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Riesgo, clima y decisiones de cultivo en Chile
(Risk, weather and cropland decisions in Chile)

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SUMMARY

Since the 1990s the agriculture in Chile has been one of the fundamental sectors in Chilean social and economic development, contributing with around 5 % of the gross domestic product (GDP) and 10 % of the national employment. However, the effects of the climate change are affecting the development in this sector. In this study, we have evaluated small-scale farmers cropland decisions and studied how these decisions interact with the risk of weather events (i.e., floods and droughts). We have used data from the 6th and 7th National Agriculture and Forestry Census, as well as, geospatial and biophysical for droughts and floods. To model small-scale farmers' decisions, we proposed a multivariate fractional model, which will account for the bounded nature of the dependent variable and a pooled fractional model as robustness check. Our findings in this study have showed that the small-scale farmers are sensitive to past weather events and that their decisions may vary given the environmental and geographical conditions.

Keywords: Land allocation, risk, multivariate fractional logit, pooled fractional probit.

RESUMEN

Desde 1990 el sector agrícola ha sido de gran importancia en Chile, contribuyendo con aproximadamente el 5 % producto interno bruto (PIB) y el 10 % de la generación de empleo. Sin embargo, los efectos del cambio climático amenazan el desarrollo de este sector. En este estudio evaluamos las decisiones de cultivo que tienen los pequeños agricultores y como estas interactúan frente a los riesgos de eventos climáticos (sequías e inundaciones). Para ello, con datos del VI y VII censo agropecuario y forestal junto a indicadores geoespaciales de sequía e inundación se busca entender el efecto de shocks climáticos en la decisión de elección. Para modelar estas decisiones proponemos un modelo multivariado fraccional el cual considera la naturaleza fraccional de la variable dependiente y un modelo pooled fraccional como test de robustez. Nuestros resultados muestran que los pequeños agricultores son sensibles a los eventos climáticos del pasado y que sus decisiones van a depender de las condiciones ambientales y geográficas en que se encuentran.

Palabras claves: distribución de suelo, riesgo, logit fraccional multivariado, pooled fraccional probit.

1. INTRODUCTION

In the last decades, the Chilean agricultural sector has developed in an open, dynamic and competitive way. Since the 1990s the sector has been one of the fundamental areas of the Chilean social and economic development. In the 1990ths, the Chilean government started to support this sector by helping the producers integrate into international markets and support their competitiveness and efficiency (Portilla, 2000). According to the Office of Studies and Agrarian Policy (ODEPA) and the National Socio-Economic Characterization Survey (CASEN), the level of exportation of the sector has increased from 2,030 million USD to 14,739 million USD from 1990 to 2015. On the other hand, the level of rural poverty decreased from 38.8 % in 1990 to 6.7 % in 2013 (ODEPA and CASEN cited in ODEPA, 2018). However, a modification of the agricultural sector is expected given the effects of climate change[1].

The Intergovernmental Panel on Climate Change (IPCC), has indicated that the climate change will have important consequences to the farmers, for example; by the reduction of crop yields, the reduction of the effectiveness of herbicides and the increase of price volatility (IPCC, 2014). The ODEPA (2013) also points out that, at a national level, the climate change will increase average temperatures and will reduce average precipitation, affecting farmers' productivity and rural landscape. Other local researches have also claimed this (see, e.g., Santibáñez et al., 2008; Bárcena et al., 2009).

[1] Climate change refers to "a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer)" (IPCC, 2014).

Since climate change may affect the productivity of crops, it could also have an *ex ante* effect upon the allocation of usable land. Hence, farmers' decisions can be shaped by the presence of an exogenous background risk (Gollier and Pratt 1996), such as extreme weather events, and by the occurrence of these events in the past (Cohen et al., 2008). These effects are relevant since they can influence the main elements of food security (i.e., availability, stability, utilization, and access to food) (Schmidhuber and Tubiello, 2007).

Several studies have discussed how climate relates to agriculture and food security, from an economic point of view. Some of these studies have used the General Equilibrium approach[2] (see, e.g., Ahmed et al., 2012; Calzadilla et al., 2013; Ponce et al., 2015). Other studies have used the Ricardian approach[3] (see, e.g., Mendelsohn et al., 1994; Seo and Mendelsohn, 2008a; González and Velasco, 2008; Mendelsohn et al., 2010; Wood and Mendelsohn, 2015; Van Passe et al., 2017) and others have tried to contribute to this problem by understanding farmers' adaptation to the climate[4] (see, e.g., Kurukulasuriya and Mendelsohn, 2007; Seo and Mendelsohn, 2008b; Wang et al., 2010; Bezabih and Di Falco, 2012; Salazar-Espinoza et al., 2015). However, to the extent of our knowledge, there is no evidence of the behavior of the Chilean farmers in relation with the climate approach. Consequently, the aim of this study is to provide new empirical evidence of the effect of weather events (i.e., droughts and floods) on

[2] This approach uses Computable General Equilibrium methods (CGE) to simulate the equilibrium theory formalized by Arrow and Debreu (1954).
[3] These studies discuss how climate viariables, such as soil, temperatures and precipitation affect farmer's revenue and land value.
[4] These studies try to understand how farmers adapt to the climate by using choice models.

cropland decisions, following the adaptation to the climate literature.

In this study we will focus on small-scale farmers decision based on the relevance of this sector. According to the National Institute for Agricultural Development (INDAP), this segment controls 85 % of the farms in the country, and generate 60,000 direct and indirect jobs, benefiting 1.2 million people (INDAP cited in Salazar-Espinoza et at., 2017). Based on Echenique and Romero (2009), the individuals who belong to this group have no more than 12 or less hectares of basic irrigation (HBI). We believe that this study will contribute to a better understanding of the Chilean agricultural sector because Chile has a great history of weather events (e.g., El Niño and La Niña) and these events may increase in frequency as global temperatures raises (Wang et al., 2017), and may affect the agricultural sector.

Because of the bounded nature of farmers cropland decision, we estimate a Multivariate Fractional Logit (Mullahy, 2012). We use farmers sociodemographic and agricultural data, from the Chilean 6th and 7th National Agriculture and Forestry Census[5] (INE, 1997; INE, 2007). We also use geospatial and biophysical data, at the commune level, such as temperatures, precipitation, erosion, and other environmental variables, such as the new Standardised Precipitation-Evapotranspiration Index (SPEI; Vicente-Serrano et al., 2010) and flood information from the Dartmouth Flood Observatory (Brakenridge, 2017), in order to identify weather events. Finally, and given the nature of our data, we will also use Geographical Information Systems (GIS) softwares to manage our geo-

[5] The 6th National Agriculture and Forestry Census was used as robustness check.

spatial and biophysical data.

This study is divided into the following sections: “Agriculture and Climate in Chile”. Here we review the main characteristics of Chilean agriculture and its climate. "Literature Review", where we discuss the economic literature and some relevant studies that relate the agriculture to the climate. "Empirical Strategy", where we present the econometric model used in this study. "Data", where we present and explain the sociodemographic and agricultural, as well as the geospatial and biophysical data used in this study. Finally, we present the “Results”, “Robustness” and “Conclusions”, where we present the principal findings, challenges and the conclusions of the study.

2. AGRICULTURE AND CLIMATE IN CHILE

2.1. AGRICULTURAL SECTOR AND SMALL-SCALE FARMING

According to the World Bank (2018), the Chilean agricultural sector has, since the 1990s, represented around 5 % of the Gross Domestic Product (GDP) and has contributed with the 10 % of the national employment (ODEPA, 2014). Based on socioeconomic and cultural factors, we can say that 73.4 % of the farmers have farms that are smaller than 20 hectares, 19 % are between 20 and 100 hectares, and 7.6% are larger than 100 hectares (ODEPA, 2015). Most of the farmers are males, at their fifties, and have not finished primary school. Since our focus are on small-scale farmers, we can say that this sector represents one-third of the Agricultural Gross Domestic Product (AGDP) and contributes to 1.2 % of the Chilean GDP. This sector also provides around 60 % of the food consumed in domestic markets and control 85 % total farms in the country (INDAP, cited in Salazar-Espinoza et al., 2017). According to the Ministry of Agriculture, small-scale farmers are those holding 12 hectares or less of basic irrigation (Echenique and Romero, 2009).

The agricultural sector also benefits from Chile's climatic and geographical diversity (ODEPA, 2015). According to the 7th National Agriculture and Forestry Census (2007) some of the major products harvested in Chile include cereals (e.g., wheat, maize and oat), legumes and tubers (e.g., beans, lentil and potatoes), industrial crops (e.g., lupine and beet), grapevines (e.g., red and white vineyards), fruits (e.g., table grapes, avocado, apple), seed crops (e.g., maize, wheat and potato), flowers (e.g., roses, carnation and tulips) and vegetables (e.g., lettuce, chicory and asparagus).

2.2. CLIMATE AND WEATHER EVENTS

Chile has a lot of climatic diversities. Cities located in the north have, on average, less precipitations and higher temperature, compared with those located in the south. According to Vicuña et al. (2013) Chilean temperatures have statistically increased and precipitations have decreased in magnitude and frequency during the last four decades. We can see similar results in Figure 2.1 and Figure 2.2. These figures show that the communal temperatures from 2002 to 2006 have increased and precipitation has decreased compared to the period 1950 - 1954.

The Chilean climate is also affected by El Niño Southern Oscillation (ENSO). This ocean-atmosphere phenomenon can be associated with above (El Niño) or below (La Niña) average rainfall in central Chile during winter (30 – 35°S) and late spring (35 – 38°S). It can also be associated with dry (El Niño) and wet (La Niña) conditions in southern-central Chile (38 – 41°S) in summer (Montecinos and Aceituno, 2003). Globally, according to the National Oceanic and Atmospheric Administration (NOAA, 2017). During the 1990s and 2000s El Niño was reported in 1992, 1995, 1998, 2003 and 2007, and La Niña during 1999, 2000 and 2008. Although we do not intend to study the ENSO effect on farmers decisions, this phenomenon can be related to the presence of droughts and floods (see, e.g., Valdés-Pineda et al., 2016). Thus, it may affect the Chilean agricultural sector (Santibáñez et al., 2008), as well as the national GDP (Cashin et al., 2017), and are expected to increase in frequency (Wang et al., 2017).

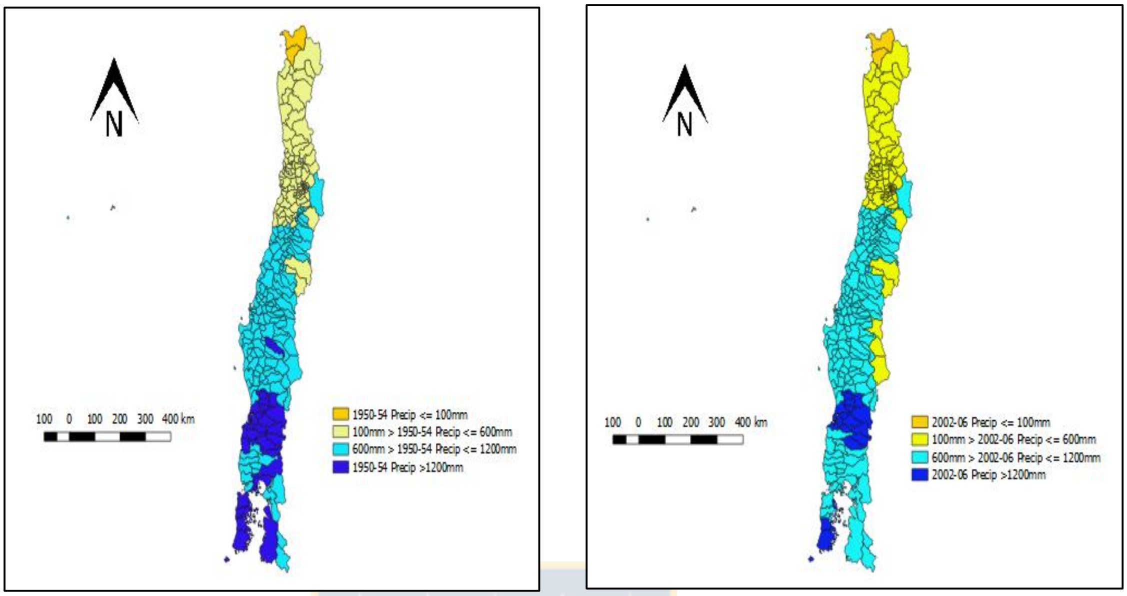

Figure 2.1. Average accumulate precipitations (mm) in Chile from 1950 to 1954 (left) and from 2002 to 2006 (right) for May to October.
Source: Own elaboration based on the CRU dataset TS 3.24.

