.

Table 3: Building the national *Chenopodium quinua* collection conserved by INIA's *Red de Bancos de Germoplasma* [Germplasm Bank Network]

Number of Accesions	Region of origin (Comunes)	Collecting Institution	Collected by	Year collected	Year added to INIA system	Duplicated	Passport Data
73	Region of Tarapacá, Iquique	INIA	A. Cubillos	1994	1994	No	Yes
51	Central Zone, Chile	CEAZA	E. Martínez, E. Veas and P. Jara	2005-2006	2005 - 2006	No	Yes
25	Region ofCoquimbo	CEAZA	E. Veas		2006	No	Yes
85	Region of Araucanía (Melipeuco, Padre las Casas, Vilcún, Cunco)	AGROGEN-Semillas Baer[1]	I. von Baer	2001	2001	No?	Yes
77	Region of Araucanía (Villarrica)	AGROGEN-Semillas Baer	I. von Baer	2008		Yes	Yes
93 accessions of quinoa and 9 of wild relatives	Regions of Tarapacá and Antofagasta	UNAP	F. Fuentes	2003	2009	Yes (but not all)	Yes
13	Central Zone,Chile	CIRAD-CEAZA	D. Bazile	2010	2010	No	Yes
24	Region of Araucanía (Villarrica, Lumaco, Melipeuco)	CET Sur	M. Thomet	1999, 2005-2009	2010	?	?

[1]Now AGROGEN

Source: Prepared by authors Bazile *et al*.

Generally, non-profit conservation centres, such as germplasm banks, depend on state contributions, institutional funds, and national and international cooperation, usually through short-term projects. This does not guarantee any long-term funding. The germplasm bank network managed by INIA was created and opened in 1990 with support from the Government of Chile and the Japanese International Cooperation Agency (JICA). Other institutions create and maintain their collections using funding obtained through projects. Though many types of grants are available, these systems generally require product development which has high costs. Generally speaking, studying and conserving phytogenetic resources *ex situ* is not a priority for national funding (despite signed international agreements aimed at preserving biodiversity). As a result, resources for developing activities, such as surveying, characterizing and evaluating phytogenetic resources, are obtained indirectly through projects including some of these activities among their secondary objectives. It is important to highlight that in the case of quinoa, many research projects focus on *in situ* conservation and sustainable use of genetic resources. As a result, agricultural communities participate directly in the development of these proposals. Nevertheless, due to a government decision to support and develop plant species breeding programmes (*Chile potencial agroalimentario y forestal* – Chile food and forest potential), as well as programmes aimed at the survival and re-evaluation of traditional varieties and species, collection and characterization activities are more viable today.

Conclusion

Quinoa is important to territorial development in Chile, despite its status as a minor crop. Quinoa's ecological diversity is broad, and it is grown in various ecosystems. Therefore, quinoa crops offer new opportunities for territorial development in Chile. Quinoa may serve as a major source of supplementary income for family farms in the north, south and central regions of the country. Quinoa crops may also be useful for crop rotation to improve soil structure. However, against a backdrop of sustainable development, quinoa crop management should be designed in line with the dynamics of its broad biodiversity, while considering the vertical (national needs and cohesion) and horizontal (between local stakeholders) relations at play. A two-pronged vertical management scheme is required, taking into account the need to provide coherence to an extensive swathe of territory, from the Aymara to the Mapuche region. Horizontal or local management is needed, where territorial coherence must translate the need for sustainable territorial development into participation from all stakeholders: farmers and non-farmers, public and private (Bazile *et al*., 2012).

The high level of diversity in Chile's ecosystem, including photoperiod, soil and climate, has generated high genetic diversity in quinoa, as a result of adaptation to salinity and other stress factors. At country level, landraces and the diversity of farming practices today are the result of a process that began with the ancestral civilisations that lived in the southern Andes, thousands of years before the arrival of the European colonists. Quinoa's current diversity is the result of dynamics that were closely linked to the ecosystems and cultures present in those regions. This makes Chilean quinoa very important, as its broad ecological and geographical distribution bodes well for its growing potential in nearly every climate or condition around the globe.

Thanks to quinoa's hardiness, family farmers and stakeholders involved in breeding have a major opportunity to continue the process of creating local varieties and improving various agronomic and nutritional features (Lutz *et al*., 2013; Miranda *et al*., 2013; Schlick and Bubenheim, 1996).

