A value chain perspective towards sustainable agricultural practices: The case of vegetables in Chile.

Francisco Benítez Altuna

Propositions

1. Farmers' mindset towards adoption of sustainable agricultural practices is shaped by economic profit rather than social and environmental improvement in Chile.
(this thesis)

2. The value chain framework cannot encompass agroecology's holistic nature.
(this thesis)

3. Researchers reveal bias by recommending their favorite branch of literature.

4. The publication process in academic journals is like the video assistant referee (VAR) in football, a spoilsport.

5. Selfishness in the PhD community challenges intrinsic generosity.

6. The "special labour agreement" between Wageningen University and sandwich PhD candidates follows neocolonialist conditions.

Propositions belonging to the thesis, entitled

A value chain perspective towards sustainable agricultural practices: The case of vegetables in Chile

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A value chain perspective towards sustainable agricultural practices: The case of vegetables in Chile

Francisco Javier Benítez Altuna

Thesis

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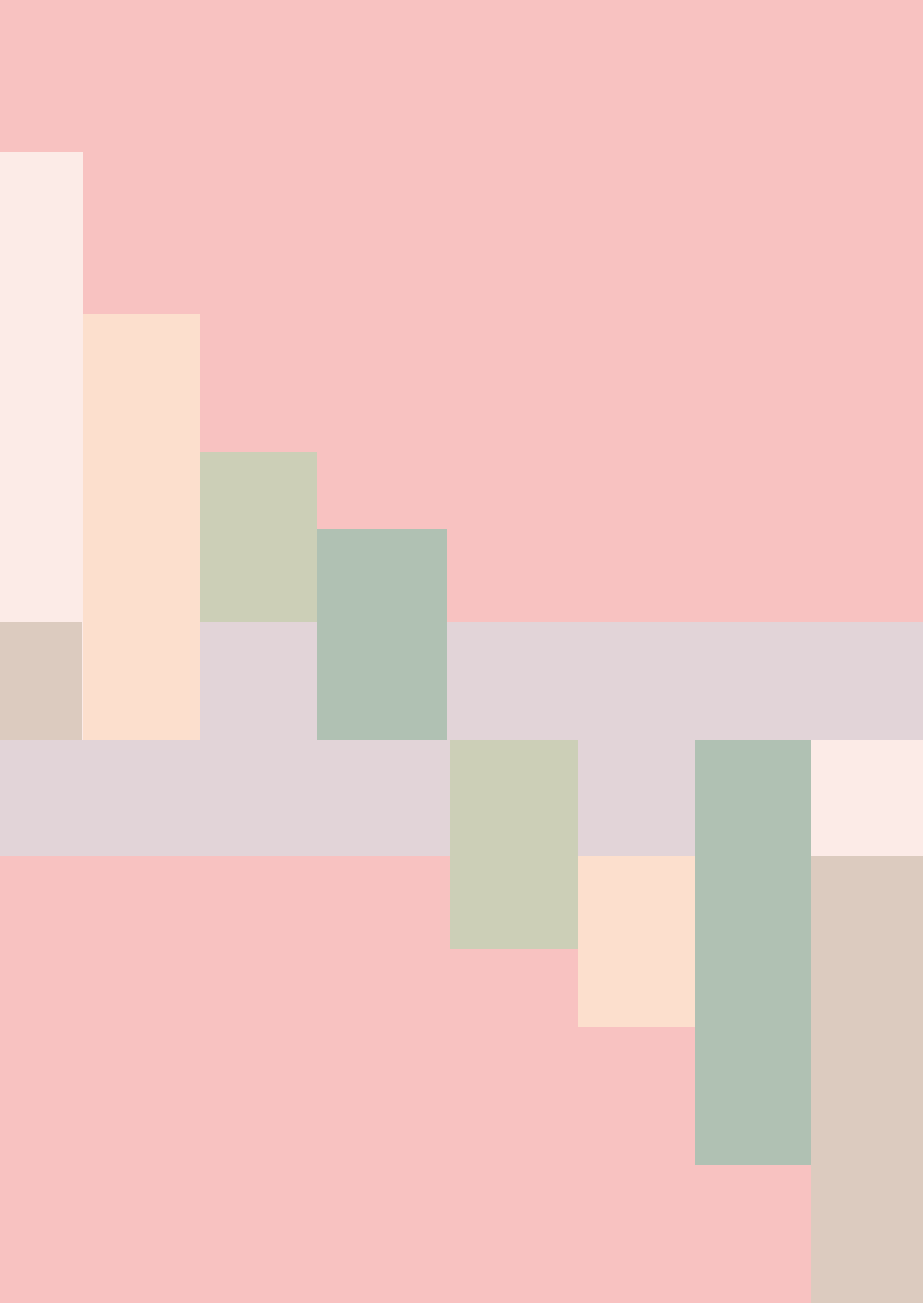
Table of contents



CHAPTER 1

General introduction

1. Introduction

This thesis investigates sustainable agricultural practices (SAPs) of farmers from a value chain perspective. Next to the introduction and conclusion chapters the thesis includes a chapter on the impact of farmer and farm characteristics on SAPs, a chapter on farming system typologies including farm and farmer characteristics, SAPs and market channel characteristics, and a chapter on farmer-buyer relationships, contract characteristics and SAPs.

In this introductory chapter first in section 1.2 the problem definition is articulated, followed by the context of the study in section 1.3, which describes the research case, i.e., the vegetable value chain in Chile and the HortEco Project (of which this thesis is part). Section 1.4 explains the theoretical framework applied in this thesis. Next, research aims and research questions and data and methods are presented in section 1.5. The chapter ends with the outline of the thesis in section 1.6.

1.1 Problem definition

1.1.1 Climate change and agricultural intensification

Human influence has triggered climate change by the emission of greenhouse gases, which have increased the average earth surface temperature with around 1 °C since pre-industrial times (IPCC, 2021). Climate change has become evident in the last few decades, warming the atmosphere, ocean and land, and affecting weather and climate. Indications of these changes are extreme natural events such as heat waves, heavy precipitation, and droughts and tropical cyclones occurring more frequently (IPCC, 2021). Consequently, the Intergovernmental Panel on Climate Change (IPCC) has identified climate change as one of humanity's greatest challenges in its 2021 report (IPCC, 2021). In this context, agri-food systems are the second largest contributor to climate change. The agri-food sector accounts for around 31% of global greenhouse gas emissions (FAO, 2021a). Further, one-third of the agri-food system emissions is due to crop production (Poore and Nemecek, 2018).

Historically, agricultural improvements have focused on how to raise yields from land, seeds and labor (Perkins and Jamison, 2008). During the 1950s trough 1970s farmers where able to duplicate and triplicate yields in crops such as wheat and rice. This era was called the Green Revolution which was made possible through alliances in agricultural science and technology (Perkins and Jamison, 2008). The main purpose of the green revolution was to provide prosperity, security and health for people and their livestock (Perkins and Jamison, 2008; Tscharntke et al., 2005). The green revolution is characterized by agricultural intensification (AI), focused on an increase of the total volume of agricultural production with one crop (monocultures) and intensive use of inorganic inputs (i.e., fertilisers and pesticides) (Perkins and Jamison, 2008; Tscharntke et al., 2005).

Together with the continuous development of science and technology (e.g., new seed varieties and better farm equipment) many other methods for improving food production were generated, which led to land conversion from forests and other ecosystems to agricultural use under the AI regime (Potter et al., 2010). Farmers transformed infertile lands into fertile fields, and today, nearly 38% of our planet's surface is used for agriculture (Townsend and Howarth, 2010; FAO, 2021a). Inorganic fertilisers have played a major role in transforming traditional agriculture and have led to a major increase in yields; their use has almost tripled in kilograms per hectare from 1961 to 2019 (Potter et al., 2010; FAO, 2021b).

However, while AI was achieving its purpose of raising productivity, it also brought irreversible harmful effects on the environment (Perkins and Jamison, 2008). The residues of inorganic fertilisers and pesticides have been spread in the environment, contaminating terrestrial and aquatic ecosystems, poisoning human foods and resulting in biodiversity loss (Townsend and Howarth, 2010; Carvalho, 2017). In addition, the use of these inputs together with improved seed varieties has stimulated the mechanization of agriculture for sawing and harvesting, which resulted in the reduction of labor costs and the production of monocultures on large surfaces of land. These monocultures have led to the expansion of the agricultural frontier, however, challenging biodiversity and the benefits derived from biodiversity (e.g., pollinators, carbon sequestration; protection against soil erosion) (Shibu 2009; Groot et al. 2021). Moreover, the harmful effects of AI on the environment are accompanied by adverse social and cultural effects, such as land concentration, rising inequality, farmer dependency, health and safety risks (Horlings and Marsden, 2011; Cánovas et al., 2018). This has incited governments, farmers and academics to explore alternative agricultural practices that redress the negative consequences of AI (Pannell et al. 2006; Knowler and Bradshaw 2007).

Currently, there are different alternative paths to deal with the negative consequences of AI, such as ecological intensification (Tittonell, 2014), agroecology (Altieri et al., 2017), organic agriculture (Muller et al., 2017) and climate-smart agriculture (Taylor, 2018). The differences between these practices lie in their scope. While some practices are focused on a single crop or a specific type of farm, others have a much wider scope, embracing the complexity of the whole landscape (Tittonell, 2014). We refer to these practices as sustainable agricultural practices (SAPs). SAPs imply that "agriculture will have to be carried out to make the best use of available natural resources and inputs, and regenerate conditions for future production (e.g., soil fertility, resilience of the ecosystem, water availability)" (Leeuwis, 2004, p. 5). The main goal of using SAPs is to achieve more environment-friendly crop production (Bommarco et al., 2013). To achieve this goal, farmers apply different practices at the farm, such as use of: traditional seeds (from seed saving-groups), organic fertilisers incl. preparing organic fertilisers at the farm, organic pesticides or preventive practices without chemicals to control pest and diseases (e.g., integrated pest management), organic herbicides or mechanic control and crop management practices (e.g., crop rotation or intercropping) (Astier et al., 2011; Barzman et al., 2015; Millner, 2017). The use of SAPs helps to reduce environmental pollution and supports ecological goods that minimize the degradation of essential ecosystem services (e.g., fresh water, soil fertility, air purification, pollination), which sustain the future economic and social development (Adnan et al., 2017; Ehiakpor et al., 2021). However, despite their potential benefits, the use of SAPs in developed and developing countries is still low (Pannell et al. 2006; Tey et al. 2017).

The adoption[1] of SAPs is highly context-specific, which means that it can be influenced by the physical environment and by social, economic, legislative, political and cultural aspects at national, regional and local level (Anibaldi et al., 2021).Most of the literature on determinants of SAP adoption has been focused on farmer and farm characteristics (Daloğlu et al., 2014; Teixeira et al., 2018), which have been studied from different disciplinary fields including economics, sociology, and psychology and through quantitative as well as qualitative methodologies (Dessart et al., 2019; Anibaldi et al., 2021). As a result, literature has identified multiple factors affecting SAP adoption, such as age, education, land tenure, environmental awareness, self-identified motivations, farm size, income, risk perception and trust in information sources (Dessart et al., 2019; Anibaldi et al., 2021).

1.1.2 Food value chain transformation and SAPs

In emerging and developing economies food value chain transformation started with market liberalizations at the beginning of the '80s, with increasing vertical coordination of farm production with lead firms[2] (e.g., processors and supermarkets) (Balsevich et al., 2003; Reardon et al., 2009). Such a transformation of food value chains was mainly characterized by the imposition of quality and safety standards by lead firms on producers of fresh fruit and vegetables (Balsevich et al., 2003). This transformation converges with three interlinked transformations: 1) a top-down consumers demand

[1] Adoption is "the process of starting to use a new method, system, law, etc." (Cambridge University, 2022)
[2] In buyer driven supply chains, lead firms are "retailers or marketers of the final products that exert the most power through their ability to shape mass consumption via strong brand names" (Gereffi, 2011 p. 40).

change, originated by urbanisation and changes in diet; 2) logistic modernisation of supermarkets, wholesalers and processors; and 3) agricultural intensification practices allowing the consistent supply of agricultural products (Reardon et al., 2019). However, the transformation of food value chains also had negative impacts on sustainability encompassing economic (e.g., as a competitive factor for corporative image), social (e.g., characterized by low pay for farm labour, labour migration, harsh working conditions and child labour) and environmental (e.g., problems with energy and water conservation, soil and water pollution, deforestation, pesticide poisoning and farming practices) aspects (Pullman et al., 2009; Lehtinen, 2017).

In this thesis, we focus on the environmental sustainability of food value chains, specifically on the use of SAPs by farmers. Most of the studies on the use of the SAPs in food value chains (FVCs) have identified two schemes. The first FVC scheme is mainly focused on a top-down approach from lead firms' perspective (Jia et al., 2018; Grabs and Carodenuto, 2021). This scheme is based on the dual relationship between lead firms and farmers. Lead firms incentivize or exert pressure on farmers to engage in sustainable environmental practices at the farm level (Jia et al., 2018; Freidberg, 2020). Lead firms usually use hybrid governance forms (e.g., formal contracts) as a tool to demand compliance with international market standards (i.e., third-party certifications e.g., Global GAP, rainforest alliance, forest stewardship council, IFOAM) (Potts, 2014; Jia et al., 2018; Freidberg, 2020). There is evidence that the use of formal contracts influences the adoption of SAPs by farmers, such as soil conservation practices (e.g., crop rotation, intercropping, organic fertilisers) and integrated pest/disease management characterized by low use of pesticides (Blasi et al., 2017; Boulestreau et al., 2022).In these schemes farmers have access to market channels, such as international markets and supermarkets, where they receive premium prices for their products (Dalcin et al., 2014; Flores, 2012; Jia et al., 2018).

Although hybrid governance forms with sustainability provisions can be useful tools to achieve sustainability at the farm level, these governance forms by themselves do not guarantee sustainable production nor are they useable for all types of farmers (Saenz-Segura 2006; Meemken and Bellemare 2020; Touboulic et al. 2021). According to Fritz and Schiefer (2008) and Touboulic et al. (2021), hybrid governance forms are in fact effective only when accompanied by "close" working relationships between lead firms and farmers. Close relationships between lead firms and farmers are characterized by mutual satisfaction, trust and non-opportunistic behaviour, among others (Kang and Jindal, 2015; Gualandris and Kalchschmidt, 2016; Murphy and Sashi, 2018; Touboulic et al., 2021). In this sense, close relationships may support environmental outcomes where lead firms and farmers are jointly engaged in more sustainable production (Mangla et al., 2018). Moreover, the use of hybrid governance forms not only can support environmental outcomes. These governance forms have in many cases proven to be an instrument to increase productivity and income, improve household welfare and food security, and provide access to credit and technology (Bijman, 2008; D'Silva et al., 2011; Bellemare and Lim, 2018), increasing the willingness of farmers to establish closer relationships and engage in joint actions such as sustainable production measurements.

The second scheme that supports the use of SAPs is short food chains (SFCs) (Chiffoleau and Dourian, 2020; González-Azcárate et al., 2021). SFSCs are defined by two characteristics: physical and social proximity. Physical proximity refers to the distance of transportation from the place of production to the place of sale. Social proximity refers to the number of intermediaries (zero or no more than two intermediaries) between producers and consumers (Galli and Brunori, 2013). SFCs emerge to face the externalities (e.g., environmental and health issues, farmers' welfare, consumers' ethical concerns) generated by conventional food supply chains schemes; usually this scheme is led by consumer cooperatives or farmers organizations (Charatsari et al., 2018; Cruz et al., 2021). Moreover, SFCs include diverse configurations such as box schemes, farmers’ markets, on-farm selling, consumer cooperatives, internet sales (Galli and Brunori, 2013). These diverse configurations allow farmers to access to diverse market channels where farmers can receive premium prices for their products (Chiffoleau and Dourian, 2020; Jarzębowski et al., 2020; González-Azcárate et al., 2021).

In general, the use of SAPs by farmers in food value chains is context-specific. Food value chains’ constraints for the use of SAPs depend on diverse factors such as, lack of governmental support (e.g., laws, weak enforcement of regulations, lack of sanctions and lack of financial incentives), knowledge gaps regarding the implementation of SAPs of farmers, buyers and policy-makers, local culture (e.g., beliefs and values), lack of awareness about sustainability along the food value chain (Beske et al., 2014; Jia et al., 2018). Typical constraints in the relations between value chain actors include challenges in adapting international standards to the local context, low buying power in emerging and developing countries, lack of training and support, lack of infrastructure to bring products to markets, lack of farmers organisation and low bargaining position of farmers and farmer-buyer relationship characteristics (e.g., contracts requirements, power asymmetry and strength of relationships) (Beske et al., 2014; Dania et al., 2018; Jia et al., 2018). Moreover, literature on food value chains and the use of SAPs has paid little attention to the farmers’ voice, especially in emerging and developing countries (Achabou et al., 2017; Jia et al., 2018).

Therefore, there is a need to better understand ex-ante constraints in the use of the SAPs in food value chains (Jia et al., 2018).

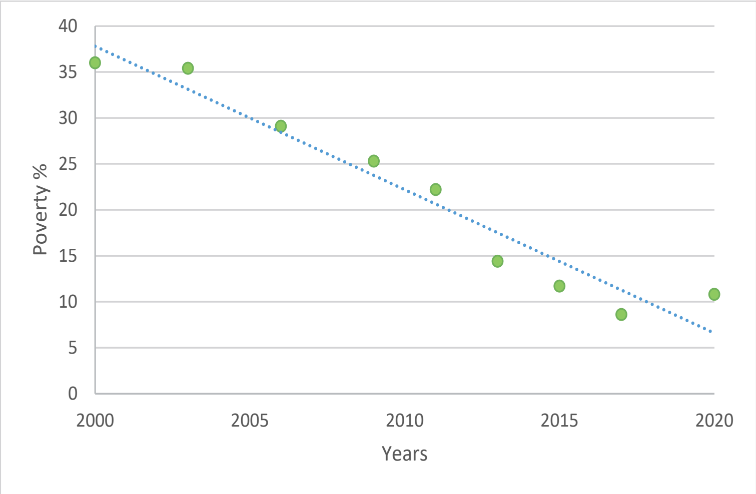
This thesis seeks to contribute to the literature by integrating a food value chain approach and the adoption of SAPs by farmers. The value chain approach allows to consider how actors (e.g., farmers, buyers) influence each other and how consecutive activities are managed in bringing goods and services to end consumers (Donovan et al., 2015). Moreover, the management of activities in the value chain involves attention to aspects related to production, technologies, logistics, labour processes, organizational relations and public and private networks (Trienekens, 2011), providing tools for analysing the diverse factors affecting the adoption of SAPs. Hence, this dissertation analyses adoption of SAPs by farmers from a value chain perspective.

1.2 Context

1.2.1 Case study: Vegetable production in Chile

Transition economies, such as Chile, are considered economies that neither face the challenges of a developing economy nor fully meet the standards of a developed economy. Usually, these are growing economies that are attractive for foreign investors (Meyer, 2004) but also open to innovative developments in specific sectors, such as developments towards modern agriculture. According to the (World Bank, 2021), Chile has one of the fastest growing economies in Latin America in recent decades, which has allowed to reduce the poverty levels in the country (Figure 1.1). One sector that contributed to the economic growth of Chile is agriculture, contributing with 11% of the Chile's GDP and employing 10% of the country's workforce. The most important agricultural sectors contributing to the GDP are the fruit sector accounting for 33% and the vegetables sector accounting for 22% of agricultural production.

Figure 1.1 Poverty headcount ratio at national poverty lines (% of population) for Chile



Source: World Bank

More than 30 years ago, Chile adopted a commercial export policy to open and diversify markets for its agricultural and food products. Nowadays, Chile belongs to the top ten agricultural exporters in the word, with main products wine, fresh fruit, dairy, meat and fishery products (ITA, 2022). This was for a large part achieved by financial incentives (e.g., tax incentives and production subsidies) by the government for agricultural exportation and technification. However, this has also led to large-scale farms and agricultural intensification supported by the extensive use of inorganic inputs (Montalba et al., 2017; Panez et al., 2020; Berasaluce et al., 2021). Nowadays there is evidence that this agricultural intensification is threatening the sector's sustainability through soil erosion, biodiversity loss and water pollution (Riquelme-Garcés et al., 2013). Contrary to the export-oriented sector, the agricultural sector supplying the national market is characterized by small-scale agriculture and low governmental support (Panez et al., 2020; Berasaluce et al., 2021). However, also in this sector the increased use of inorganic inputs calls for more sustainable production (ODEPA, 2017; Panez et al., 2020; Berasaluce et al., 2021). The nationally oriented sector has developed towards a diverse range of farming systems with different approaches to (sustainable) production and market relationships (Gaitán-Cremaschi et al. 2020). This makes Chile an excellent case for the study of opportunities and tensions in the development towards more sustainable agriculture.

The vegetable sector in Chile represents a total area under cultivation of approximately 77,000 hectares, accounting for outdoor and greenhouse areas (ODEPA, 2019). Vegetables are produced mainly for the national market, divided in fresh consumption and agro-industry (e.g., frozen, dried, juices) (ODEPA, 2019). The main crops for fresh consumption are sweet corn (known locally as *choclo*), lettuce, tomato, onion, pumpkin and carrot, while the main crops for processing are corn, tomato, artichoke, green beans, asparagus, green peas and bell pepper (ODEPA, 2019). Vegetable production is one of Chile's main agricultural activities and is the source of work for 34,000 farmers (ODEPA, 2017). Almost 65% of these farmers are smallholders with less than five hectares who mainly supply fresh produce to the domestic market (Núñez and Osses, 2014; ODEPA, 2017). Vegetables are produced all over Chile and the largest production regions are Coquimbo, Valparaiso, Metropolitana, O'Higgins and Maule, contributing 85% of national production volume (ODEPA, 2017).

The production of vegetables in Chile is characterized by improper and excessive use of pesticides resulting in environmental pollution and human health risk (Elgueta et al., 2020; Calderon et al, 2022). Elgueta (2020) found that tomatoes and lettuce produced in the Metropolitan Region contained residue levels considerably exceeding maxima allowed in Chile. Similarly, Calderon et al. (2020) found residues of prohibited pesticides in the chard crop. The high levels of pesticides residues pose chronic health risks for consumers (specially children) (Muñoz-Quezada, 2011; Elgueta et al., 2020; Calderon et al., 2022). Moreover, research in rural areas in Chile has indicated that farmers exposed to pesticides have cognitive deficits (Corral et al., 2017) and that pesticides may affect the intellectual capacity of children living near agricultural activities (Muñoz-Quezada et al., 2016). The evidence of the negative effects of pesticides in Chile suggests a need to adopt sustainable agricultural practices (SAPs) that favour the use of organic farm inputs and support biological processes and biodiversity (Adnan et al., 2017; Coria and Elgueta, 2022).

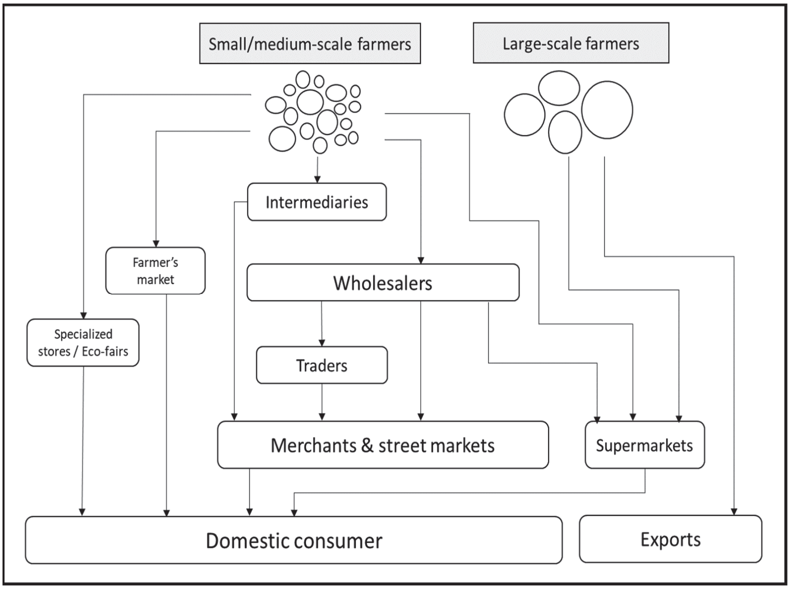
Organic agriculture is one of the most popular schemes for the adoption of SAPs. In Chile, there are two formal certification schemes for organic[3] products. One concerns certification by a third-party organization, that can be national or international, public or private, registered in Servicio Agricola Ganadero (SAG)[4]. The other is organic certification with a participatory guarantee system (PGS). This is a certification where farmers organise themselves into organic farmer associations. These associations have an internal control system to comply with organic regulations and to grant the organic certificate to their members. The associations are audited and registered by SAG (SAG, 2019). Besides these formal schemes, there are farmers that produce organically but do not have a formal certificate; these are known as

[3] Organic products, "are those coming from holistic production management systems in agricultural, livestock or forestry sector, which promotes and improves the health of the agroecosystem and, in particular, biodiversity, biological cycles and the biological activity of the soil" (SAG, 2019).
[4] Servicio Agricola Ganadero (SAG) is an institute within the Chilean Ministry of Agriculture (SAG, 2019)

agroecological farmers (Gaitán-Cremaschi et al., 2020). These farmers base their production on agroecological principles focused on recycling of organic matter to feed the soil and diversification of the agroecosystem (INDAP, 2016). Chilean organic production statistics show that in 2017 less than 1% of vegetables in Chile were sold under an organic certificate (ODEPA, 2017), and around 1.4% of the farmers (approximately 1,800 smallholders) self-recognised themselves as agroecological (INDAP, 2017). The limited presence of organic certification and the low number of agroecological farmers – together with evidence of the negative effects of intensive agriculture – has pushed governmental institutions, as well as multiple Chilean grassroots organisations involving consumers and farmers, to develop and promote the adoption of more sustainable agricultural practices (ODEPA, 2011).

The dual reality in Chile of large-scale and small-scale farmers has prevented the emergence of agricultural national social movements, leaving small-scale farmers to face the pressures of mainstream conventional markets (Pizarro et al., 2021). In the vegetable sector there is a low level of organization. There are organizations of large-scale farmers (e.g., Hortach) focused on international markets, but there are only a few small-scale farmer organisations, mainly related to PGS schemes (Gaitán-Cremaschi et al., 2020; Pizarro et al., 2021). This low level of organization is associated with the heterogeneity of marketing channels, especially in the informal markets (Figure 1.2). In Chile, the informal vegetable market (e.g., street markets, wholesale markets) has a share of 80% and supplies mainly for local demand. The main suppliers of informal markets are small-scale and medium-scale farmers (Boitano 2011; Schwartz et al. 2013; Gaitán-Cremaschi et al. 2020). The main buyers operating in informal markets are wholesalers and intermediaries trading products through diverse market channels to the final consumer. Intermediaries usually buy directly from the farms and use informal contracts (Boitano 2011; Schwartz et al. 2013; Gaitán-Cremaschi et al. 2020). Wholesalers operate through spot market transactions. Overall, the largest wholesaler sales volume of vegetables is concentrated in wholesale markets in the capital city of Santiago where most of the transactions are of a spot market type. Formal markets (e.g., supermarkets and agro-industries) have a share of 20% and supply national and international demand (Schwartz et al. 2013; Gaitán-Cremaschi et al. 2020). Mainly large-scale farmers participate in formal markets and around 96% of these transactions are through formal contracts (ODEPA, 2020b).