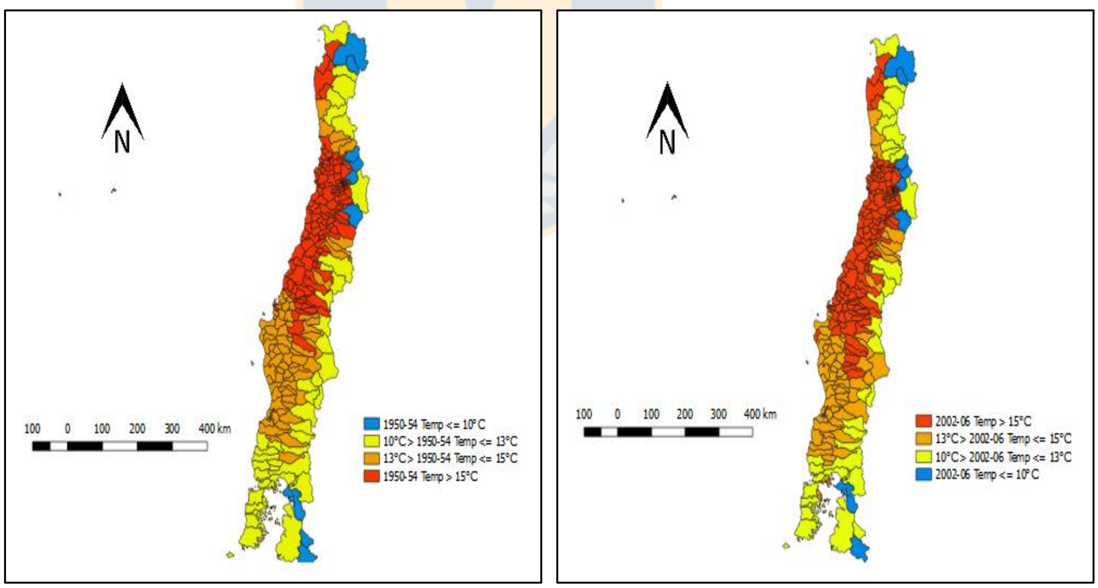

Figure 2.2. Average monthly temperatures in Chile from 1950 to 1954 (left) and from 2002 to 2006 (right) for September to March.
Source: Own elaboration based on the CRU dataset TS 3.24.

3. LITERATURE REVIEW

It is a fact the farmers must consider and handle a many of risks and uncertainties such as; weather conditions, changes in input and output prices, as well as political and technological uncertainties (Aimin, 2010). Many of these uncertainties are also expected to increase as global temperatures rise.

Catastrophic risks, such as floods and droughts, can also have an accumulative effect on decision and individual’s behavior (Cohen et al., 2008). It can also rise individual’s risk vulnerability, and according to Gollier and Pratt (1996), increase farmer’s background risk. This effect may induce individuals to take lower levels of risk activities, creating *ex ante* effects on farmers’ crop allocation decision. Following Salazar-Espinoza et al. (2015) weather risk can also be proxied as past realization of weather-related shocks.

Adaptation can be considered as a response to risk, associated to environmental hazards or human vulnerability (Smith and Wandel, 2006). One of the typical ways to deal with risks is by using insurance (Dercon, 2000). However, less than 1 % of the Chilean farmers use farm insurance, which mean that they rely on their own crop choices. As a result, to this, and in sense of the background risk (Gollier and Pratt, 1996), Chilean farmers may adapt by choosing low risk cropping activities instead of the ones with higher risks. According to the “farmers’ index of capital use and technology” presented by Santibáñez et al. (2008), Chilean farmers may prefer annual crops[6], such as cereals or legumes and tubers, instead of fruits or grapevines because they require less capital and less

[6] Legumes and tubers, industrial crops and cereals.

technology.

From an agronomic point of view, during a drought farmers' may prefer crop categories that have shorter growing periods and, therefore, lower water requirements. The latter is based on the crop coefficient7 criteria described by Allen et al. (1998). When it comes to floods farmers' may prefer crops that can be planted at the end of the winter season. This is because floods can affect all type of crops, but its relevance will depend on the timing (i.e., planting season), severity and length of the flood (Kozlowski, 1982). Some of the agro-productive strategies against droughts developed in central Chile during 2007/2008 are the reduction of the cultivated area and the prioritization of crops (Meza, 2010). For floods, we can mention the tile drainage and the subsurface tile drainage.

Some of the studies that relate climate and agriculture are those using the General Equilibrium approach (see, e.g., Ahmed et al., 2012; Calzadilla et al., 2013; Ponce et al., 2015). This approach uses Computable General Equilibrium methods (CGE) to simulate the equilibrium theory formalized by Arrow and Debreu (1954) (Ponce et al., 2012). Another approach in the economic literature is the Ricardian approach (see, e.g., Mendelsohn et al., 1994; Seo and Mendelsohn, 2008a; González and Velasco, 2008; Mendelsohn et al., 2010; Wood and Mendelsohn, 2015; Van Passe et al., 2017). These studies discuss how climate variables, such as soil, temperatures and precipitation affect farmers' revenue and land value (using most of the time linear models). Here, for example,

[7] This crop coefficient (Kc) is a factor for estimating crop water requirements. It integrates: crop type, climate, soil evapotranspiration and growth stage.

Seo and Mendelsohn (2008a) studied how the climate may impact on South America agriculture using farmland values. They concluded that temperature and precipitations increase would be harmful to farmland values and that this effect may have may vary across the region, having greater consequences in the Amazons and Equatorial regions. In a similar study for Chile, González and Velasco (2008), concluded in that changes in temperature and precipitation show less impact on the land value, than in other warmer regions of America. They also concluded that an increase on precipitation and temperatures may lead to better land values.

Another approach in the economic literature is related to understand how farmers adapt to the climate (see e.g., Kurukulasuriya and Mendelsohn, 2007; Seo and Mendelsohn, 2008b; Wang et al., 2010; Bezabih and Di Falco, 2012; Salazar-Espinoza et al., 2015). Here, with a multinomial choice model Seo and Mendelsohn (2008b) studied how South American farmers adapt by changing their crops. They studied how the seven most popular crops in the region (maize, potato, rice, soybean, squash and wheat) responded to climatic variables such as temperatures and precipitations. Their conclusion was that farmers that work in colder regions are more likely to choose potatoes and wheat, while those that work in regions with average temperatures tend to choose maize, soybeans and rice. Farmers in warm locations choose fruits and vegetables and squash. Similar studies were done in Africa (Kurukulasuriya and Mendelsohn, 2007) and in China (Wang et al., 2010). These two studies estimated farmers' crop choice in response to temperature and precipitations. Later, with data from Mozambique Salazar et al. (2015) studied how farmers shifted land use patterns after weather shocks (droughts and floods). Using a Pooled Fractional model, they concluded that crop choices are sensitive to recent weather shocks and that the farmers are more responsive to more severe droughts. They also found that farmers tend to relocate farms from high risk to lower risks cropping activities.

4. EMPIRICAL STRATEGY

To analyze the effect of weather events on farmers cropland decisions we propose estimating two models; the Multivariate Fractional Model for cross-sectional data (Mullahy, 2015) and the Pooled Fractional Probit (Papke and Wooldrige, 2008). The latter will be reviewed in the robustness section.

The Multivariate Fractional Logit (MFL)

Based on Mullahy (2015), we consider a random sample of $i = 1, \ldots, N$ farmers. The variable of interest is $0 \leq y_{ik} \leq 1$, which represents the share of cropland for k-th, $k = 1, \ldots, M$, crop category for the i-th individuals. This is:

$$E[y_{ik}| \, x_i, z_{it-1}] = G(x_i\beta_k + z_{it-1}\gamma_k) \in (0,1), \;\; k = 1, \ldots, M. \qquad (1)$$

$$\sum_{m=1}^{M} E[y_{ik}| \, x_i, z_{it-1}] = 1 \qquad (2)$$

Where x_i represents the vector of the producer, household and farm physical characteristics, and z_{it-1} represents the vector of past weather characteristics (e.g., drouths and floods) that we will present later on. The coefficients β and γ are the parameters to be estimated. G represents the linking function, which in this case corresponds to the logarithmic function, Λ. Thus, the conditional mean of our empirical model is:

$$E[y_{ik}|\ x_i, z_{it-1}] = \frac{exp\ (x_i\beta_k + z_{it-1}\gamma_k\ )}{\sum_{m=1}^{M} exp(\ x_i\beta_k + z_{it-1}\gamma_k\ )},\ \ k = 1, \dots, M. \qquad (3)$$

Mullahy (2015) suggests the estimation procedure proposed by Papke and Wooldrige (1996). This is a Quasi-Maximum Likelihood method (QML) which relies on the Bernoulli log-likelihood function[8], $Q(\cdot)$.

$$Q(\beta, \gamma) = \prod_{i=1}^{N}\prod_{m=1}^{M} E[y_{ik}|\ x_i, z_{it-1}]^{y_{im}} \qquad (4)$$

Which is maximized to obtain the QML estimator:

$$J(\beta, \gamma) = log\ (Q(\beta, \gamma)) = \sum_{i=1}^{N}\sum_{m=1}^{M} y_{im} \cdot log\ E[y_{ik}|\ x_i, z_{it-1}] \qquad (5)$$

Then, the partial effects are obtained.

$$PE_{imk} = \frac{\partial E[y_{im}|x_i, z_{it-1}]}{\partial[x_{ik}, \mathrm{z_{ik}}]} \qquad (6)$$

Finally, the estimated average partial effects (APE) are given by:

$$\widehat{APE}_{jk} = \frac{1}{N}\sum_{i\,=\,1}^{N} \widehat{PE}_{imk} \qquad (7)$$

[8] This allow us the possibility that the dependent variable can take corner values or and values in between.

5. DATA

This study uses data with individual and communal characteristics from the Chilean 6th and 7th National Agriculture and Forestry Census. This information is combined with geospatial and biophysical data with communal characteristics (e.g., temperatures, precipitations, droughts, floods and erosion) obtained from the British Ministry of East Anglia’s Climatic Research University (CRU), Global SPEI database, the Dartmouth Flood Observatory and the and the Chilean Center for Natural Resources Information (CIREN).

5.1. SOCIODEMOGRAPHIC AND AGRICULTURAL DATA

The Chilean 6th and 7th National Agriculture and Forestry Census[9] (INE, 1997; 2007) report surveyed data, aggregated at different levels. The 6th census contains aggregated communal information, while the 7th census contains more detailed information at farmer’s level. The data reported from these two Census provide information on farmers’ sociodemographic and productive characteristics such as land distribution, type of irrigation system, use of credit, among others. Notice that, at the moment of this study, this was the only public data available that represents Chilean agriculture.

Because most of the farms are located in central Chile, we have excluded the regions located in the extreme north and the extreme south of country. Hence, we

[9] The surveyed data for the 6th census was taken from 31.03.1997 to 30.05.1997. The data included all information of agricultural year 1996-97.
The surveyed data of the 7th was taken from 12.03.2007 to 31.05.2007. The data included all crops cultivated by the producer during the census’ year (from 01.05.2006 to 30.04.07).

have only included the following regions: Coquimbo, Valparaiso, Libertador General Bernardo O'Higgins, El Maule, Bio-Bio, La Araucaria, Los Rios, Los Lagos and the Metropolitan Region. To identify small-scale farmers, we used the criterion used by the Ministry of Agriculture based on size. This mean, we selected those farmers that hold 12 or fewer HBI.

The sociodemographic and agricultural characteristics were divided into three groups: Crop categories, producer's characteristics and farm's characteristics, as shown in Table 5.1. Regarding crop categories we have cereals (CERP), legume and tubers (LTOR), industrial crops (CINDU), grapevines (VINPL), fruits (FRUT), seed crops (CSEED), vegetables[10] (VEGT), and land under "set aside" scheme (BARB).

Producer's characteristics include a dummy variable for the gender of the producer which takes the value 1 for males (GENDER), an age index for the producer (AGE), an education index for the producer (EDU), the total number of plots in an agricultural exploitation (TPRD), the total area of usable land (AAGRI), the proportion of the farm owned by the producer (TCTP), and wheat yield per hectare[11] (RENDHA).

Farm's characteristics include the type of exploitation, which is a categorical variable, where 1 means unique exploitation, 2 means main exploitation, and 0 means complementary exploitation (TEXPLO), the proportion of the farm with

[10] This category includes vegetables and flowers.
[11] Quintal per hectare or 100 Kg per hectare.

modern[12] irrigation systems (SRMOD), the proportion of the farm with traditional[13] irrigation systems (SRTRAD), a set of dummy variables for; the use of technology[14] (USTEC), the use of credits[15] (USCRED), the use of any governmental instrument of support[16] (USFOM), the use of any other type support[17] (USOINS), and a dummy variable for those that belong to an farm association (ASOC), where the value 1 means that the individual has the desired attribute.

[12] Micro-sprinkling, microjet, drip and pivot.
[13] Furrow, strip irrigation or other traditional irrigation method.
[14] Certified seeds, biologic pest control, organic farming and fertirrigation.
[15] Bank credit, INDAP credit or other.
[16] SIRSD (degraded soil program), ProChile-FPEA, Law N°18,450 (irrigation) and Law N° 19,561.
[17] INDAP, GTT, CORFO, FIA, BPA, PABCO, SENCE and insurances.