This chapter on quinoa's genetic diversity model reveals major challenges for scientists, crop breeders and rural producers themselves. These challenges come from the development of initiatives aimed at increasing and maintaining collections of quinoa and its wild relatives' germplasms *in situ* and *ex situ*, while also increasing characterization of those resources, and thereby contributing to new genetic improvement programmes (classic and participative) and revealing the true power of current germplasm collections.

On the other hand, the global demand for quinoa is for organic quinoa, which is a major challenge in Chile if farmers truly want to access the international quinoa market, abiding by the certification criteria necessary to market their wares.

Acknowledgements: *The authors would like to express their gratitude to the farmers who have cared for their seeds and trusted us with their stories, and the projects that have financed the research activities presented BRG08, ICGEB-TWAS (CRP.PB/CHI08-01), IMAS (ANR07 BDIV16-01), FONDECYT (1060281y 1100638), IRSES (PIRSES-GA-2008-230862), Innova Chile by CORFO (04CR9PAD04, BioTecZA 06FC01IBC-71 and BioaCu2+8CM01-12).*

References

Achkar, M. 2005. Indicadores de sostenibilidad. *In* M. Achkar, V. Canton, R. Cayssials, A. Domínguez, G. Fernández, & Pesce, F., eds. *Ordenamiento Ambiental del Territorio Comisión Sectorial de Educación Permanente*. DIRAC, Facultad de Ciencias. Montevideo.

Aleman, J. 2009. *Caract*érisation *de la diversit*é *des vari*été*s et des modes de culture du quinua dans les communaut*é*s Mapuche du Sud du Chili*. Univ. Montpellier Sup'Agro, France. (thesis)

Aleman, J., Thomet, M., Bazile, D. & Pham, J.-L. 2009. *Dinámica de los flujos de semillas en la conservación de las variedades locales de quinua (Chenopodium quinua Willd.) en comunidades Mapuche de la región de la Araucanía (Chile)*. En: INIA, Proceedings VII Simposio de Recursos Genéticos para América latina y El Caribe, SIRGEALC. Pucón, Chile. Tomo 1, 2009, p. 459-460.

Aleman, J., Thomet, M., Bazile, D. & Pham, J.-L. 2009. *Impacto de proyectos de fomento del cultivo de quinua (Chenopodium quinua Willd.) sobre la conservación de las variedades locales en comunidades Mapuche de la Región de la Araucanía (Chile)*. En: INIA, Proceedings VII Simposio de Recursos Genéticos para América latina y El Caribe, SIRGEALC. Pucón, Chile. Tomo 1, 2009, p. 449-450.

Alfonso D. 2008. *La gestion de la biodiversit*é par *les paysans: Le quinua au Chili*». Spécialité Recherche: Innovations et Développement des Territoires Ruraux. SupAgro- IAMM-UMIII-CIRAD, Montpellier-Francia. (thesis)

Anabalón, R.L.Y. & Thomet, I.M. 2009. Comparative analysis of genetic and morphologic diversity among quinua accessions (*Chenopodium quinua* Willd.) of the South of Chile and highland accessions. *Journal of Plant Breeding and Crop Science*, 1(5): 210-216.

Arar, M. 2009. *Análisis de estrategias de cooperativas Aymara y gestión de la biodiversidad de Quinua*, ISARA-CIRAD, Lyon-France.

Arenas, J. & Lanino, M. 2008. Antecedentes agros meteorológicos y evapotranspiración del sector Vilacollo, Comuna de Colchane. *Revista de Agricultura del Desierto*, 4: 10-22.

Aubertin, C. & Vivien, F.-D. 1998. *Les Enjeux de la Biodiversit*é. Collection Poche Environnement. Economica, Paris.

Ayala G., Ortega, L. & Moron, C. 2001. Valor nutritivo y usos de la quinua. *In* FAO. *Quinua (*Chenopodium quinua *Willd.), Ancestral cultivo andino, alimento del presente y futuro*. Roma (Italia): Ediciones de la Organización de las Naciones Unidas para la Agricultura y la Alimentación (FAO).

Bañuelos, G.S., Ajwa, H.A., Caceres, L. & Dyer, D. 1999. Germination responses and boron accumulation in germplasm from Chile and the United States grown with boron-enriched water. *Ecotoxicology and environmental safety*, 43(1): 62-67.