Figure 1.2 Vegetable market channels in Chile

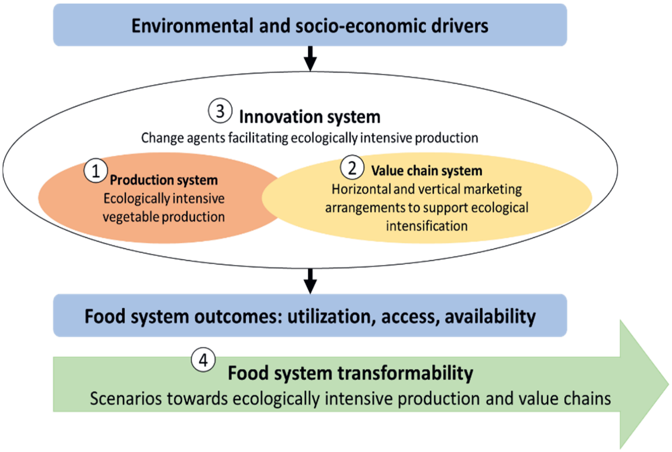


Source: The author

1.2.2 HortEco project

This thesis is one of the outcomes of the HortEco project "Horticultural food systems based on ecologically intensive production and socio-economically sustainable value chains in the transition economies Chile and Uruguay". HortEco is funded by the Dutch Science Council (NWO-WOTRO) and has the objective to enhance the sustainability of horticultural food systems in transitioning countries. Food systems are conceived as the network of actors and activities, interacting with each other within an ecological, social, political and economic environment (Gaitán-Cremaschi et al., 2019). The activities range from provisions of inputs and recycling through growing, processing and distribution to food disposition (Ericksen, 2008). Public and private actors involved in the food systems implement policies, standards and certifications according to which activities are performed (IPES-Food, 2015). Enhancing sustainability in food systems implies, next to food security and economic goals, taking into consideration societal goals such as environmental protection, social welfare and food safety (Gaitán-Cremaschi et al., 2019). In this respect, HortEco aims to enhance sustainability of food systems with a multidisciplinary approach focused on investigating and supporting organizations working on the sustainable production of vegetables in Chile and Uruguay (Figure 1.3).

Figure 1.3 Structure of the HortEco project



Source: HortEco project

The HortEco project is structured around four components: (1) the Production system, focusing on farming practices and their impact on ecological intensification; (2) the Value chain system, focusing on how farmer sustainable production relates to market channels and farmer-buyer relationships and arrangements; (3) the Innovation system, focusing on system transitions to sustainable production and the role of change agents; and (4) the food system transformability, focusing on potential sustainability transitions in food systems. This thesis contributes to component 2 of the project, Value chain system, taking as a case study the vegetable value chain in Chile.

1.3 Theoretical framework

1.3.1 Value chain upgrading

The value chain is defined as "the full range of activities which are required to bring a product or service from conception, through the different phases of production, delivery to final consumers, and final disposal after use" (Kaplinsky and Morris, 2000, p. 4). The value chain approach allows to identify strategic and operational misalignments between activities, processes or actors and hence provides the opportunity to overcome them (Fearne et al., 2012). Moreover, as accountability is desirable for negative environmental and social impacts of agricultural production and distribution, value chain analysis allows identifying the actors responsible (Fearne et al., 2012).

From a value chain approach, upgrading implies improving a product or process based on learning and putting learnings into action, thus creating added value over the product (Matheis and Herzig, 2019). SAPs adoption requires the use of new processes, practices and knowledge to improve both the crop and the production environment, thereby adding value to the crop. Under this lens, SAPs adoption can be seen as value chain upgrading. According to (Trienekens, 2011), there are three major categories of constraints and/or opportunities for value chain upgrading in emerging and developing economies: resources, market access and institutional voids.

1.3.1.1 Resources

Resources refer to the factors that enable the production of goods and services. According (Porter, 1990) these factors are labour, land, natural resources, capital and infrastructure. Therefore, for value chain upgrading, skilled human resources, science-based technologies and the efficient use of the production factors are important (Porter, 1990; Meyer-Krahmer and Schmoch, 1998). Under this lens, resources can be grouped in four categories: human, capital, natural resources and technology (Hussen, 2005; UMN, 2016). **Human resource** refers to the knowledge, training, skills, know-how, and talent of an individual to produce goods and services (Hussen, 2005). The strength of these resources often relates to characteristics such as age, gender, education, where in many studies human resources are divided in uneducated and educated (UMN, 2016). However the productivity or in this case the adoption of SAPs of an individual can also be affected by attitudes and motivations towards environmental aspects (Wright et al., 2001; Anibaldi et al., 2021). Under this lens, value chain upgrading can be achieved by increasing the total quantity of labor (number of people or number of work hours), increasing the education level of laborers, or applying policies that incentivize individuals (Wright et al., 2001; UMN, 2016). **Capital** refers to an item that is used to produce goods and services (e.g., financial capital, farm assets (e.g. machinery), size of land, greenhouses, roads). For example, (Alwang et al., 2019) describes distance to paved roads and to agro-processing plants as constraints for value chain upgrading. **Natural resources** include all the elements on earth that support life systems such as air, water, radiation from the sun, arable land, wilderness areas (Hussen, 2005). Moreover, natural resources are usually divided in renewable and non-renewable resources. For example, in the north of Chile the poor management of water by the government has generated water scarcity limiting agricultural productivity (Muñoz et al., 2020). **Technology** refers to the knowledge that can be applied for the efficient production of goods and services, i.e. the knowledge needed to resolve problems across the value chain related to scarcity, choice, opportunity, among others (UMN, 2016).

1.3.1.2 Market access and market orientation

From an economic point of view marketing is an economic activity in which goods and services are produced for the purpose of exchange, mediated by a monetary equivalent where goods and services are assigned a monetary value (Radaev, 2000). Under this lens market access refers to the recognition of the product's value and assurance of its sale (Mohan, 2016). Since market as an economic activity has social roots, the access to markets depends on social structures, governing rules, right to use resources, available infrastructures, networks, power, and market orientation (Radaev, 2000; Trienekens, 2011). Market orientation reflects the heterogeneity of end-users and how the chain organizes itself to satisfy end-user needs (Grunert et al., 2005). Market orientation in the value chain is defined "as chain members' generation of intelligence pertaining to current and future end-user needs, dissemination of this intelligence across chain members, and chain wide responsiveness to it" (Grunert et al., 2005, p. 430). Intelligence generation refers to the information of end-user demands (e.g., through consumer market research). Dissemination refers to the information exchange between chain members. Responsiveness refers to the value chain actions to create superior value for the end-user (Grunert et al., 2005). Thus, for value chain upgrading it is necessary to understand the market channels in which farmers and buyers are operating, build relationships and governance arrangements (e.g. contracts) between the actors of the value chains and develop practices for the right response to end-users demands.

1.3.1.3 Institutional voids

Institutions refer to aspects of social structure that act as authoritative guidelines and constraints for behaviour (Stephan et al., 2015). Institutions can be formal and informal. Formal institutions prescribe the guidelines, rules or norms implemented by governments (e.g., rules sanctioned and enforced by the state) (Stephan et al., 2015; Doh et al., 2017). Informal institutions prescribe the unwritten guidelines, rules or norms implicated by cultural and social constructs, entities that do not officially sanction or enforce (Stephan et al., 2015; Doh et al., 2017). Institutional voids are often referred to as the absence or underdevelopment of formal institutions, for example laws and business norms that govern transparency and market efficiency (Rehman et al., 2020; Ge et al., 2019). However, when formal institutions lack, these can be replaced by informal institutions. Then unwritten norms and rules take the upper hand. Personal relationships and networks between actors in the value chain play an important role in the maintenance of these institutions. Networks often have a local nature (Chipp et al., 2019; Ge et al., 2019) and are built from personal contacts and informal agreements based on trust and cooperation (Chipp et al., 2019; Ge et al., 2019). These informal institutions such as formal and informal contracts and spot markets can overcome the absence of formal institutions. Another way to fill the gap of institutional voids is to develop formal institutions at a different level. For example, international standards on food safety and quality have emerged to replace the lack of national quality and safety assurance systems (Henson, 2006; Goedhuys and Sleuwaegen, 2016; Brenes et al., 2019; Chiappetta-Jabbour et al., 2020).

These constraints and enablers show that the use of SAPs is influenced by a wide variety of factors across the value chain. The above presented value chain framework stresses the importance of the interaction and interdependence between these factors. This thesis takes a farmer perspective, taking into account constraints and opportunities mentioned previously such as economic resources (e.g., land, assets, income, greenhouse), human resources (e.g., training, education, attitudes and motivations towards SAP adoption), market channel characteristics (e.g., type of buyer and type of agreements) and relationship attributes between farmers and buyers. Understanding the role of these factors and how these factors interact and impact on the adoption of SAPs has important implications from an academic viewpoint. Moreover, understanding these factors may inform policies and development interventions that enhance the adoption of SAPs. To analyse the role of these factors on the impact on SAPs adoption, we use, besides the value chain upgrading perspective, the lenses of social capital theory and transactions cost economics.

1.3.2 Theories used to analyse value chains

The value chain literature uses different scientific disciplines to analyze upgrading constraints (Bolwig et al., 2010; Trienekens, 2011; Devaux et al., 2018; Norris et al., 2021). To understand how vegetable value chain characteristics impact the farmer's adoption of SAPs in Chile, we used different concepts that help to understand this complex process. Farmer and farm characteristics were mainly analysed using social capital (SC) theory and transactions cost economics (TCE). SC theory helps to analyse horizontal relationships among farmers, for instance the support provided by the farmers' network (Häuberer, 2010). SC theory allows to identify the resources that farmers may have access to through their network, such as information, emotional support or financial support, that can be key for the adoption of SAPs. TCE helps to understand the costs of accessing new markets linked to the adoption of SAPs (Valdivia et al., 2012). TCE allows identifying how farmers perceive the adoption of SAPs related to costs or how new (uncertain) environments may be perceived as a risk or a barrier by farmers to adopt SAPs. Farming heterogeneity was mainly analysed using TCE, by analysing the costs of accessing new markets and the governance forms used for vertical transactions between suppliers and buyers in each market channel (Williamson, 1998). Therefore, TCE allows understanding the organization of the market channels in relation to the adoption of SAPs. Finally, farmer-buyer relationships were analysed mainly using SC theory to analyse the support of vertical farmer-buyer relationships (Häuberer, 2010; Tefera and Bijman, 2021). SC theory allows to understand how "good" attributes of the relationship between farmers and buyers may improve cooperation and hence support the adoption of SAPs. SC theory and TCE helps to analyse the overall relationship between farmers and buyers in the value chain, focusing on the type of contracts and relationship attributes for the adoption of SAPs (Häuberer, 2010; Tefera and Bijman, 2021).

1.3.2.1 Social capital theory

Social capital (SC) is defined as a "property of relationships among individuals that are a resource that actors can use and benefit from (Häuberer, 2010, p. 249)". SC refers to relationships that provide support when this is needed. The amount of SC possessed by an individual depends on the range of relationships that he/she can build and on the resources owned by the partners (Häuberer, 2010). SC theory is one approach for understanding how farmer networks and farmer-buyer relationships could benefit from developing closer ties (Carey and Lawson, 2011). The achievement of SC in farmer networks and farmer-buyer relationships is related to rational choices, where individuals are willing to cooperate to improve mutual economic performance (Putnam et al., 1993; Carey and Lawson, 2010). In general, SC in farmer networks and farmer-buyer relationships provides many advantages such as work coordination, reducing free-rider issues, improving economic performance, sense of safety and good reputation (Häuberer 2010; Nilsson et al. 2012). In this sense, SC is equally important as physical capital and human capital to increase the productivity of farmer networks and farmer-buyer relationships (Putnam et al., 2000; Requena, 2003; Alghababsheh and Gallear, 2020). Many factors can condition SC between individuals, such as trust, social norms, collective assets (e.g., social status, historical background) and individual characteristics (e.g., sex ethnicity) (Häuberer, 2010). Trust is one of the key concepts often used as an indicator to measure SC in farmer networks as well as farmer-buyer relationships (Son and Feng, 2019). However, concepts such as opportunistic behaviour and satisfaction are also used as a proxy for SC in farmer-buyer relationships (Murphy and Sashi, 2018; Alghababsheh and Gallear, 2020; Touboulic et al., 2021). Trust is defined as the belief that an individual is reliable and benevolent (Ganesan, 1994). Individuals who trust each other and share the same norms will tend to work in collaborative forms characterized by low transaction costs (Putman et al., 1933). Opportunism is defined as "self-interest seeking with guile" (Williamson, 1985), characterized by deliberate selfish behaviour based on information distortion and reneging on agreements (Jap and Anderson, 2003). Satisfaction can be defined as a positive affective state that emerges from the overall relationship with a business partner and encapsulates the economic and non-economic aspects of the farmer-buyer relationship (Geyskens et al. 1999; Gorton et al., 2015). In this sense farmer networks and farmer-buyer relationships characterized by trust, satisfaction and non-opportunistic behaviour will more easily conduce to establish closer ties or agreements with business partners. Regarding SC and governance, literature found that contractual governance (e.g., formal and informal contracts) and relational governance (e.g., behavioural norms, trust, opportunism) are associated with social capital development in farmer-buyer relationships (Carey and Lawson, 2011).The theory of SC, in our thesis, captures the issues related to trust, satisfaction and opportunistic behaviour that condition the cooperation in farmer networks and farmers-buyers relationships in the value chain for the adoption of SAPs.

1.3.2.2 Transactions cost economics

Transaction Cost Economics (TCE) studies the costs that buyers and sellers incur for market exchange (Williamson 1979, 1985). These costs mainly reflect the costs of searching for an exchange partner, transfering the product and monitoring the agreements (Williamson 1979, 1985). In order to mitigate transaction costs, (Williamson 1985, 1998) argues that individuals/firms identify the most economical governance structure to improve the coordination between them, avoiding conflicts, and to achieve mutual gains. Governance structure is defined as "the institutional framework within which the integrity of a transaction is decided” (Williamson, 1979, p. 235). According to Williamson (1998), one of the reasons governance structures emerge is to mitigate the risks related to human beings' bounded rationality and opportunistic behaviour. There are different forms of governance structures ranging from spot markets through various types of contracts to vertical integration (Frank and Henderson, 1992). The choice of governance structure is determined by the cost of transactions and the cost of the governance structures themselves. The transaction costs are determined by the transaction-specific investments of partners and the uncertainty faced by the partners (Williamson, 1998). Some authors have used to risk and barriers perception to measure uncertainty (Vignola et al., 2010; Leite et al., 2014; Kernecker et al., 2021). Risk perception represents a real concern of a person, and can be defined as the cognitive representation and evaluation of the chance that an investment (e.g., time and money) will generate gains or not (Aven and Renn, 2010; Vignola et al., 2010). Barriers perception can be defined as perceived challenges to overcome and could derive from lack of information and resource constraints (Leite et al., 2014; Kernecker et al., 2021). If investment costs and uncertainty are low, a spot market governance structure is most efficient. If investment costs and uncertainty are high, contract or vertical integration governance structures are most efficient. In emerging and developing countries, agriculture's most common governance structures are spot market, informal contract and formal contract (Bijman, 2008; Keco et al., 2019). Spot market transactions take place where the identity of farmer and buyer are unknown (Prowse, 2012; Mugwagwa et al., 2020) . Informal contracts are defined as verbal commitment to provide a product under pre-agreed conditions (e.g., price, quantity). Formal contracts are written commitments to provide a product under pre-agreed conditions, usually seeking to assure quality and volume (Bijman, 2008; Michler and Wu, 2020). In our thesis, TCE theory allows understanding how different organizational structures between farmers and buyers may support the adoption of SAPs.

1.4 Research aims and questions

This thesis aims to empirically identify how vegetable value chain relationships are related to the farmer's use of sustainable agricultural practices (SAPs) in Chile. This general aim is addressed by exploring three groups of factors related to the adoption of SAPs: farm and farmer characteristics; farming systems; and farmer-buyer relationships.

1.4.1 Farm and farmer characteristics

There is extensive literature on the factors correlated to SAP adoption in developing and developed countries (Dessart et al., 2019; Tey et al., 2017; Anibaldi et al., 2021). These studies have been carried out in different disciplinary contexts such as economics, sociology and psychology, resulting in the identification of categories such as socio-economic factors (e.g., farm size, financials, education of the farmer), biophysical factors (e.g., water quality, soil erosion), institutional factors (e.g., provision of information, government support, consumer demand) and factors related to farmer perceptions (e.g., attitude towards sustainable practices, environmental awareness) (Knowler and Bradshaw, 2007; Baumgart-Getz et al., 2012; Tey et al., 2017). However, although several literature reviews have summarized key factors for SAP adoption, the results of these studies are not unequivocal, and the factors differ according to context (Knowler and Bradshaw, 2007; Anibaldi et al., 2021). For example, Prokopy et al. (2008) and Baumgart-Getz et al. (2012) in the context of developed countries, found education level, income, farm size, environmental attitudes, environmental awareness, training, risk, financial capacity and networking to be positively related to SAP adoption. In studies in a developing country context, factors such as farmer gender, education level, land size and land tenure were found to be related to SAP adoption (Tey et al. 2017). Moreover, although a wide range of factors affecting SAP adoption has been identified in different contexts, there is no information about how these factors interact and jointly impact the adoption of SAPs.

Further, most studies on SAP adoption refer to a ‘yes or no’ decision and focus on the adoption of a single farming practice, such as conservation tillage, the use of cover crops and compost, contour barriers, integrated pest management or water conservation (Tey et al., 2017) or on a single production stage, such as planting, manuring or weeding (Kassie et al., 2013). Similarly, these studies do not consider possible interactions amongst SAPs, although some practices have to be adopted simultaneously during different production stages to be effective (Kassie et al., 2013). Moreover, most of these studies consider agriculture an engineering process where cause-effect relations are linear, identifying key factors supporting SAP adoption but underestimating the interaction between these factors. As Darnhofer (2021) has argued, it is necessary to study the interaction between factors to better understand how changes in farmer behaviour are brought about. This leads to the following research question:

RQ1: What farmer and farm characteristics are related to SAP adoption and how do these factors interact in affecting SAP adoption?

1.4.2 Categorizing farming systems

The farming system approach considers the complexity and variability of farmers' production environments considering factors such as farm characteristics, agricultural practices, socio-economic characteristics, market channel characteristics, and relationships with stakeholders, such as the government (Darnhofer et al., 2010; Dumont et al., 2020; Gaitán-Cremaschi et al., 2020). In the last decade, governments have implemented numerous sustainable agriculture policies to foment SAP adoption, however, the adoption of these practices has been low (Eyhorn et al., 2019). An evaluation study carried out in Chile in 2016 by the Organisation for Economic Co-operation and Development (OECD) concluded that the sustainable agriculture policies do not achieve the environmental results aimed for (Martínez et al., 2017). According to Lockie (2020), sustainable agricultural policies face five main challenges: a) responsibility identification due to the diverse forms of agricultural resources used; b) misunderstanding between public and private benefits; c) the unclear relationship between farmers and access to resources (agriculture is associated with an absolutist perception of private property); d) the globalization of value chains and contradictory obligations; and e) polarization of political views. Ganpat and Bekele (2002) argue that the limited effect of extension strategies or education packages in rural areas is due to policymakers' and researchers' standardized view of farmers. Policymakers often classify farmers into only two categories: small-scale and large-scale. They fail to take into account the contexts in which farmers interact, their behavioral patterns and the commercial channels in which they sell (Fernández et al., 2019). In particular, they treat small-scale farmers as one undifferentiated group, assuming that all farmers in this group have similar characteristics such as homogeneous capabilities, circumstances and resources (Ganpat and Bekele, 2002). Consequently, the standardization of farmers leads to inflexible policies, following one-size-fits-all paths that do not consider the farmers' particular aspirations and resources (Dumont et al., 2020).

The adoption of SAPs is a unique process for each farmer. It depends on the specific characteristics of the farmer and of the farm as well as on the context in which production takes place (Daloğlu et al., 2014; Teixeira et al., 2018). The farming system approach uses an integrated and multidisciplinary perspective which allows to account for farmer heterogeneity as well as the complexity and variability of the production environment (Darnhofer et al., 2010). A method that allows investigating the diversity of farming systems is the development of a farming typology (Righi et al., 2011). A farming typology[5] measures heterogeneity (Alvarez et al., 2018) and groups farms by similar constraints and opportunities (Ganpat and Bekele, 2002). Thus far, little research has sought to construct a farming typology that takes a farming system approach and considers socio-economic, farm production and market characteristics together with sustainability levels of agricultural practices (Teixeira et al., 2018). Indeed, various food value chain schemes present farmer-buyer agreements that allow farmer access to market channels where they can receive premium prices for sustainable production, supporting the adoption of SAPs (Dumont et al., 2020). This integrated approach we advocate is essential for the understanding of farmer adoption of SAPs (Lam et al., 2020). This leads to the second research question:

RQ2: What types of farming systems exist and how are these related to the adoption of SAPs?

1.4.3 Farmer-buyer relationships

In the transformation of food systems[6] in the last decades, farmer-buyer relationships had an essential role, where farmers and buyers started to coordinate food chains, increasing effective communication, reducing risk, uncertainty and transactions costs for mutual benefits (Reardon et al., 2009; Dlamini-Mazibuko et al., 2019; Lees et al., 2020). This transformation allowed a consistent supply of products that met high safety and quality standards (Mergenthaler et al., 2009; Bellemare and Lim, 2018). However, despite the benefits of transforming food supply chains towards growth and specialisation, there were also negatively impacts the environment, such as soil degradation, water pollution and deforestation (Rueda et al., 2017). Nowadays, strategies to reduce the negative environmental impact of food supply chains are common conditions for premium markets, where farmers are incentivised to implement SAPs through new production standards and certifications (e.g., organic certification, UTZ, rainforest alliance, Global GAP) (Vanderhaegen, 2018; Della Navarrete et al., 2020; Grabs and Carodenuto, 2021).

[5] Farming typology refers to the classification, description, comparison and interpretation of a set of elements, allowing to simplification of farming elements into types (Alvarez, et al., 2018).
[6] Food systems are perceived as the interaction of farmers with upstream and downstream value chains, linking input suppliers (i.e., R&D agricultural industries), wholesalers, processors, retailers and consumers (Reardon et al., 2019).

Most of the literature on food chains that has studied adoption of SAPs focuses on the dyadic relationship between farmers and lead firms (Freidberg, 2020), specifically on the role of lead firms and the governance forms used to coordinate the adoption of SAPs with farmers (Achabou et al., 2017; Freidberg, 2020). To pursue the adoption of SAPs, lead firms usually operate through hybrid governance forms (e.g., formal contracts) and, in parallel, stimulate close relationships with farmers to sustain the relationship and create mutual benefits (Dubbert et al., 2021; Touboulic et al., 2021; Veldwisch and Woodhouse, 2021). Hence, this literature has investigated how contractual provisions (e.g., quality, price, payment schemes) and relationship attributes (e.g., trust and satisfaction) between farmers and lead firms can support farmers to adopt SAPs (Gualandris and Kalchschmidt 2016). However, far too little attention has been paid to the relationship between farmers and other types of buyers (e.g., intermediaries and wholesalers) and even less attention to how the relationship with other types of buyers affects the adoption of SAPs (Thorlakson, 2018; Grabs and Carodenuto, 2021). In developing and emerging economies, especially in chains of fresh products, farmers mostly supply to intermediaries and wholesalers (Guarín, 2013; Mariyono et al., 2020). Very little is known about the relationships of farmers with intermediaries and wholesalers and the adoption of SAPs. Therefore, there is the need to study the adoption of SAPs in the relationship between farmers and these other types of buyers (Thorlakson, 2018; Grabs and Carodenuto, 2021). This leads to third research question:

RQ3: How do different farmer-buyer relationships link to different levels of SAP adoption?

1.5 Data and methods

The research performed in this PhD dissertation builds on insights which are derived from different sources. Previous qualitative research was performed during my MSc study program (Benitez-Altuna, 2016) which provided an overview of the agricultural extension programs that support farmers and informed about the everyday life of small-medium-scale farmers in Chile. Furthermore, having the opportunity to work in the Horteco project since 2017 gave me the chance to conduct exploratory research by means of informal conversations with project partners such as Chilean vegetable growers and public servants from the Chilean Ministry of Agriculture. In the context of Horteco, several workshops[7] were in fact organized which provided insights on the different sustainable farming practices in Chile. The workshops provided the context to discuss challenges and opportunities for organic certification,

[7] The HortEco project organized several workshops with different themes in Chile and Uruguay. Some workshops were part of the annual HortEco project meetings, and others were workshops organized by HortEco partners in home countries with specific themes. The HortEco project organized around ten workshops during the four years of the project, and more information can be found on the following link: https://knowledge4food.net/research-project/gcp3-horticultural-food-systems-chile-uruguay-horteco/.

production commercialization and agroecological transitions in Chile, technical organisational aspects for organic agriculture in Chile and exchange of experiences in participatory guarantee systems in Chile and Uruguay. These workshops provided rich information over the main opportunities and constraints for the adoption of SAPs, taking into consideration organic certification schemes, governmental institutional voids and commercialization challenges. This has led to a joint publication[8] with HortEco partners that provided a rich context for discussing concepts and methods applied to this thesis.

1.5.1 Data collection

A large-scale face to face (i.e. personal interview) survey among vegetable farmers in Chile was used to collect the data used for the analyses performed in this thesis. The survey aimed to gather information related to farmers' and farms' resources and characteristics and farmer's network, market channels, buyer-supplier relationships and agricultural practices. The topics and concepts measured in the survey were informed by an extensive literature study and conversations with HortEco partners at regular project meetings and during intensive workshops in Chile. Before conducting the personal interview surveys, the questionnaire was tested in a focus group discussion with three staff members from the Pontificial Catholic University of Valparaiso with fieldwork experience in the vegetable sector in Chile. Then, the questionnaire was tested with a pilot among 13 farmers. These farmers were selected randomly from a contact list provided by two main sources: organic production organizations and private extension agricultural services[9] (this last included conventional and organic farmers). As a result of the focus group and piloting of the survey, some questions were modified (e.g., questions on the types of livestock, the level of education and the values of the households' monthly income were readjusted), the order of the questions was changed (e.g., bring questions regarding environmental awareness and motivations to the beginning of the survey), and some words were adjusted to the rural slang (e.g., inorganic inputs by agro-chemicals, organic or sustainable by agricultural practices without chemicals). Together with two enumerators, the lead author surveyed a sample of 352 farmers. The lead author trained the two enumerators about the research objective, the concepts to be measured with the questionnaire and how to perform the survey (what region and locations to focus on, how to approach a farmer, how to conduct the questionnaire and how to apply snowball sampling). On average, each enumerator conducted between 2 and 3 surveys per day. Each interview lasted 30 to 40 minutes with the farm holder. All the

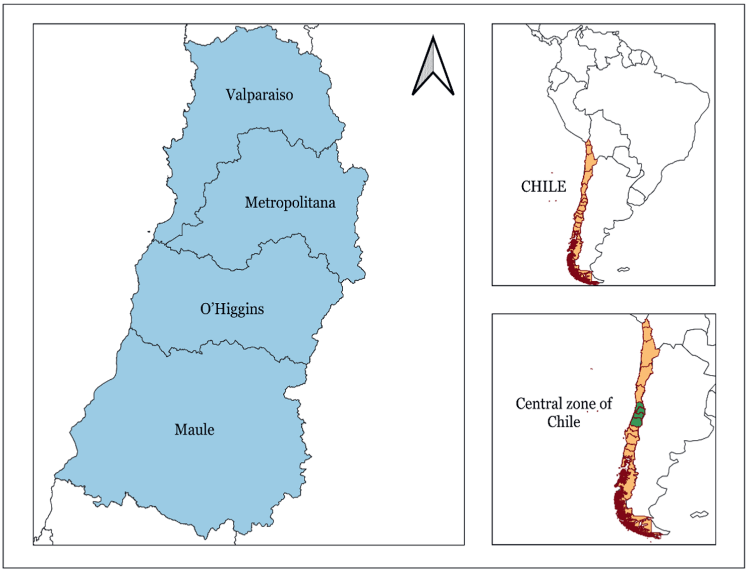
[8] Gaitán-Cremaschi, D., Klerkx, L., Duncan, J., Trienekens, J.H., Huenchuleo, C., Dogliotti, S., Contesse, M., Benitez-Altuna, F., Rossing, W., 2020. Sustainability transition pathways through ecological intensification. An assessment of vegetable food systems in Chile. Int. J. Agr. Sustain. 18 (2), pp. 131–150. https://doi.org/10.1080/14735903.2020.1722561.

[9] The names of the organizations and extension agricultural services cannot be mentioned due to guarantee the protection of personal data and anonymity.

fieldwork was conducted in Chiles' official language Spanish. Most farmers were visited in the field and at their homes, and a small percentage (5%) were visited at fairs.