Table 5.1. Summary statistics for the small-scale farmers.

Variable	Mean	Std. Dev.	Min	Max
Crop categories				
CERP	2.451	5.2297	0.1	261.9
LTOR	0.7482	1.6783	0.05	80
CINDU	2.9954	4.7539	0.1	130
VINPL	1.5857	3.1053	0.01	127
FRUT	0.6438	2.2917	0.05	500.3
CSEED	3.5948	5.6201	0.02	74
VEGT	0.5198	1.5451	0.001	210
BARB	3.0246	5.6342	0.03	200
Producer´s characteristics				
GENDER	0.7009	0.4579	0	1
AGE	56.415	12.669	20	70
EDU	6.4614	4.2709	0	17
TPRD	1.5602	1.5126	0	200
AAGRI	2.4308	5.3012	0.001	500.9
TCTP	0.896	0.2439	0	1
RENDHA	24.634	13.432	0	76
Farm's characteristics				
TEXPLO	1.0407	0.2705	0	2
SRMOD	0.0192	0.1088	0	1
SRTRAD	0.1817	0.3268	0	1
USTEC	0.1848	0.3881	0	1
USCRED	0.2024	0.4018	0	1
USOINS	0.1856	0.3888	0	1
USFOM	0.1293	0.3355	0	1
ASOC	0.1355	0.3422	0	1
Regional characteristics				
REG5	0.046	0.2096	0	1
REG6	0.0765	0.2658	0	1
REG7	0.1367	0.3436	0	1
REG8	0.228	0.4195	0	1
REG9	0.2325	0.4224	0	1
REG10	0.1293	0.3356	0	1
REG13	0.0328	0.1782	0	1
REG14	0.0639	0.2446	0	1

Source: Own elaboration based on data from the 7th National Agriculture and Forestry Census.

Notes: CERP: Cereals, LTOR: Legumes and tuber, CINDU: Industrial crops, VINPL: grapevines, FRUT: fruits, CSEED: seed crops, VEGT: vegetables and flowers, BARB: set-aside, GENDER: for gender of the producer, AGE: age of the producer, EDU: education of the producer, TPRD the total number of plots in an exploitation, AAGRI: total usable land, TCTP: proportion of the farm owned by the producer, RENDHA: wheat yield (quintal per hectare), TEXPLO: type of exploitation, SRMOD: area with modern irrigation system, SRTRAD: area with traditional irrigation system, USTEC: use of technology, USCRED: use of credits, USOINS: any other type of support, USFOM: use of any governmental instrument of support, ASOC: association, REG4: Coquimbo, REG5: Valparaiso, REG6: Libertador General Bernardo O'Higgins, REG7: El Maule, REG8: Bio-Bio, REG9: La Araucaria, REG10: Los Rios, REG13:Metropolitan Region, REG14: Los Lagos.

5.2. GEO-SPATIAL AND BIOPHYSICAL DATA

5.2.1. DROUGHT IDENTIFICATION

For drought identification we use the Standardised Precipitation-Evapotranspiration Index (SPEI). This drought index that was proposed by Vicente-Serrano et al. (2010) and can be used as an alternative to other drought index such as the Palmer Drought Severity Index[18] (PDSI; Palmer, 1965) and the Standardised Precipitation Index[19] (SPI; McKee et al., 1993) since it combines features from both. Briefly, the climatic water balance proposed by Vicente-Serrano et al. (2010). was first calculated as the following:

$$D_i = P_i - PET_i \tag{8}$$

Where P_i is the precipitation, PET_i the potential evapotranspiration and D_i their differences at different time scales. Later, they changed the PET for the FAO-56 Penman–Monteith equation presented in Allen et al. (1998). For this study we used the SPEI 6 months, from where, for February for 2006/1996 (t - 1) and for February 2005/1995 (t – 2), from September to February. This period covers the time in the year where crops require more water for their physiological growth across Chile. We used the SPEI 12 months for February, from 1950 to 2006/1996, to create an historical ratio of droughts which will capture the background risk of the farmers to the droughts. To understand farmers' response, we isolated the SPEI index to those values that report moderate and/or severe/extreme drought (Table 5.2).

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[18] Based on the soil water balance.
[19] Based on the probability of precipitations.

Table 5.2. Drought classification used for the SPEI Index.

Drought class	SPEI value
Non-drought	SPEI ≥ 0
Mild drought	-1 < SPEI < 0
Moderate drought	-1.5 < SPEI ≤ - 1
Severe / Extreme drought	SPEI ≤ - 1.5

Source: McKee et al., 1993; Alam et al., 2017.

Since the SPEI index provides information at a global level, with 0.5° spatial resolution. We transformer the information to communal data using GIS. Figures 5.1 and 5.2 presents the areas affected by the droughts during the evaluated periods.

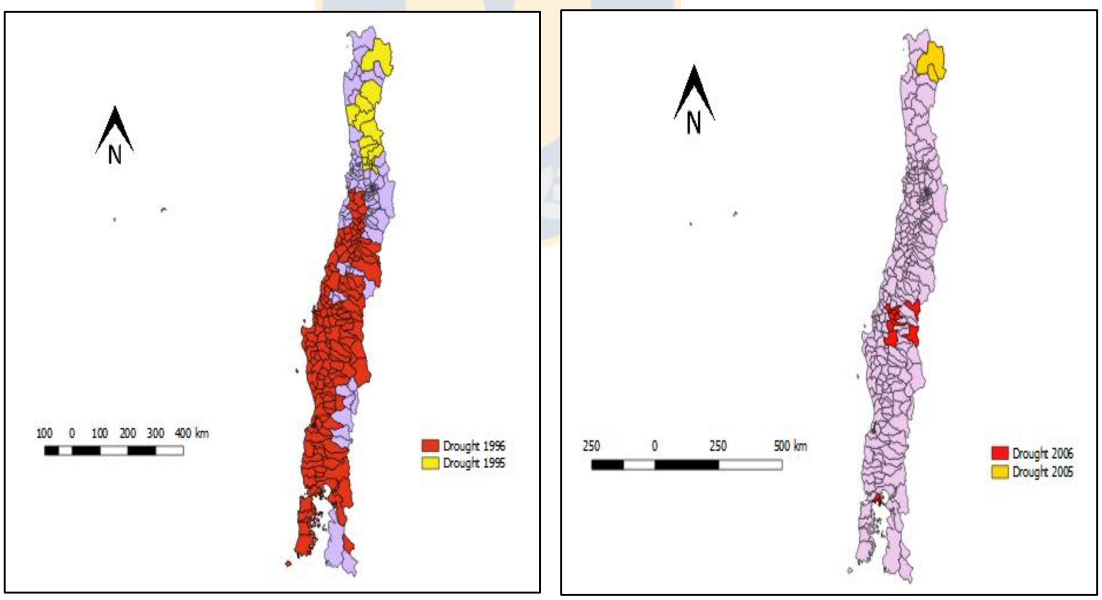

Figure 5.1. Drought and communal identification based on the 6-months SPEI dataset for February 1995/96 (left) and 2005/06 (right).

Source: Own elaboration based on the SPEI base v.2.5.

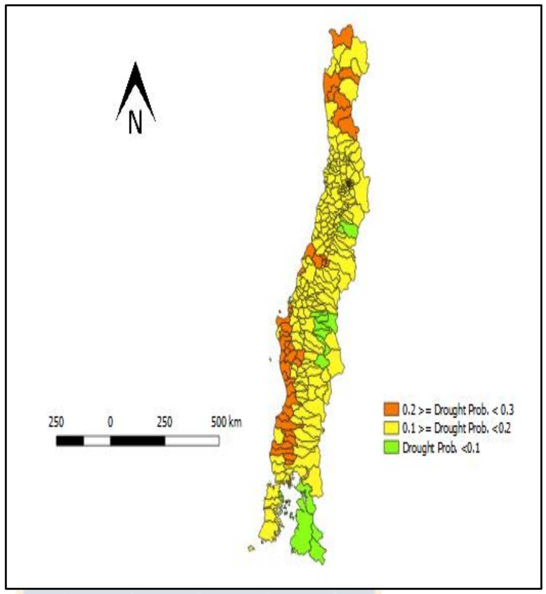

Figure 5.2. Drought probably and communal identification based on 12-months SPEI dataset. Data from 1950 to 2006.
Source: Own elaboration based on the SPEI base v.2.5.

5.2.2. FLOOD IDENTIFICATION

To identify the flooded areas, we use geospatial data from the Dartmouth Flood Observatory. The Dartmouth Flood Observatory obtained the data from different sources such as news, governmental, instrumental and remote sensing sources. As for the droughts, to understand farmers response to these weather events, we identified those flood events that were classified at least as class 1 or large (See Appendix 6). This type of flood events indicates significant damage to structures or agriculture; fatalities; and/or 1 – 2 decades-long reported intervals since the last similar event (Brakenridge, 2017). In the sense of the background risk we created an historical ratio of floods with data from 1986 to 2005. Notice that for the Chilean case, differed in duration and extension but the main cause of these events were heavy rain.

Similarity to what was done with the SPEI index, flood information was also transformed to communal data using GIS. Here, we assigned these environmental values to their respective communes by overlapping the data, as shown in Figures 5.3 and 5.4.

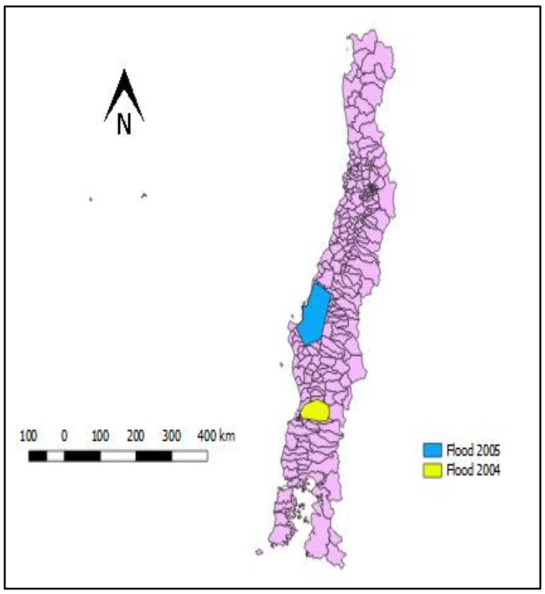

Figure 5.3. Polygons of flooded areas and communes in Chile. Data for 2004 and 2005.
Source: Own elaboration based on data from the Dartmouth flood observatory.

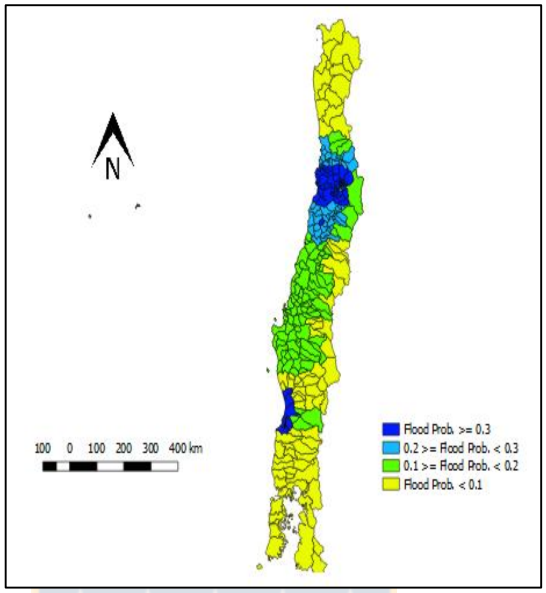

Figure 5.4. Probabilities of Floods. Data from 1986 to 2005.
Source: Own elaboration based on data from the Dartmouth Flood Observatory.

5.2.3. OTHER GEO-SPATIAL AND BIOPHYSICAL VARIABLES

Communal shapefiles were obtained from Albers (2016) and their level of communal erosion from CIREN (2010). Temperatures and precipitations were taken from the CRU TS 3.24 dataset and they transformed to communal data using GIS.

Summary statistics for the geospatial data are presented in Table 5.3. The variables were aggregated into two categories: Climatic characteristics and Soil characteristics. Regarding climate's characteristics, we include average temperature (°C) from mars 1994/2004 to mars 1996/2006 (TPROM), average precipitation (mm) from mars 1994/2004 to mars 1996/2006 (PPROM), a dummy variable for the SPEI 6 months for February 1996/2006 which takes the value 1 for mild drought or higher (DUGHT t - 1), a dummy variable for the SPEI 6 months for February 1995/2005 which takes the value 1 for mild drought or higher (DUGHT t - 2), a historical ratio of mild drought or higher taken from the SPEI 12 months from 1950 to 2006 (DROUST), a dummy variable for the flood event registered during 1995/2005 (FLOOD t - 1), a dummy variable for the flood event registered during 1994/2004 (FLOOD t - 2), a historical ratio of floods from 1986 to 2005 (FLOODST). Similarly, soil's characteristics include the communal ratio of soil erosion (EROSION).

Table 5.3. Summary statistics of the geospatial and biophysical data at communal level.