Bastías, E., Alcazaz-López, C., Bonilla, I., Martinez-Ballesta, M., Bolaños, L. & Carvajal, M. 2010. Interactions between salinity and boron toxicity in tomato plants involve apoplastic calcium. *Journal of Plant Physiology*, 167(1): 54-60.

Bazile, D., Fuentes, F. & Mujica, A. 2013. Historical Perspectives and Domestication. *In* A. Bhargava & S. Srivastava, ed. *Quinua: Botany, Production & Uses,* p. 16-35. Wallingford, UK, CABI Publisher.

Bazile, D. & Weltzien, E., ed. 2008. Agrobiodiversités. *Cahiers Agricultures*, 17(2): 73-256.

Bazile, D. & Negrete, J. 2009. Quinua y biodiversidad: ¿cuáles son los desafíos regiónales? *Revista Geográfica de Valparaíso*, 42: 1-141.

Bazile, D., Chia E. & Hocde, H. 2012. Le détournement d'instruments de politiques publiques de développement rural au Chili au bénéfice de la production du quinua. Reflets et perspectives de la vie économique (TomeLI), p. 35-56. http://dx.doi.org/10.3917/rpve.512.0035

Bhargava, A., Shukla, S. & Ohri, D. 2005. *Chenopodium quinua*, an Indian perspective. *Industrial Crops and Products*, 23: 73-87.

Bosque, H., Lemeur, R., Van Damme, P. & Jacobsen, E. 2003. Ecophysiological analisys of drought and salinity stress of quinua (*Chenopodium quinua*, Willd.). *Food Reviews Internacional*, 19: 111-119.

Brundtland, G.H. 1987. *Notre avenir* à *nous tous*. Commission mondiale pour l'Environnement et le Développement.

Camacho-Cristóbal, J., Rexach, J.A. & González-Fontes. 2008. Boron in Plants: Deficiency and Toxicity. *Journal of Integrative Plant Biology*, 50(10): 1247-1255.

Castri di Francesco. 1968. Esquisse écologique du Chili. *In C.* Delamare Debouteville & E. Rapoport. Biologie de l'Amérique Australe. Volume IV. Etudes sur la faune du sol. Documents biogéographiques. Extrait. Paris (Francia): Ediciones del Centre National de la Recherche Scientifique, p. 7-52.

Chevassus-Au-Louis, B. & Bazile, D. 2008. Cultiver la diversité**.** *Cahiers Agricultures*, 17(2): 77-78.

Christensen, S.A., Pratt, D.B., Pratt, C., Nelson, P.T., Stevens, M.R., Jellen, E.N., Coleman, C.E., Fairbanks, D.J., Bonifacio, A. & Maughan, P.J. 2007. Assessment of genetic diversity in the USDA and CIP-FAO international nursery collections of quinua (*Chenopodium quinua* Willd.) using microsatellite markers. *Plant Genetic Resources*, 5: 82-95.

Delatorre, J., Arenas, J. & Lanino, I. 1995. Comparación Morfológica de nueve ecotipos de quinua. *Revista de Horticultura Internacional*, 11: 17-18.

Delatorre, J., Salinas, A. & Sánchez, M., ed. 2008. Cultivo de la Quinua. *Revista Agricultura del Desierto*, 4: 1-119.

Fuentes, F. & Bhargava, A. 2011. Morphological Analysis of quinua Germplasm Grown Under Lowland Desert Conditions. *Journal of Agronomy and Crop Science,* 197: 124-134.

Fuentes, F.F, Espinoza, P.A., Von Baer, I., Jellen, E.N. & Maughan, P.J. 2009a. Determinación de relaciones genéticas entre *Chenopodium quinua* Willd del sur de Chile y parientes silvestres del género *Chenopodium*. *In: Anales del XVII Congreso Nacional de Biología del Perú*: 45. Tacna, Perú.

Fuentes, F.F., Martínez, E.A., Hinrichsen, P.V., Jellen, E.N. & Maughan, P.J. 2009b. Assessment of genetic diversity patterns in Chilean quinua (*Chenopodium quinua* Willd.) germplasm using multiplex fluorescent microsatellite markers*. Conservation Genetics*, 10(2): 369-377.