The contact lists were divided into organic, small-scale farmers and large-scale farmers, which provides an overview of the farmers' population in Chile. The farmers contained in the lists were selected using the random number generator in Excel. During the day-to-day operations, snowball sampling was also used to complement the observations needed per day and achieve a sufficient number of observations for the statistical analyses. Farmers were asked to recommend other farmers who mainly produce vegetables and who potentially might also be willing to participate in the survey. The rule used for the snowball sampling was that farmers had to be at least one km away from the farmer who advised the new respondent. Most of the farmers surveyed were identified from the contact lists (70% approx.), and the others were approached through snowball sampling (30% approx.). Farmers were contacted by phone to schedule an appointment for the survey. Hence, the fieldwork was mainly executed according to farmers' predisposition to participate in the survey. We implemented the questionnaire from October 2018 to April 2019 (summer season) in four regions in central Chile: Valparaiso, Metropolitana, O'Higgins and Maule (Figure 1.4). These four regions include 50,000 hectares dedicated to vegetable production, which represents 70% of vegetable production in Chile (Valparaiso 11%, Metropolitana, 31%, O'Higgins 14% and Maule 14%). Moreover, these regions contain the major concentration of vegetable farmers in Chile and are the largest suppliers of vegetables for the capital (Santiago) region, with the highest concentration of people. The sample is illustrative only for the central region in Chile, due to the differences in agroecological and socio-economic conditions between regions. As our descriptive statistics related to age, gender, and land, among others, match up to high level the results of previous studies on the vegetable sector in the central regions of Chile (Boza et al., 2019), we assume a fair representativity of our sample for this region. For example, the descriptive statistics of Boza et al. (2019) show an average age of investigated vegetable farmers of 52.47 years old, 53,34% of farmers who did not complete high school, an average land size of farmers of 10.31 ha., and 8.49% of farmers being females. While our results show that the average age of farmers is 52.68 years, farmers score 4.56 in education, which means that the average farmer did not complete high school, the land size of farmers on average being 10.23 ha. and 21% of farmers surveyed being females.

Figure 1.4 Research area



Source: The author

1.5.2 Sustainable agricultural practices, a farm-level index

Sustainable Agricultural Practices (SAPs) imply that "agriculture will have to be carried out to make the best use of available natural resources and inputs, and regenerate conditions for future production" (Leeuwis, 2004, p. 5). The use of SAPs involves substituting synthetic resources produced out-farm (i.e., fertilisers, insecticides, herbicides) for on-farm resources to achieve effective and efficient short-and-long term use of natural resources (Taylor et al., 1993). Some examples of on-farm resources are integrated pest management, crop rotations, green manures and cover crop (Taylor et al., 1993; Kleijn et al., 2019). The sustainability level of agricultural practices depends on how on-farm resources substitute out-farm resources. Therefore, if a farm substitutes all the out-farm resources with on-farm resources, it can be called "sustainable". In contrast, if a farm only uses out-farm resources it can be called "unsustainable". However, because SAPs involve different practices in different stages of farming, the sustainability level of a farm is not bimodal, with one cluster of farms "sustainable" and another "unsustainable". Instead, the sustainability level of a farm ranges from "low sustainability" to "high unsustainability" (Taylor et al., 1993).

In order to quantitively analyse the level of sustainability at farms, literature has developed many sustainability indicators (Rigby et al., 2001; Bockstaller et al., 2008; Gómez-Limón and Sanchez-Fernandez, 2010; Waas et al., 2014). These studies are focused on environmental, social and/or economic dimensions. For example, there are studies focusing only on specific environmental dimension, e.g., assessing nitrogen losses in soils (Bockstaller et al., 2008); and there are more holistic frameworks taking into consideration the three dimensions of sustainability, such as MESMIS (Astier et al., 2011; Merlín-Uribe et al., 2013; González-Esquivel et al., 2020), SAFE-Sustainability Assessment of Farming and the Environment framework (Gómez-Limón and Sanchez-Fernandez, 2010) and Bellagio STAMP, a framework that also includes an assessment of supporting decisions (Waas et al., 2014). However, there is no single, universally accepted set of indicators to measure sustainability in farming practices due to the complexity of farm-level practices, making it difficult to measure the indicators. Therefore, in most cases these indicators can only be conceived as proxy values of the use of SAPs (Bockstaller et al., 2008; Gómez-Limón and Sanchez-Fernandez, 2010; Waas et al., 2014). Despite of the difficulties to measure sustainability of agricultural practices, literature agrees that integrated sustainability indexes may provide valuable information necessary for the design, implementation and monitoring of agricultural policies towards sustainability (Gómez-Limón and Sanchez-Fernandez, 2010).

In this study, we focus on the measurement of (environmental) sustainability practices at the farm. As suggested in literature (Koohafkan et al., 2012; Weltin et al., 2018), we applied a framework focusing on measuring a broad range of these practices that farmers are currently using. For measuring sustainability practices, this study is based on the farm-level index of Rigby et al. (2001), which has been applied in similar studies (Parra-López and Calatrava-Requena, 2006; Kleemann and Abdulai, 2013). This index includes as much as possible the different agricultural practices used for vegetable production, encompassing sustainable agricultural practices (SAPs) and conventional agricultural practices (Rigby et al., 2001). Moreover, this farm-level index uses data that can be easily obtained through face-to-face interviews with farmers (Castoldi and Bechini, 2010). According to Rigby et al. (2001), this index supports detailed comparative assessments of large samples, where it is possible to exclude/include components (e.g., use of technology, type of irrigation systems) or modify the weighting of the components. The farm-level index of Rigby et al. (2001), measures specifically the sustainability level of agricultural practices used by farmers such as the use of traditional seeds, synthetic fertilisers, organic fertilisers, green manure, wildflower strips, beetle banks, synthetic pesticides, organic herbicides, resistant varieties, intercropping and crop rotation. Rigby et al. (2001) classified the different agricultural practices in five stages of vegetable production: Seed sourcing, soil fertility, pest/disease control, weed control and crop management.

The index of Rigby et al. (2001) is calculated for each production stage and is based on four sustainability dimensions of the agricultural practices, namely minimization of off-farm inputs, minimization of non-renewable inputs, maximization of natural biological processes and promotion of local biodiversity. The dimensions score in the range from -1 to 3 points according to the following scheme: -1 indicates the practice has a negative impact on the specific sustainability dimension; 0 indicates no significant impact; and 3 a strong positive impact. The sum of each sustainability dimension's scores per agricultural practice is shown in the "Total" column in Table 1.1. This enables the calculation of five indexes (seed, fertiliser, pest, weed and crop). The scores of the indexes are interpreted from -3 to +3, where: ±3 indicates a strong negative/positive impact; ±2 indicates a medium negative/positive impact; ±1 a moderate negative/positive impact; and 0 has no significant impact. For the total scores across the different dimensions that are not between -3 and +3 (e.g., the total score of chemical pesticides receives a score of -8), we applied the cross-multiplication technique.

In order to adapt the five indexes to the local Chilean context, I multiplied the scores by the percentage of farm area on which each agricultural practice was applied. For instance, if a farmer used chemical herbicides on 80% of her/his field, the final sustainability score for weed control would result from multiplying -4 (index associated with the use of chemical herbicides in weed control as in Table 1.1) by 80%, resulting in a final score of -3.2. Moreover, I modified/aggregated the following practices from the work of Rigby et al. (2001) in order to adapt to the local context after a literature review on practices in emerging and developing countries (Astier et al., 2011; Kassie et al., 2013; Roco et al., 2014; Gaviglio et al., 2017). In the stage seed sourcing, I modified the practice, ''own seeds'' in two practices ''reused and traditional seeds''. In the stage of soil fertility, I modified ''natural fertilisers'' in ''organic fertiliser purchased'', and ''organic, composted and green manure'' were grouped into one practice ''prepared organic fertiliser''. In the stage pest/disease control, I modified the "natural pest control" in three practices "organic pesticide purchased", "prepared organic pesticide" and "preventive practices without chemicals". In the stage of weed control, I modified the practices of "crop-compost management" and "management of the crop" in three practices "organic herbicides purchased", "mechanic control" and "preventive practices without chemicals". In crop management, I modified "resistant varieties" by "crop rotation plus intercropping". The sustainability dimensions of the new modified/aggregated practices were scored based on the work of Rigby et al. (2001).

Table 1.1 Farm-level index

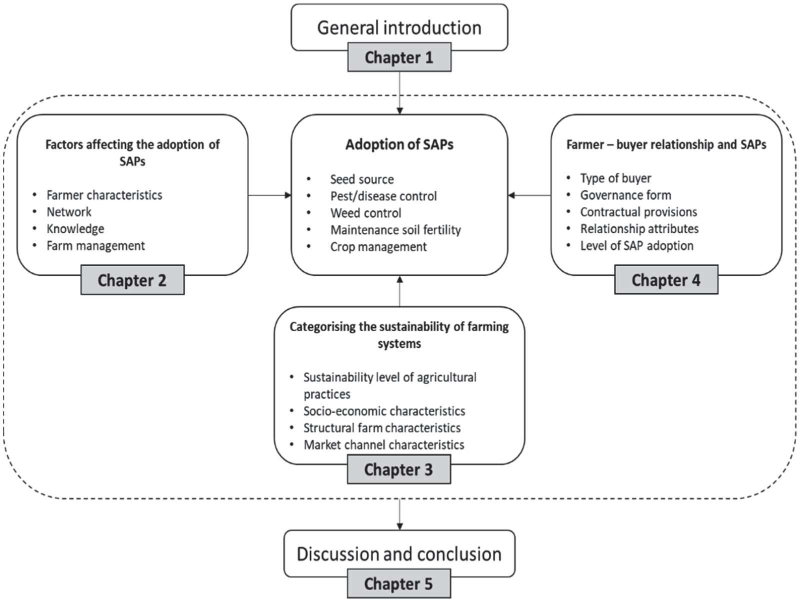
Production stage	Sustainability dimensions				TOTAL
	Minimises off-farm inputs	Minimises non-renewable inputs	Maximises natural biological processes	Promotes local biodiversity	
Seed sourcing					
1 Conventional seed					0
2 Organic seed		1			1
3 Reused	1				1
4 Traditional	1				1
Soil fertility					
1 Conventional synthetic	-1	-1	-1		-3
2 Organic fertiliser purchased		1	1		2
3 Prepared organic fertiliser	2	2	1	3	8
Pest/disease control					
1 Chemical pesticides	-1	-1	-3	-3	-8
2 Organic pesticide purchased		1	1		2
3 Prepared organic pesticide	1	1	1	1	4
4 Preventive practices without chemicals	2	2	2	2	8
Weed control					
1 Chemical herbicides	-1	-1	-1	-1	-4
2 Organic herbicides purchased		1	1		2
3 Mechanic control	1	0.5	1	0.5	3
4 Preventive practices without chemicals	1	1	1	1	4
Crop management					
1 Crop rotation	0.5	0.5	1		2
2 Intercropping	1	1	1	1	4
3 Crop rotation + intercropping	1.5	1.5	2	1	6

Source: Based on Rigby et al. (2001)

1.6 Outline of the thesis

The outline of the thesis is presented in Figure 1.5; a general introduction in (Chapter 1), three research chapters covering the research questions (Chapter 2-4) and a general discussion and conclusion (Chapter 5).

Figure 1.5 Thesis outline



Chapter 2[10] - empirically analyses what factors are correlated to the simultaneous adoption of various SAPs by farmers in different vegetable crop production stages. Further, since the literature on SAP adoption mainly analyses these factors as separate from each other, this chapter explores the interactions between factors and how these jointly impact the application of SAPs. We identify which factors are correlated to SAP adoption through multiple linear regression. Then, based on the results of this step, we carry out a literature review to see how the factors related to the adoption of SAPs interact. We identify that the perception of risk and barriers is correlated to diverse factors such as economic resources (e.g., assets and income), trust in people and training on SAPS. Subsequently, these elements were analysed by performing a structural equation modelling (SEM).

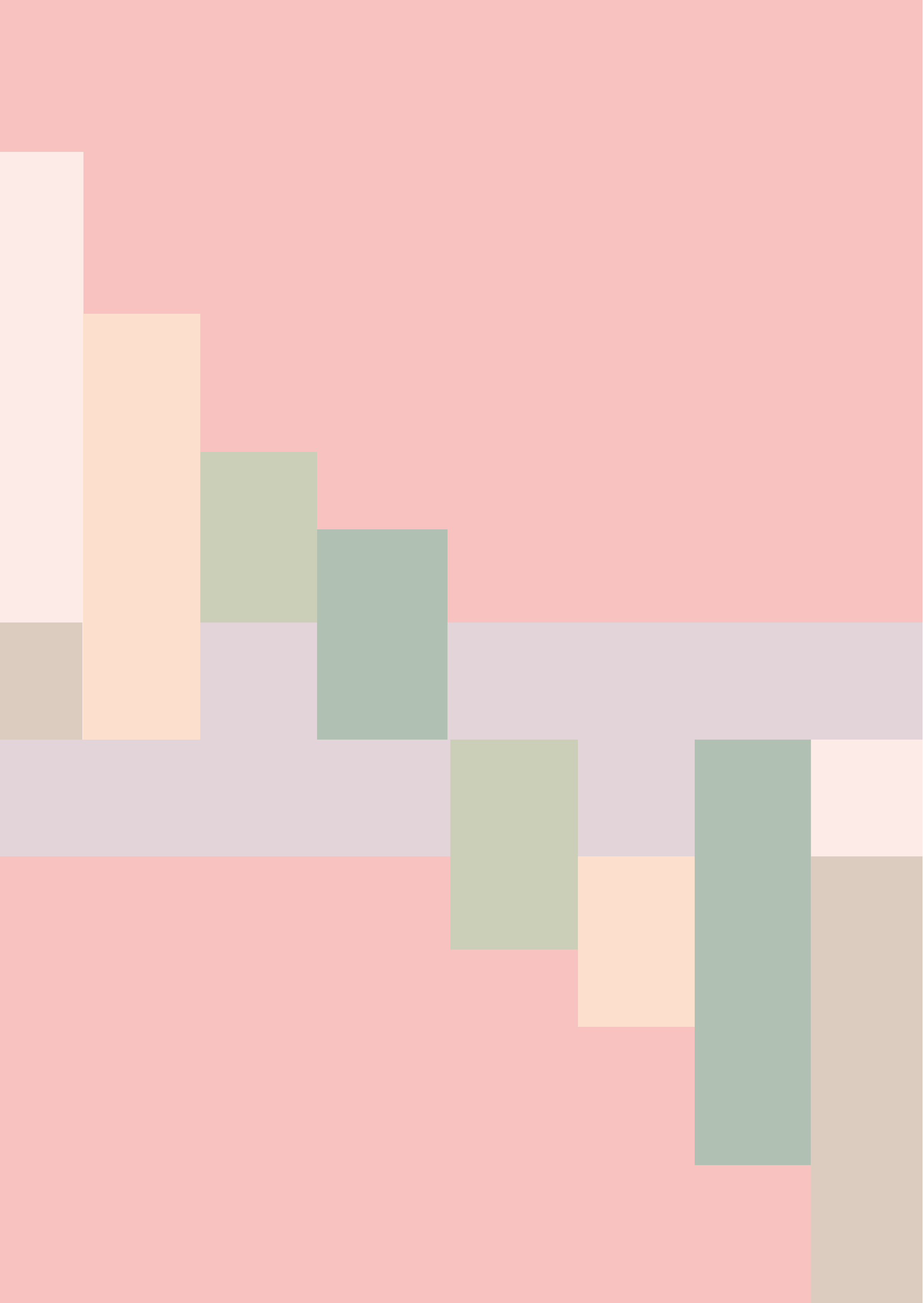
Chapter 3 - characterises farmers' heterogeneity and their initial starting point in the transition to SAPs. Specifically, this chapter classifies farming systems, with elements including the sustainability level of agricultural practices and market channel and buyer-supplier relationships characteristics, in combination with socio-economic and farm characteristics. The chapter applies a farming typology approach, and conducts an empirical analysis to unravel the diversity of co-existing farming systems in the vegetable

[10] In Chapter 2, we used the term ecological intensification (EI) to refer to sustainable agricultural practices (SAP). However, during the introduction and conclusion section, we use the term SAP in order to maintain consistency across the thesis.

sector. We developed the typology using multivariate analysis techniques including principal component analysis (PCA) and hierarchical clustering (CA).

Chapter 4 – explores how different farmer-buyer relationships are linked to different levels of SAP adoption. First we explore what farmer characteristics are related to each type of buyer, then we analyze what governance form (spot market, informal contract, formal contract) is used for buyer farmer transactions and finally we investigate whether there is a relationship between type of contract (formal or informal) and (a) provisions in contracts with farmers (e.g., quality, quantity and the provision of services); (b) attributes of relationships with the farmer (i.e., satisfaction, trust and opportunism); and (c) levels of SAP adoption by farmers. This analysis is performed using ANOVA and logit modelling.

Chapter 5 – discusses the overall results and insights derived from the three research chapters. It indicates how the three research questions support the achievement of the main objective. Besides, it reflects on the theoretical and methodological contributions. Finally, this chapter provides policy implications, gives insights for future research and presents the main conclusions.



CHAPTER 2

Factors affecting the adoption of ecological intensification practices: A case study in vegetable production in Chile

A version of this chapter is published as:

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ABSTRACT

Vegetable production is highly dependent on chemical fertilisers and pesticides, but the intensive use of these inputs negatively impacts the environment and human health. Ecological Intensification (EI) has the potential to counter the adverse effects of agricultural intensification and improve sustainability. Despite the potential benefits of EI for the environment, the adoption rate of EI in vegetable production is low. Moreover, most studies on EI adoption focus on implementing a single farming practice or a single production stage. This article aims to empirically analyse what factors influence the simultaneous adoption of various EI practices in different vegetable crop production stages by farmers in the context of an emerging economy such as Chile. Further, since the literature on EI practices adoption mainly analyses these factors as separate from each other, we aim to explore the interactions between factors and how these jointly impact the application of EI practices. We collected data via a survey to vegetable growers in the central zone in Chile. First, we measure EI practices adoption through a farm-level index that reflects the sustainability of farming practices in five production stages. Second, we identify which factors affect EI practices adoption through multiple linear regressions. Third, based on the results of the previous steps, we carried out a literature review to see how the factors predicting the adoption of EI could interact. This analysis was performed using structural equation modelling. Our results show that being a woman, receiving training on EI practices, and being pro-environment are positively related to EI practices adoption. Contrarily, obstacles include the perception of risk and barriers, better access to credit and higher income from farm activities, all of which are negatively related to EI practices adoption. With reference to the interaction among the factors, we found that economic resources, trust and training are the main correlated factors to the perception of risk and barriers amongst Chilean farmers when it comes to adopting EI practices. Embracing a broad perspective, including different farming practices and production stages, allowed us to offer insights into the complex processes of adopting EI practices. Identifying which factors are important and how these factors interact with each other, contributes to the debate on what policymakers and scholars need to focus in order to increase the use rate of EI practices.

Key words: Sustainability; risk perception; barrier perception; agroecology; emerging economies

2.1 Introduction

Agricultural Intensification (AI) is characterised by the intensive use of agrochemicals and monocultures (Tscharntke et al., 2005). AI has multiple detrimental consequences for ecosystems such as biodiversity loss (Plue et al., 2018), reduction of environmental quality (Cánovas et al., 2018), soil degradation (Bardgett and van der Putten, 2014) and adverse social and cultural effects (Horlings and Marsden, 2011). This has encouraged governments, farmers and scientists to explore alternative agricultural practices that have fewer negative effects on agro-ecosystems. A promising alternative to counter the adverse effects of AI is ecological intensification (EI) (Bommarco et al., 2013). EI is defined as "the means to make intensive and smart use of the natural functionalities of the ecosystem (support, regulation) to produce food, fiber, energy and ecological services in a sustainable way" (Tittonell, 2014, p. 58). EI also embraces the complexity of the rural landscape and local management interventions (Bommarco et al., 2013). EI includes concepts such as agroecology and organic, bio-diverse and restorative agriculture. These concepts differ in the degree they internalise diversity, ecosystem services, social movements among other elements. However, they share the principles of biodiversity and natural regulation (Tittonell, 2014).

The goals of EI practices are to achieve more environment-friendly crop production (Bommarco et al., 2013), while at the same time improving food security and farm-product quality (Martin-Guay et al., 2018). To achieve these goals EI practices include farming practices such as soil structure management, water conservation, crop diversification, and the use of organic fertilisers and pesticides (Astier et al., 2011). The benefits of EI practices are context-dependent (Geertsema et al., 2016), as shown by several experiments around the world. Recent EI applications on co-culture practice in cauliflower-aquaculture (Wan et al., 2019), soil transformation in maize crop (Ullah et al., 2020), plant diversity (Wan et al., 2020), intercropping maize, bean, and squash (Novotny et al., 2021), and livestock farm redesign (Ruggia et al., 2021) found that EI enhances ecosystems services, crop yields and economic value, decreasing the negative effects of pesticide use. However, despite the goals of EI and its potential benefits, the use rate of EI practices in developed and developing countries is still low (Pannell et al. 2006a; Tey et al. 2017).

In Latin America, the negative impact of AI on society and the environment, and the higher demand for sustainable[11] products has triggered the emergence of alternative farming and alternative agri-food systems (Le Coq et al., 2020). At the same time there have been numerous studies on alternative models to AI (Giraldo and McCune, 2019; Le Coq et al., 2020; Schiller et al., 2020). A model that has received much

[11] Throughout the paper we use the term "sustainable" to refer to any product or practice that could be framed within ecological intensification.

attention is organic agriculture. Organic agriculture is characterised as such if it is certified according to international and/or national organic production standards. However, in large parts of Latin America the organic certification model seems to be only accessible and affordable for large-scale farmers who mostly deliver to international markets (Parrott and Marsden, 2002; IICA, 2020; Le Coq et al., 2020). The agroecology approach proposes a whole new business model, as opposed to the export-oriented business model based on AI. It encompasses an integral vision combining social, environmental, economic and cultural characteristics (Gaitán-Cremaschi et al. 2020; Le Coq et al. 2020). This model is usually promoted by rural or new urban agriculture movements. Moreover, some governments have institutionalised agroecology, and they have even included it in law (e.g. Brazil, Nicaragua) (Giraldo and McCune, 2019; Schiller et al., 2020). Further, there are other sustainable agriculture approaches that promote the adoption of specific production techniques aimed to provide or conserve environmental services. The latter approaches have been promoted by policies in some countries (e.g. Costa Rica, Chile and Mexico) to encourage conventional farmers to produce more environmentally friendly (Le Coq et al., 2020). Although these agroecology and sustainable agriculture models have been mostly promoted from bottom-up, with the support of social movements and NGOs, and governments have tried to institutionalise these models, the low adoption rates of environment-friendly practices are still a challenge (Le Coq et al., 2020; Schiller et al., 2020). Until now, the top-down support and public policies in favour of AI and agri-export models evidence the asymmetrical balance of power between the conventional and the alternative models in Latin America (Le Coq et al., 2020; Schiller et al., 2020; Loch et al., 2021; López-García et al., 2021).

EI practices adoption is a dynamic process that depends on factors such as environmental challenges, farmers' and farms' characteristics and government policies (Daloğlu et al., 2014). For example, Pannell et al. (2006) argue that EI practices adoption depends on a range of farmers' personal, social, cultural and economic characteristics. Knowler and Bradshaw (2007) argue that financial factors and farmers' knowledge of farming practices, amongst others, might explain their adoption. However, the literature concludes that there are no universal factors that explain EI adoption and that factors differ according to the context. In a developed country context, for example, Prokopy et al. (2008) and Baumgart-Getz et al. (2012) find that factors such as access to information, capital and networking are positively related to EI practices adoption. In a developing country context, Tey et al. (2017) also find that EI practices adoption is positively related to gender, education level, farm size and land tenure.

Most of the studies on EI practices adoption refer to a ‘yes or no’ decision and focus on the implementation of a single farm practice, such as conservation tillage, the use of cover crops and compost, contour barriers, integrated pest management or water conservation (Tey et al., 2017) or on a single production stage (e.g., planting, manuring or weeding) (Kassie et al., 2013). Similarly, these studies do not consider possible interactions amongst EI practices, although some have to be adopted simultaneously during different production stages to be effective. Moreover, these research approaches may underestimate the interaction between natural, technological, and social factors on farmers’ adoption decision (Kassie et al., 2013; Darnhofer, 2021). In addition, Serebrennikov et al. (2020) suggest utilising standardised surveys to better study factors influencing farmers’ adoption decision.

Therefore, this article aims to analyse which factors are related to the simultaneous adoption of various EI practices in different vegetable production stages, by farmers in an emerging economy such as Chile. Additionally, since most of the literature on the adoption of EI practices analyses factors separately (e.g., age, education, received training, risk behaviour, income), this paper aims to explore the interactions between factors and how these jointly are related to the application of EI practices. Although there is an extensive body of literature on experiments supporting the adoption of EI, this paper is one of the first to report, based on a survey among farmers, on the adoption of EI practices in different vegetables production stages. We argue that such an approach is crucial for designing policies that improve the adoption rate of EI practices.

Our paper is organised as follows. Section 2 presents the characteristics of the vegetable farming sector in Chile. Section 3 details the methods of our study, and section 4 describes the results of our data collection and analysis. This is followed by the discussion in section 5. Section 6 presents our conclusions, including implications for policy.

2.2 Case study: Vegetable production in Chile

Emerging economies as Chile, are considered as economies that neither meet all the standards of a developing economy nor fully meet the standards of a developed economy. Usually, these are growing economies that are attractive for foreign investors (Meyer, 2004) but also open to innovative developments in specific sectors, such as modern agriculture. According to the (Worl Bank, 2021), Chile has improved economically and has reduced poverty levels in the last few decades. Moreover, it has a fast-developing agricultural export sector next to strong domestic calls for more sustainable agricultural production. These dual challenges make a country like Chile an excellent case for the study of opportunities and tensions in the development towards more sustainable agriculture.

Vegetable production is socially and economically significant in Chile. The main vegetables produced are tomatoes, sweet corn (known locally as *choclo*), lettuce, onions and pumpkin. Vegetable production is one of Chile's main agricultural activities and is the source of work for 34,000 farmers (ODEPA, 2017). Most of these farmers are smallholders with less than five hectares who mainly supply the local market (Núñez and Osses, 2014; ODEPA, 2017). From 2007 to 2018, 75,000 hectares were dedicated to vegetable production on average every year. Vegetables are produced all over Chile, and the largest production regions are Coquimbo, Valparaiso, Metropolitana, O'Higgins and Maule, contributing 85% of national production volumes (ODEPA, 2017).

However, vegetable production in the country makes intensive use of chemical inputs (e.g., fertilisers and pesticides) in order to increase production and reduce costs (Altieri and Rojas 1999; David et al. 2000). The intensive use of these inputs threatens the sector's sustainability through soil erosion, biodiversity loss and water pollution (Riquelme-Garcés et al., 2013). Additionally, it has negatively impacted human health. Research in rural areas in Chile has indicated that farmers exposed to pesticides have cognitive deficits (Corral et al., 2017) and that pesticides may affect the intellectual capacity of children living near agricultural activity areas (Muñoz-Quezada et al., 2016). Additionally, consumers are affected by the high residue levels of pesticides found in vegetables (Muñoz-Quezada, 2011).

To counterbalance these effects, two types of ecological farmers have emerged in Chile: those with organic[12] certifications (certified through a participatory guarantee system[13] (PGS) or a third-party organisation) and those without certifications, also known as 'agroecological farmers' (Gaitán-Cremaschi et al., 2020). In 2017, less than 1% of vegetables in Chile were sold with an organic certification (ODEPA, 2017), and around 1.4% of the farmers (approximately 1,800 smallholders) self-recognised themselves as 'agroecological' (INDAP, 2017). The limited presence of organic certifications and low number of agroecological farmers – together with evidence of the negative effects of intensive agriculture – indicate the need for a better understanding of what influences EI practices adoption in the vegetable sector in Chile.

[12] Organic products, "are those coming from holistic production management systems in agricultural, livestock or forestry sector, which promotes and improves the health of the agroecosystem and, in particular, biodiversity, biological cycles and the biological activity of the soil" (SAG, 2019).