Variables	1997		2007	
	Mean	**Dev.**	**Mean**	**Dev.**
Climate's characteristics				
TPROM	12.47244	2.27533	11.16022	2.570646
PPROM	60.64338	42.12381	61.68658	26.53364
DROU (t-1)	0.527869	0.500043	0.038869	0.193626
DROU (t-2)	0.432787	0.496276	0.190813	0.393638
DROUST	0.154811	0.056459	0.16469	0.049433
FLOOD (t-1)	0	0	0.120438	0.326069
FLOOD (t-2)	0	0	0.021898	0.146618
FLOODST	0.07483	0.118202	0.151364	0.100821
Soil's characteristics				
EROSION	-	-	0.472123	0.290465

Source: Own elaboration based on the CRU dataset TS 3.24, the SPEI base v.2.5 and data from the Dartmouth Flood Observatory and CIREN.
Notes: TPROM: average temperature (°C) from mars 1994/2004 to mars 1996/2006, PPROM: average precipitation (mm) from mars 1994/2004 to mars 1996/2006, DUGHT t - 1: dummy of SPEI 6 months for February 1996/2006, DUGHT t - 2: dummy of SPEI 6 months for February 1995/2005, DROUST: historical ratio of droughts from 1950 to 1996/2006, FLOOD t - 1: dummy of floods during 1995/2005, FLOOD t - 2: dummy of floods during 1994/2004, FLOODST: ratio of floods from 1986 to 1995/2005.

6. RESULTS

The main results that correspond our base model (equation 7 from section 4) are presented in Table 6.1 (see also Appendix 1). The reported partial (marginal) effects and their p-values are based on robust standard errors.

From our results, as for Salazar-Espinoza et al. (2015), small-scale farmers are sensitive to past weather events. However, they response depends on the level of refinement of the data and the evaluated period. Covariables in t – 1 and t – 2 account for the effect of droughts and/or floods one and two years before period t, respectively. Differences in their magnitudes and signs from one to another period can be related to the stabilization or the compensation of the cultivated area given the over production or the lack of production after a drought or a flood. Similarly, the persistence of the negative response two years after the flood or the drought, in most cases, can be linked to the persisting damages after the event.

6.1. SMALL-SCALE FARMING (BASELINE MODEL)

Response to droughts and floods

One year after a drought (Table 6.1), small-scale farmers may reduce their land share of legumes and tubers and the set-aside option while increase their land share of vineyards and fruits. The reason to this can be linked to the prioritization of water resources to the permanent crops[20]. This logic is in line to what Meza et al. (2010) pointed out as one of the private strategies to manage droughts in

[20] Fruits and vineyards.

central Chile. As we will see later, this strategy will depend on whether the production takes place on dryland farming areas or not. Two years after a drought, we can also see that small-scale farmers tend to increase their land shared for vineyards, fruits, seed crops and the set-aside option. This time, the increase of the first three crop categories can be linked to the stabilization of the investment two years after the drought. In an opposite way, the increase in the set-aside option and the decrease in industrial crops can be associated to the persistence of damages after two years of a drought.

Floods seems to have a greater effect than droughts on farmer’s decisions. However, this depends on the level of refinement of the data. From the results, is interesting to see the different response that the farmers may have to cope with the effects of the droughts or the floods one and two years after the event. One year after a flood, small-scale farmers may increase their land share proportion to vineyards, legumes and tubers, and the set-aside option, and they may reduce cereals, industrial crops and vegetables. Two years after a flood, they may increase their land share to all crop categories with exception to the industrial crops and the vineyards. The positive response of the crop categories one year after a flood may be linked to the selection of crops that can be planted after the winter (or rainy season) or that are less likely to be affected by a flood (e.g., permanent crops, since they are under dormancy during the winter season). The negative effects may be associated to the losses that farmers may have after one year a flood. As for droughts, changes in the second year can be attributed to the overproduction or the lack of production among the different categories the year before.

Cropland decisions are also affected by producer´s and farm's characteristics (See Appendix 1). Overall, males are more likely to plant crop categories such as cereals and legumes and tubers, while women are more likely to plant fruits and vegetables. Age, education and tenancy seem to be related to the selection of permanent crops while the total number of farms and their size seem to have a negative effect on the selection of the same crop categories.

Farms' characteristics, such as the presence of modern irrigation systems (e.g., micro-sprinkling, microjet, drip and pivot) and the access to private and/or governmental programs are relevant for the selection of permanent crops. Meanwhile, the use of technology (e.g., Certified seeds, biologic pest control, etc.) and the access to governmental promotion instruments are associated to the increase of annual crops. Traditional irrigation systems (e.g., furrow, strip irrigation) have positive effect on all crop categories. Communal erosion and the regional distribution also have a relevant effect on farmers decisions.

Table 6.1. APE of the MFL for the farmers response to the weather (Baseline model).

Variables	CERP	LTOR	CINDU	VINPL	FRUT	VEGT	CSEED	BARB
DROU (t-1)	0.004	-0.215***	-0.004	0.020***	0.200***	0.005	0.005	-0.016*
	(0.011)	(0.015)	(0.009)	(0.003)	(0.013)	(0.012)	(0.003)	(0.009)
DROU (t-2)	-0.082	-0.003	-0.441***	0.132***	0.189***	0.046	0.007*	0.151***
	(0.105)	(0.038)	(0.012)	(0.009)	(0.031)	(0.038)	(0.004)	(0.021)
DROUST	-0.157***	0.421***	-0.108***	0.193***	-0.210***	-0.169***	0.001	0.029
	(0.036)	(0.024)	(0.011)	(0.029)	(0.039)	(0.038)	(0.008)	(0.031)
FLOOD (t-1)	-0.074***	0.040***	-0.035***	0.024***	0.011	-0.028***	0.003	0.057***
	(0.007)	(0.005)	(0.005)	(0.004)	(0.009)	(0.008)	(0.002)	(0.005)
FLOOD (t-2)	0.087***	0.038***	-0.040***	-0.481***	0.244***	0.074***	0.005***	0.072***
	(0.012)	(0.006)	(0.014)	(0.020)	(0.010)	(0.008)	(0.002)	(0.011)
FLOODST	0.290***	-0.261***	0.054***	0.336***	-0.399***	0.234***	-0.030**	-0.224***
	(0.041)	(0.029)	(0.011)	(0.036)	(0.044)	(0.042)	(0.006)	(0.032)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dummy Region	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	68,394	68,394	68,394	68,394	68,394	68,394	68,394	68,394

Source: Own elaboration based on the CRU dataset TS 3.24, the SPEI base v.2.5 and data from the Dartmouth Flood Observatory, CIREN and the 7th National Agriculture and Forestry Census.
Notes: CERP: Cereals, LTOR: Legumes and tubers, CINDU: Industrial crops, VINPL: grapevines, FRUT: fruits, CSEED: seed crops, VEGT: vegetables and flowers, BARB: set-aside, DUGHT t - 1: dummy of SPEI 6 months for February 2006, DUGHT t - 2: dummy of SPEI 6 months for February 2005, DROUST: historical ratio of droughts from 1950 to 2006, FLOOD t - 1: dummy of floods during 2005, FLOOD t - 2: dummy of floods during 2004, FLOODST: ratio of floods from 1986 to 2005. Robust standard errors are shown in parentheses. Legend: * p<0.05; ** p<0.01; *** p<0.001.

Response to the background risk.

From the effect of the background risk associated to droughts (Table 6.1), we can say that legumes and tubers and vineyards are more likely to be planted in areas with higher probabilities of drought. Similarly, cereals, industrial crops, fruits and vegetables, are less likely to be panted in the same areas. One of the reasons to the positive response of vineyards could be related to the benefits that farmers may have by planting some it varieties in dry areas. There are some agricultural techniques where vineyards are exposed to hydric stress to produce wines with better quality (Romero et al., 2013). The increasement of legumes and tubers can be associated to a shorter growing period (See Appendix 9) and their lower capital and technological requirements (See Appendix 10). Here, for example, potatoes represent the 70 % of this crop category and they can be harvested 140 days after planting. The effects of the background risk associated to floods are, in most cases, opposite to the effect associated to droughts. Cereals, Industrial crops, vineyards and vegetables are more likely to be planted in areas with high probabilities of flood while legumes and tubers, fruits and seed crops are less likely to be planted in the same areas. The opposite response between historical floods and droughts may be farmers adaptation and, hence, to the selection of crops that are more suitable to their climatic conditions.

6.2. DRYLAND AGRICULTURE

Dryland farming is a term that can be associated to agricultural activities that are located in areas where the lack of water limits crop production (Steward et al., 2006). In Chile, dryland farming is specific to some regions, such as the coastal, the interior, the little north and the intermediate depression's drylands. These areas have a high level of erosion (CIREN, 2010) and most of the farmers rely only on seasonal rainfall to their agricultural activities. Estimated APE for the subsample of farmers in dryland agriculture are presented in Table 6.2.

From Table 6.2, we can see that, one year after a drought, farmers are more likely to increase their land share to cereals, legumes and tubers and vegetables, while decrease industrial crops, vineyards, seed crops and the set-aside option. This response seems to be more in line to the risk behavior that we are expected to see in farmers decisions. The selection of the first three crop categories may be linked to lower technological and capital requirements that they may have when comparing them with the other categories (See Appendix 10). In the same manner, two years after a drought, we can see a decrease of the land share of all crops categories and an increment in the set-aside option associated negative consequences the drought two years after.

The effect of the background risk for droughts is showing that dryland farmers are adapting to these conditions by planting only vineyard and vegetables in these areas. Again, this can be explained by the benefits that the farmers can have by exposing vineyards to drought conditions and because of the great variety of species, and planting periods, that the vegetables have. As presented in ODEPA (2017) some vegetables can be planted during spring, summer or autumn and they also have short growing period, making them more suitable for the dryland farmers to adapt to the droughts conditions

When we compare floods in dryland conditions with our baseline model, we can see its positive effect in legumes and tubers and vineyards, but a negative effect on fruits, vegetables and seed crops. As before, the positive response may be liked to the selection of crop categories that can be planted after the winter while the reduction of fruits, vegetables and seed crop may be linked to the damages associated to the floods. The variation of the effects one and two years after a flood may related to the over production or the lack of production of the previous year. The effect of the background risk for floods is only positive for cereals and vineyards, which may be linked to the adaptation of the dryland farming to these conditions. However, the positive response and the magnitude of the set-aside option may be showing the destructive effects of the floods on dryland conditions. As indicated before, dryland farming is often associated to areas with high levels of erosion and therefore the effects foods may be stronger.

Table 6.2. APE of the MFL for the farmers in dryland agriculture.

Variables	CERP	LTOR	CINDU	VINPL	FRUT	VEGT	CSEED	BARB
DROU (t-1)	0.041***	0.018***	-0.012***	-0.006**	0.007	0.025***	-0.018***	-0.053***
	(0.005)	(0.004)	(0.003)	(0.003)	(0.004)	(0.003)	(0.002)	(0.007)
DROU (t-2)	-0.918***	-0.486***	-0.023***	-0.192***	-0.299***	-0.167***	-0.006***	2.091***
	(0.012)	(0.009)	(0.003)	(0.009)	(0.009)	(0.007)	(0.001)	(0.018)
DROUST	-0.305***	-0.303***	-0.087***	0.472***	-0.092***	0.223***	-0.008***	0.101***
	(0.034)	(0.027)	(0.008)	(0.030)	(0.026)	(0.020)	(0.003)	(0.034)
FLOOD (t-1)	0.004	0.253***	-0.002	0.054***	-0.120***	-0.173***	-0.021***	0.006
	(0.006)	(0.008)	(0.003)	(0.002)	(0.011)	(0.011)	(0.002)	(0.005)
FLOOD (t-2)	0.292***	0.163***	-0.009	-0.724***	0.143***	0.087***	0.001	0.047***
	(0.009)	(0.006)	(0.008)	(0.009)	(0.004)	(0.003)	(0.001)	(0.011)
FLOODST	0.149***	-1.406***	-0.152***	0.815***	-0.793***	-0.303***	0.004*	1.686***
	(0.025)	(0.036)	(0.015)	(0.014)	(0.036)	(0.027)	(0.001)	(0.016)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dummy Region	No	No	No	No	No	No	No	No
Observations	58,922	58,922	58,922	58,922	58,922	58,922	58,922	58,922

Source: Own elaboration based on the CRU dataset TS 3.24, the SPEI base v.2.5 and data from the Dartmouth Flood Observatory, CIREN and the 7th National Agriculture and Forestry Census.
Notes: CERP: Cereals, LTOR: Legumes and tubers, CINDU: Industrial crops, VINPL: grapevines, FRUT: fruits, CSEED: seed crops, VEGT: vegetables and flowers, BARB: set-aside, DUGHT t - 1: dummy of SPEI 6 months for February 2006, DUGHT t - 2: dummy of SPEI 6 months for February 2005, DROUST: historical ratio of droughts from 1950 to 2006, FLOOD t - 1: dummy of floods during 2005, FLOOD t - 2: dummy of floods during 2004, FLOODST: ratio of floods from 1986 to 2005. Robust standard errors are shown in parentheses. Legend: * p<0.05; ** p<0.01; *** p<0.001.