Fuentes, F., Maughan, P.J. & Jellen, E.R. 2009c. Diversidad genética y recursos genéticos para el mejoramiento de la quinua, (*Chenopodium quinua* Willd.). *Revista Geográfica de Valparaíso*, 42: 20-33.

Fuentes, F. F., Bazile, D., Bhargava, A. & Martínez, E.A. 2012. Implications of farmers' seed exchanges for on-farm conservation of quinua, as revealed by its genetic diversity in Chile. *Journal of Agricultural Science*, 150: 702-716.

Fuentes, F. & Zurita-Silva, A. Molecular studies. 2013. *In* A. Bhargava & S. Srivastava, ed. Quinua: Botany, Production & Uses. CABI Publisher, Wallingford, UK. ISBN: 9781780642260.

Gandarillas, H. 1979. Mejoramiento genético. *In* M.E. Tapia, ed*. Quinua y Kanihua, Cultivos Andinos,* p. 65-82. Bogotá, IICA.

Gonzales, A. 1997. *Fisiología de la resistencia a la sequía en quinua. Ecofisiología y morfología del estrés debido a factores adversos*. Primer Curso Internacional sobre Fisiología de la Resistencia a la Sequía en Quinua, Proyecto Quinua CIP-DANIDA y la Escuela de Post-grado de la Universidad Nacional del Altiplano. Facultad de Ciencias Agrícolas de la UNA-Puno**.**

Harvey, D. 2005. *A Brief History of Neoliberlism*. Oxford, UK & NewYork, USA. Oxford's University Press.

Harvey, D. 2001. Globalizacion and resistance in post-cold war Mexico: difference, citizenship and biodiversity conflicts in Chiapas. *Third World Quaterly*, 22(6): 1045-1061.

Hocdé, H., Sogoba, B., Bazile, D. & Lançon, J. 2008. Tables rondes des paysans chercheurs : simples échanges ou vrais débats ? *Cahiers Agricultures*, 17(2): 222-230.

INDAP & Qualitas, A.C. 2009. *Estudio de Caracterización de la pequeña agricultura a partir del VII Censo Nacional Agropecuarios y Forestal*. Ediciones Qualitas AC, Santiago.

INE. 1997. VI Censo Nacional Agropecuario.

INE. 2002. Estadísticas Nacionales de Población.

INE. 2007. VII Censo Nacional Agropecuario y Forestal.

Jacobsen, E. & Mujica, A. 1999. Quinua: Cultivo con resistencia a la sequía y otros factores adversos. *In: Primer Taller Internacional en Quinua: Recursos Genéticos y Sistemas de Producción*. Proyecto Quinua CIP-DANIDA, Universidad Agraria, La Molina (UNALM), Centro Internacional de la Papa (CIP) & Universidad Nacional del Altiplano (UNAP). La Molina, Lima, Perú, Mayo.

Jacobsen, S. E. & Mujica, A. 2002. Genetic resources and breeding of the Andean grain crop quinua (Chenopodium quinua Willd.). *Plant genetic resources Newsletter*, 130: 54-61.

Jarvis, D.E. 2006. *Simple sequence repeat development, polymorphism and genetic mapping in quinua (Chenopodium quinua Willd.).* Department of Plant and Animal Sciences. Brigham Young University. Utah, USA. (thesis)

Jellen, E.N., Kolano, B.A., Sederberg, M.C., Bonifacio, A. & Maughan, P.J. 2009. Wild and Weedy Genetic Resources for Improving the quinuas (*Genus Chenopodium* L.). *In* C. Kole, ed. *Wild Crop Relatives: Genomic and Breeding Resources*. Vol 4. Springer- Verlag.

Junge, I. 1978. *La quinua y Lupinus en Chile*. Chile, Universidad de Concepción.

Kaine, G. & Tozer, W. 2005. Stability, Resilience and Sustainability in pasture based grazing systems. *Agricultural Systems*, 83: 27-48.

Köppen, W. 1931. *Grundiss der klimakunde*. Berlin, Germany, Ediciones De Gruiter.

Lanino, I. 1976. *La quinua: Cultivo del altiplano chileno, zona de Isluga*. Universidad del Norte, Sede Iquique, Chile.