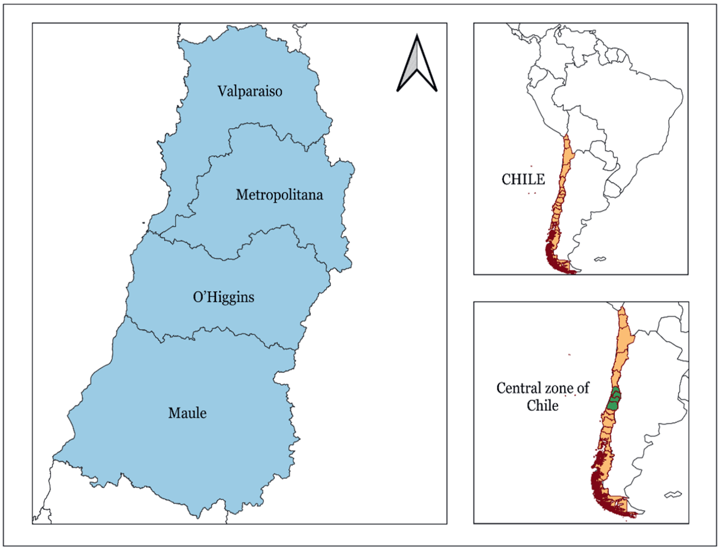
[13] PGS is a certification where farmers organise themselves into organic farmers' associations. These associations have internal control systems to comply with organic regulations and to grant the organic certifications to their members. The associations are audited and registered by the Servicio Agricola Ganadero (SAG) which is an institute within the Chilean Ministry of Agriculture (SAG, 2019).

2.3 Methods

2.3.1 Data collection

We collected data for our study by conducting manual face-to-face interviews with vegetable growers in Chile. The questionnaire was designed based on literature review with the aim to gather information related to factors that could explain farmers' adoption of EI practices (Appendix 2.A). Before conducting the interviews, a pilot test with 13 farmers and a group discussion with three members of the Pontificial Catholic University of Valparaiso were carried out to test the survey. After the pilot, some questions were modified, some questions were reordered, and some words were changed according to the rural slang. Together with two enumerators, the lead author surveyed a total of 352 farmers. Each interview lasted 30 to 40 minutes. All the fieldwork was conducted in Chile's official language Spanish. Vegetable growers were visited in the field, at their home or at fairs, and were randomly sampled. We implemented the questionnaire from October 2018 to April 2019 in four regions in central Chile: Valparaiso, Metropolitana, O'Higgins and Maule (Figure 2.1). These four regions include 50,000 hectares dedicated to vegetable production, which represents 70% of vegetable production in Chile (Valparaiso 11%, Metropolitana, 31%, O'Higgins 14% and Maule 14%) (ODEPA, 2017). The sample is ilustrative only for the central region in Chile, due to the differences in agroecological and socio-economic conditions between regions. However, the sample represents the regions with a major concentration of vegetable farmers and vegetable production.

Figure 2.1 Research area



The survey gathered information on five data categories (details in Table 2.2) related to EI practices adoption: 1) Type of farm practices (e.g., organic or conventional practices), measured through a farm-level index (explained in section 2.3.2); 2) farmers' characteristics, including socio-economic traits, perceptions, attitudes and beliefs related to the adoption of EI practices (Leite et al., 2014); 3) network, including indications of trust in people (e.g., farm labourers, input suppliers and neighbours), personal links and membership in farmers' organisations (Baumgart-Getz et al., 2012) –being a beneficiary of the Chilean INDAP[14] was also included in this category as has been used in other Chilean studies (Jara-Rojas et al., 2013); 4) knowledge, including information on farmers' education level, training, technical assistance, access to internet and attending technical agricultural talks (Prokopy et al., 2008; Tey et al., 2017); and 5) farm management, including information regarding land tenure, income from the farm, land size, use of a greenhouse, number of assets, number of animals, access to credit and total household income (Baumgart-Getz, et al. 2012). For analysis, the interviews were tabulated to build a digital database.

2.3.2 Measurement of EI practice adoption: A farm-level index

A large number of studies have proposed indexes and developed frameworks for measuring the adoption of EI practices (Lefroy et al., 2000; Astier et al., 2011). However, there is no single, universally accepted index to measure EI practices due to the complexity of farm-level practices. To measure EI practices adoption, we used a farm-level index, which builds on the work of Rigby et al. (2001) (Table 2.1) and encompasses organic and conventional farming practices. Moreover, this index serves three purposes. First, it allows a comparison among diverse agricultural practices by their sustainability dimensions. Second, it supports detailed comparative assessments for large samples. Third, it is a versatile index which can be modified according to the research needs. It is possible to exclude/include components (e.g., use of technology, type of irrigation systems) or modify the weighting of the components (Rigby et al., 2001).

Rigby et al.'s (2001) index reflects the level of EI practices adoption in five agricultural production stages: seed sourcing, soil fertility, pest control, weed control and crop management. The index scores of the farming practices used in each production stage, were based on four sustainability dimensions: minimisation of off-farm inputs; minimisation of non-renewable inputs; maximisation of natural biological processes; and promotion of local biodiversity. These dimensions are scored from -1 to 3 points according to the following scheme: -1 indicates the practice has a negative impact on the specific sustainability

[14] The Institute of Agricultural Development (INDAP), within the Chilean Ministry of Agriculture, provides assistance to family farmers (INDAP, 2020).

dimension; 0 indicates it has no significant impact; and 3, a strong positive impact. The index is the sum of each sustainability dimension's scores per farming practice used and is shown in the "Total" column in Table 2.1. The scores of the total index are interpreted from -3 to +3. Where ±3 indicates strong negative/positive impact, ±2 indicates medium negative/positive impact, ±1 moderate negative/positive impact, and 0 has no significant impact. The total scores are transformed between the range of -3 to +3 using a rule of three, considering that the lowest possible value is -8 and the highest possible value is 8.

Once we obtained the production stage index and in order to adapt it to the local context, we multiplied the index by the percentage of farm area on which that farming practice was used. For instance, if a farmer used chemical herbicides on 80% of her fields, the final index for weed control would be the result of multiplying -4 (the total sustainability score associated with the use of chemical herbicides as in Table 2.1) by 80%, obtaining a final score of -3.2. Rigby et al. (2001) calculate five indexes (SEEDX, SOILX, PESTX, WEEDX and CROPX). We add a final one (TOTALX), that represents the sum of the average scores of the previous indexes.

Table 2.1 Scoring EI practices

Production stage		Sustainability dimensions				TOTAL
		Minimises off-farm inputs	Minimises non-renewable inputs	Maximises natural biological processes	Promotes local biodiversity	
Seed sourcing						
1	Conventional seed					0
2	Organic seed		1			1
3	Reused	1				1
4	Traditional	1				1
Soil fertility						
1	Conventional synthetic	-1	-1	-1		-3
2	Organic fertiliser purchased		1	1		2
3	Prepared organic fertiliser	2	2	1	3	8
Pest/disease control						
1	Chemical pesticides	-1	-1	-3	-3	-8
2	Organic pesticide purchased		1	1		2
3	Prepared organic pesticide	1	1	1	1	4
4	Preventive practices without chemicals	2	2	2	2	8
Weed control						
1	Chemical herbicides	-1	-1	-1	-1	-4
2	Organic herbicides purchased		1	1		2
3	Mechanic control	1	0.5	1	0.5	3
4	Preventive practices without chemicals	1	1	1	1	4
Crop management						
1	Crop rotation	0.5	0.5	1		2
2	Intercropping	1	1	1	1	4
3	Crop rotation + intercropping	1.5	1.5	2	1	6

Source: Based on Rigby et al. (2001)

2.3.3 Data analysis methods

To identify the factors related to EI practices adoption, we estimated a multiple linear regression model. Building on the results of this regression, we applied a structural equation model (SEM) to inspect the interaction amongst the factors, allowing us to explore the factors related to adoption and potential policy actions to enhance the latter.

2.3.3.1 Multiple linear regression

The multiple linear regression technique serves to analyse whether a set of independent variables (and which ones, in particular) is a significant predictor of a dependent variable.

A linear regression model for p independent variables is as follows:

$$Yi = \beta 0 + \beta 1X1 + \beta 2X2 + \dots + \beta pXp + \varepsilon$$

In this model, *Y* is the estimated dependent variable; $X1, X2, \dots Xp$ are the independent variables; $\beta_0, \beta_1, \dots, \beta_p$ are the parameters indicating the magnitude of the influence of the independent X variables on the dependent one; and, finally, ε is a statistically independent error term normally distributed with mean 0 and variance σ.

The dependent variables in this study are the practices described in the previously calculated indexes (SEEDX, SOILX, PESTX, WEEDX, CROPX and TOTALX), whereas the independent variables are divided into four categories as per our survey: farmers' characteristics, network, knowledge and farm management (see Table 2.2).

Some variables, such as "awareness" (statements 8.1, 8.2 and 8.4 Appendix 2.A), "motivations" (statement 8.3 and 8.4 Appendix 2.A), "barriers" (statements 29.5, 29.6 and 29.8 Appendix 2.A) and "trust" (statements 8.18 and 8.20 Appendix 2.A) were created as a composite factor of two or more variables that were designed to measure these concepts. In fact, we used different items (or statements) in the survey to help us to identify these variables. We measured the reliability of each of these constructs we created using Cronbach's alpha, where values above 0.5 indicate that consistency was achieved (Taber, 2018).

We performed a descriptive statistics analysis using IBM SPSS Statistics 25 on the variables to check for normality, correlations and outliers, thus avoiding overfitting and multicollinearity in our model. We adjusted the following variables to achieve normal distribution and eliminate outliers[15]: 1) the variables

[15] We use percentiles and box plots to detect outliers (Schwertman et al., 2004; Ghosh and Vogt, 2012).

contacts, tech visits, talks, vegi-size, tech visits and technical talks were adjusted with winsorization; 2) the variable income-farm was adjusted with logarithm 10. Moreover, the value of the variable pro-environment framed as a negative statement in the questionnaire was inverted for the analysis.

We estimated six multiple linear regression equations (one for each dependent variable) with RStudio version 3.6.0. using all the independent variables in Table 2.2

2.3.3.2 SEM

The main objective of performing a SEM is to identify how the factors related to EI practices adoption interact. The SEM test used the output of the multiple linear regressions to identify indirect relations and relations amongst the independent variables.

This process comprised three steps. First, we derived the design of the structural equation model from the outputs of the linear regressions. We then complemented these outputs with a literature review to identify which variables could initially be grouped to form a construct and how these constructs could interact with each other.

Second, we carried out a confirmatory factor analysis (CFA) with RStudio version 3.6.0 (Lavaan package). CFA allows checking wether the variables can be grouped in the identified constructs. CFA also checks for unidimensionality, internal consistency and convergent and discriminant validity for each construct.

We measured the validity of the CFA model through goodness-of-fit indexes. Unidimensionality checks whether the set of variables grouped together measures only one construct (Danes, 1984). In addition, unidimensionality is evaluated by checking the values of the variables' completely standardised loadings (> 0.5) and their significance (p-value > 0.05) in the constructs (Hair et al. 2014). We removed variables that did not present loadings above 0.5 or had a p-value higher than 0.5 from the construct. Internal consistency explores whether the variables measure the intended construct (Vaske et al., 2016). We tested the internal consistency of the construct with Cronbach-α and composite reliability (CR), where values above 0.5 indicated that the internal consistency of the construct was achieved (Taber, 2018). Convergence of the construct examines how strong the relationship between the variables measuring a given construct is (Lee et al., 2005). We measured this convergence by the average variance extracted (AVE) in which values should be 0.5 or higher (Hair et al., 2014). Finally, discriminant validity examines whether the variables measuring a given construct are not related to the variables measuring another construct (Lee et al., 2005). We tested for this discriminant validity by looking at the modification indexes. These illustrated whether there was a strong relationship amongst variables from different constructs.

In the third step, the SEM was estimated in RStudio version 3.6.0 (Lavaan package) with a maximum likelihood estimator. SEM tested the interactions amongst observed variables through unobserved latent constructs. We checked the model's goodness-of-fit using two types of indexes (absolute and incremental) which provide sufficient basis for model evaluation. Finally, we evaluated the model's operational relevance, checking the regression coefficients of the linear relationships between constructs (Hair et al., 2014).

2.4 Results

We organise the results of the paper into the following steps: 1) descriptive results, where we present an overview of the farmers surveyed summarising the information of the farm practices, farmer characteristics, network, knowledge and farm management; 2) factors affecting EI practices adoption, where we present the factors that predict the adoption of EI practices in each stage of production (seed sourcing, soil fertility, pest control, weed control and crop management); and 3) exploring interactions amongst variables. Because the SEM used in 3) is based on the results of 2), we present a literature review to support the structure of the SEM, and then we present the outcomes from the SEM, notably the interactions between factors.

2.4.1 Descriptive results

The distribution of the farmers surveyed in each region was: Valparaiso 45%, Metropolitana 26%, O'Higgins 13% and Maule 16%. Table 2.2 provides details of the surveyed farmers' descriptive statistics. The index scores for the farm practices reflect the heterogeneity of farming practices (namely, conventional and EI practices) used in Chile. Some of the applied EI practices registered during the survey range from endemic seeds, humus, compost, nettle tea as biofertiliser, manure, insect traps, biological pest control, chilli pepper tea, intercropping and crop rotation. From the 352 farmers surveyed, 225 farmers present an index score below 0 (i.e., use of conventional practices), 1 farmer presents an index score equal to 0 (i.e., balanced mix of conventional and EI practices) and 126 farmers present an index score above 0 (i.e., use of EI practices). The overall impact (TOTALX) of vegetable production shows a negative effect on the environment, with a mean of -0.40.

The average age of the sample is 53, with an average 29 years of experience in agriculture. Only 21% of the sample comprises women. Most of the farmers are aware that the use of agrochemical inputs is negative for the environment; farmers scored 6.62 out of 7 in the environmental awareness statements. Moreover, the majority of them are motivated to produce vegetables until the end of their lives and to bequeath the land to their children (6.14). However, the majority of farmers do not seem to have a clear position in terms of their perception of which actions they can take to preserve the environment. They are actually neutral in terms of the statement that describes whether they consider it easy to take actions to preserve the environment, with a score of 4.46. When it comes to the perception of risk and barriers regarding EI practices adoption, farmers also take a neutral position (4.05 and 4.06, respectively). Most farmers consider that people are opportunistic (5.57), so they do not trust them. Most farmers also perceive difficulty in obtaining credit (4.88). On average, vegetable producers indicate they rely on four contacts to reach out in case of problems. The majority of farmers (80%) are not members of any farmers' associations; however, nearly all farmers (71%) receive training or have access to credit via INDAP.

Half of the farmers surveyed completed high school, while the other half started high school but did not finish. Farmers receive nine technical visits per year on average and attend four technical talks per year. Only 28% of farmers have participated in a specific training programme related to sustainable production practices during the last five years, and a small majority of the farmers have access to internet.

Although the average size of land exploited is 10 hectares, there are farmers with 100 m^2 and farmers with 600 hectares. A small majority of the farmers (57%) own their land. The average number of animals that farmers have is 12. Almost half of the farmers surveyed (49%) use greenhouses to produce vegetables. The average percentage of income derived from farming activities is 80%. On average, farmers score 1.87 out of 5 on asset ownership, including tractors, trucks, pick-ups, cars and motorcycles. On average, the total monthly income of the households surveyed is 560,000 Chilean pesos (±700 USD).

Table 2.2 Descriptive statistics

Variable name	Description	Type of variable	Min.	Mean	Max.
		Dependent variables			
Farm practices					
SEEDX	Type of seed used	Continuous variable, index	0.00	0.20	1.00
SOILX	Type of fertiliser used	Continuous variable, index	-3.00	0.30	8.00
PESTX	Type of pesticide used	Continuous variable, index	-8.00	-3.30	8.00
WEEDX	Type of herbicide used	Continuous variable, index	-4.00	-0.19	4.00
CROPX	Strategy for crop management	Continuous variable, index	0.00	2.58	6.00
TOTALX	Average of the farming practices indexes SEEDX, SOILX, PESTX, WEEDX and CROPX	Continuous variable	-15.00	-0.40	26.00
		Independent variables			
Farmer characteristics					
Age	Age of the farmer (years)	Continuous variable	24.00	52.68	91.00
Experience	Numbers of years working in agriculture	Continuous variable	1.00	29.07	78.00
Gender	Gender of the farmer	Dummy, 1 woman, 0 man	0.00	0.21	1.00
Awareness	Environmental awareness (three statements)	Likert scale from 1 (disagree) to 7 (agree)	1.00	6.62	7.00
Motivations	Motivations to preserve the land (two statements)	Likert scale from 1 (disagree) to 7 (agree)	1.00	6.14	7.00
Pro-environment	Easiness to act in favour of the environment	Likert scale from 1 (disagree) to 7 (agree)	1.00	4.46	7.00
Risk perception	Risk perception to adopt EI practices	Likert scale from 1 (disagree) to 7 (agree)	1.00	4.05	7.00
Barrier perception	Barrier perception to adopt EI practices (three statements)	Likert scale from 1 (disagree) to 7 (agree)	1.00	4.06	7.00
Network					
Trust	Farmers' trust in farm labourers, input suppliers and neighbours (two statements)	Likert scale from 1 (disagree) to 7 (agree)	1.00	5.57	7.00
Contacts	Number of contacts to reach out in case of problems	Continuous variable	0.00	4.12	80.00
Coop-Mem.	Membership in farmers' organisations	Dummy, 1 yes, 0 no	0.00	0.20	1.00
INDAP-benef.	Beneficiary of INDAP, farmers who have access to training and funding.	Dummy, 1 yes, 0 no	0.00	0.71	1.00
Knowledge					
Education	Level of formal education	Categorical variable from 1 to 7	1.00	4.56	7.00
Tech. visits	Number of visits by an agricultural technician per year	Continuous variable	0.00	9.10	72.00
Talks	Agricultural technical talks attended per year	Continuous variable	0.00	3.98	90.00
Training	Participation in training programmes related to EI practices	Dummy, 1 yes, 0 no	0.00	0.28	1.00
Internet	Internet access	Dummy, 1 yes, 0 no	0.00	0.59	1.00
Farm management					
Vegi-size	Total area of land exploited (ha)	Continuous variable	0.01	10.23	600.00
Tenure	If the farmer owns the land	Dummy, 1 yes, 0 no	0.00	0.57	1.00
Animals	Number of the animals on the farm	Continuous variable	0.00	11.92	271.00
Credit	Ability to get credit	Likert scale from 1 (disagree) to 7 (agree)	1.00	4.88	7.00
Greenhouse	Use of greenhouses	Dummy, 1 yes, 0 no	0.00	0.49	1.00
Income-farm	Percentage of income that comes from the farm	Continuous variable in %	0.00	0.80	1.00
Assets	Number of assets related with the farm	Continuous variable	0.00	1.87	5.00
Total income	Total household income	Categorical variable from 1 to 8	1.00	2.95	8.00

Note: we acknowledge that there are two schools of thought, one only allowing to consider the Likert scale as ordinal and the other as interval, for analysis purposes (Joshi et al., 2015). However, most of the literature agrees on using mean values of Likert scale to give indicative information about the data.

2.4.2 Factors affecting EI practices adoption

The choice of sustainable seeds (SEEDX) for vegetable production only seems to be explained by gender: women farmers seem to be the ones most likely to use sustainable seeds (e.g., traditional or reused seeds) compared to men (Table 2.3). Further, perceived barriers such as the availability or accessibility of organic inputs, the fact that conventional production is adopted in their surroundings and the time required to transition to EI practices, all seem to be negatively related to the use of sustainable seeds. When it comes to preserving soil fertility (SOILX), the use of organic fertilisers positively correlates with gender (namely, being a woman); in addition, those considering it easy to take actions to preserve the environment (pro-environment variable) and with a network of contacts to reach out to in case of problems are more likely to adopt such practices. However, farmers who perceive the adoption of EI practices as risky and those who perceive barriers to their adoption are less likely to use organic fertilisers.

When it comes to a practice such as pest and disease control (PESTX), we found that awareness of the impact agrochemicals has on the environment together with attending agricultural technical talks and participating in training programmes related to EI practices all positively correlated to the use of organic pesticides or preventive practices without chemicals, in particular, amongst women. In contrast, farmers who perceive barriers for the adoption of EI practices, who see the adoption of EI practices as risky and those who also have better access to credit are less likely to apply EI practices for pest and disease control. Regarding weeding practices (WEEDX), farmers who believe that taking action to preserve the environment is easy, who participate in training programmes related to EI practices and who have access to internet are more likely to adopt more sustainable practices such as using chemical-free organic herbicides, control mechanisms and preventive practices. On the other hand, farmers who perceive EI practice adoption as risky and who derive a higher percentage of their income from farming activities are less likely to use sustainable weeding practices.

Regarding crop rotation and intercropping practices (CROPX), we found that having a safety network, namely, relying on close contacts in case of problems, participating in training programmes related to EI practices and owning the cultivated land all positively correlate to the use of crop rotation and intercropping techniques. In contrast, farmers with more experience in agriculture, those who perceive the adoption of EI practices as risky, those who perceive great barriers and those with access to internet are negatively related to use crop rotation and intercropping practices.

Table 2.3 Linear regression results

Variables	SEEDX		SOILX		PESTX		WEEDX		CROPX		TOTALX	
Intercept	0.145		-0.422		-10.442		0.295		3.275		-7.150	
Farmers' characteristics												
Age	0.004		0.016		0.026		-0.032		0.011		0.025	
Experience	-0.002		0.016		-0.031		0.017		-0.024	*	-0.024	
Gender	0.185	*	2.699	***	2.236	*	0.821		0.520		6.461	***
Awareness	0.043		0.278		1.546	*	0.246		0.161		2.274	
Motivations	-0.024		-0.114		0.122		0.018		-0.020		-0.018	
Pro-environment	0.000		0.263	*	0.198		0.238	*	0.036		0.736	*
Risk perception	-0.011		-0.524	***	-0.791	***	-0.269	**	-0.216	***	-1.812	***
Barrier perception	-0.050	**	-0.358	*	-0.509	*	0.086		-0.227	**	-1.059	*
Network												
Trust	0.000		-0.019		-0.026		-0.099		0.137		-0.006	
Contacts	0.007		0.162	*	-0.013		0.031		0.092	*	0.278	
Coop-Mem.	0.031		0.273		1.173		0.355		0.225		2.056	
INDAP-Benef.	-0.107		0.048		-0.342		-0.574		-0.086		-1.062	
Knowledge												
Education	0.012		0.288		0.460		-0.002		-0.002		0.757	
Tech. visits	-0.001		-0.026		-0.063		0.025		-0.022		-0.086	
Talks	0.001		0.032		0.224	*	0.087		-0.010		0.334	
Training	0.106		0.900		1.787	*	1.211	**	0.697	*	4.700	**
Internet access	-0.017		-0.501		-0.043		1.402	**	-0.611	*	0.230	
Farm management												
Vegi-size	-0.010		-0.077		-0.054		-0.084		-0.022		-0.246	
Tenure	0.037		0.748		0.718		0.292		0.606	*	2.401	
Animals	0.001		0.004		0.003		0.000		0.002		0.010	
Credit	0.002		-0.149		-0.656	***	-0.130		-0.071		-1.004	**
Greenhouse	0.005		0.515		0.639		0.776		-0.399		1.536	
Income-farm	-0.069		-1.377		-1.455		-1.466	*	-0.912		-5.278	*
Assets	-0.015		-0.027		0.062		-0.033		-0.044		-0.057	
Total income	0.008		-0.041		0.180		-0.205		0.095		0.037	
Adjusted R2	0.276		0.501		0.542		0.421		0.437		0.638	
p-value	0.276		0.000		0.000		0.000		0.000		0.000	

Significance: *P<0.05, **P<0.01, ***P<0,001

Finally, the dependent variable, TOTALX, which groups all the farming practices mentioned before, represents the average adoption of EI practices by farmers. We found that being a woman, considering it easy to take actions to preserve the environment, having a network with contacts to reach out to in case of problems and having participated in training programmes related to EI practices all positively related to the use of EI practices (e.g., organic fertilisers, chemical-free preventive practices and crop rotation). On the other hand, farmers who perceive EI practice adoption as risky, those who perceive numerous barriers, have better access to credit and derive a higher percentage of their income from farming activities are less likely to use EI practices.

The linear regressions undertaken provide information on which variables are important for EI practice adoption during each production stage. What is particularly relevant from these results is that variables such as the perception of risk and barriers show significance for EI practice adoption during all production stages. Regardless of the practice (or stage) analysed, they maintain their negative influence on the decision to adopt that practice or not. Hence, we assume that knowing which factors affect these perceptions of risk and barriers could potentially predict EI practices adoption not just in each separate production stage but, in particular, overall, across all the different production stages. To examine this further, in the next section we explore interactions amongst the independent variables by applying the SEM model.

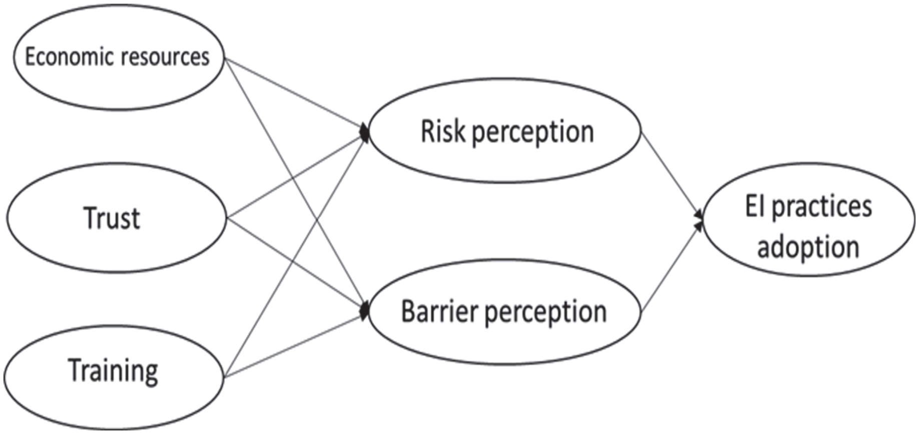
2.4.3 Exploring interactions amongst variables

Our structural equation model (SEM) is based on our linear regression results, which identified the perception of risk and barriers as the main factors correlated to the adoption of EI practices across all production stages. The aim of this analysis is to disentangle which factors are correlated to these two variables. To understand how factors could interact with these two variables we conducted a literature review focused on these relationships.

In line with our findings, the literature shows that risk perception is a key factor explaining EI practice adoption (Ghadim et al., 2005). Perceived risk represents a real concern of a person (Aven and Renn, 2010); it can be defined as the cognitive representation and evaluation of the chance that an investment (e.g., time and money) will generate gains or not (Vignola et al., 2010). The cognitive representation and evaluation of risk will be limited by the human mind capacity (Thaler, 1980). Literature has identified an extensive list of factors (e.g., socio-economic characteristics, attitudes, beliefs) that affect farmers' risk perception. However, economic resources (Flaten et al., 2005), trust (Dovey, 2009) and training (Leeuwis, 2004) have been identified as the most relevant factors by multiple sources. Further, Mekoya et al., (2008) and Sewell et al., (2017) found that, even if farmers perceive low levels of risk to adopt EI practices, their adoption may be impeded by their perception of barriers. The latter can be seen as perceiving challenges to overcome and could derive from different factors such as resource constraints, the lack of information, social infrastructure and technology (Leite et al., 2014; Kernecker et al., 2021).

Based on our literature review and acknowledging that the perception of risk and barriers can be affected by diverse factors, our SEM tested if any of the independent variables (Table 2.2) had an indirect relation to EI practices adoption due to these perceptions. To design the SEM, we grouped the independent variables into constructs (e.g., economic resources and training) according to what was found in the literature. During the validation of the SEM, variables such as pro-environment, credit, and income-farm (identified as significant for some practices in the regression analysis) did not fit the SEM model and were thus discarded. Contrarily, other variables (e.g., trust and assets) which were not identified as having a significant (direct) correlation to EI practices adoption in the regression analysis, were still included in the final set of variables for the SEM, as indirect correlations to the adoption of EI practices. The SEM's final configuration is illustrated in Figure 2.2.