6.3. BY CROPS IN DRYLAND

Table 6.3 presents the estimated APE for the subsample of the most planted crops in Chile; white wheat (TRIG), maize (MAIZ) and potatoes (POTT), in dryland conditions. Notice that white wheat and maize belong to the cereals, while the potatoes belong to the legumes and tubers. The remaining crops species for the cereals and the legumes and tubers are gathering in nontraditional cereals (NTCR) and nontraditional legumes and tubers (NTLT). The other crop categories (vineyards, fruits, etc.) are included in this model, but their corresponding effects are not reported to conserve space.

From the results, after a drought, farmers may prefer to plant white wheat, nontraditional cereals (e.g., barley, triticale, etc.) and nontraditional legumes and tubers (e.g., chickpea, beans, etc.) rather than potatoes and maize. Two years after the drought, they may not prefer to plant any of these traditional and nontraditional crops. As before, this effect can be linked to negative consequences the drought and to the difficulties that dryland farmers may have to cope with this effect two years after it. Still, given the relevance of this sector and these traditional crops, this effect may also have negative consequences in the national market by reducing the national supply of these products and, therefore, increasing their prices. The background risk for droughts is showing that the farmers may reduce their land share to white wheat and other nontraditional cereals while they will increase their land share to other nontraditional legumes and tuber. The latter can also be linked to crop rotation we are not considering this variable.

After a flood, farmer may increase their land share proportion to other nontraditional legumes and tuber, while after the second year they may prefer any of these crops with exception to maize. As before, differences in signs and magnitudes between one year to another may be linked to the normalization of the production. From the background risk we can see that farmers may adapt by preferring white wheat and maize.

Table 6.3. APE of the MFL for the farmers in dryland agriculture by crops.

Variables	TRIG	MAIZ	POTT	NTCR	NTLT
DROU (t-1)	1.269***	-0.129***	-1.196***	0.851***	0.088***
	(0.018)	(0.008)	(0.021)	(0.016)	(0.008)
DROU (t-2)	-0.675***	-0.039***	-0.080***	-0.349***	-0.148***
	(0.014)	(0.003)	(0.015)	(0.010)	(0.007)
DROUST	-0.479***	0.008	0.024	-0.098***	0.382***
	(0.034)	(0.006)	(0.027)	(0.023)	(0.018)
FLOOD (t-1)	0.006	-0.011***	-0.131***	0.099***	-0.001
	(0.007)	(0.002)	(0.018)	(0.005)	(0.001)
FLOOD (t-2)	0.226***	-0.076***	0.034***	0.145***	0.000***
	(0.011)	(0.005)	(0.005)	(0.007)	(0.000)
FLOODST	0.121***	0.039***	-0.796***	-0.275***	-0.004*
	(0.025)	(0.003)	(0.028)	(0.023)	(0.002)
Control	Yes	Yes	Yes	Yes	Yes
Dummy Region	No	No	No	No	No
Observations	40,255	40,255	40,255	40,255	40,255

Source: Own elaboration based on the CRU dataset TS 3.24, the SPEI base v.2.5 and data from the Dartmouth Flood Observatory, CIREN and the 7th National Agriculture and Forestry Census.
Notes: TRIG: wheat, MAIZ: maize, POTT: Potatoes, NTCR: nontraditional cereals, NTLT: nontraditional legumes and tubers, DUGHT t - 1: dummy of SPEI 6 months for February 2006, DUGHT t - 2: dummy of SPEI 6 months for February 2005, DROUST: historical ratio of droughts from 1950 to 2006, FLOOD t - 1: dummy of floods during 2005, FLOOD t - 2: dummy of floods during 2004, FLOODST: ratio of floods from 1986 to 2005. Robust standard errors are shown in parentheses. Legend: * p<0.05; ** p<0.01; *** p<0.001.

7. ROBUSTNESS

7.1. POOLED FRACTIONAL MODEL

One of the weakness of the cross-sectional data models is their limitation to control for time trends, time variating characteristics and address unobserved individual heterogeneity. This problem can be solved using panel data models. However, for this study there will be a tradeoff based on the number of individual observations and in the correlation among crop categories, which are the costs of using the Pooled Fractional Probit (PFP).

Based on Papke and Wooldrige (2008), let us consider a random sample of $i = 1, \ldots, N$ communes repeated across time $t = 1, \ldots, T$. The variable of interest is $0 \leq y_{it} \leq 1$, which represents the share of cropland to a crop category, as follows:

$$E[y_{it} | \, x_{it}, z_{it}, c_i \,] \; = \; \Phi(x_{it}\beta + z_{it-1}\gamma \; + c_i \,) \tag{9}$$

Where x_{it} represents the vector of the average producers, producers' household and farm characteristics at a communal level, and z_{it-1} represents the vector of past weather characteristics. The coefficients β and γ are the parameters to be estimated. c_i refers to individual-specific unobserved characteristics and Φ is the normal cumulative density function. To restrict the distribution of c_i, given the covariables, Papke and Wooldrige (2008) proposed a conditional normality assumption based on Chamberlain (1980):

$$c_i = \psi + \xi\overline{x_i} + \varphi\overline{z_i} + a_i \qquad (10)$$

Where $\overline{x_i} = T^{-1}\sum_{t=1}^{T} x_{it}$ and $\overline{z_i} = T^{-1}\sum_{t=1}^{T} z_{it-1}$ are vector of time average; and $a_i \sim \mathrm{N}(0, \sigma_a)$. With these assumptions, vectors β and γ and associate partial effects can be identified up to a positive scaling factor. Time dummies, which do not vary across i, are omitted from $\overline{x_\iota}$.

$$E[y_{it}|\, x_{it}, z_{it}, c_i\,] = \Phi(x_{it}\beta + z_{it-1}\gamma + \psi + \xi\overline{x_i} + \varphi\overline{z_i} + a_i\,) \qquad (8)$$

Then, we employ a standard mixing property of the normal distribution (Wooldridge, 2010):

$$E[y_{it}|\, x_{it}, z_{it}, c_i\,] = \Phi\left[\frac{(x_{it}\beta + z_{it-1}\gamma + \psi + \xi\overline{x_i} + \varphi\overline{z_i} + a_i\,)}{(1 + \sigma_a^2)^{1/2}}\right] \qquad (9)$$

And estimate via maximum likelihood treating σ_a^2 as a parameter to be estimated.

Estimated APE for the PFP are presented in Table 7.1. From the results, we can say that effects of a drought are stronger after two years of the event. This is because the only variable that is responding to this effect is in t - 2. Here, farmers seem to reduce their land share proportion to cereals and increase their land share to the set-aside option, which is in line to what we described in the baseline model.

When we look at the floods, they seem to have some consistence with some results, such as legumes and tubers and the set-aside option. However, some inconsistence can be seen in the other variables. The latter can be associated to the high level of aggregation of the data, lower number of observation, and the fact that we had zero floods during 1995 and 1994 making the result less accurate capered to the cross-sectional model.

Table 7.1 APE of the PFP for the farmers response to the weather.

Variables	(1) CERP	(2) LTOR	(3) CINDU	(4) VINPL	(5) FRUT	(6) CSEED	(7) VEGT	(8) BARB
DROU (t-1)	-0.002	-0.008	0.004	0.009	0.005	0.0495	0.003	0.002
	(0.027)	(0.007)	(0.033)	(0.035)	(0.015)	(0.041)	(0.008)	(0.034)
DROU (t-2)	-0.103**	-0.023	0.100	-0.052	0.014	0.014	0.0121	0.100**
	(0.041)	(0.015)	(0.051)	(0.051)	(0.022)	(0.080)	(0.013)	(0.051)
FLOOD (t-1)	-0.028	0.019*	0.066	-0.029	0.0413	0.057	0.021*	-0.108*
	(0.037)	(0.010)	(0.051)	(0.062)	(0.028)	(0.074)	(0.011)	(0.055)
FLOOD (t-2)	0.097	0.028*	-0.208**	0.000	-0.002	-0.013	0.017	-0.365***
	(0.068)	(0.017)	(0.097)	(0.000)	(0.032)	(0.169)	(0.015)	(0.076)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dummy Region	No	No	No	No	No	No	No	No
Observations	502	499	387	317	515	356	516	447

Source: Own elaboration based on the CRU dataset TS 3.24, the SPEI base v.2.5 and data from the Dartmouth Flood Observatory, CIREN and the 6th and 7th National Agriculture and Forestry Census.
Notes: CERP: cereals, LTOR: legumes and tubers, CINDU: industrial crops, VINPL: grapevines, FRUT: fruits, CSEED: seed crops, VEGT: vegetables and flowers, BARB: set-aside, TPROM: average temperature (°C) from mars 1994/2004 to mars 1996/2006, PPROM: average precipitation (mm) from mars 1994/2004 to mars 1996/2006, DUGHT t - 1: dummy of SPEI 6 months for February 1996/2006, DUGHT t - 2: dummy of SPEI 6 months for February 1995/2005, FLOOD t - 1: dummy of floods during 1995/2005, FLOOD t - 2: dummy of floods during 1994/2004. Bootstrapped standard errors are shown in parentheses. (Replications = 500). Legend: * p<0.05; ** p<0.01; *** p<0.001.

7.2. RURAL POPULATION

Table 7.2 presents the estimated APE for the subsample of communes where the rural population represents at least 40 %. The level of urbanization is relevant, especially for floods since, as indicated by Konrad (2003), rainfalls in undeveloped areas have a lower effect than in urban areas due to the capacity to store the precipitations on the vegetation and the soil. Thus, the aim of this robustness is to provide a refinement of the APE for the floods.

As we can see in Table 7.2, the effects of droughts are similar to the ones our baseline model. Still, we see some differences two years after a drought, where small-scale farmers in rural communes may increase their land share to cereals and vegetables and reduce their land share proportion legumes and tubers. When we look at the background risk effect, these farmers may also prefer vegetables and reduce the set-aside option.

When we compare floods on Table 7.2 with Table 6.1, we can see that there is an overestimation of the effects of the floods in our baseline model. As explained before, the baseline model is considering communes with lower levels of rurality and therefor they are more affected by floods. When we compare the two models, we can se that after a flood three crops have a positive response in the rural population model, while only two in the baseline model. This may be indicating the positive effects that floods may have for some farmers. As mentioned by Few (2003), in some regions farmers may distinguish between beneficial and destructive floods because they irrigate and fertilize fields and recharge reservoirs. As for the baseline model, changes in the second year can be attributed to the overproduction or the lack of production among the different categories the year before. Background risk values are consistent with the baseline model.

Table 7.2. APE of the MFL for the farmers response to the weather by rural population.

Variables	CERP	LTOR	CINDU	VINPL	FRUT	VEGT	CSEED	BARB
DROU (t-1)	0.009	-0.257***	-0.031**	-0.029***	0.261***	0.088***	0.002	-0.044***
	(0.015)	(0.018)	(0.014)	(0.007)	(0.015)	(0.014)	(0.004)	(0.009)
DROU (t-2)	1.591***	-3.878***	-0.744***	0.411***	1.403***	0.866***	-0.106***	0.458***
	(0.122)	(0.046)	(0.024)	(0.014)	(0.047)	(0.086)	(0.010)	(0.029)
DROUST	-0.074	0.409***	-0.322***	0.637***	-0.476***	0.502***	-0.007	-0.669***
	(0.057)	(0.034)	(0.037)	(0.052)	(0.065)	(0.059)	(0.011)	(0.055)
FLOOD (t-1)	0.031**	0.037***	-0.049***	0.082***	-0.008	-0.096***	0.001	0.004
	(0.014)	(0.010)	(0.015)	(0.007)	(0.018)	(0.015)	(0.004)	(0.008)
FLOOD (t-2)	-0.124***	-0.112***	0.007	-0.094***	0.046**	-0.027	0.057***	0.245***
	(0.032)	(0.011)	(0.027)	(0.010)	(0.021)	(0.017)	(0.006)	(0.071)
FLOODST	-0.023	0.022	0.128***	0.687***	-0.467***	-0.164	-0.029	-0.153***
	(0.063)	(0.043)	(0.023)	(0.076)	(0.079)	(0.059)	(0.011)	(0.057)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dummy Region	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	30,839	30,839	30,839	30,839	30,839	30,839	30,839	30,839

Source: Own elaboration based on the CRU dataset TS 3.24, the SPEI base v.2.5 and data from the Dartmouth Flood Observatory, CIREN and the 7th National Agriculture and Forestry Census.
Notes: CERP: Cereals, LTOR: Legumes and tubers, CINDU: Industrial crops, VINPL: grapevines, FRUT: fruits, CSEED: seed crops, VEGT: vegetables and flowers, BARB: set-aside, DUGHT t - 1: dummy of SPEI 6 months for February 2006, DUGHT t - 2: dummy of SPEI 6 months for February 2005, DROUST: historical ratio of droughts from 1950 to 2006, FLOOD t - 1: dummy of floods during 2005, FLOOD t - 2: dummy of floods during 2004, FLOODST: ratio of floods from 1986 to 2005. Robust standard errors are shown in parentheses. Legend: * p<0.05; ** p<0.01; *** p<0.001.