Leff, E. 2005. La Geopolítica de la Biodiversidad y el Desarrollo Sustentable: economización del mundo, racionalidad ambiental y reapropiación social de la naturaleza. *In: Semináro Internacional REG GEN: Alternativas Globaliza*ção (8 al 13 de Octubre de 2005, Rio de Janeiro, Brasil). UNESCO, Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura, Rio de Janeiro, Brazil.

Leidi, E. & Pardo, J. 2002. *Tolerancia de los Cultivos al estrés salino:* ¿Qué *hay de nuevo?* [online] <www. fcagr.unr.edu.ar/Investigacion/revista/rev2/5. htlm> [accessed on 20 April 2007].

Looser, G. 1943. *Chenopodium quinua*, un cultivo que desaparece de Chile. Revista Argentina de Agronomía, Tomo 10, p. 111-113.

Lutz, M., Martínez, E.A. & Martínez, A. 2013. Daidzein and genistein contents in seeds of quinua (*Chenopodium quinua* Willd) from local ecotypes grown in arid Chile. *Industrial Crops and Products*, 49: 117-121.

Madrid, D. 2011. *Aportes de la geografía a la conservación ex situ de los recursos genéticos de importancia agrícola: el caso de la quinua en Chile*. Mémoire présenté pour obtenir le titre de Géographe de l'Institut de Géographie de la PUCV, Valparaiso, Chile. 178 p.

Madrid, D., Bazile, D., Martinez, E.A. & Negrete Sepulveda, J. 2011. Herramientas de la geografía para mejorar la conservación de la biodiversidad agrícola. *Anales de la Sociedad Chilena de Ciencias Geográficas*: 304-310.

Manzur, M.I. 2003. *Experiencia en Chile de Acceso a Recursos Genéticos, Protección del Conocimiento Tradicional y Derechos de Propiedad Intelectual*. Santiago, Ediciones Fundación Sociedades Sustentables.

Meadows. 1992. *Beyond the limits*. White River Junction, Chelsa Green Publ. Company.

Miranda, M., Vega-Gálvez, A., Martinez, E.A., López, J., Rodríguez, M-J., Henríquez, K. & Fuentes, F. 2012. Genetic diversity and comparison of physicochemical and nutritional characteristics of six quinua (Chenopodium quinua Willd.) genotypes cultivated in Chile. *Ciência e Tecnologia de Alimentos* (now Food science and Technology), 32(4): 835-843.

Miranda, M., Vega-Gálvez, A. Martínez, E.A., Lopez, J., Marin, R., Aranda, M. & Fuentes, F. 2013. Influence of contrasting environments on seed composition of two quinua genotypes: nutritional and functional properties*. Chilean Journal of Agronomical Research*, 73(2): 108-116. DOI: 10.4067/S0718-58392013000200004

Molina, J.I. 1810. *Ensayo sobre la historia Natural de Chile*. Libro III Vegetales de Chile.

Munss, R. 2002. Comparative physiology of salt and water stress. *Plant Cell and Environment*, 25: 239-256.

Nable, R., Buñuelos, G. & Paull, J. 1997. Boron toxicity. *Plant Soil*, 193: 181-198.

Naredo, J.-M. 1996. Sostenibilidad, diversidad y movilidad horizontal en los modelos de uso del territorio. *In* MOPTMA, ed. *Ciudades para un futuro más sostenible*. Primer catálogo español de buenas prácticas. Comité Español Habitat-II. Madrid.

Olcer, H. & Kocacaliskan, I. 2007. Excess boron reduces polyphenol oxidase activities in embryo and endosperm of maize seed during germination. *Journal of Biosciences*, 61(1-2): 111-115.

Olguín, P. 2011. Dinámicas espaciales de los sistemas de producción de quinua de la región del Libertador B. O'Higgins de Chile, con relación a los factores económicos y del medio ambiente. Instituto de Geografía de la PUCV, Valparaiso, Chile, 178 p. (thesis)

Parra, F. 2007. La cultura del territorio: la naturaleza contra el campo. *Ciudad y Territorio, Estudios Territoriales*, XXXIX(151): 27-51.

Rescia, A., Schimtz, M.F., de Pablo, C. T. L & Pineda F.D. 2002. Organización, dinámica y diversidad del territorio. *In* F.D. Pineda, J.M. De Miguel, M.A. Casado & J. Montalvo, eds. La diversidad biológica de España. Prentice Hall, Madrid, Vol IV. Capitulo 9, p. 111-123.