Figure 2.2 Structural equation model (SEM)



The SEM model analyses how farmers' perceptions of risk and barriers are directly related to the adoption of EI practices, and how economic resources, trust and training are related to those perceptions in terms of EI practices adoption. Table 2.4 describes the set of variables used to build the constructs presented in the SEM model (Figure 2.2).

Table 2.4 Variables that compose the SEM

Constructs	Variable	Variable ID	Question/Statement
Economic resources	Vegi-size	E1	How much of your land is dedicated only to vegetable production?
	Assets	E2	Do you have the following assets? (Multiple answers) Tractor □ Truck □ Pick-up □ Car □ Motorcycle □
	Total-income	E3	In which monthly income bracket is your household income?
Trust	Trust	T1	Most people only look after their own interests
		T2	Given the opportunity, most people would try to take advantage of me
Training	Training	K1	During the last five years, have you participated in any training programme related to sustainable production?
Risk perception	Risk	R1	The adoption of agricultural practices without agrochemicals represents a risk to me
Barrier perception	Barriers		A main barrier for the adoption of EI practices is…
		B1	* Availability and/or accessibility of organic inputs
		B2	* Surroundings with conventional production practices
		B3	* The time required for the transition
EI practices adoption	SEEDX	A1	What type of seed do you use? / In what percentage of your property do you use this seed?
	SOILX	A2	What type of fertiliser do you use? / In what percentage of your property do you use this fertiliser?
	PESTX	A3	How do you control pests and diseases? / In what percentage of your property do you use this practice?
	WEEDX	A4	How do you control weeds? / In what percentage of your property do you use this practice?
	CROPX	A5	What strategy do you use for crop management? / In what percentage of your property do you use this strategy?

Although this model has two constructs (training and risk perception) expressed by only one variable, the model helps us to systematically investigate the interaction amongst factors that affect EI practices adoption, forming the basis for future discussion and research. Moreover, the set of variables used in our model is supported by the results of the SEM's goodness-of-fit (Table 2.5). The values of the factor loadings and p-values in each construct met the conditions for unidimensionality, being above the cut-off value of 0.5 and significant at p-value 0.000. Regarding internal consistency, the construct's economic resources and barrier perception presented values of Cronbach-α and CR higher than 0.6, indicating good internal consistency (Taber, 2018). The trust construct presented the lowest value for Cronbach-α and CR. However, both were above the cut-off value of 0.5, indicating that the set of variables are internally consistent and can be grouped in the construct (Taber, 2018).

The EI practice adoption construct showed robust consistency because the Cronbach-α and CR values were higher than 0.8. Regarding the convergence of the constructs, AVE values for the economic resources and barrier perception constructs were below the 0.5 cut-off. However, due to their CR values above 0.6, the validity of the constructs is still adequate (Fornell and Larcker, 1981). The trust construct presented a value of AVE below the 0.5 cut-off, which means that less than 50% of the variance is explained or, in other words, the variables poorly measure the trust construct (Fornell and Larcker, 1981). Finally, the EI practice adoption construct explained more than 50% of the variance with a value of AVE above 0.5.

Table 2.5 Factor loadings and construct reliability measures

Constructs	Variables ID	Factor loading	P-value	Cronbach α (cut-off 0.6)	CR (cut-off 0.6)	AVE (cut-off 0.5)
Economic resource				0.672	0.674	0.412
	E1	0.747	0.000			
	E2	0.552	0.000			
	E3	0.610	0.000			
Trust				0.531	0.538	0.372
	T1	0.685	0.000			
	T2	0.524	0.000			
Barrier perception				0.674	0.636	0.368
	B1	0.612	0.000			
	B2	0.560	0.000			
	B3	0.646	0.000			
EI practices adoption				0.862	0.862	0.560
	A1	0.680	0.000			
	A2	0.890	0.000			
	A3	0.814	0.000			
	A4	0.625	0.000			
	A5	0.703	0.000			

To evaluate the model's goodness-of-fit, we started with the absolute indexes (Table 2.6). The p-value of the chi-square was significant at 0.000, but, according to Hair et al. (2014), for a sample with more than 250 observations, significant p-values are expected. The value of RMSEA is 0.07, which showed an acceptable level of fit. GFI showed an acceptable fit with a value of 0.91. Based on the absolute indexes, it seems that the model specified in the conceptual framework fits the sample data well. The values of the TLI and CFI incremental indexes should be close to the cut-off value of 0.90 for an acceptable fit. The value of TLI is 0.88, and CFI is 0.91. Thus, both showed an acceptable fit, which means that the proposed model has an acceptable fit in comparison to an alternative baseline model.

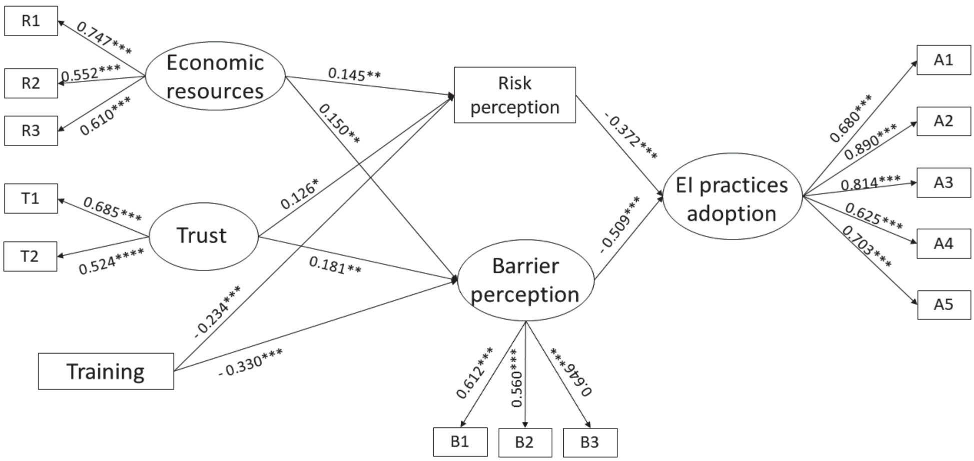
Table 2.6 Fit indexes and their acceptable thresholds

	Indexes	Acceptable fit	Good fit	Results
Absolute fit indexes	Chi-square	p-value above 0.05		0.00
	Root mean square error of approximation (RMSEA)	≤ 0.07	≤ 0.05	0.07
	Goodness-of-fit statistic (GFI)	≥ 0.90	≥ 0.95	0.91
Incremental fit indexes	Tucker-Lewis index (TLI)	≥ 0.90	≥ 0.95	0.88
	Comparative fit index (CFI)	≥ 0.90	≥ 0.95	0.91

References: Brown (2006) and Hair et al. (2014)

Figure 2.3 shows the results of the proposed model. It reveals that risk perception (p-value 0.00) and barrier perception (p-value 0.00) have a significant negative correlation to EI practice adoption. In other words, farmers who perceived higher levels of risk and barriers are less willing to adopt EI practices. Moreover, the model showed that, in the Chilean case, farmers with more land, assets and monthly income (economic resources) were more likely to perceive higher levels of risk and barriers. In addition, the model showed that trust has a significant positive correlation to risk and barrier perceptions. Hence, farmers who have less trust in the people around them were more likely to perceive higher levels of risk and barriers to EI practice adoption. Finally, training has a significant negative correlation on risk and barrier perceptions. Consequently, farmers with more training related to EI practices are correlated to perceive lower levels of risk and barriers, and are more likely to adopt EI practices.

Figure 2.3 SEM regression - Farmers' perceptions of EI adoption practices



*P<0.05, **P<0.01, ***P<0.001

2.5 Discussion

2.5.1 Factors affecting EI practices adoption

The linear regression equations identified the factors that are correlated to EI practices adoption in the Chilean vegetable production sector. In each stage of production and for each dependent variable (SEEDX, SOILX, PESTX, WEEDX and CROPX) we found different factors related to EI practices adoption. However, we will only discuss the results of the dependent variable which groups all the production stages (TOTALX). We found seven factors having a statistically significant correlation to the adoption of EI practices. Three factors are positively related: a) being a woman; b) perception about the ease of acting in favour of the environment; c) participating in training programmes related to EI practices. However, the following factors are negatively related to the use of EI practices: d) perception about the risk of adopting EI practices; e) perception about the barriers of adopting EI practices; f) access to credit; and g) high percentage of income deriving from the farming activities.

Regarding the factor being a woman, these results could be explained by women farmers having stronger attitudes towards conserving the environment than male farmers (Karami and Mansoorabadi, 2008), and women being in the frontline of agroecology transition in Latin America (Mestmacher and Braun, 2020). According to Karami and Mansoorabadi (2008), these stronger attitudes of women may be due to women's lack of access to economic resources and gender-based division of labour, mainly for women's role in caring for family and household needs. A study that confirms women's attitude is by Peredo-Parada et al. (2020), who highlighted the aptitude of women in establishing an agroforestry system using agroecological principles in southern Chile. The positive correlation of the pro-environment variable, which reflects whether farmers consider it easy to take actions to preserve the environment, is in line with Kollmuss and Agyeman (2002) who argue that pro-environmental behaviour affects EI practices adoption. However, the easiness perceived by individuals to take actions in a way that protects and preserves the environment could be influenced by socio-cultural constraints beyond individuals' control (Kaiser et al., 1996). In addition, our results show that formal training on EI practices is positively related to the adoption of EI, confirming the findings of Rajendran et al. (2016), who carried out a literature review on factors correlated to the adoption of sustainable agricultural practices.

Our results also support evidence from previous studies which state that perceptions of risk (Rolfe and Gregg, 2015) and barriers (Kheiri, 2015; Kernecker et al., 2021) are negatively related to EI practice adoption. Another finding of our study was that access to credit is not positively related to the adoption of sustainable practices *per se*. This contrasts with Jara-Rojas et al. (2012), who argue that access to credit has a positive correlation to EI practice adoption. Rather, what seems to be predominant is a risk-adverse behaviour: even with resources at hand, Chilean farmers still prefer to avoid the perceived risks of adopting EI practices for their vegetable production. We also found that farm income has a negative correlation to EI practice adoption, contradicting Baumgart-Getz et al.'s (2012) findings. This might be explained by the fact that Chilean farmers who derive a lower percentage of income from their farming activity are less economically dependent on the farm itself and feel more inclined to experiment with vegetable production (e.g., adopting EI practices) than if farming were their households' main economic activity. Finally, in the Chilean case, being an INDAP beneficiary is not significant related to EI practice adoption. This is in line with Le Coq et al. (2020) and López-García et al. (2021), who argue that in Latin America, governments and urban actors strongly support agricultural intensification while agroecology still faces problems such as access to land, training, and the implementation of administrative tools.

2.5.2 Exploring interactions amongst variables

Concerning the SEM results, we found that risk perception is an important factor in EI practices adoption, confirming previous researchers' findings (Lee, 2005; Shiferaw et al., 2009). In the Chilean context, several of the farmers we interviewed indicated two main risk perception dimensions. The first is related to uncertainty at the crop production level. Most of the farmers believe that adopting EI practices entails lower crop production and quality. The second dimension is related to the farmers' health benefits. They believe that they can avoid diseases or improve their health if they use fewer synthetic fertilisers, herbicides and pesticides. In this context, the uncertainty regarding crop production and crop quality increases the perceived risk, while the perceived improvement in their health decreases the perceived risk of adopting EI practices. However, in the end, most of the farmers assign more importance to production, and that is why they perceive EI practices adoption as risky. In Chile, the reasons why farmers tend to find the uncertainty of production levels more important may be related to the fact that they not only need to compete in the local market but, also, they need income to afford credit payments, rent payments, and family education. On the other hand, one possible explanation why farmers give less importance to improving health-related circumstances may be so-called 'risk denial' (Sjöberg, 2000). Risk denial could be explained by people's overconfidence; in this case, farmers seem unrealistically optimistic about their health (e.g., among peers, a farmer believes that the harmful effect of pesticides on his own health will always be lower) (Dunning et al., 2004).

Our research also shows that barrier perception is an important factor in EI practices adoption. The results uncovered, that farmers perceive three main barriers to EI practices adoption: 1) the availability and/or accessibility of organic inputs; 2) being surrounded by others adopting conventional production methods; and 3) the time required to transition to these practices. Most of the farmers in our sample have never tried to adopt EI practices; that is why we define the barriers as hypothetical. The low availability and/or accessibility of organic inputs and the long time required to a transition are in line with Valdivia et al. (2012) who found that a major component of these barriers are transaction costs related to information access and establishment costs. On the other hand, being surrounded by others adopting conventional production techniques has not been identified as a barrier in any other study. Farmers are aware that the synthetic fertilisers, herbicides and pesticides that neighbouring conventional farms use might contaminate their farms. Although the prior barriers are not directly linked to governmental policies, the adoption rate of EI practices could be influenced when farmers are supported by policies (e.g., financing programmes for transition farmers).

Our study found that having economic resources is not correlated to perceiving low levels of risk and barriers. We found that those who have the most economic resources (e.g., land and income) are more likely to perceive higher levels of risk and barriers when they consider adopting EI practices. In contrast, previous researchers found that farmers who lacked assets, capital and land would not invest in activities that they perceived as risky (e.g., EI practices) (Baumgart-Getz et al., 2012). And, on the other hand, farmers with more economic resources are better able to adopt EI practices because they can bear the risk (Shiferaw et al., 2009; Baumgart-Getz, et al. 2012). Our findings could be explained by (Tversky and Kahneman, 1973) who argue that individuals whose wealth status is sufficiently high will prefer to maintain their status quo if the process of changing implies transition costs. In other words, if a farmer is wealthy or more economically stable, he will not risk his economic patrimony. However, it could also be explained by the local context of organic product consumption and vegetable production in Chile. Although organic product consumption in Chile has tended to increase, the growth rate is low, and Chile is still a net exporter of organic products (IICA, 2020). Unlike the agro-export sector (e.g., fruits), vegetables for the local market are not supported by the government (Altieri and Rojas, 1999; David et al., 2000). As a result, vegetable production in Chile faces competitive and unfavourable conditions. We believe that, under current market conditions, farmers perceive vegetable production in Chile as risky; even farmers with greater wealth are afraid of potentially low economic returns as a consequence of transitioning to EI production methods.

Our research offers insights in the interaction between trust and the perception of risk and barriers for EI practices adoption. This study uses the term trust as the belief that a partner is reliable and benevolent (Ganesan, 1994). We found that farmers with low levels of trust in farm labourers, input suppliers and neighbours are more likely to perceive high levels of risk and barriers. These findings are in line with the work of Small et al. (2016) and Hunecke et al. (2017) who argued that trust in networks is positive correlated to the adoption of new practices. From another perspective, our results are also confirmed by Wossen et al. (2015), who found that farmers who do not trust their social network will probably perceive higher risk levels of adopting EI practices. According to Corsten and Kumar (2005), trust results in greater knowledge and appreciation between partners. Hence, if farmers trust actors in their social network who are already involved in EI practices, the adoption will be facilitated (Vanclay, 2004; Lee, 2005). On the contrary, if conventional agriculture is predominant in the social network, farmers feel more social pressure not to adopt EI practices, which has been identified as a barrier (Rodriguez et al., 2009; Home et al., 2019). Overall, when people trust each other, the process of cooperating, collaborating and creating social networks is easier (Nilsson et al., 2012).

Lastly, training is a way to acquire particular knowledge (Leeuwis, 2004). Through this lens, our results show that a lack of knowledge is correlated to perceiving higher levels of risk to EI practice adoption. These results corroborate Greiner et al. (2009), who found that improving knowledge and human capacity is fundamental to manage risk regarding EI practices adoption. According to O'Connor et al. (1999), knowing the causes of a problem (e.g., soil degradation) and its possible meliorative solutions could lead to promote pro-environmental actions. An Individual with more knowledge about a topic will be able to estimate the risk more objectively (Tversky and Kahneman, 1974; Knight et al., 2003). Similar to our results, Kernecker et al. (2021) identified the lack of training for managing complex agroecological systems as a barrier for EI practices adoption. In general, and in terms of the influence knowledge has on perceived barriers, many studies have shown that a lack of knowledge is a key barrier for the adoption of new practices or technologies (Grothmann and Patt, 2005; García de Jalón et al., 2015). We thus assume that farmers who have participated in training programmes related to EI practices have been provided relevant information and have the knowledge to implement EI practices.

2.6 Conclusion

Our study aimed to analyse which factors are correlated to the simultaneous adoption of various EI practices in different vegetable production stages by farmers in the context of an emerging economy such as Chile. We identified that, depending on the production stage, various factors have a different correlation to EI practices adoption (e.g., awareness of the impact agrochemicals have on the environment only has a positive correlation to the use of organic pesticides). In general, the most significant factors positively or negatively correlated to the adoption of EI practices are gender, the degree of farmers' pro-environment attitude, their perception of risk and barriers, access to training and credit, and farm income. Further, we found that factors pertaining to economic resources, trust and training are correlated to the perception of risk and barriers and, therefore, have an indirect relation to EI practices adoption. This study also highlights the potential role of women fomenting EI adoption and indicates the appearance of farmers' health dimension within risk perception in adopting EI.

The exploratory nature of this study allows obtaining new insights into how factors interact and it contributes to the debate on which factors should be prioritised by policymakers and scholars in order to improve the adoption rate of EI practices. Overall, our study offers insights on sustainable vegetable production from a broad perspective, taking into account different farming practices and production stages, all of which contributes to the discussion on the complex processes at farm level.

We acknowledge that our research has some limitations related to methodology and data measurement. Although our model does not comply with all of the cut-off criteria suggested in the literature on SEM methodology, our results open the way for further investigating the relationships as exposed by our model, and for theory building. Regarding the data measurement limitations, we acknowledge that other factors not currently considered may also correlated to EI adoption. Because the survey used in this study did not include measurement on the two risk dimensions (crop production and farmers' health), this would be an interesting topic for further research. Moreover, future studies analysing the interactions between risk and barriers could provide more insights, likewise analysing why farmers integrate EI practices in one production stage but not in another. In addition, further investigation on the measurement of farmers' trust in farm labourers, input suppliers and neighbours would help to establish a larger degree of accuracy on this matter. Finally, future research should also focus on how farmers obtain knowledge and what motivates them to increase their knowledge related to EI practices.

Our results also have implications for practitioners and policymakers. Knowing which factors are related to EI practices adoption and how these factors interact can support governments to prioritise and focus policies. One strategy to increase adoption rates is offering technical assistance programmes related to EI practices in Chile. For instance, as results show that women seem to be more inclined to use agroecological practices, these programmes could start with women farmers and then progressively incorporate other farmers. Moreover, the low levels of trust perceived by farmers in farm labourers, input suppliers and neighbours highlighted in our study should be taken into account by the Chilean government when designing programmes to promote EI practices adoption. These programmes could provide farmers with guidance on shared decision-making and co-governance, and offer non-specific support that stimulates community connectedness, thereby building trust (Jagosh et al., 2015; Fretwell et al., 2018).

APPENDICES

Appendix 2.A

SURVEY FOR VEGETABLE FARMERS IN CHILE 2018 – 2019
WAGENINGEN UNIVERSITY & RESEARCH – NWO HORTECO PROJECT

This questionnaire is part of the HortEco project, led by Wageningen University and supported by the Pontifical Catholic University of Valparaíso and ODEPA. The objective of this questionnaire is to collect information related to the production and marketing of vegetables. The information obtained will be used solely for academic purposes, and the results will be shared with policymakers. Your participation is voluntary, and the information you provide will be treated confidentially.

Do you agree to participate in the survey? Yes □ No □
Has producing vegetables been one of your main activities in the last year? Yes □ No □

Full name:
Address: **Region:**
Sector: **Date:**

1. How big is your farm? ________ hectares

2. How much land do you use only for vegetable production? ________ hectares

3. Mention the 3 most important vegetables produced on your farm:

____

4. What type of irrigation system do you primarily use to produce vegetables?

Drip irrigation □ Sprinkler irrigation □ Irrigation by hoses □ Irrigation by furrows □ Other, specify □

5. In addition to vegetables, do you produce other types of agricultural products intended for sale?

Yes □ No □

6. If answering "yes": Can you mention the most important? ___________________________________

7. What is the ownership status of your land? Rented □ Owned □ Owned+Rented □

8. Do you agree with the following statements? 1 = totally disagree / 4 = neutral / 7 = totally agree

Environmental awareness statements	**1**	**2**	**3**	**4**	**5**	**6**	**7**
8.1 I am aware of environmental pollution							
8.2 The intensive use of agrochemicals is harmful for the environment							
8.3 Harming the environment will have a negative impact on agriculture							
8.4 Agricultural practices that do not use agrochemicals are beneficial for the environment							
8.5 My actions can really influence the environment							

1 = totally disagree / 4 = neutral / 7 = totally agree

Motivation statements	1	2	3	4	5	6	7
8.6 Consumers are willing to pay more for vegetables produced without agrochemicals							
8.7 The members of my household or our laborers have had health problems related to the use of fertilisers, pesticides or herbicides							
8.8 I will keep producing vegetables until the end of my life							
8.9 My children will inherit my land							
8.10 It is very difficult for a person like me to do something for the environment							

1 = totally disagree / 4 = neutral / 7 = totally agree

Farm statements	1	2	3	4	5	6	7
8.11 My farm's soil is productive							
8.12 The water used to irrigate my farm is polluted							
8.13 I have not had problems with drought during the last five years							

1 = totally disagree / 4 = neutral / 7 = totally agree

Risk statements	1	2	3	4	5	6	7
8.14 It is very easy to get farm credit							
8.15 I am totally willing to take risks							
8.16 I am willing to adopt new agricultural practices without agrochemicals that could increase my income							
8.17 The adoption of agricultural practices without agrochemicals represents a risk for me							

1 = totally disagree / 4 = neutral / 7 = totally agree

Relationships statements	1	2	3	4	5	6	7
8.18 Most people only look out for their own interests							
8.19 I trust most people							
8.20 Given the opportunity, most people would try to take advantage of me							
8.21 I form my own opinion, regardless of what others think							

9. Are you a member of INDAP? Yes □ No □ / PRODESAL □ SAT □ Other □ None □

10. How old is the head of your household? ________years

11. How many years of experience do you have in vegetable production? ________years

12. What is the farmer's gender? Female □ Male □

13. How far is the nearest market from your farm? ______km

14. How sloped is your land? Flat land □ Medium slope □ Large slope □

15. Only if answering "medium" or "large slope" in the previous question: Do you use any of the following practices to conserve soil or water? (**Multiple answers**) Terraces □ Infiltration trenches □ Level curves □ None □

16. Do you have a greenhouse to produce vegetables? Yes □ No □

17.Only if answering "yes" in the previous question: How big is the greenhouse? ________ m^2

18. What percentage of your income comes from your farm? ________%

19. How many technical support visits have you received in the last year? ______

20. How many technical support talks have you attended in the last year? ______

21. How many of the following types of livestock do you currently own?

1. Big livestock (oxen, cows) ______ 3. Poultry ______ 5. Beehive ______
2. Small livestock (pigs, sheep) ______ 4. Horse, donkey or mule ______

22. Do you have any of the following assets? (**Multiple answers**) Tractor □ Truck □ Pick-up □ Car □ Motorcycle □

23. During the last five years, have you ever participated in a training programme related to sustainable production? Yes □ No □

24. Do you have internet at home? Yes □ No □

25. Do you have a bank account? Yes □ No □

26. If you have an urgent problem related to managing your farm, to how many people can you turn for help? ________

27. Do you have one of the following organic certificates for the vegetables you produce?

Participative certification □ Third-party certification □ Certification in transition □ None □

28. Only if he/she has a certificate: How long have you had this certificate? ________ years

29. Do you agree with the following statements?

1 = totally disagree / 4 = neutral / 7 = totally agree

A main barrier for the adoption of sustainable practices is...	**1**	**2**	**3**	**4**	**5**	**6**	**7**
29.1 access to market							
29.2 working capital							
29.3 government policies							
29.4 technical assistance/knowledge							
29.5 availability and/or accessibility to organic inputs							
29.6 surrounding farms using conventional production practices							
29.7 difficult to reach the same production levels							
29.8 the time required for the transition							
29.9 availability of manpower							

30. Are you or anyone in your household a member of a farmer's organisation? Yes □ No □

Only if answering "yes":

31. What is the name of the organisation? ____

32. How long have you been a member of that organisation? ________years

33. Do you agree with the following statements related to your organisation?

1 = totally disagree / 4 = neutral / 7 = totally agree

Farmer Organisation statements	**1**	**2**	**3**	**4**	**5**	**6**	**7**
33.1 The organisation always provides information on time							
33.2 The current leaders take members' opinions into account							
33.3 There are opportunities to discuss organisational issues with the leaders							
33.4 I can influence the organisation's decision-making							
33.5 I regularly volunteer to undertake specific tasks in the organisation							

1 = totally disagree / 4 = neutral / 7 = totally agree

Benefits/Services statements	**1**	**2**	**3**	**4**	**5**	**6**	**7**
33.6 I receive training from the organisation							
33.7 I have access to organic certification through the organisation							
33.8 I have access to the market through the organisation							
33.9 I have access to farm inputs through the organisation							
33.10 I have access to machinery through the organisation							
33.11 I have access to transport my crop trough the organisation							
33.12 I have increased my network with universities and research institutions through the organisation							
33.13 I have increased my network with government institutions through the organisation							
33.14 I have increased my network with NGOs through the organisation							
33.15 I am satisfied with the organisation							

34. Only if answering "no": Why aren't you a member of any agricultural organisation?

I am not interested □ I have had bad experience in the past □ I have not had the opportunity □

35. Are you a member of another type of organisation? Yes □ No □

36. Only if answering "yes": What type of organisation?

Sports □ Social assistance □ Political □ Religious □ APR □ Other □

37. In the last two years, who have been your two main buyers?

37.1 Type of buyer?	**Buyer 1**	**Buyer 2**
1. Direct sale-retailer		
2. Direct sale-wholesaler		
3. Farmers' organisation		
4. Intermediary/dealer		
5. Specialised store		
6. Supermarket		
7. Agro-industry		
8. Restaurant		
37.2 Type of arrangement?		
1. Spot market		
2. Verbal agreement		
3. Written agreement		
37.3 What percentage of your production do you sell to each buyer?		
37.4 What specifications does the arrangement include? (Multiple answers)		
1. Quality		
2. Volume		
3. Price		
4. Payment mode		
5. Frequency		
6. Delivery place		
7. Delivery of inputs		
8. Other, specify		
37.5 When was the agreement made?		
1. Before planting		
2. After planting but before the harvest		
3. During the harvest		
4. After the harvest		
37.6 How long is the agreement for? (# Days)		
37.7 What is the mode of payment?		
1. Cash		
2. Cheque		
3. Transfer		
37.8 On average, how many days does it take the buyer to pay? (# Days)		
37.9 Do you provide some kind of service for this buyer? (Multiple answers)		
1. Deliver to a specific distribution point		
2. Sorting		
3. Packing		
4. Other, specify		
37. 10 Do you receive any kind of service from this buyer? (Multiple answers)		
1. Advance payment		
2. Provision of inputs		
3. Support for harvesting		
4. Transport		
5. Technical assistance		
6. Credit		
7. Other, specify		

38. Do you agree with the following statements related to your main buyer?

1 = totally disagree / 4 = neutral / 7 = totally agree

Trust Statements	1	2	3	4	5	6	7
38.1 I trust my main buyer							
38.2 My main buyer is always honest							
38.3 My main buyer takes my interests into account							
38.4 I believe the information provided by my main buyer							
38.5 A deal with my main buyer is risky							
38.6 My main buyer acts opportunistically							

1 = totally disagree / 4 = neutral / 7 = totally agree

Satisfaction and Power Statements	1	2	3	4	5	6	7
38.7 There is good cooperation between my main buyer and myself							
38.8 My main buyer meets my expectations							
38.9 My main buyer is quick to handle complaints							
38.10 My main buyer has the best offer relative to others buyers							
38.11 My main buyer controls all the information in our deals							
38.12 I am more dependent upon my main buyer than he/she is upon me							