In Table 7.3 we re-estimated the PFP model for the rural population (40 %). From the results we can see some consistence with our baseline model. However, as mentioned previously, given the high level of aggregation of the data and lower number of observation, there are some inconsistences that might be evaluated in future studies.

Table 7.3. APE of the PFP for the farmers response to the weather by rural population.

Variables	(1) CERP	(2) LTOR	(3) CINDU	(4) VINPL	(5) FRUT	(6) VEGT	(7) CSEED	(8) BARB
DROU (t-1)	0.014	0.012	-0.094	0.032	-0.008	0.014*	0.080	-0.070
	(0.027)	(0.012)	(0.072)	(0.073)	(0.024)	(0.008)	(0.078)	(0.070)
DROU (t-2)	-0.126*	0.052	0.092	0.052	0.020	-0.003	0.026	0.047
	(0.071)	(0.040)	(0.181)	(0.171)	(0.079)	(0.029)	(0.371)	(0.123)
FLOOD (t-1)	0.009	0.015	0.311	0.103	0.067*	0.010	-0.069	-0.392**
	(0.055)	(0.030)	(0.218)	(0.187)	(0.041)	(0.016)	(0.153)	(0.169)
FLOOD (t-2)	0.209***	0.008	-0.750***	0.000	0.023	0.0109	-0.139	0.084
	(0.037)	(0.015)	(0.094)	(0.000)	(0.028)	(0.009)	(0.099)	(0.075)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dummy Region	No	No	No	No	No	No	No	No
Observations	137	135	109	91	138	138	99	119

Source: Own elaboration based on the CRU dataset TS 3.24, the SPEI base v.2.5 and data from the Dartmouth Flood Observatory, CIREN and the 6th and 7th National Agriculture and Forestry Census.
Note: CERP: cereals, LTOR: legumes and tubers, CINDU: industrial crops, VINPL: grapevines, FRUT: fruits, CSEED: seed crops, VEGT: vegetables and flowers, BARB: set-aside, TPROM: average temperature (°C) from mars 1994/2004 to mars 1996/2006, PPROM: average precipitation (mm) from mars 1994/2004 to mars 1996/2006, DUGHT t - 1: communal ratio of SPEI 6 months for February 1996/2006, DUGHT t - 2: dummy of SPEI 6 months for February 1995/2005, FLOOD t - 1: dummy of floods during 1995/2005, FLOOD t - 2: dummy of floods during 1994/2004. . Bootstrapped standard errors are shown in parentheses. (Replications = 500). Legend: * p<0.05; ** p<0.01; *** p<0.001.

7.3. WITHOUT PERMANENT CROPS

There are many differences between the permanent crops and the other crops categories evaluated in this study. Permanent crops, for example, can have a productive life up to 40 years or more after planted while most of the other crops must be planted every year after harvested. Permanent crops may also have additional expenses to their installation and maintenance. They may require supportive and protective structures, soil leveling, the installation of irrigation systems, and others economic and technical evaluations making them more expensive for the farmer in initial stage (Lemus and Donoso, 2008). Hence, by taking permanent crops out of the model, we are expecting to see farmers response in a more dynamic environment, where farmers are more likely to change their whole cultivated area to any other crop category. Estimated APE for farmers without permanent crops are presented in Table 7.4.

From Table 7.4, we can see that in one year after a drought farmer may increase their land share of the cereals, vegetables, seed crops and the set-aside option. Here the selection for vegetables seem to be responding for flexibility in the planting season while cereals may be selected because of their lower capital and technological costs. Two years after a drought farmers may prefer to increase their land share option to vegetables and the set-aside option. Background risk values are similar to what we found in our baseline model.

Floods have a similar effect to the baseline model. This could mean that after a flood, the farmers decisions will not depend upon the presence or not of permanent crops. Crop decisions may be more related to the gains or losses after a flood, rather to the prioritization of crops.

Table 7.4. APE of the MFL for the farmers response to the weather without permanent crops.

Variables	CERP	LTOR	CINDU	VEGT	CSEED	BARB
DROU (t-1)	0.064***	-0.246***	-0.003	0.124***	0.008**	0.052***
	(0.015)	(0.018)	(0.011)	(0.017)	(0.004)	(0.011)
DROU (t-2)	-0.063	0.026	-0.291***	0.128**	0.008	0.192***
	(0.109)	(0.049)	(0.011)	(0.059)	(0.005)	(0.029)
DROUST	-0.265***	0.537***	-0.160***	-0.264***	-0.012	0.164***
	(0.044)	(0.033)	(0.015)	(0.048)	(0.011)	(0.040)
FLOOD (t-1)	-0.080***	0.053***	-0.045***	-0.030***	0.003	0.099***
	(0.008)	(0.006)	(0.006)	(0.009)	(0.003)	(0.007)
FLOOD (t-2)	-0.002	0.003	-0.054***	0.054***	0.006**	-0.007
	(0.014)	(0.008)	(0.017)	(0.011)	(0.003)	(0.013)
FLOODST	0.386***	-0.416***	0.065***	0.459***	-0.039***	-0.456***
	(0.051)	(0.039)	(0.015)	(0.056)	(0.009)	(0.044)
Control	Yes	Yes	Yes	Yes	Yes	Yes
Dummy Region	Yes	Yes	Yes	Yes	Yes	Yes
Observations	55,066	55,066	55,066	55,066	55,066	55,066

Source: Own elaboration based on the CRU dataset TS 3.24, the SPEI base v.2.5 and data from the Dartmouth Flood Observatory, CIREN and the 7th National Agriculture and Forestry Census.
Note: CERP: Cereals, LTOR: Legumes and tubers, CINDU: Industrial crops, CSEED: seed crops, VEGT: vegetables and flowers, BARB: set-aside, DUGHT t - 1: dummy of SPEI 6 months for February 2006, DUGHT t - 2: dummy of SPEI 6 months for February 2005, DROUST: historical ratio of droughts from 1950 to 2006, FLOOD t - 1: dummy of floods during 2005, FLOOD t - 2: dummy of floods during 2004, FLOODST: ratio of floods from 1986 to 2005. Robust standard errors are shown in parentheses. Legend: * p<0.05; ** p<0.01; *** p<0.001.

8. CONCLUSIONS

In this study we have studied the effects of droughts and floods on cropland decisions of the Chilean farmers. We used a theoretical framework related to the background risk (Gollier and Pratt, 1996) and the effect of risk events in the past (Cohen et al., 2008). We also used sociodemographic and agricultural data, as well as geospatial and biophysical data. Based on the nature of the cropland decision, we proposed multivariate fractional logit, and in order to use all available information we used the pooled fractional probit as robustness check.

From the results, small-scale farmers are sensitive to past weather events. However, small-farmers cropland decision differs whether there is a drought or a flood and whether they are in dryland conditions or in rural environments. Their decisions may also vary from one year to another. In the sense of the risk behavior, they seem to be more sensitive to weather events one year after its occurrence than during the second year, where they seem to response depending on the lack or the over production of the previous year.

When it comes to droughts, farmers seem to have more adverse behaviors in dryland environments reducing high risk cropping activities, which is in line with Salazar-Espinoza et al. (2015). This is because their crop decisions will depend on the seasonal rainfall. This can make them, select crop categories with short growing periods and lower capital and technological cost. After a drought they may refuge in white wheat and other nontraditional crops or nontraditional legumes and tubers. Farmers that are not in these environments or have access to water are, apparently, more willing to invest in crops categories with higher capital and technological cost. As for droughts, with floods, farmers decisions will also depend on the level of refinement of the data. However, there is not a clear response of farmers decisions in the sense of the risk behavior. This is because some farmers can also obtain benefits from floods or because their planting decisions occur after the raining season or because they are using other cultural mechanisms to cope with the floods, that we are not considering in this study.

In the sense of the background risk, farmers seem to adapt to their environments. They may prefer legumes and tubers and vineyards in arid environments while cereals, industrial crops, vineyards and vegetables in wet environments. The farmers response, however, may also change depending on whether they are in dryland environments and the level of rurality. It is also interesting to see how farmers will response when we take out the permanent crops. There, arid environments, farmers may prefer legumes and tuber or the set-aside option while in wet environments they may prefer cereals, industrial crops and vegetables.

Despite the efforts to capture the time trends, the PFP model did not allowed us to see how farmers decisions may change in time. Therefore, future studies may incorporate more desegregated data that can be used to give more robust recommendations to the policymakers.

From our findings, policymakers' decisions may be oriented to help small-scale farmers in dryland conditions given difficulties that they may have to cope with the effects of the droughts, even after two years of the event. As we saw, from our results, policies should focus on improve dryland farmers access to water as droughts are expected to increase as, the climate change continues. They may also consider the soil erosion problems that may be associated to areas with high probability of floods. As we saw in this study, a huge proportion of their cultivated area is leaving to the set-aside option in drylands and that can lead to runoffs and the reduction of soils' productive capacity, which can also be accelerate rural-urban migration from these areas.

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APPENDIX

Appendix 1. APE of the Multinomial Fractional Logit for the farmers response to the weather. All variables.

Variables	CERP	LTOR	CINDU	VINPL	FRUT	VEGT	CSEED	BARB
Climate's characteristics								
DROU (t-1)	0.004	-0.215***	-0.004	0.020***	0.200***	0.005	0.005	-0.016*
	(0.011)	(0.015)	(0.009)	(0.003)	(0.013)	(0.012)	(0.003)	(0.009)
DROU (t-2)	-0.082	-0.003	-0.441***	0.132***	0.189***	0.046	0.007*	0.151***
	(0.105)	(0.038)	(0.012)	(0.009)	(0.031)	(0.038)	(0.004)	(0.021)
DROUST	-0.157***	0.421***	-0.108***	0.193***	-0.21***	-0.169***	0.001	0.029
	(0.036)	(0.024)	(0.011)	(0.029)	(0.039)	(0.038)	(0.008)	(0.031)
FLOOD (t-1)	-0.074***	0.040***	-0.035***	0.024***	0.011	-0.028***	0.003	0.057***
	(0.007)	(0.005)	(0.005)	(0.004)	(0.009)	(0.008)	(0.002)	(0.005)
FLOOD (t-2)	0.087***	0.038***	-0.040***	-0.481***	0.244***	0.074***	0.005***	0.072***
	(0.012)	(0.006)	(0.014)	(0.020)	(0.01)	(0.008)	(0.002)	(0.011)
FLOODST	0.290***	-0.261***	0.054***	0.336***	-0.399***	0.234***	-0.030**	-0.224***
	(0.041)	(0.029)	(0.011)	(0.036)	(0.044)	(0.042)	(0.006)	(0.032)
TPROM	-0.002	-0.005***	-0.001***	0.009***	-0.003***	-0.001	-0.001***	0.002***
	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)
PPROM	-0.001***	0.000***	0.000***	0.001***	0.001***	0.000***	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Producer's characteristics								
GENDER	0.020***	0.018***	0.001	0.000	-0.013***	-0.013***	0.001	-0.013***
	(0.003)	(0.002)	(0.001)	(0.002)	(0.003)	(0.003)	(0.001)	(0.002)
AGE	0.000***	-0.001***	0.000***	0.001***	0.002***	0.000***	0.000	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
EDU	-0.006***	-0.003***	-0.001***	0.002***	0.011***	-0.003***	0.000***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
TPRD	0.001	0.000**	0.000**	0.001	-0.001	-0.002*	0.000	0.000
	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)
AAGRI	0.021***	0.005***	0.002***	0.003***	-0.021***	-0.027***	0.000***	0.015***
	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)
TCTP	-0.002	-0.009**	-0.007***	0.022***	0.030***	-0.021***	0.000	-0.012***
	(0.005)	(0.003)	(0.001)	(0.004)	(0.005)	(0.005)	(0.001)	(0.004)
RENDHA	-0.001***	-0.002***	0.000***	-0.001***	0.003***	0.000	0.000***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Farm's characteristics								
TEXPLO	-0.013**	0.008**	-0.006***	-0.004	0.006	0.000	-0.001	0.010***
	(0.004)	(0.003)	(0.001)	(0.002)	(0.005)	(0.005)	(0.001)	(0.003)
SRMOD	-0.744***	-0.173***	-0.002	0.128***	0.754***	0.192***	-0.001	-0.155***