Sachs, I. 1997. *L'écodéveloppement*. La Découverte & Syros (Alternatives économiques), Paris.

Salazar, E., Bazile, D., Martínez, E.A. & Léon-Lobos, P. 2009. Conservacion ex situ de los recursos geneticos de Maiz (*Zea mays*), quinua (*Chenopodium quinua*) Y Algarrobo (*Prosopis chilensis*) en Chile. *In* INIA. *Proceedings VII Simposio de Recursos Genéticos para América latina y El Caribe,* p. 433-434. SIRGEALC. Pucón, Chile.

Salazar, E., León, P., Muñoz, C. & Rosas, M. 2006. Estado de la conservación ex situ de los recursos fitogenéticos cultivados y silvestres en Chile. *Boletín INIA*, 156: 1-180.

Sánchez, M., Espinoza, P., Zurita-Silva, A. & Delatorre- Herrera, J. 2009. Las "variedades" Aymaras del Altiplano Chileno y el uso de la selección genética para generar nuevas variedades. *Revista Geográfica de Valparaíso*, 42: 45-60.

Schlick, G. & Bubenheim, D.L. 1996. Quinua: Candidate crop for NASA's Controlled Ecological Life Support Systems. *In* J. Janick, ed. *Progress in New Crops,* p. 632-640. Arlington, VA, USA, ASHS Press.

Sepúlveda, A.J, Thomet, I.M., Palazuelos, F.P & Mujica, M.A. 2003. *La Kinwa Mapuche, recuperación de un cultivo para la alimentación*. CET-Sur, Fundación para la Innovación Agraria (Ministerio de Agricultura), Chile.

Serrano, E. C. 2005. La transformación de valores éticos en la interfaz del Estado y de Sociedad Civil y su importancia en el manejo de la biodiversidad, tierra y territorio – El caso del Parque Nacional Tunari en los Andes de Bolivia. *In* F. Delgado & J.C. Mariscal, eds. Gobernabilidad social de las áreas protegidas y biodiversidad en Bolivia y Latinoamerica. Bolivia, AGRUCO, PLURAL.

Tagle, M.B. & Planella, M.T. 2002. *La quinua en la zona central de Chile: supervivencia de una tradición prehispana*. Santiago, Ediciones Iku.

Thomet, M. & Bazile, D. 2013. The role of "curadoras" in the conservation of quinua varieties in the Mapuche communities in southern Chile. *In* E. Coudel, H. Devautour, C. Soulard, G. Faure & B. Hubert, eds. *Renewing innovation systems in agriculture and food: How to go towards more sustainability?* p. 174-175. Wageningen, Wageningen Academic Publishers.

Thomet, M., Sepúlveda, J. & Palazuelos, P. 2003. Manejo Agroecológico de la kinwa. *In* J. Sepúlveda, M. Thomet, P. Palazuelos & M. Mujica, eds. La kinwa Mapuche, recuperación de un cultivo para la alimentación. Temuco: CET-Sur & Fundación para la Innovación Agraria (Ministerio de Agricultura), Chile, p. 44-94.

Valdivia don Pedro de al emperador Carlos V. 1861. (Cartas de) *Colección historiadores de Chile.* Tomo I. Imprenta del Ferrocarril. Santiago de Chile.

Vidal, A. 2012. La valorización del patrimonio agrícola e identitario de las comunas Aymaras de Colchane a través del cultivo de la quinua (*Chenopodium quinua* wild). Instituto de Geografía de la PUCV, Valparaíso, Chile, 278 p. (thesis)

Von Baer, I., Bazile, D.; Martinez, E. (2009) Cuarenta años de mejoramiento de la quinua *(Chenopodium quinua* Willd*.)* en la Araucanía: Origen de "La Regalona-B". *Revista Geográfica de Valparaíso*, 42: 34-44.

Wilson, H.D. 1988. Quinua biosystematics II: free living populations. *Econ. Bot*., 42: 478-494.

Zalabata, L. 2003. Control sobre el territorio, la biodiversidad y las investigaciones en territorios indígenas de la Sierra Nevada de Santa Marta. *Revista Semillas,* 19: 4.

Zhu, J. 2002. Salt and Drought Stress Signal Transduction in Plants. *Annual Review Plant Biology*, 53: 247-273.