39. How often do you use the following agricultural practices to produce vegetables?

39.1 In general, what type of seed do you use?		**On what percentage of your property do you use this seed?**
1. Conventional		
2. Organic - bought		
3. Reused		
4. Traditional		
39.2 In general, what type of fertiliser do you use?		**On what percentage of your property do you use this fertiliser?**
1. Conventional/synthetic		
2. Organic fertiliser - bought		
3. Organic fertiliser - own		
4. Organic fertiliser - bought + own		
39.3 In general, how do you control pests and diseases?		**On what percentage of your property do you apply this practice?**
1. Chemical pesticides /preventive - sanatory		
2. Organic pesticide - bought		
3. Organic pesticide - own		
4. Preventive practices without chemicals		
39.4 In general, how do you control weeds?		**On what percentage of your property do you apply this practice?**
1. Chemical herbicides		
2. Organic herbicides		
3. Mechanic control		
4. Preventive practices without chemicals		
39.5 In general, what strategy do you use to manage crops?		**On what percentage of your property do you apply this strategy?**
1. Crop rotation		
2. Intercropping or companion cropping		
3. Crop rotation + intercropping		

40. What is your highest educational level?

1. No formal education ______
2. Basic education - incomplete ______
3. Basic education - complete ______
4. High school - incomplete ______
5. High school - complete ______
6. Technician degree ______
7. University/higher ed. ______

41. What is your household's monthly income?

1. Less than $280 thousand ______
2. $280 to $560 thousand ______
3. $560 to $840 thousand ______
4. $840 to $1,120 thousand ______
5. $1,120 to 1,400 thousand ______
6. $1,400 to $1,960 thousand ______
7. $1,960 to $2,520 thousand ______
8. More than $2,520 thousand ______

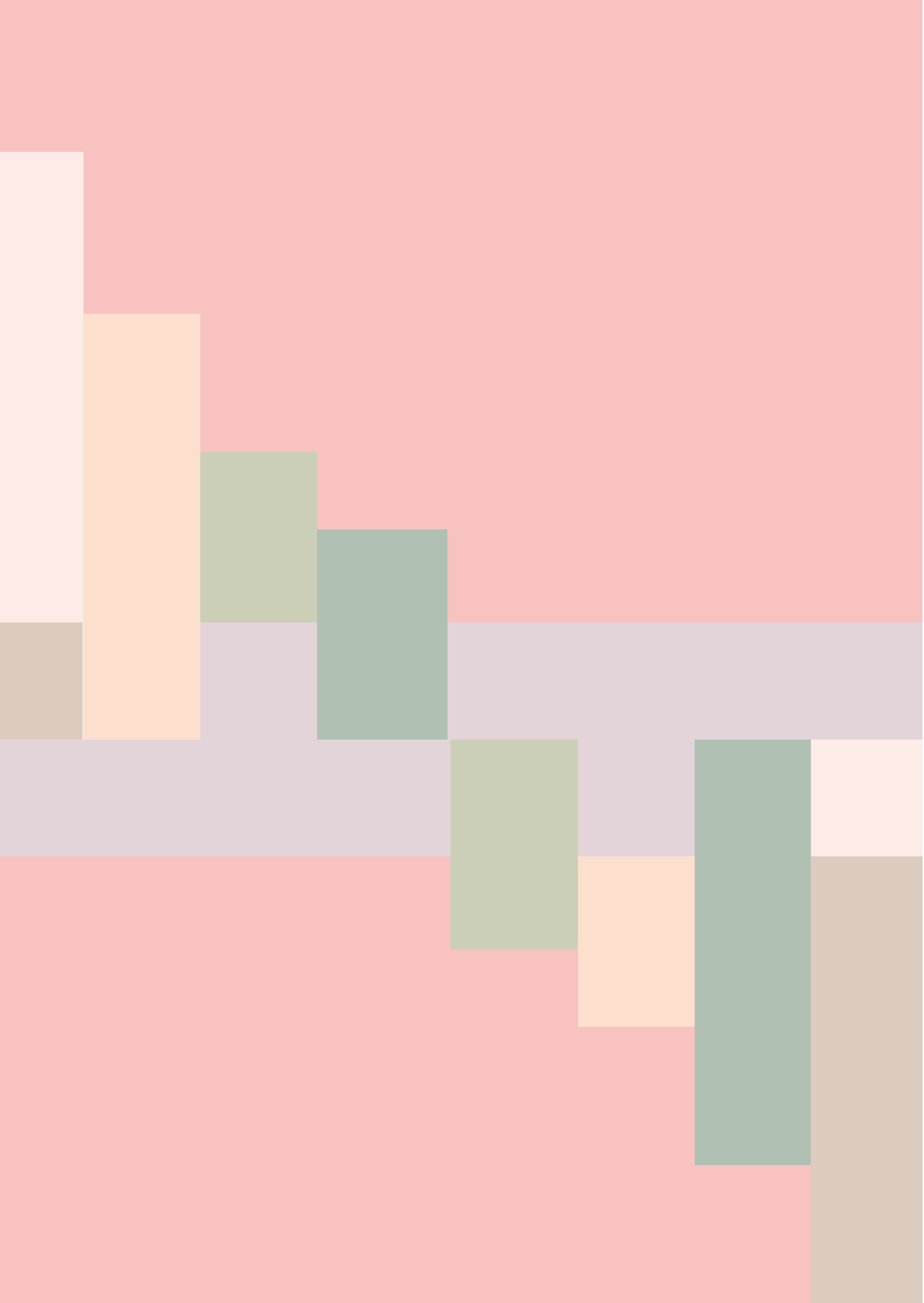
42. Do you agree with the following statements?

1 = totally disagree / 4 = neutral / 7 = totally agree

Statements	1	2	3	4	5	6	7
35.1 I make the big decisions affecting the farm by myself							
35.2 I consult the big decisions affecting the farm with my family							
35.3 I consult the big decisions affecting the farm with other farmers							
35.4 I consult the big decisions affecting the farm with my input provider							
35.5 I consult the big decisions affecting the farm with researchers (INIA, universities or private institutes)							
35.6 I consult the big decisions affecting the farm with agricultural extension agents							
35.7 I consult the big decisions affecting the farm with my main buyer							

43. If things are not clear, can I contact you by phone? Yes □ No □

44. If answering "yes": Can you provide me with your contact number, please? ____________________



CHAPTER 3

Categorizing the sustainability of vegetable production in Chile: A farming typology approach

This chapter is in the second round of review and has been submitted as:

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ABSTRACT

Sustainable practices are seen as one of the solutions to redress the negative impact of agriculture's growing intensification. Despite efforts by many governments, the adoption rate of sustainable practices amongst farming systems is still low. One of the causes is policymakers' insufficient knowledge of farming-system diversity. In order to account for such diversity, this paper proposes classifying farming systems, including new elements such as the sustainability level of agricultural practices and market channel traits, in combination with socio-economic and structural farm characteristics. We apply a farming typology approach, using vegetable production in Chile as our case study. We developed the typology using multivariate analysis techniques including principal component analysis (PCA) and hierarchical clustering (CA). We collected data using surveys (n=352) in the central region of Chile. The results reveal five farming-system types: (1) Large dual farming, (2) ecological farming, (3) traditional farming, (4) conventional small-scale farming, and (5) conventional medium-scale farming. The five farming system types provide insights on the different agricultural practices used and their different starting points in terms of their transition towards more sustainable agriculture practices. We also propose possible policies based on these farming-system types that can be useful for policymakers to promote sustainable practices.

Keywords: sustainable agriculture; farm typology; transition pathways; market channel; emerging economies

3.1 Introduction

World-wide economic growth and the ever-growing demand for food in the last few decades have led to agriculture's industrialisation, characterised by monoculture production and the extensive use of synthetic agricultural inputs (Perkins and Jamison, 2008). As a result of this industrialisation, environmental degradation (e.g., biodiversity loss and soil erosion) and the growing impact of climate change are now challenges society has to cope with (Blazy et al., 2009). This has incited governments, farmers and academics to explore alternative agricultural practices that redress the consequences of conventional agriculture (Pannell et al., 2006; Knowler and Bradshaw, 2007). Currently, there are different sustainable paths to deal with the consequences of conventional agriculture, such as agroecology (Altieri et al., 2017), climate-smart agriculture (Taylor, 2018) and organic agriculture (Muller et al., 2017). We refer to these alternative agricultural practices as sustainable agricultural practices (SAPs). SAPs imply that "agriculture will have to be carried out to make the best use of available natural resources and inputs, and regenerate conditions for future production" (Leeuwis, 2004, p. 5) e.g., traditional seeds, organic fertilisers, preventive practices without chemicals to control pest and diseases, organic herbicides and crop rotation.

In the last decade, governments have implemented numerous projects to foment SAP adoption; however, the transition to these practices has been slow (Eyhorn et al., 2019). The limited effect of these projects in rural areas is largely due to policymakers' and researchers' standardised views of farming systems (Ganpat and Bekele, 2002). Policymakers often classify farming systems into only two categories: Small and large-scale. Thus, they fail to take into account the diversity within these categories (Fernández et al., 2019). In particular, they treat small-scale systems as one undifferentiated category, assuming that all farming systems in this group have similar characteristics such as homogeneous capabilities, circumstances and resources (Ganpat and Bekele, 2002). Moreover, the standardisation of farming systems leads to inflexible strategies, following one-size-fits-all paths that do not consider the farmers' particular aspirations and resources (Dumont et al., 2020).

The transition to SAPs is a gradual and unique process for each farming system. It depends on the specific characteristics of both farmers and their farms (e.g., crop, size land and irrigation) as well as the context in which production takes place (Daloğlu et al., 2014; Teixeira et al., 2018). Thus, to design better strategies to stimulate SAP adoption, identifying the diversity of farming systems is essential. Farming typology considers the complexity and variability of farming' production environments, acknowledges the limitations of the economic approach (profit maximisation) and recognises the heterogeneity of farming systems (Darnhofer et al., 2010). Hence, the farming typology considers factors such as economic, political, social, ecological and climatic factors (Dumont et al., 2020). As a result, the farming typology helps to identify less standardised strategies to promote SAPs that are more in line with different realities and goals of farming systems (Darnhofer et al., 2010). Moreover, farming typology allows to understand how farmers' and farms' characteristics interact, which can provide insights to identify future interventions promoting SAPs (e.g., identify responses to emerging challenges, identification of evolution patterns, ex-ante impact assessments,) (Alvarez et al., 2018; Templer et al., 2018; Kebede et al., 2019). Therefore the use of farming typology allows to investigate the diversity of farming systems (Righi et al., 2011), measures heterogeneity (Alvarez et al., 2018) and groups farming systems by similar constraints and opportunities (Ganpat and Bekele, 2002). Hence, a typology provides a more accurate description of the reality of farming systems and helps to design and identify the advantages and disadvantages of new sustainable strategies in different systems and contexts. (Righi et al., 2011; Nainggolan et al., 2013).

Farming typology studies in most cases have a different focus. For example, more traditional studies focused on socio-economic and farm production indicators (e.g. Andersen et al., 2007), often in relation to policies focusing on increasing production and farm profit at that time. Similarly, with the growing attention for environmental issues, farming typology studies started to include diverse sustainability indicators such as soil quality (Tittonell et al., 2005; Sierra et al., 2017), the response to climate change (Nainggolan et al., 2013), technology adoption (Goswami et al., 2014) and agroecological practices (Teixeira et al., 2018). Thus far, however, little research has sought to construct a farming typology that considers socio-economic and structural farm production characteristics together with agricultural practices' sustainability levels (Teixeira et al., 2018).

In order to provide more information about farming systems' heterogeneity and their initial starting point in the transition to SAPs, we characterise farming systems by combining socio-economic elements, structural farm production characteristics including market channel traits with the sustainability level of agricultural practices. To this end, we conduct an empirical analysis in the vegetable sector in an emerging economic context, in this case, Chile. Beyond the case of vegetable farming systems in Chile, the paper aims to demonstrate the value of mapping the diversity of farming systems and their sustainability levels to better define objectives and target strategies in rural areas to promote wider adoption of SAPs.

The paper is organised as follows: Section 2, presents the case study of vegetable production in Chile; Section 3, explains our data collection process and multivariate analyses; Section 4, provides the results of the farming system typology for the vegetable sector in Chile and; Section 5, explores the pathways towards sustainability and policy implications based on the farming systems types that were identified. This section also discusses methodological limitations and further research. Lastly, Section 6 presents the conclusions of this study.

3.2 Case study: Vegetable production in Chile

Emerging economies such as Chile have developed dualistic agricultural sectors. Fast economic growth has generated an agricultural structure wherein small farming systems coexist alongside large-scale farming systems (Kostov and Lingard, 2003). In Chile, the combination of neoliberal agrarian policies and a green revolution perspective has focused on increasing productivity over the short term with the intensive use of inputs (Montalba et al., 2017). This has caused problems such as environmental deterioration (Montalba et al., 2017), human health decline (Muñoz-Quezada et al., 2016), the loss of ecological diversity due to monoculture production and the exclusion of smallholders (Sarandon and Marasas, 2017). Therefore, different governmental institutions as well as multiple Chilean grassroots organisations involving consumers and farmers have sought to develop and promote the adoption of more sustainable practices (ODEPA, 2011).

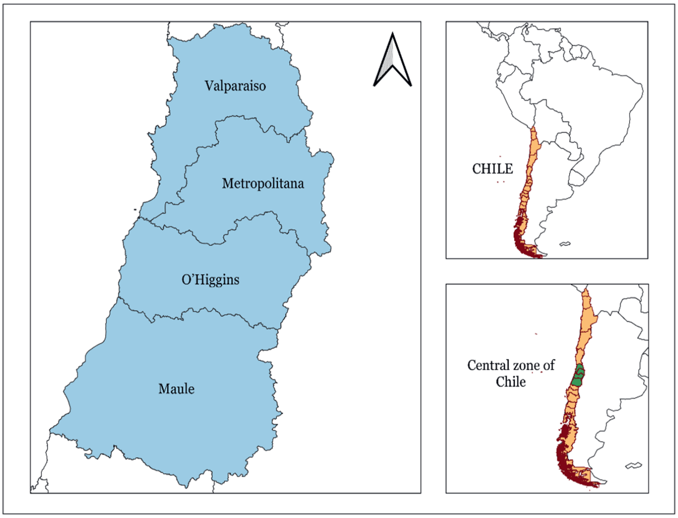
Vegetable production is one of the main agricultural activities in Chile. In 2019, vegetable production occupied 77,000 hectares and encompassed 34,000 farmers distributed all over the country. Farming systems mostly supply local markets (ODEPA, 2020). The sector primarily includes small-scale farming systems (less than 5 hectares), followed by a smaller number of large-scale farming systems (exceeding 300 hectares). Vegetable farming systems are characterised by substantial differences due to economic factors and managerial strategies and skills, making it a heterogeneous sector (ODEPA, 2020). The largest vegetable production area is located in Chile's central area, specifically in the regions of Valparaiso, Metropolitana, O'Higgins and Maule. These regions dedicate approximately 54,000 hectares to vegetable production and produce around 70% of the country's vegetables (ODEPA, 2020). The main vegetables produced are sweet corn (*choclo*), onions, lettuce, tomatoes and beans. The four regions are characterised by a Mediterranean climate, consisting of temperate warm winters with rain and warm summers.

3.3 Methods

3.3.1 Data collection

We collected data for our study via face-to-face surveys with vegetable growers in Chile. The survey aimed to capture the diversity of vegetable production farming systems. Each survey lasted 30 to 40 minutes. We conducted all the fieldwork in Chile's official language, Spanish. Vegetable growers were visited in the field, at their home or at fairs, and were randomly sampled. A total of 352 farmers participated in the survey. The survey was implemented from October 2018 to April 2019 in the Valparaiso, Metropolitana, O'Higgins and Maule regions (Figure 3.1). The sample represents the regions with a major concentration of vegetable growers and vegetable production. As mentioned, these four regions dedicate 54,000 hectares to vegetable production, representing 70% of all vegetable production in Chile (Valparaiso, 11%; Metropolitana, 31%; O'Higgins, 14%; and Maule, 14%) (ODEPA, 2017).

Figure 3.1 Research area



3.3.2 Variable selection for the farming typology

We selected the variables based on a literature review of previous farming typology studies representing the essential characteristics related to social, production and structural attributes of farming systems (Tittonell et al., 2010; Alvarez et al., 2018) and also on literature focused on factors affecting the adoption of SAPs (Baumgart-Getz et al. 2012; Tey et al., 2017). Moreover, our selection criteria was to use the variables that provided the greatest statistical diversity. We used 25 variables (Table 3.1) divided into four categories: 1) Agricultural practices, measured by a farm-level sustainability index (explained in section 3.2); 2) socio-economic characteristics, including variables related to capital, social features and knowledge (e.g., age, sex, education, experience) (Blazy et al., 2009; Tittonell et al., 2010; Righi et al., 2011); 3) structural farm traits, including variables related to infrastructure, scale of the farm, area allocated to vegetables and organic certificates (Sanogo et al., 2010; Pacini et al., 2014; Goswami et al., 2014); and 4) market channel characteristics, encompassing variables related to the proximity to the main market, types of buyers and types of agreements (Guarín et al., 2020).

Table 3.1 Variables description

Category	Variable	Description	Type of Variable
Agricultural practices	Seed	Type of seeds	numerical index
	Soil	Type of fertilisers	numerical index
	Pest	Type of pesticides	numerical index
	Weed	Type of herbicides	numerical index
	Crop	Type of crop management	numerical index
Socio-economic characteristics	Age	Head of household's age	ratio/years
	Experience	Head of household's years of experience in vegetable production	ratio/years
	Education	Highest educational level	ordinal/7 categories
	Gender	Head of household's gender	dummy/ female-male
	INDAP	Household is beneficiary of INDAP*	dummy/yes-no
	Links	Number of people they can reach out to in case of an urgent problem on the farm	ratio/# of people
	Tech. visits	How many technical visits did you receive in the last year?	ratio/# of visits
	Tenure	Land owner	dummy/own-rent
	Assets	Number of assets: tractor, truck, pick-up, car and motorcycle	interval/# of assets
	Income-farm	Income from the farm	interval/percentage
	Income-total	Total monthly household income	ordinal/8 categories
Structural farm characteristics	Vegi-size (ha.)	Size of the land used for vegetable production	ratio/hectares
	Crop-variety	Farming systems with only vegetable crops or with vegetable & other crops	dummy/yes-no
	Greenhouse	Use of greenhouses	dummy/yes-no
	Certification	Participatory certification, third-party certification, certification in process, no organic certification	nominal/3 categories
	Irrigation	Type of irrigation: furrows, drip and others	nominal/3 categories
Market channel characteristics	Distance	Distance to market	ratio/kilometres
	Buyer-type	Type of buyer: retailer, wholesaler, intermediary and high-standards (supermarkets, agroindustry and restaurants)	nominal/4 categories
	Agree-type	Type of arrangement with buyer: spot, verbal and written	nominal/3 categories

* The National Institute for Agricultural Development (INDAP) within the Chilean Ministry of Agriculture provides assistance to family farmers (INDAP, 2020).

3.3.3 Measuring the sustainability levels of agricultural practices: A farm-level index

The use of SAPs involves substituting synthetic resources produced out-farm (i.e., fertilisers, insecticides, herbicides) for on-farm resources to achieve effective and efficient short-and-long term use of natural resources (Taylor et al., 1993). Some examples of on-farm resources are integrated pest management, crop rotations, green manures and cover crop (Taylor et al., 1993; Kleijn et al., 2019). The sustainability level of agricultural practices depends on how on-farm resources substitute out-farm resources. Therefore, if a farm substitutes all the out-farm resources with on-farm resources, it can be called "sustainable-ecological". In contrast, if a farm only uses out-farm resources it can be called "unsustainable-conventional". However, because SAPs involve different practices in different stages of farming, the sustainability level of a farm is not bimodal, with one cluster of farms "sustainable" and another “unsustainable”. Instead, farms range from “very sustainable” to “very unsustainable” (Taylor et al., 1993). In order to quantitively analyse sustainability levels on farms, literature has developed many sustainability indicators (Rigby et al., 2001). These indicators are conceived as a proxy value of the use of SAPs, due to the difficulty in measuring them (Rigby et al., 2001).

A large number of studies have proposed indexes and developed frameworks to measure the sustainability levels of agricultural practices (Lefroy et al., 2000; Astier et al., 2011). However, there is no single, universally accepted index to measure sustainability in farming practices due to the complexity of farm-level practices. The index used in this paper to measure the sustainability level of agricultural practices is based on the work of Rigby et al. (2001) which encompasses sustainable agricultural practices (SAPs) and conventional agricultural practices. Moreover, according to Rigby et al. (2001), this index supports detailed comparative assessments of large samples, where it is possible to exclude/include components (e.g., use of technology, type of irrigation systems) or modify the weighting of the components. The index assesses the sustainability level of agricultural practices (e.g., beetle banks, synthetic pesticides, organic herbicides) divided in five production stages: Seed sourcing, soil fertility, pest control, weed control and crop management. Rigby et al. (2001) calculated an index for each agricultural practice based on different sustainability dimensions: Minimisation of off-farm inputs, minimisation of non-renewable inputs, maximisation of natural biological process and promotion of local biodiversity. Rigby et al. (2001) scored the previous dimensions from -1 to 3 points according to the following scheme: -1 indicates the practice has a negative impact on the specific sustainability dimension; 0 indicates no significant impact; and 3 a strong positive impact. The sum of each sustainability dimension's scores per agricultural practice is shown in the “Total” column in Table 3.2. In order to adapt the five indexes to the local Chilean context, we multiplied the scores by the percentage of farm area on which each agricultural practice was applied. For instance, if a farmer used chemical herbicides in 80% of her field, the final sustainability score for weed control would result from multiplying -4 (index associated with the use of chemical herbicides as in Table 3.2) by 80%, resulting in a final score of -3.2. This framework allows to calculate five indexes (seed, fertiliser, pest, weed and crop). The scores of the total index are interpreted in a general way, scores below 0 have a negative impact, scores above 0 have a positive impact and scores equal to 0 indicates no significant impact.

Table 3.2 Scoring sustainability of agricultural practices

Production stage		Sustainability dimensions: Minimises off-farm inputs	Minimises non-renewable inputs	Maximises natural biological processes	Promotes local biodiversity	TOTAL
Seed sourcing						
1	Conventional seed					0
2	Organic seed		1			1
3	Reused	1				1
4	Traditional	1				1
Soil fertility						
1	Conventional synthetic	-1	-1	-1		-3
2	Organic fertiliser purchased		1	1		2
3	Prepared organic fertiliser	2	2	1	3	8
Pest/disease control						
1	Chemical pesticides	-1	-1	-3	-3	-8
2	Organic pesticide purchased		1	1		2
3	Prepared organic pesticide	1	1	1	1	4
4	Preventive practices without chemicals	2	2	2	2	8
Weed control						
1	Chemical herbicides	-1	-1	-1	-1	-4
2	Organic herbicides purchased		1	1		2
3	Mechanic control	1	0.5	1	0.5	3
4	Preventive practices without chemicals	1	1	1	1	4
Crop management						
1	Crop rotation	0.5	0.5	1		2
2	Intercropping	1	1	1	1	4
3	Crop rotation + intercropping	1.5	1.5	2	1	6

Source: Based on Rigby et al. (Rigby et al., 2001)

3.3.4 Farming typology construction

3.3.4.1 Multivariate analysis

We used the 25 variables (Table 3.1) to develop our farming typology. We applied a two-step process to analyse these variables. The first step consisted of a principal component analysis (PCA), and the second step comprised a cluster analysis (CA) based on the PCA output.

We conducted the PCA to reduce the number of variables amongst the principal components (PCs). A PCA requires standardised variables (Nainggolan et al., 2013) and complete datasets (Dray and Josse, 2015). To fulfil these requirements, we removed the dummy and nominal variables with less than 5 categories (gender, INDAP, tenure, crop-variety, greenhouse, certification, irrigation, buyer-type and agree-type) from the 25 variables, as well as eliminating observations with missing values. We based our multivariate analysis on 342 complete observations. In addition, we transformed some variables (support links, number of technical visits and hectares dedicated to vegetable production) to achieve symmetrical distributions using logarithm 10 and we used winsorization[16] to reduce potential outliers.

The PCA technique is a dynamic process where some variables are eliminated until the final number of PCs is determined. Each PC represents a set of variables that are not correlated within the PC or with another set of variables in a different PC. Consequently, PCs condense the main similarities and dissimilarities of the data at the same time in different PCs. We determined the final number of PCs according to three criteria: 1) Kaiser's criterion, which suggests selecting all PCs with an eigenvalue higher than 1 (Hervé, 2016); 2) the number of PCs selected have to explain a minimum of 60% of the variance (Hair et al., 2014); and 3) the interpretability of PCs (Kuivanen et al., 2016).

Subsequently, we performed the CA, using the PCs as our input. The CA technique allows researchers to cluster variables according to their dissimilarity. Clusters tend to be homogeneous within themselves and heterogeneous between each other (Goswami et al., 2014). We used a hierarchical agglomerative cluster and Ward's computation method based on the work proposed by Alvarez et al. (2014). The results of the previous steps are presented visually as a dendrogram. The dendrogram represents the hierarchical relationship (dissimilarity) between observations within and between clusters (Alvarez et al., 2014). Therefore, it shows a number of clusters at different levels of dissimilarity (height). This means that at height "0", the dendrogram represents the highest level of dissimilarity (greatest number of clusters). As this height increases, the level of dissimilarity decreases (lower number of clusters). However, the dendrogram does not provide an ideal number of clusters. The definition of clusters is subjective, depending on researchers' interpretations and the dendrogram's overall appearance. According to Alvarez et al. (2014), the number of clusters should be between 3 and 7, and these are determined by the practical interpretability of each cluster.

[16] In winsorization, "extreme values are replaced by a less extreme value instead of being discarded as with trimming. Typical usage is that 90% Winsorization sets values to be no more extreme than the 5th and 95th percentiles" (Sullivan et al., 2021, p. 536).

3.3.4.2 Cluster characterisation

We analysed the resulting clusters from the previous exercise for characterisation. This analysis consisted of testing whether the variables (Table 3.1) have individual importance in the clusters' characterisation. The variables we tested in this section were the ones eliminated through the PCA. We separated the variables into two groups: Continuous and categorical variables. For the continuous variables, we used the non-parametric Kruskal-Wallis (or also called "one-way ANOVA on ranks") test and the Dunn test. A p-value less than 0.05 in the Kruskal-Wallis test implies a significant relationship between a variable and one or more clusters. It can also mean that the variable has individual importance in one or more clusters. We conducted the Dunn test to identify in which cluster each variable had individual importance. For the categorical variables, we used Pearson's Chi-squared and Fischer tests. These check for the independence between two categorical variables. In other words, these tests compare the clusters' distribution with respect to the distribution of other categorical variables. A p-value less than 0.05 in the Pearson's Chi-square and Fisher tests indicates that the distribution of the cluster is related to the categorical variable to which it is compared.

3.4 Results

3.4.1 Descriptive statistics

The sample's main characteristics related to the variables used in our multivariate analysis are presented in Table 3.3. The agricultural practices are represented by the five indexes for each production stage (i.e., seed, soil, pest, weed and crop). Results showed that only the average scores of the pest and weed indexes were negative (-3.30 and -0.19, respectively), suggesting that these agricultural practices are unsustainable.

In terms of socio-economic characteristics, the average age amongst the sample was 52, with 29 years of agricultural experience on average. The mean education level amongst surveyed farmers was between uncompleted and completed high school. Of the total sample, only 21% were women, and most of the respondents (70%) were beneficiaries of the National Institute for Agricultural Development (INDAP). On average, farmers had 4 people that they could reach out to in case of problems on the farm. Farmers received an average of 9 technical assistance visits within the last year, including from both government and private institutions. A small majority of the farmers (56%) owned their farmland. Farmers scored an average of 1.87 in terms of asset ownership, including tractors, trucks, pick-ups, cars and motorcycles. On average, the total monthly income of the households surveyed was 560,000 Chilean pesos (±700 USD). The mean percentage of income stemming from farming activities was 80%.