	(0.048)	(0.024)	(0.014)	(0.007)	(0.020)	(0.022)	(0.003)	(0.013)
SRTRAD	0.037***	0.045***	0.034***	0.017***	0.118***	0.086***	0.000	-0.338***
	(0.005)	(0.004)	(0.002)	(0.003)	(0.005)	(0.005)	(0.001)	(0.004)
USTEC	0.120***	0.006**	0.006***	-0.037***	-0.129***	0.061***	0.005***	-0.031***
	(0.003)	(0.002)	(0.001)	(0.002)	(0.003)	(0.003)	(0.001)	(0.002)
USCRED	0.008**	0.022***	0.000	-0.004	0.01***	-0.01***	0.000	-0.027***
	(0.003)	(0.002)	(0.001)	(0.002)	(0.003)	(0.003)	(0.000)	(0.003)
USOINS	-0.021***	-0.008***	0.003	0.001	0.055***	-0.016***	0.000	-0.013***
	(0.003)	(0.002)	(0.001)	(0.002)	(0.003)	(0.003)	(0.000)	(0.003)
USFOM	0.041***	0.011***	-0.004**	0.002	-0.012***	-0.045***	0.001	0.007**
	(0.004)	(0.002)	(0.001)	(0.002)	(0.004)	(0.004)	(0.001)	(0.003)
ASOC	-0.024***	-0.004	0.001	0.032***	0.002	0.001	0.001***	-0.008***
	(0.004)	(0.003)	(0.001)	(0.002)	(0.003)	(0.003)	(0.000)	(0.002)
Soil's characteristics								
EROSION	-0.054***	0.082***	0.001	0.12***	0.045***	-0.133***	-0.009***	-0.052***
	(0.01)	(0.005)	(0.003)	(0.007)	(0.008)	(0.010)	(0.002)	(0.007)
Regional characteristics								
REG5	-0.017***	0.011***	0.001	-0.119***	0.056***	-0.034***	0.002	0.100***
	(0.003)	(0.002)	(0.001)	(0.008)	(0.012)	(0.007)	(0.002)	(0.013)
REG6	0.172***	0.054***	0.005***	-0.094***	-0.066***	0.006	0.005**	-0.082***
	(0.006)	(0.003)	(0.001)	(0.009)	(0.011)	(0.008)	(0.002)	(0.013)
REG7	0.179***	0.099***	0.014***	-0.024**	-0.086***	0.019***	0.004***	-0.204***
	(0.004)	(0.003)	(0.001)	(0.009)	(0.009)	(0.007)	(0.001)	(0.010)
REG8	0.383***	0.101***	0.01***	-0.024**	-0.181***	0.043***	-0.002	-0.33***
	(0.007)	(0.003)	(0.002)	(0.009)	(0.009)	(0.008)	(0.001)	(0.009)
REG9	0.282***	0.063***	0.122***	-0.118***	-0.036***	0.016**	0.000	-0.329***
	(0.008)	(0.003)	(0.010)	(0.008)	(0.009)	(0.007)	(0.001)	(0.010)
REG10	0.063***	0.502***	0.000	-0.117***	-0.087***	0.031***	-0.002**	-0.389***
	(0.005)	(0.011)	(0.001)	(0.008)	(0.010)	(0.009)	(0.001)	(0.009)
REG13	-0.004	0.097***	-0.003***	-0.115***	0.023	0.035***	0.009**	-0.042**
	(0.004)	(0.009)	(0.001)	(0.008)	(0.017)	(0.013)	(0.005)	(0.020)
REG14	0.200***	0.247***	0.001	-0.119***	-0.09***	0.143***	-0.002**	-0.389***
	(0.008)	(0.009)	(0.003)	(0.008)	(0.010)	(0.010)	(0.001)	(0.009)
Observations	68,394	68,394	68,394	68,394	68,394	68,394	68,394	68,394

Source: Own elaboration based on the CRU dataset TS 3.24 and data from the Dartmouth Flood Observatory, CIREN and the 7th National Agriculture and Forestry Census.

Notes: CERP: Cereals, LTOR: Legumes and tubers, CINDU: Industrial crops, VINPL: grapevines, FRUT: fruits, CSEED: seed crops, VEGT: vegetables and flowers, BARB: set-aside, GENDER: for gender of the producer, AGE: age of the producer, EDU: education of the producer, TPRD the total number of farms in an exploitation, AAGRI: total usable land, TCTP: proportion of the farm owned by the producer, RENDHA: wheat yield (quintal per hectare), TEXPLO: type of exploitation, SRMOD: area with modern irrigation system, SRTRAD: area with traditional irrigation system, USTEC: use of technology, USCRED: use of credits, USOINS: any other type of support, USFOM: use of any governmental instrument of support, ASOC: association, REG4: Coquimbo, REG5: Valparaiso, REG6: Libertador General Bernardo O'Higgins, REG7: El Maule, REG8: Bio-Bio, REG9: La Araucaria, REG10: Los Rios, REG13:Metropolitan Region, REG14: Los Lagos. Robust standard errors are shown in parentheses. Legend: * p<0.05; ** p<0.01; *** p<0.001.

Appendix 2. APES of the PFP for the farmers response to the weather (baseline model)

Variables	CERP	LTOR	CINDU	VINPL	FRUT	CSEED	VEGT	BARB
Model's covariables								
DROU (t-1)	-0.002	-0.008	0.004	0.009	0.005	0.0495	0.003	0.002
	(0.027)	(0.007)	(0.033)	(0.035)	(0.015)	(0.041)	(0.008)	(0.034)
DROU (t-2)	-0.103**	-0.023	0.100**	-0.052	0.0139	0.014	0.0121	0.100**
	(0.041)	(0.015)	(0.051)	(0.051)	(0.022)	(0.080)	(0.013)	(0.051)
FLOOD (t-1)	-0.028	0.019*	0.066	-0.029	0.0413	0.057	0.021*	-0.108*
	(0.037)	(0.010)	(0.051)	(0.062)	(0.028)	(0.074)	(0.011)	(0.055)
FLOOD (t-2)	0.097	0.028*	-0.208**	0.000	-0.002	-0.013	0.017	-0.365***
	(0.068)	(0.017)	(0.097)	(0.000)	(0.032)	(0.169)	(0.015)	(0.076)
TPROM	0.009	0.0002	-0.003	0.002	0.003	-0.001	-0.002	-0.013
	(0.005)	(0.001)	(0.007)	(0.008)	(0.003)	(0.007)	(0.002)	(0.008)
PPROM	0.000	0.000	0.001	0.000	0.001*	-0.002*	0.001***	-0.000
	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)
GENDER	-0.319	-0.021	0.258	-0.055	0.073	0.556**	-0.001	0.197
	(0.203)	(0.039)	(0.191)	(0.234)	(0.089)	(0.240)	(0.062)	(0.201)
AGE	-0.013	0.004**	0.009	-0.005	0.0013	-0.013	0.006*	0.009
	(0.009)	(0.002)	(0.009)	(0.009)	(0.004)	(0.012)	(0.003)	(0.009)
EDU	0.014	-0.008*	-0.018	-0.008	0.018	0.042	-0.015***	0.000
	(0.021)	(0.005)	(0.024)	(0.019)	(0.012)	(0.026)	(0.006)	(0.022)
TPRD	0.102	0.003	-0.004	-0.044	0.029	0.111	-0.045**	-0.038
	(0.069)	(0.014)	(0.071)	(0.073)	(0.042)	(0.080)	(0.021)	(0.071)
AAGRI	-0.002***	-0.001***	0.001	0.000	-0.002***	0.002***	-0.001***	0.001
	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)
TCTP	0.232*	0.048	0.083	0.214	0.112	0.177	0.032	0.043
	(0.139)	(0.036)	(0.196)	(0.195)	(0.111)	(0.233)	(0.043)	(0.212)
RENDHA	-0.002**	-0.001***	0.001	0.001	-0.001	-0.002	-0.000	0.002
	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)
SRMOD	-0.653**	0.062	-0.079	-0.113	0.224*	-0.215	0.179***	0.501*
	(0.288)	(0.069)	(0.368)	(0.429)	(0.134)	(0.440)	(0.059)	(0.289)
SRTRAD	0.0625	-0.019	0.020	0.123	-0.026	0.250**	-0.029	-0.279**
	(0.096)	(0.020)	(0.089)	(0.085)	(0.047)	(0.119)	(0.043)	(0.118)
PEOPH	0.067**	-0.001	-0.027	0.032	-0.004	0.003	-0.011	-0.0537
	(0.027)	(0.007)	(0.028)	(0.027)	(0.011)	(0.035)	(0.009)	(0.033)
Average values of the variables included in the model								
TPROM_M	-0.008	-0.001	0.003	0.004	-0.008*	-0.011	0.002	0.009
	(0.006)	(0.002)	(0.008)	(0.009)	(0.005)	(0.012)	(0.002)	(0.010)
PPROM_M	-0.000	-0.000	-0.001	-0.001	-0.000	0.003***	-0.001***	-0.000
	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)

DROU (t-1)_M	-0.031	-0.014	0.073	-0.058	-0.041	0.034	-0.032**	-0.030
	(0.039)	(0.012)	(0.048)	(0.063)	(0.028)	(0.059)	(0.013)	(0.045)
DROU (t-2)_M	-0.019	0.038	-0.015	-0.002	0.013	-0.171	-0.041**	-0.158**
	(0.058)	(0.025)	(0.081)	(0.088)	(0.034)	(0.121)	(0.017)	(0.071)
FLOOD (t-1)_M	-0.039	-0.042**	-0.105	0.126	-0.059*	-0.176	0.011	0.155*
	(0.059)	(0.020)	(0.092)	(0.101)	(0.035)	(0.122)	(0.022)	(0.089)
FLOOD (t-2)_M	-0.136	-0.114***	0.140	0.000	-0.081	-0.045	-0.057*	0.668***
	(0.096)	(0.029)	(0.140)	(0.000)	(0.071)	(0.218)	(0.032)	(0.094)
GENDER_M	0.269	-0.021	-0.449	-0.245	0.131	-0.037	0.133	-0.346
	(0.239)	(0.089)	(0.333)	(0.407)	(0.130)	(0.404)	(0.112)	(0.274)
AGE_M	0.016*	-0.005*	-0.009	0.025*	-0.000	0.004	-0.007*	-0.0153
	(0.009)	(0.003)	(0.010)	(0.013)	(0.005)	(0.014)	(0.004)	(0.0104)
EDU_M	0.006	0.013**	0.019	0.003	-0.015	-0.053**	0.017***	0.001
	(0.022)	(0.005)	(0.025)	(0.022)	(0.011)	(0.027)	(0.006)	(0.023)
TPRD_M	-0.098	-0.001	-0.083	-0.011	-0.052	-0.057	0.031	0.032
	(0.069)	(0.017)	(0.079)	(0.099)	(0.049)	(0.095)	(0.022)	(0.086)
AAGRI_M	-0.600***	0.028	0.119	-0.015	-0.117	-0.435	0.015	0.192
	(0.217)	(0.067)	(0.292)	(0.316)	(0.208)	(0.322)	(0.085)	(0.290)
TCTP_M	-0.000	-0.000**	0.001	0.001	0.000	-0.001	0.000	-0.003***
	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)
SRMOD_M	0.521	-0.060	-0.181	0.359	0.106	0.036	-0.007	-1.487***
	(0.403)	(0.116)	(0.533)	(0.537)	(0.179)	(0.659)	(0.091)	(0.433)
SRTRAD_M	-0.252**	0.005	-0.400***	0.093	0.181***	-0.200	0.048	0.066
	(0.105)	(0.026)	(0.117)	(0.123)	(0.049)	(0.139)	(0.046)	(0.138)
RENDHA_M	0.003***	0.001**	0.002*	-0.001	0.001	0.000	0.001	-0.005***
	(0.001)	(0.000)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
PEOPH_M	-0.045	0.018*	0.014	0.068	-0.007	-0.028	0.016	0.024
	(0.028)	(0.001)	(0.046)	(0.043)	(0.016)	(0.050)	(0.013)	(0.037)
OBS	502	499	387	317	515	356	516	447

Source: Own elaboration based on the CRU dataset TS 3.24 and data from the Dartmouth Flood Observatory and the 6ht and 7th National Agriculture and Forestry Census.

Notes: CERP: Annual crops, LTOR: Legumes and tubers, CINDU: Industrial crops, VINPL: grapevines, FRUT: fruits, CSEED: seed crops, VEGT: vegetables and flowers, BARB: set-aside, DUGHT t - 1: dummy of SPEI 6 months for February 1996/2006, DUGHT t - 2: dummy of SPEI 6 months for February 1995/2005, FLOOD t - 1: dummy of floods during 1995/2005, FLOOD t - 2: dummy of floods during 1994/2004, TPROM: average temperature (°C) from mars 1994/2004 to mars 1996/2006, PPROM: average precipitation (mm) from mars 1994/2004 to mars 1996/2006, GENDER: for gender of the producer, AGE: age of the producer, EDU: education of the producer, TPRD the total number of farms in an exploitation, AAGRI: total usable land, TCTP: proportion of the farm owned by the producer, RENDHA: wheat yield (quintal per hectare), TEXPLO: type of exploitation, SRMOD: area with modern irrigation system, SRTRAD: area with traditional irrigation system, USTEC: use of technology, USCRED: use of credits, USOINS: any other type of support, USFOM: use of any governmental instrument of support, ASOC: association, PEOPH: number of persons in the producer's household. Bootstrapped standard errors are shown in parentheses. (Replications = 500). Legend: * p<0.05; ** p<0.01; *** p<0.001.