Table 3.3 Descriptive statistics, variables prior to modifications (logarithm 10 and winsorizing)

Category	Variable	Min	Mean	Max
Agricultural practices	Seed	0.00	0.20	1.00
	Soil	-3.00	0.30	8.00
	Pest	-8.00	-3.30	8.00
	Weed	-4.00	-0.19	4.00
	Crop	0.00	2.58	6.00
Socio-economic characteristics	Age (years)	24.00	52.68	91.00
	Experience (years)	1.00	29.07	78.00
	Education	1.00	4.56	7.00
	Gender (women)	0.00	0.21	1.00
	INDAP	0.00	0.70	1.00
	Links	0.00	4.12	80.00
	Tech. visits	0.00	3.98	90.00
	Tenure (owners)	0.00	0.56	1.00
	Assets (units)	0.00	1.87	5.00
	Income-farm (%)	0.00	79.56	100.00
	Income-total (category)	1.00	2.95	8.00
Structural farm characteristics	Vegi-size (ha.)	0.01	10.23	600.00
	Crop-variety	0.00	0.30	1.00
	Greenhouse	0.00	0.49	1.00
	Certification			
	- Participatory	0.00	0.04	0.00
	- Third-party	0.00	0.02	0.00
	- Transition	0.00	0.05	1.00
	- No certification	0.00	0.89	1.00
	Irrigation			
	- Drip	0.00	0.46	1.00
	- Furrows	0.00	0.45	1.00
	- Others	0.00	0.08	1.00
Market channel characteristics	Distance (km)	0.00	23.45	250.00
	Buyer-type			
	- Retailer	0.00	0.22	1.00
	- Wholesaler	0.00	0.25	1.00
	- Intermediary	0.00	0.40	1.00
	- High-standards	0.00	0.08	1.00
	Agree-type			
	- Spot	0.00	0.53	1.00
	- Verbal	0.00	0.38	1.00
	- Written	0.00	0.07	1.00

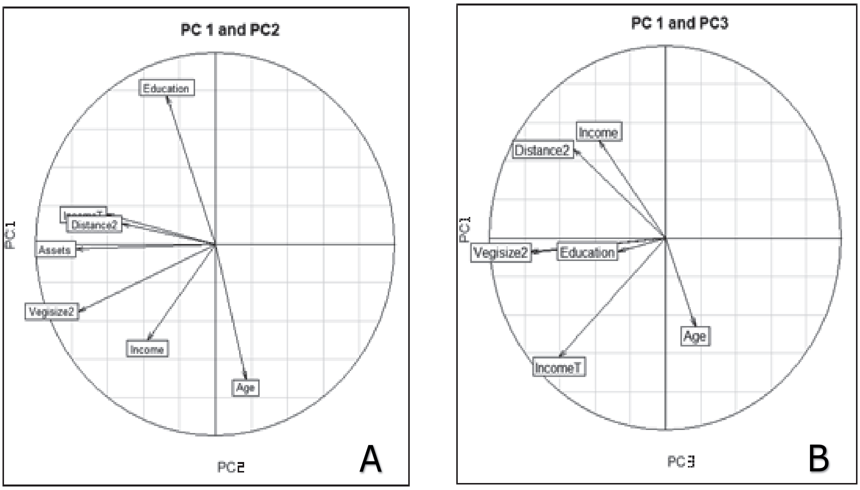
As regards structural farm characteristics, the average size of land exploited was 10 hectares. However, there was significant variability between study participants, ranging from farming systems with 100 m^2 to others with 600 hectares. Only 30% of the farming systems produced crops other than vegetables. Almost half of the farmers surveyed (49%) used greenhouses to produce vegetables. These greenhouses had an average size of 7,504 m^2. Only 6% of the farmers surveyed had an organic certification and 5% had a certification stating that the farming system was in the process of transitioning to SAPs. The remaining 89% did not have any organic certification. In terms of irrigation systems, most farming systems used drip systems (46%) or irrigation by furrows (45%).

Regarding market channel characteristics, the average distance between farming systems and the closest market was 23.45 km. Farmers' principal market channels were intermediaries (40%), wholesalers (25%), retailers (22%) and supermarkets, agroindustry and restaurants (8%). Most of the transactions in the vegetable sector did not include any previous agreement with buyers (53%); however, some farmers had verbal agreements (38%), and a small percentage had written agreements (8%).

3.4.2 Multivariate analysis and defining the number of farming typologies

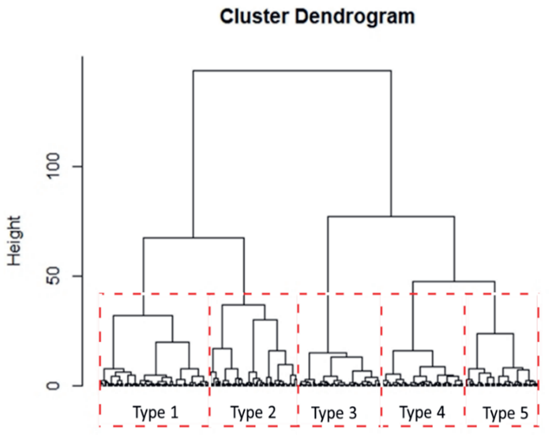
We obtained three PCs from the PCA. These PCs explained 67% of total data variation: PC1 explained 30%, PC2 22% and PC3 15%. The three PCs comprised 7 variables, i.e., assets, vegi-size (hectares), education, age, income-total, income-farm and distance to market. Figure 3.2 illustrates the correlation between the variables and the PCs. In the figure, the vector length of each variable represents the strength of the relationship with each PC. PC1 strongly and positively correlated with assets and vegi-size; PC2 strongly and positively correlated with education and age; and PC3 strongly and positively correlated with total income, income from the farm and distance to market.

Figure 3.2 Correlation circles for PCs. In *Chart A Correlation Circle for PC1-PC2,* the variables with longer vectors on the horizontal axis correlate with PC1, and the variables with longer vectors on the vertical axis correlate with PC2. In *Chart B Correlation Circle for PC1-PC3*, the variables with longer vectors on the vertical axis correlate with PC3.



We used the three PCs obtained from the PCA for our cluster analysis. As a result of the latter, we obtained a dendrogram (Figure 3.3). The dendrogram was cut at a height of 40, resulting in five clusters. We based our decision to leave five clusters on the interpretation of the PCs and their interpretability in the local context.

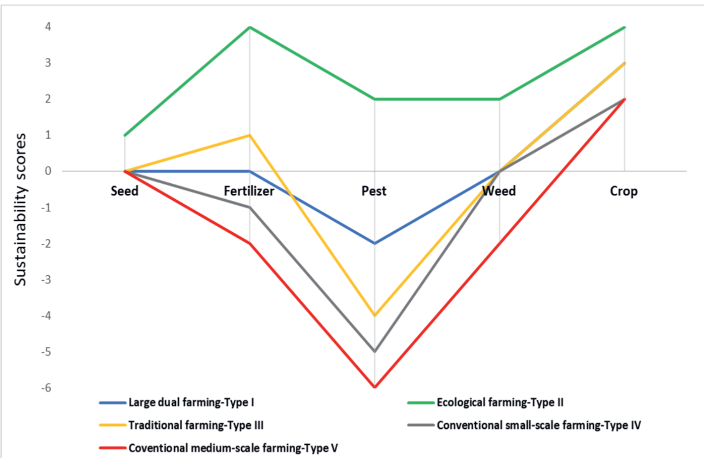
Figure 3.3 Agglomerative hierarchical cluster dendrogram of the 342 farmers, classified into 5 clusters.



3.4.3 Cluster characterisation

As explained at the outset, this paper aims to identify the predominant farming system types regarding their different sustainability levels in combination with their socio-economic, structural and market channel characteristics. The clusters are described with an emphasis on these variables and their statistical significance. Appendix 3.A shows the boxplots per numerical variables, and Appendix 3.B features a table summarising the statistical tests. We identified five farming systems: Large dual farming (Type I); ecological farming (Type II); traditional farming (Type III); conventional small-scale farming (Type IV); and conventional medium-scale farming (Type V). Figure 3.4 shows the sustainability scores per farming activity for each farming category.

Figure 3.4 Farming types and sustainability of agricultural practices



Type I – Large dual farming

Type I represents 20% (n = 69) of the sample. In Figure 3.4 we can observe that this type earns sustainability scores which are the closest to 0, meaning that the agricultural practices that these farming systems use have a limited impact on the environment. Farming systems of this type, practice both extensive and intensive vegetable production and possess a large expanse of cultivated land on average (33 ha.). This type also has the highest percentage of third-party organic certifications. In addition, this type represents farms with more economic resources, making them versatile producers, explaining why we can find organic, conventional or both conventional and organic production systems.

In this type, we also find the farms with the highest percentage of written agreements (16%). Farms in this type are market-oriented. They are the leading suppliers for high-standard market channels such as supermarkets, agroindustry and restaurants. More than half of the farmers in this category own their land (80%) and they have the highest number of assets (at least 3) for field work support and transportation, as these farms are most distant from their main market (54 km.). Farmers in this type show the lowest percentage of INDAP beneficiaries (53%) but receive support from private services and have a higher number of technical visits (i.e., at least one visit per month) and have a larger number of contacts that they can reach out to in case of problems. Farmers in this type and have the highest monthly income per household.

Type II – Ecological farming

Type II represents 17% (n = 57) of the research sample. This type has positive sustainability scores, representing that the agricultural practices used in these farming systems positively impact the environment, especially practices related to soil fertility, which have a strong significant impact. These farming systems adopt sustainable practices to conserve seeds, produce bio-inputs (i.e., mulch, compost, organic herbicides), rotate and diversify their crops and reject synthetic inputs. Most of these farming systems cultivate small expanse of land (1 ha.). Type II represents the farms with the highest number of organic certifications by a participatory guarantee system[17] (PGS) and a higher number of farms with organic certifications in transition. Within this farming type, some farms are not interested in obtaining organic certifications and refer to themselves as 'agroecological'.

[17] The PGS is a certification issued by farmers who organise themselves into organic farmers' associations. These associations have internal control systems to comply with organic regulations and grant the organic certification to their members. The Agricultural-Ranching Service (*Servicio Agricola Ganadero*, SAG), a body within the Chilean Ministry of Agriculture of Chile, audits and registers these associations (SAG 2020).

This type also includes the highest percentage of farms (81%) without market agreements. Their market strategy generally consists of offering a wide variety of products and selling them directly to end consumers in street markets and specialised stores, directly on the farms or through home delivery services. In addition, most of these farmers produce other crops alongside vegetables. Like Type-I farms, the majority of farmers in this type own their land (65%). However, farmers in this type own a low number of assets (max. 1). This type also includes the highest percentage of women (53%). Farmers in this group have diversified sources of income and, therefore, the lowest percentage of income from the farm (35%). Finally, farmers in this category receive the lowest number of technical visits by INDAP (4 per year).

Type III – Traditional farming

Type III represents 19% (n =65) of the sample. This type has positive sustainability scores in soil fertility and in crop management practices, both of which positively impact the environment. However, these farming systems also have negative sustainability scores in pest/disease control, negatively impacting the environment. The majority of these farming systems have small areas of land cultivated (2 ha.). This type is characterised by using a mix of natural inputs and synthetic inputs. These farming systems habitually adopt three traditional agricultural practices: Fertilisation with animal manure, weeding by hand and crop rotation. They use synthetic inputs to control pests or diseases. The kind of synthetic inputs used depends on the individual farmers' purchasing power and previous experience.

Farmers in this category have long-term relationships with their buyers, making this type the one with the highest percentage of verbal agreements (62%). Moreover, this type provides the largest percentage of their production to intermediaries at farm-gate (62%). Less than half of the farmers in this type own their land (46%). Similar to Type-II farmers, most of farmers in this type own at least 1 asset. This type primarily stands out due to the farmers' average age (64), their experience (41 years on average) and the lowest level of education (basic education completed). The latter is usually because farmers started to work as day labourers at an early age.

Type IV – Conventional small-scale faming

Type IV represents 19% (n = 65) of the sample. This category has mostly negative sustainability scores, which means that the agricultural practices used by these farming systems negatively impact the environment. The only agricultural practice amongst this type with positive scores is crop management. The majority of these farmers cultivate a small amount of land (2 ha.), just like those in Type III. Commonly, farmers in this type opt to use synthetic inputs which mostly serve to fertilise and control pests and diseases. These farmers' purchasing power limits their use of synthetic inputs, and they are likely to weed by hand to reduce production costs.

Similar to those in Type III, farmers in this type trade mostly in spot markets, selling their crops primarily to intermediaries (43%), retailers (25%) and wholesalers (23%). Moreover, less than half of the farmers own their land (46%) and at least one asset, just like Type-II and III farmers. Finally, farmers in this group represent the highest percentage of INDAP beneficiaries (91%) and receive at least ten technical visits per year.

Type V – Conventional medium-scale farming

Type V represents 25% (n = 86) of the sample. This category has the lowest sustainability scores. The scores related to soil fertility, pest/disease control and weed control reveal a strong negative impact on the environment. Most of the farmers cultivate a medium-size expanse of land (10 ha.). These farming systems adopt a low-cost strategy with higher production volumes. This type has a significant amount of money invested in establishing the farming system. Thus, this type tries to avoid risks and uncertainties in crop production using the "best" plants and preparing the soil with the "best" synthetic fertilisers to ensure high production levels. This type encompasses the lowest number of farming systems with organic certifications.

Amongst these farming systems, we find farmers with the highest percentage of sales to wholesalers (40%). In addition, this type is essentially divided between farmers without agreements and farmers with verbal agreements. Similar to Type-III and IV farmers, most of the farmers in this type do not own the land (52%). Moreover, these farmers own at least two assets and travel an average distance of 28 km. to deliver their products. This type includes the lowest percentage of women (5%). Farmers in this type also earn the highest percentage of income from their farms (97%) and they receive at least ten technical visits per year, just like those in Type IV.

3.5 Discussion

We have identified five distinct farming system types in the central region of Chile: Large dual farming (Type I), ecological farming (Type II), traditional farming (Type III), conventional small-scale farming (Type IV) and conventional medium-scale farming (Type V). We divide the discussion of our findings into two sections. First, we discuss which variables previous studies have used to categorise farming systems and how they are related with the farming types we identify. Second, we discuss the sustainability policy implications based on the different starting points of the various farming system types in their transition to sustainability practices.

3.5.1 Typology categorisation

In terms of our typology's construction, as far as we know, our study is one of the first to combine the sustainability level of agricultural practices with socio-economic, structural farm and market channel characteristics to categorise farming systems into different types. The majority of previous farming typology studies have mainly focused on socio-economic and structural farm characteristics (Blazy et al., 2009; Righi et al., 2011). A comparison of our findings with previous Chilean farming typology studies confirms that the variables which provide the greatest diversity when categorising farming systems are related to socio-economic and structural farm characteristics, specifically: age, education, assets, income from the farm, total income and cultivated area (Escobar and Berdegué, 1990; Köbrich et al., 2003; Georges, 2019). However, we also found that distance to market is one of the variables that provides the most diversity to characterise farming types. According to Tefera et al. (2004) and Guarín et al. (2020), distance to market is related to farmers' strategies related to market specialization, orientation, and the use of the land. Moreover, our study agrees with earlier observations (Köbrich et al., 2003; Tittonell et al., 2005; Alvarez et al., 2018), indicating that socio-economic and structural farm characteristics affect the agricultural practices used and the social interactions between farmers. This is in line with Efole et al. (2017) and Alvarez et al. (2018) who stress that the diversity of resource endowments and constraints may lead to different livelihood strategies.

By impacting the type of agricultural practices used, socio-economic and structural farm characteristics also influence their level of sustainability. Our Type-I farming system coincides with previous studies which argue that farming types with better sustainability levels are associated to larger plot sizes, greater economic performance and higher education levels (Bánkuti et al., 2020; Escobar et al., 2019; Mutyasira, 2020; Stylianou et al., 2020). This result may be explained by the fact that farming systems with more resources are in a position to make the changes needed to meet sustainability standards. Moreover, our Type-II farming system supports evidence from Masi et al. (2021) and Teixeira et al. (2018) who found that agroecological principles are associated with farming types led by women. In terms of the variables used to measure the sustainability level of agricultural practices, we used similar variables to those found in prior studies focused on the importance of including environmental sustainability aspects in farming typologies, namely, the use of pesticides, the amount of nitrogen released, the preservation of native flora and fauna and the use of manure (Berre et al., 2019; Bánkuti et al., 2020; Kansiime et al., 2021; Stylianou et al., 2020). However, our study differs from the others by using a farm-level index that aggregates the different sustainability variables (Table 3.2), making it easier to operationalise the sustainability concept and understand the complex dynamics between sustainability and farming systems.

Socio-economic and structural farm characteristics also affect the market channel in which farmers operate. Previous farming typology studies that have taken into consideration market-related factors have used variables such as market-orientation to identify the percentage of production output going to the market (Kansiime et al. 2021), the distance to markets as a proxy for market access (Mutyasira, 2020) and the type of buyers (e.g., farmers' markets, wholesalers and cooperatives) (Guarín et al., 2020). Bánkuti et al. (2020) and Guarín et al. (2020) found that farming types with formal agreements with agribusiness (e.g., supermarkets, processors and specialised stores) are linked with relatively wealthy farming systems, similar to our results for Type-I and II farming systems. Furthermore, there is evidence that market channel characteristics are connected with the sustainability level of agricultural practices. Guarín et al. (2020) found that farming types with organic certifications are linked to more formal market channels. Similarly, Kansiime et al. (2021) found that market-oriented farming types are more likely to make intensive use of pesticides, which is consistent with our results for Type-III, IV and V systems which are more dependent on farm income and use pesticides to ensure high production yields. Our results for Type II also seem to be consistent with Mutyasira (2020) who states that farming types located closer to markets have greater potential for crop diversification and high-value commercialisation.

3.5.2 Policy implications for sustainability

Type I includes farming systems with a limited impact on the environment. This may be because the agricultural practices used by farmers in this category have to meet the high safety standards demanded by their buyers (e.g., supermarkets and processors). This farming system may be framed by a Western worldview, where sustainability is based on technology, management and social changes and where economic growth is the primary objective (Kothari et al., 2014). This is why organic farms in Type I rely on technology (e.g., replacing conventional synthetic inputs with external synthetic inputs authorised for organic production) and focus on product uniformity (cosmetic fresh food quality), with their main market channel being supermarkets where consumers are willing to pay premium prices. Type I is mainly driven by the market. Consequently, one strategy to increase the organic component is raising legal requirements and industry norms (e.g., mandatory standards for minimum soil cover, afforestation, legal limits for pesticide residues, biological pest control, traceability) in order to eliminate unsustainable practices. These strategies could be combined with consumer information campaigns and financial support (e.g., tax reductions for organic inputs, organic exports and organic certifications) (Teixeira et al., 2018). As for organic farms in this category, the conventionalisation[18] of these farms has to be prevented by toughening regulations for organic certifications and setting additional conditions such as limitations on large-scale monocultures or requiring the sustainable use of water resources (Darnhofer et al., 2010; Eyhorn et al., 2019).

Type II incorporates the only farming systems with a positive impact on the environment. We can attribute this to the holistic approach towards agriculture that most farmers in this category have. This holistic approach abides by agroecological principles related to ancient worldviews, where nature and society live in harmony through a mutually supportive relationship (Carbonnier et al., 2011). Moreover, a large percentage of these farming systems are managed by *neo-rurals,*[19] characterised as professionals with economic activities both in urban and in rural areas (Ratier, 2002), who promote agroecological production systems and alternative marketing networks and build new relationships between producers and end consumers (Orria and Luise, 2017). A possible way for governments to support these types of farming systems is by sustaining culture concepts of these farmers by, e.g. the facilitation of participatory spaces, where farmers can trade their products and exchange experiences (Templer et al., 2018), guaranteeing land rights for conservation, and fomenting the participatory guarantee system (Teixeira et al., 2018).

Type III represents farming systems with a mix of agricultural practices. This may be explained by the direct relation with territorial heritage and indigenous roots. This finding also coincides with work by Gaitán-Cremaschi et al. (2020), who found that some farmers combine traditional and indigenous practices to reduce the use of pesticides and avoid mono-cropping. A possible explanation is that farmers in Type III are the oldest and most experienced farmers, who may have more attachment to indigenous farming practices. However, these farmers have restricted access to capital and land. Thus, governments can create incentives for SAP adoption by these farmers, regularise land tenure and provide them with technical assistance to control pests and diseases through agroecological principles (e.g., biocides, plant species selection, natural barriers, traps) (INDAP, 2016), also as a way to save money. Moreover, governments can connect these farmers with the network of farmers in Type II who have a developed market for organic products and have more experience in agroecological practices.

[18] This implies complying with the organic regulations but not with organic farming principles (Darnhofer et al., 2010).
[19] Individuals migrating from urban to rural areas seeking an alternative lifestyle to the capitalist system (Trimano, 2019).

Type IV includes systems that have a negative impact on the environment. For most of the farmers in this category, their primary source of income is their farms, making them risk-averse to changing conventional cash farming practices towards sustainable farming practices (Templer et al., 2018). Like farmers in Type III, these farmers also have restricted access to capital and land. Hence, drivers to motivate SAP adoption would be regularisation of land tenure, financial support such as crop insurance, greening payments or subsidies when adopting SAPs (Teixeira et al., 2018). Moreover, Type-II, III and IV have similar farm sizes and have similar market traits. As a result, governments can support them with strategies related to network development (e.g., farmers organizations) where farmers can be stimulated to adopt sustainable practices (Iyabano et al., 2021). Moreover, network development can support the exchange of experiences to strengthen cooperative market channels (Rossing et al., 2020).

Type V represents farming systems with the greatest negative impact on the environment. There are two likely causes for this. First, most farmers in this category do not work with a market channel that requires high-quality safety standards (Gaitán-Cremaschi et al., 2020). Second, similar to Type-IV farming systems, their primary source of income is their farms but with the difference that these farmers occupy larger tracts of land, implying greater investment risk. Moreover, like farmers in Type III and IV, most of these farmers do not own the land. Therefore, most of these farmers are risk-averse and have no incentive to adopt SAPs. One option to induce these farmers to embark on sustainable pathways is by replacing conventional synthetic inputs with organic inputs accompanied by financial support (e.g., tax reductions for organic inputs, crop insurance, greening payments and subsidies) (Iyabano et al., 2021).

Despite the fact that there are similarities between some farming systems (Type III, IV and V), such as limited economic resources, these farmers have different market channels and apply different agricultural practices. Consequently, the divergence between types presented in this study suggests that the transition to SAPs cannot be generalised (Loboguerrero et al., 2020). Although any pathway to sustainable practices requires large-scale societal reconfiguration, the transition must be understood as a nonlinear, complex, long-term, multilevel, multiphase and cross-scale process (Lam et al., 2020). Therefore, governments have to define complementary policies at the national level to support farmers during the transition period towards SAPs and to promote focal actions adapted to local needs. In this regard, governments may also invest in consumer education to shift consumer perception of acceptable cosmetic fresh food quality, which may lead to disincentivising the use of pesticides to attain the ideal colour and shape and limit the level of damage (Zakowski and Mace, 2021).

Finally, we do not consider the farming types identified in our study to be conclusive or fixed. Farming systems evolve continuously and shift from one category to another; in addition, types can overlap. We agree with Loboguerrero et al. (2020) who argue that identifying farming types helps to target strategies for the transition to sustainable agriculture and keeps vulnerable farms from being omitted. Moreover, farming types enable us to understand that strategies to support the transition to SAPs can coexist and coevolve, even if those strategies are seen as contradictory (Plumecocq et al., 2018).

3.6 Conclusions

This study aimed to characterise farming systems in the vegetable sector in the context of an emerging economy. The farming types identified in our study add to the literature by stressing the heterogeneity of farming systems and underlining how the sustainability of agricultural practices is interconnected with socio-economic, structural farm and market channel characteristics. Our study shows that the transition to sustainable agriculture can have different starting points, and, although the transition to sustainable agriculture may imply contradictory pathways, they can coexist. Policymakers can use these farming types as a point of departure to understand farmers' heterogeneity and become aware of the diversity of possible solutions to encourage the adoption of sustainable practices.

The multivariate analysis methodology (PCA and CA) we applied does, however, imply a limitation for our study. PCAs and CAs are based on clustering the average values of the variables, which makes "typical" groups prevail over "atypical" groups (Tittonell et al., 2020). For example, Types I and II had the highest percentage of farms with third-party organic certifications and with PGS organic certifications, respectively. However, this does not mean that Type-III, IV and V categories do not include any farms with organic certifications. It means that the farms with organic certifications in Types III, IV and V are "atypical" and do not align with average values in their groups. However, the farming types presented in this study can serve as the basis for further research focused specifically on the characteristics of "atypical" farmers. Likewise, we acknowledge that the farm-level index used in this study, based on the work of Rigby et al. (2001), has some limitations. For example, Dale and Polasky (2007) highlighted the limitation of not embracing a broader perspective considering the spatial context of agricultural lands. Likewise, Gómez-Limón & Sanchez-Fernandez (2010) pointed out the difficulty of interpreting the combination of indicators. However, the literature also mentioned some advantages of this index; Gómez-Limón & Sanchez-Fernandez (2010) and Waas et al. (2014) argued that this index allows ranking agricultural practices from best to worst, expressing negative and positive effects. Moreover, Bockstaller et al. (2008)

stressed the usefulness of this index for interpreting results by aggregation of the indicators in stages (e.g., seed sourcing, soil fertility pest and disease control).

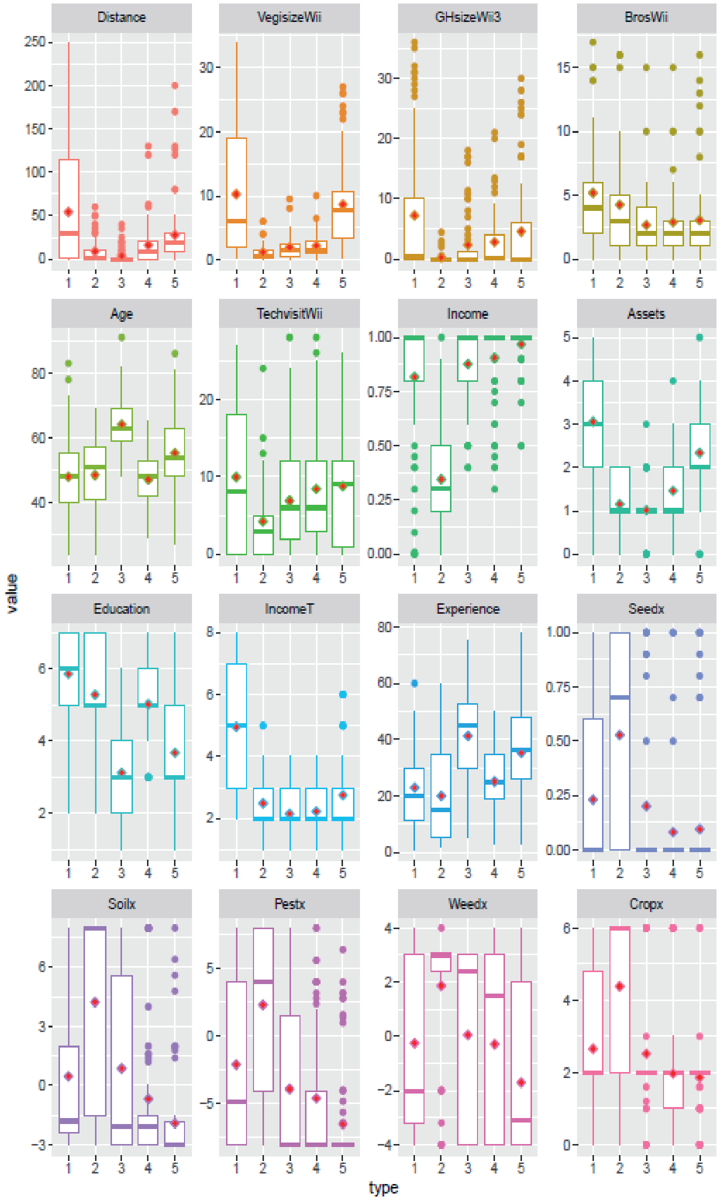
In Chile, the findings presented in this study could be used to fine-tune programmes promoted by INDAP (e.g., sustainable agriculture and land tenure regularisation program) and to thus gradually boost the transition towards sustainable production systems. This study evidences that smallholders' economic limitations in Chile could be seen as an opportunity to promote vegetable production through the use of available natural resources in order to reduce production costs. Moreover, another way to move sustainability forward at the national level is by issuing legal norms or laws to prohibit highly toxic inputs for agricultural use in Chile.