Appendix 3. Summary statistics of farmers' sociodemographic and farms' productive characteristics aggregated at communal level. Summary statisictis for the panel data model.

Variables	1997		2007	
	Mean	Dev.	Mean	Dev.
Crop categories				
CERP	5.516	6.472	5.224	5.762
LTOR	0.946	1.466	1.527	1.995
CINDU	9.708	14.907	7.939	13.169
VINPL	11.238	17.04	6.786	10.190
FRUT	2.305	3.382	2.716	3.774
CSEED	9.943	12.108	9.936	19.543
VEGT	0.738	0.829	1.424	2.342
BARB	8.358	15.001	5.348	7.746
Producer´s characteristics				
GENDER	0.865	0.062	0.721	0.087
AGE	55.096	2.379	57.025	2.365
EDUC	6.655	1.748	7.507	1.932
TPRD	1.604	0.370	1.595	0.312
AAGRI	31.348	30.677	32.751	32.739
TCTP	0.912	0.117	0.902	0.064
RENDHA	35.406	18.599	27.574	13.430
Farm's characteristics				
SRMOD	0.008	0.018	0.034	0.059
SRTRAD	0.115	0.181	0.249	0.271

Source: Own elaboration based on data from the 7th National Agriculture and Forestry Census.
Notes: CERP: Cereals, LTOR: Legumes and tuber, CINDU: Industrial crops, VINPL: grapevines, FRUT: fruits, CSEED: seed crops, VEGT: vegetables and flowers, BARB: set-aside, GENDER: for gender of the producer, AGE: age of the producer, EDU: education of the producer, TPRD the total number of plots in an exploitation, AAGRI: total usable land, TCTP: proportion of the farm owned by the producer, RENDHA: wheat yield (quintal per hectare), SRMOD: area with modern irrigation system, SRTRAD: area with traditional irrigation system.

Appendix 4. APE of the Multinomial Fractional Logit for the farmers by crops (baseline model)

Variables	TRIG	MAIZ	POTT	OTHC	OTHL
DROU (t-1)	0.217***	-0.758***	-1.149***	0.131***	0.001
	0.007	0.009	0.011	0.006	0.006
DROU (t-2)	-1.130***	0.049	0.175***	0.204***	-0.966***
	-0.040	0.048	0.024	0.040	0.014
DROUST	-0.210***	-0.179***	-0.121***	0.064***	0.131***
	0.023	0.022	0.020	0.016	0.013
FLOOD (t-1)	0.045***	-0.164***	-0.161***	0.083***	0.062***
	0.005	0.020	0.012	0.003	0.002
FLOOD (t-2)	0.175***	-0.764***	0.097***	0.096***	-0.037**
	0.007	0.009	0.004	0.005	0.015
FLOODST	-0.215***	0.107***	-0.378***	-0.209***	0.034***
	-0.015	0.009	0.013	0.013	0.008
Control	Yes	Yes	Yes	Yes	Yes
Dummy Region	No	No	No	No	No
Observations	68,384	68,384	68,384	68,384	68,384

Source: Own elaboration based on the CRU dataset TS 3.24 and data from the Dartmouth Flood Observatory, CIREN and the 7th National Agriculture and Forestry Census.
Notes: TRIG: wheat, MAIZ: maize, POTT: Potatoes, OTHC: other nontraditional cereals, OTHL: other nontraditional legumes and tubers, DUGHT t - 1: dummy of SPEI 6 months for February 2006, DUGHT t - 2: dummy of SPEI 6 months for February 2005, DROUST: historical ratio of droughts from 1950 to 2006, FLOOD t - 1: dummy of floods during 2005, FLOOD t - 2: dummy of floods during 2004, FLOODST: ratio of floods from 1986 to 2005. Robust standard errors are shown in parentheses. Legend: * p<0.05; ** p<0.01; *** p<0.001.

Appendix 5. APE of the PFP for the farmers by crops (baseline model)

Variables	TRIG
DROU (t-1)	0.0558
	(0.0562)
DROU (t-2)	-0.0356
	(0.0749)
FLOOD (t-1)	-0.00183
	(0.0869)
FLOOD (t-2)	0
	(0)
Control	Yes
Dummy Region	No
Observations	263

Source: Own elaboration based on the CRU dataset TS 3.24 and data from the Dartmouth Flood Observatory and the 6th and 7th National Agriculture and Forestry Census.
Notes: TRIG: wheat, DUGHT t - 1: dummy of SPEI 6 months for February 2006, DUGHT t - 2: dummy of SPEI 6 months for February 2005, DROUST: historical ratio of droughts from 1950 to 2006, FLOOD t - 1: dummy of floods during 2005, FLOOD t - 2: dummy of floods during 2004, FLOODST: ratio of floods from 1986 to 2005. Robust standard errors are shown in parentheses. Bootstrapped standard errors are shown in parentheses. (Replications = 500). Legend: * p<0.05; ** p<0.01; *** p<0.001.

Appendix 6. Detailed information of floods.

Began	Duration	Dead	Displaced	Main cause	Affected
26-06-2005	3	5	800	Heavy rain	12,210
30-06-2004	2	3	9,000	Heavy rain	4,600
24-08-2002	6	2	8,000	Heavy rain	62,180
24-05-2002	13	9	50,000	Heavy rain	166,900
05-06-2000	12	-	41,000	Heavy rain	84,000
15-08-1997	5	10	-	Heavy rain	224,900
10-06-1997	15	20	51,000	Heavy rain	144,400
03-05-1993	1	21	1,225	Heavy rain	1,200
18-06-1991	2	120	30,000	Brief torr. Rain	15,850
19-06-1989	3	-	-	Heavy rain	10,680
12-07-1987	7	47	90,000	Heavy rain	36,280
15-06-1986	4	40	45,000	Heavy rain	27,960
27-05-1986	3	8	17,000	Brief torr. Rain	27,960

Source: Own elaboration based on data from the Dartmouth Flood Observatory.
Notes: duration: number of days of a flood, affected: area affected by a flood in square km.

Appendix 7. SPEI values

Variable	Obs	Mean	Std. Dev.	Min	Max
SPEI6 6M Feb-06	284	0.234774	0.889249	-1.4	2.2
SPEI6 6M Feb-05	284	0.362546	0.537137	-1.6	1.7
SPEI6 6M Feb-96	284	-1.03987	0.532609	-1.9	0.9
SPEI6 6M Feb-95	284	0.113621	0.727906	-1.3	1.8

Source: Own elaboration based on the CRU dataset TS 3.24.

Appendix 8. Small-scale farmers' crop allocation across Chile

REGION	CERP	LTOR	CINDU	VINPL	CSEED	FRUT	VEGT	BARB
REG4	976.8	931.2	88.8	1877.6	13.5	4451.2	2984.2	7379.1
REG5	891.3	1100.1	231.2	51.7	64.42	6652.9	4616.5	6260.1
REG6	12843.7	1616.7	1640.7	1149.6	685.7	6118.0	5226.9	9224.9
REG7	24543.4	6194.2	3971.2	6391.4	1398.3	8688.8	6370.5	17055.1
REG8	54321.1	10612.9	3737.5	10183.9	168.5	5099.7	5339.8	19029.6
REG9	46227.1	10345.6	8119.9	7.8	687.8	6312.9	4112.7	15006.2
REG10	6041.9	7632.2	375.5	4.0	136.6	4386.5	1837.6	640.5
REG13	1814.5	1525.5	46.3	130.9	324.4	4450.2	7626.8	5561.8
REG14	8239.8	2785.5	270.1	0	152.9	2677	1444.1	761.6
TOTAL:	155899.7	42744.0	18481.2	19797.2	3632.1	48837.4	39559.5	80918.9

Source: Own elaboration, based data from the 7th National Agriculture and Forestry Census.
Notes: CERP: cereals, LTOR: legumes and tuber, CINDU: industrial crops, VINPL: vinyards, FRUT: fruits, CSEED: seed crops, VEGT: vegetables and flowers, BARB: set-aside, REG4: Coquimbo, REG5: Valparaiso, REG6: Libertador General Bernardo O'Higgins, REG7: El Maule, REG8: Bio-Bio, REG9: La Araucaria, REG10: Los Rios, REG13: Metropolitan region, REG14: Los Lagos.

Appendix 9. Length of growth stages

Variable	Obs.	Mean	Std. Dev.	Min	Max
Vegetables	49	131.1	46.2	35	275
Cereals	28	149.5	50.6	80	335
Legumes and tubers	21	122.4	38.7	75	235
Grapes and Berries	4	208.8	24.6	180	240
Fruit Trees	7	242.1	69.4	150	365

Source: own elaboration, based on FAO irrigation and Drainage Paper No. 24.
Notes: average values are based on general lengths for the four distinct growth stages and the total growing period of various types of climates and locations (Allen et al., 1998). Permanent vegetables are not included.

Appendix 10. Farmers index of capital use and technology

Rank	Index of capital use and technology	%
1	Fruits	1
2	Vineyards	0.95
3	Seed crops	0.8
4	Vegetables	0.77
5	Industrial crops	0.6
6	Chacras	0.52
7	Other annual crops	0.2
8	Cereals	0.2

Source: Santibañez et al. (2008).
Note: annual crops; cereals, legumes and tubers, and industrial crops.

Appendix 11. Legumes and tubers (LTOR) by crop type.

Rank	Legumes and tubers	%
1	Potato dryland	46.9
2	Potato irrigation	33.8
3	Beans irrigation	10.9
4	Chickpea dryland	3.5
5	Beans dryland	1.4
6	Beans exportation irrigation	0.9
7	Vetch dryland	0.8
8	Lentil dryland	0.6
9	Vetch irrigation	0.6
10	Other legumes and tubers	0.6

Source: Own elaboration based on the 7th National Agriculture and Forestry Census.

Appendix 12. Cereals (CERP) by crop type.

Rank	Cereals	%
1	White wheat dryland	39.7
2	Maize irrigation	20.1
3	Oat irrigation	13.5
4	White wheat irrigation	9.1
5	Barley dryland	5.9
6	Rice irrigation	3.9
7	Triticale dryland	3.7
8	Barley dryland	2.6
9	Wheat (candeal) irrigation	1.6
10	Other cereals	5.8

Source: Own elaboration based on the 7th National Agriculture and Forestry Census.

Appendix 13. Fruits (FRUT) by crop type.

Rank	Fruits	%
1	Avocado total	9.9
2	Grapes total	8.6
3	Blueberry total	6.4
4	Olive total	6.4
5	Walnut total	5.5
6	Plum total	5.3
7	Cherry tree total	4.7
8	Blueberry plantation	4.6
9	Avocado plantation	4.6
10	Other fruits	43.7

Source: Own elaboration based on the 7th National Agriculture and Forestry Census.

Appendix 14. Vegetables and flowers (VEGT) by crop type

Rank	Vegetables and flowers	%
1	Orchard	14.1
2	Corn	10.8
3	lettuce	7.1
4	tomatoes	5.5
5	Zapallo	5.3
6	artichoke	5.2
7	onions	4.2
8	Carrots	3.9
9	Other vegetables and flowers	43.6

Source: Own elaboration based on the 7th National Agriculture and Forestry Census.

Appendix 15. Industrial crop (CINDU) by crop type

Rank	Industrial crop	%
1	Lupine (bitter) dryland	22.2
2	Raps dryland	21.6
3	Beet irrigation	19.8
4	Lupine (sweet) dryland	19.3
5	Lupine (australian) dryland	15.4
6	Beet dryland	1.3
7	Other industrial crops	0

Source: Own elaboration based on the 7th National Agriculture and Forestry Census.

Appendix 16. Vineyards (VINPL) by crop type

Rank	Vineyards	%
1	Red (FI) irrigation	43.2
2	White (FI) irrigation	15.2
3	Red (CO) dryland	11.4
4	Pisco irrigation (P)	6.8
5	Red (CO) irrigation	5.3
6	White (CO) dryland	4.8
7	Red (FI) irrigation (P)	4.3
8	Red (FI) dryland	2.2
9	Red (CO) irrigation (P)	1.7
10	Other vineyards	5

Source: Own elaboration based on the 7th National Agriculture and Forestry Census.
Notes: FI: refined vineyard (i.e., Cabernet, Merlot, Carmenere, Syra, Chardonnay, Sauvignon blanc, Riesling, and others.). CO: common vineyard (Pais, Cinsaut, Tintoreras, Carignan, Semillon, Torontel, Moscatel de Alejandría, Moscatel Rosada, and others).

Appendix 17. Seed crops (CSEED) by crop type.

Rank	Seed crops	%
1	Maize	52
2	Clover	10.4
3	Maravilla	5.8
4	Ballica	1.8
5	Potato	1.5
6	Other seed crops	28.4

Source: Own elaboration based on the 7th National Agriculture and Forestry Census.