As a final reflection, Chile has already suffered an agricultural emergency with the painted-bug (*Bagrada hilaris*) infestation. This emergency evidenced the fragility of an agricultural production system relying only on synthetic inputs. On the other hand, the emergency highlighted the role of SAPs (e.g., integrated pest management and biological control) as a means to overcome the infestation and mobilise different actors to create new networks to support sustainable production (Contesse et al., 2021). In order to avoid future agricultural emergencies caused by pests, disease and climate change, we have to keep working through these sustainable innovation networks with a long-term perspective. It is necessary to provide more adaptative policies to increase the adoption rate of sustainable practices and ensure the agricultural sector's resilience (Milhorance et al., 2021).

APPENDICES

Appendix 3.A

Visualisation of the five farming types versus quantitative variables. The ends of the boxes represent the 1st and 3rd quartiles, and the small circles represent the outlier values. The red dots represent the mean, and the horizontal bar the median.



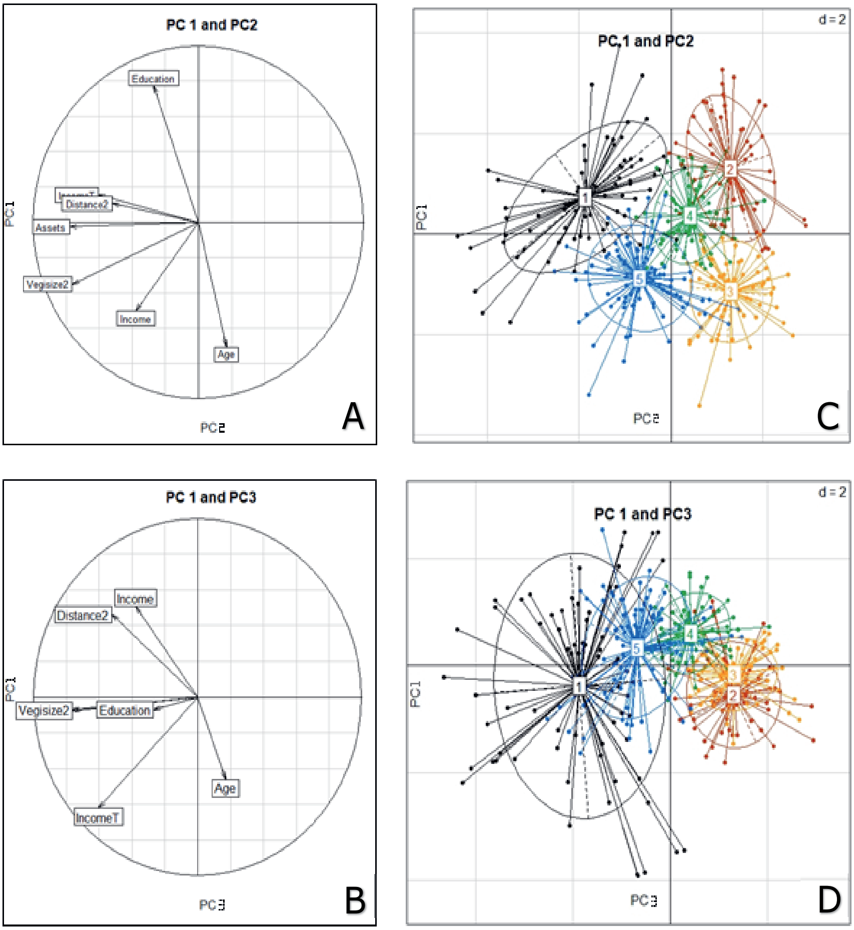
Appendix 3.B

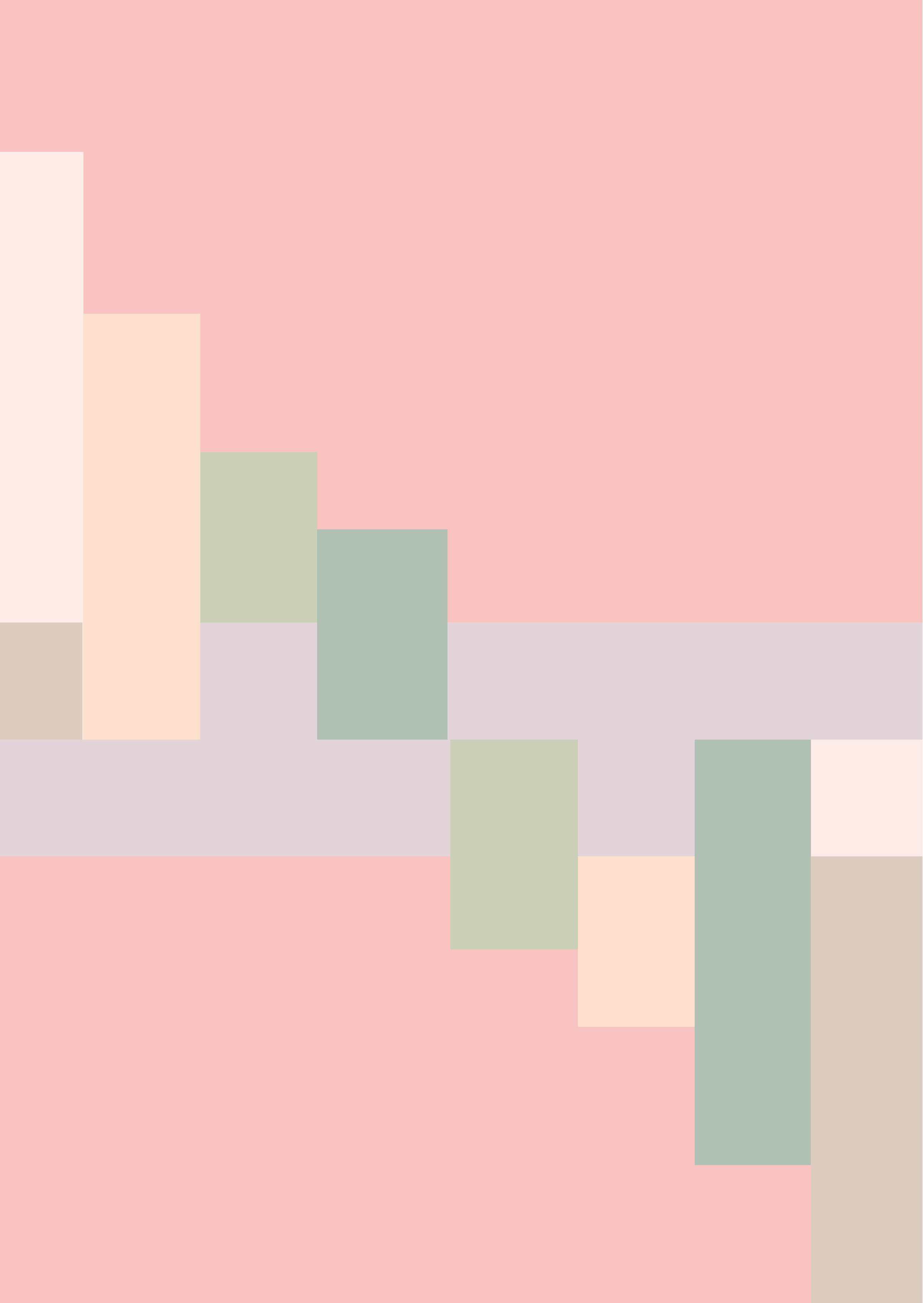
Results of the statistical tests used for cluster characterisation. The asterisk (*) next to the values identifies if the variable is significant (statistical different) for each farming system type.

Category	Variables	Type I	Type II	Type III	Type IV	Type V
Number of farmers		69	57	65	65	86
Regions	Valparaiso	20%	19%	28%	21%	12%
	Metropolitana	26%	19%	10%	12%	34%
	O'Higgins	21%	19%	10%	21%	29%
	Maule	12%	5%	16%	22%	45%
Sustainable farming characteristics	Seed (index)	0	1*	0	0	0
	Fertiliser (index)	0	4*	1*	-1	-2*
	Pest (index)	-2*	2*	-4	-5	-6*
	Weed (index)	0	2*	0	0	-2
	Crop (index)	3	4*	3	2	2
Socio-economic characteristics	Age (years)	48	48	64*	47	55*
	Experience (years)	23	20	41*	25	35*
	Education (category)	6*	5	3*	5	4*
	Gender (female)	14%	53%	18%	23%	5%
	INDAP (% beneficiaries)	52%	72%	72%	91%	72%
	Links (number people)	6*	5	3	3	3
	Techvisit (number of visits)	12	4*	8	10	10
	Tenure (owners)	80%	65%	46%	46%	48%
	Assets (units)	3*	1	1	1	2*
	Income-farm	82%	35%*	88%	91%	97%*
	Income-total (category)	5*	2	2	2	3*
Farm characteristics	Vegi-size (ha)	33*	1	2	2	10*
	Crop-variety	39%	56%	22%	28%	15%
	Greenhouse	58%	40%	51%	54%	42%
	Certification					
	- Participatory	7%	11%	2%	2%	0%
	- Third-party	7%	0%	0%	2%	1%
	- Transition	6%	12%	3%	5%	1%
	- No certification	80%	77%	95%	92%	98%
	Irrigation					
	- Drip	51%	44%	49%	52%	37%
	- Furrows	45%	37%	45%	38%	63%
	- Others	4%	19%	6%	9%	0%
Market channel characteristics	Distance (km)	54*	9	4*	16	28*
	Type of buyer					
	- Retailer	16%	60%	14%	25%	6%
	- Wholesaler	28%	14%	14%	23%	40%
	- Intermediary	33%	25%	62%	43%	43%
	- High-standards	23%	2%	11%	9%	12%
	Type of agreement					
	- Spot	51%	81%	34%	57%	48%
	- Verbal	33%	19%	62%	37%	45%
	- Written	16%	0%	5%	6%	7%

Appendix 3.C

The results of the principal component analysis and the hierarchical cluster are used together to interpret the meaning of each cluster. The images on the left (A-B) represent the correlation circles for PC1-PC2 and PC1-PC3. Those on the right (C-D) represent the clusters in the PC1-PC2 and PC1-PC3 planes.





CHAPTER 4

Farmer-buyer relationships and sustainable agricultural practices in the food supply chain: The case of vegetables in Chile

This chapter is in the second round of review and has been submitted as:

Benitez-Altuna, Francisco; Materia, Valentina C.; Bijman, Jos; Gaitán-Cremaschi, Daniel; Trienekens, Jacques. Farmer-buyer relationships and sustainable agricultural practices in the food supply chain: The case of vegetables in Chile. To *Agribusiness: an International Journal*

Abstract

Farmer-buyer governance forms and relationship attributes may be correlated to the use of sustainable agricultural practices (SAPs). Existing studies focus on dyadic relationships between farmers and lead firms (i.e., supermarkets and processors), showing that the use of contracts and specific relationship attributes support farmers to engage in sustainable production. However, other types of buyers are disregarded in this literature. Our study aims to explore how different farmer-buyer relationships relate to different levels of adopting SAPs in the production of vegetables in Chile. We analyse relations between contract provisions, relationship attributes and SAPs in formal and informal contracts. We collected survey data among 352 vegetable farmers in Chile and used ANOVA and logit modelling for our analysis. Our results show that small-scale farmers trade with intermediaries using informal contracts, medium-scale farmers with wholesalers using spot markets and large-scale farmers with lead firms using formal contracts. We found that farmers are more satisfied trading with intermediaries than with other buyers. The sustainability level of SAPs with respect to the governance forms differs mainly in seed sourcing, pest and weed control. Although it is well known that market forces have a major influence on shaping SAP adoption, the role of intermediaries and wholesalers is still unclear and often not considered in policy interventions. A deeper understanding of buyers and their interaction with farmers can strengthen policies that encourage SAP adoption in local and regional fresh food supply chains.

Keywords: vegetable supply chain; sustainable agricultural practices; contract elements; relationship attributes; governance forms; Chile

4.1 Introduction

Farmer-buyer relationships have been recognized as essential for the transformation of food systems[20] (Dlamini-Mazibuko et al., 2019; Lees et al., 2020). The transformation of food systems has been characterised by economic growth, globalisation, specialisation and the coordination between business partners (e.g., farmers, retailers, processors, input suppliers) and has allowed for a consistent supply of products that meet high safety and quality standards (Mergenthaler et al., 2009; Bellemare and Lim, 2018). This modernisation process was mainly driven by business partners starting to coordinate in food supply chains, which implies effective communication to reduce risk, uncertainty and transaction costs for mutual benefits (Reardon et al., 2009; Dlamini-Mazibuko et al., 2019; Lees et al., 2020). However, growth and specialisation in food supply chains also have negative impacts on the environment, such as soil degradation, water pollution and deforestation (Rueda et al., 2017).

In the past decades, the awareness about strategies to support the reduction of the negative environmental impact of food supply chains has increased. These strategies are mainly focused on farmer-buyer relationships where farmers are incentivised to implement production standards and certifications (e.g., organic certification, UTZ, rainforest alliance, Global GAP), thereby facilitating access to premium markets (Vanderhaegen, 2018; Della Navarrete et al., 2020; Grabs and Carodenuto, 2021). In fresh-food value chains, support strategies are predominantly focused on farmer adoption of specific sustainable agricultural practices (SAPs)[21] (e.g., organic fertilisers, integrated pest management and crop management) (De Marchi et al., 2019; Thomson et al., 2020).

The adoption of SAPs has been studied from different perspectives, including a value chain perspective. Value chain research has mainly focused on the role of lead firms[22] and the governance forms used to coordinate with farmers to support the adoption of SAPs (Achabou et al., 2017; Freidberg, 2020). To successfully support the adoption of SAPs, lead firms operate through hybrid governance forms (e.g., formal contracts) and stimulate close relationships with farmers by for instance trust building and creating mutual benefit (Freidberg, 2020; Dubbert et al., 2021; Touboulic et al., 2021; Veldwisch and Woodhouse, 2021). Thus, this literature has analysed how contractual provisions (e.g., quality, price, payment schemes) and relationship attributes (e.g., trust and satisfaction) between farmers and lead firms can help

[20] Food systems are perceived as the interaction of farmers with upstream and downstream value chains, linking input suppliers (i.e., R&D agricultural industries), wholesalers, processors, retailers and consumers (Reardon et al., 2019).

[21] SAPs imply that "agriculture will have to be carried out to make the best use of available natural resources and inputs, and regenerate conditions for future production" (Leeuwis, 2004, p. 5).

[22] In buyer-driven chains, lead firms are "retailers or marketers of the final products that exert the most power through their ability to shape mass consumption via strong brand names" (Gereffi, 2011, p. 40).

farmers to adopt SAPs (Gualandris and Kalchschmidt 2016). However, scholars have, thus far, paid limited attention to the relations between farmers and other types of buyers (e.g., intermediaries and wholesalers), and even less attention to how the relationship with other types of buyers affect the adoption of SAPs (Thorlakson, 2018; Grabs and Carodenuto, 2021).

The majority of the farmers in developing and emerging economies operate with intermediaries or wholesalers rather than with lead firms (Guarín, 2013; Mariyono et al., 2020), and only a limited number of farmers use SAPs (Elgueta et al., 2020; Calderon et al., 2022). There is a lack of knowledge on the relationships of farmers with other buyers and SAP adoption. One example of a supply chain where most produce is sold to other buyers rather than to lead firms and where negative environmental impacts are a significant problem is the vegetables chain in Chile. The majority of vegetable production in Chile is destined for the national market and only a small portion to export (Schwartz et al., 2013; ODEPA, 2020a), indicating less attention to (international) safety and sustainability standards. The Chilean vegetables market is characterised by different types of buyers such as intermediaries, wholesalers and lead firms (the latter including supermarkets and agro-industries) (Schwartz et al., 2013; ODEPA, 2020a). This diversity of buyers provides a good opportunity to study how farmer-buyer governance forms and relationships attributes relate to SAP adoption, and to find indications on how to improve the adoption of SAPs by these farmers.

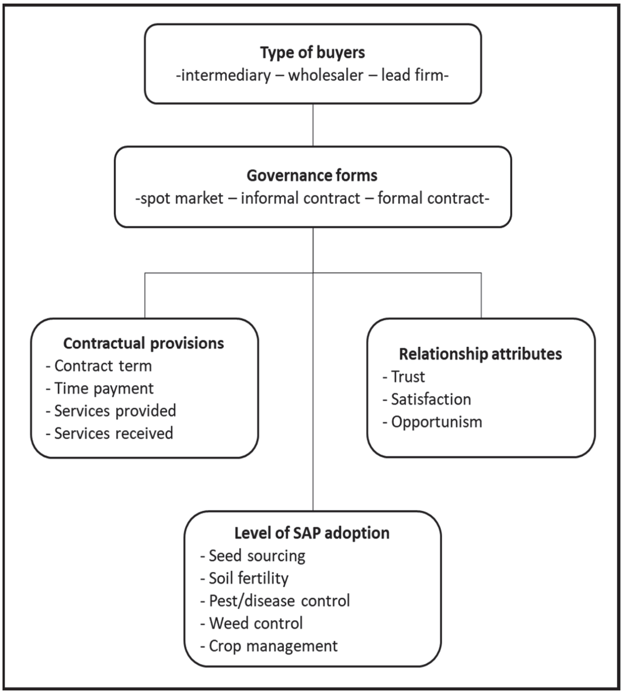
In our study we address the knowledge gaps on the role that key buyers (i.e., intermediaries, wholesalers and lead firms) play related to SAP adoption by farmers in the vegetable sector in Chile. We explore how different farmer-buyer relationships are linked to different levels of SAP adoption. Specifically, this study aims to explore: i) what farmer characteristics are related to each type of buyer? ii) what type of governance form (spot market, informal contract, formal contract) is related to each type of buyer? and iii) how do contract forms (formal or informal) relate to specific contract provisions (e.g., quality, quantity and the provision of services), relationship attributes (i.e., trust, satisfaction and opportunism) and different levels of SAP adoption by farmers? This study seeks to contribute to the literature by exploring different types of buyers, their relationships with farmers and the adoption of SAPs. Moreover, beyond the case of Chile, this study aims to provide valuable insights to further SAP adoption in fresh-food supply chains.

This paper is structured as follows. In section 2, we present our theoretical framework. In section 3, we present an overview of the vegetable sector in Chile. In section 4, we present our data collection process, literature to measure the level of SAPs adoption, and the types of analyzes used (e.g., ANOVA and logit model). In section 5, we present the results and discuss the implications of the different farmer-buyer relationships and their different levels of adopting SAPs in the vegetable sector in Chile, and in section 6, we present the conclusions of this study. Lastly, in section 7 we offer the limitations of this study and recommendations for future research.

4.2 Theoretical framework

Food supply chain literature shows that lead firms support the adoption of SAPs only when formal contracts and close relationships exist (Della Navarrete et al., 2020; Freidberg, 2020; Lemma et al., 2020). In the case of the banana value chain in Ethiopia, Lemma et al. (2020) found that one way for a supply chain to respond to sustainable requirements is through coordination between farmers and buyers. The coordination involves the alignment among several activities like production, processing and marketing. However, coordination works better if farmers and buyers maintain close and sustainable business relationships based on long-lasting, stable and mutual advantages. Studies have found that lead firms involve farmers through formal contracts (Bush et al., 2015; Ghadimi et al., 2016; Freidberg, 2020), in which contractual provisions specify SAP adoption (e.g., the intensity and types of inputs used) (Ghadimi et al., 2016; Thomson et al., 2020; Dubbert et al., 2021). However, Touboulic et al., (2021) stress that the pressure to adopt SAPs is effective only when there is a close, mutually trustworthy, relationship between the lead firm and the farmer. A close relationship between the two is reflected in behaviour that maintains or improves the strength of the relationship (Autry and Golicic, 2010; Tangpong et al., 2015). Figure 4.1 depicts our study's theoretical framework. This is followed by an in-depth discussion of the type of buyers and the elements of this framework, exploring contractual provisions and relationship attributes and how these may relate to SAP adoption. In the next sections the elements of the framework will be further explained.

Figure 4.1 Theoretical framework



4.2.1 Types of buyers

Different types of buyers operate in the vegetable supply chain in Chile. However, the largest quantity of vegetables is traded through three main types (apart from final consumers) as mentioned above: intermediaries, wholesalers and lead firms (Schwartz et al. 2013; Gaitán-Cremaschi et al. 2020; ODEPA 2020b). **Intermediaries** are familiar with their rural territory and operate at the local level. They buy small quantities of products from small-scale farmers at their farms. Intermediaries typically have verbal (informal) contracts and closer relationships with farmers. Moreover, they pay immediately in cash, based on quality and quantity provided, and they occasionally use their own human resources to support harvesting. Intermediaries operate as merchants in street markets or farmers' markets (Schwartz et al. 2013; Gaitán-Cremaschi et al. 2020; ODEPA 2020b). By contrast, **wholesalers** operate at the regional and national levels. They often have a fixed space in urban public wholesale markets (Alam, 2018). They buy large quantities of products, and the terms of the transactions are basic, focused mainly on four attributes: price, size, colour and firmness. At times, wholesalers also specialise by product category. Usually, they buy from small-medium-scale farmers. Wholesalers do not have close relationships with individual farmers, and all their transactions take place in cash. They resell the products in wholesale markets in other regions or to lead firms (Balsevich et al. 2003; Schwartz et al. 2013; Gaitán-Cremaschi et al. 2020; ODEPA 2020b). Lastly, **lead firms** include supermarkets and agro-industries. These generally operate through formal contracts to trade with medium-large-scale farmers. The terms of these contracts can be divided in two: quality and logistics. In relation to quality standards, lead firms can set the requirements according to international or national standards, including norms such as safety (usually, regarding to SAPs, maximum residue levels of pesticides), size, colour, shape, level of damage. Regarding to logistics, lead firms set requirements namely volume, frequency of delivery, fixed prices by month or year, payments in 30-90 days and fees for shelf placement (in the case of supermarkets). Lead firms have the infrastructure to process and store products, as well as the economic and human resources to support the whole supply chain process (Schwartz et al. 2013; Gaitán-Cremaschi et al. 2020; ODEPA 2020b).

4.2.2 Governance forms

Governance forms represent different levels of integration and can range from spot market, through hybrid governance forms (e.g. contracts) to full vertical integration (i.e. intra-firm transactions) (Trienekens, 2011; Bellemare and Lim, 2018). However, the most common agricultural governance forms in fresh food supply chains in developing countries are characterised by spot market transactions (e.g. farmers' markets or wholesale markets) and informal (verbal) contracts, and only a small portion of transactions are through formal (written) contracts (Keco et al., 2019).

Spot markets define the price of a product as a function of supply and demand, in an environment of uncertainty with low specificity (e.g., quality and safety) and where the identity of the buyer is unknown (Prowse, 2012; Mugwagwa et al., 2020). Contracts emerge to avoid the uncertainties of spot market transactions and are defined as a verbal or written commitment to provide an agricultural product under pre-agreed terms and conditions (e.g., price, quantity, quality) (Singh, 2000; Bijman, 2008). Contracts can be divided in formal (written) and informal (verbal), both contracts essentially perform the same function (Beninger and Shapiro, 2019; Veldwisch and Woodhouse, 2022). Farmers and buyers trading through contracts have economic as well as social incentives to stabilise their transaction relationships (Bijman, 2008; Escobal et al., 2015). Contracts are seen as a tool to reduce transaction costs resulting from uncertainty, risk, market imperfections and coordination failures (Abebe et al. 2013). Moreover, a large body of literature suggests that contracts can stimulate economic development, higher yields, crop diversity, access to new technology and adoption of SAPs (Bijman, 2008; Bellemare and Lim, 2018; Meemken and Bellemare, 2020).

4.2.3 Contractual provisions

Contractual provisions are seen as a way to steady contracts (Escobal et al., 2015). Since buyers and farmers are aware of each other's bargaining skills and opportunistic behaviour, they only engage in business if contractual conditions are specified (Beninger and Shapiro, 2019). Contractual provisions may relate to volume, quality, price, payment mechanisms, delivery requirements, contract length and adoption of SAPs and can vary greatly across types of contracts (Bijman, 2008; Barrowclough et al., 2019). For example, in dyadic relationships between lead firms and farmers, lead firms usually incentivize farmers to adopt SAPs through formal contracts to access premium markets (De Marchi et al., 2019; Freidberg, 2020). Lead firms identify the main environmental issues at the farm and transform these into standards that are included in the formal contracts as contractual provisions, along with an offer of a premium price if farmers fulfil the standards (Bolwig et al., 2010; Ghadimi et al., 2016). In some cases, standards compliance must be proven through third-party certification (e.g., organic farming certification). Moreover, on other occasions, lead firms adopt mentoring-driven approaches, providing farmers technical or financial support for the adoption of SAPs (De Marchi et al., 2019; ODEPA, 2020b).

4.2.4 Relationship attributes

The attributes of farmer-buyer relationships have been measured by different terms (e.g., trust, commitment, satisfaction, dependence, power) (Lees et al., 2020). Farmer-buyer relationships is a construct that aims to reflect the overall strength and continuity of a relation (Lages et al., 2005; Lees, 2020). One of the most common dimensions included in the literature is trust (Lees et al., 2020). However, there is not consensus in the literature of what other dimensions "must" be measured together with trust (Lees et al., 2020). This research will use trust (Gualandris and Kalchschmidt, 2016), satisfaction (Murphy and Sashi, 2018) and (non-)opportunistic behaviour (Touboulic et al., 2021; Kang and Jindal, 2015) to measure the strength and continuity of the farmer-buyer relationship.

Trust is a multidimensional construct and is defined as the belief that a business partner is reliable and benevolent (Ganesan, 1994). ''Reliable'' is related to the belief that the partner has the necessary expertise to perform the corresponding activity effectively and reliably (Ganesan, 1994). Benevolent is related to the belief that the partner has good intentions and will not act only out of self-interest (Ganesan, 1994). Trust is viewed as a unique governance mechanism that promotes voluntary exchanges of assets and services between partners (Uzzi, 1996). Some factors such as coercive behaviour, cultural dissimilarity, opportunism and a lack of cooperation can threaten trusted relationships between business partners (Ali, 2021). Trust is also associated with long-term relationships, reduced perceived risk and reduced transaction costs (Batt et al., 2006).

Satisfaction represents a summary of psychological states (e.g., rewarding, profitable, problematic and frustrating) that evaluate the relationship experience (Lees, 2017). With this lens, satisfaction can be defined as a positive affective state that emerges from the overall relationship with a business partner (Gorton et al., 2015). According to Geyskens et al. (1999), satisfaction encapsulates the economic and non-economic aspects of the business relationship. The economic aspect reflects the financial rewards that flow from the relationship; thus, a business relationship is satisfactory when it achieves the overall targeted financial results (Geyskens et al., 1999). The non-economic aspect reflects positive affective responses when interactions with the exchange partner are fulfilling, gratifying and easy (Geyskens et al., 1999). When business partners are satisfied with previous transactions, re-transactions are more likely to occur (Murphy and Sashi, 2018). Hence, satisfaction supports long-term relationships, loyalty and reputation (Otto et al., 2020).

Opportunism is defined as “self-interest seeking with guile” (Williamson, 1985). Opportunism is a deliberate, selfish behaviour based on information distortion and reneging on agreements (Jap and Anderson, 2003), leading to feelings of deception in the exchange partner (Kang and Jindal, 2015). Opportunistic behaviour can be expressed in different ways, such as exaggerating one’s difficulties, withholding efforts and even outright lying, the aim being to not honour previous agreements (Kang and Jindal, 2015). Opportunism is common in business relationships, usually when there are asymmetrical power relations between partners, where less powerful partners may be vulnerable to opportunistic behaviour (Nyaga et al., 2013; Handley et al., 2019). This type of behaviour amplifies the potential for conflict and reduces the business relationship’s lifetime (Gorton et al., 2015; Kang and Jindal, 2015).

4.2.5 Level of sustainable agricultural practices (SAP) adoption

Sustainable Agricultural Practices (SAPs) imply that "agriculture will have to be carried out to make the best use of available natural resources and inputs, and regenerate conditions for future production" (Leeuwis, 2004, p. 5). These practices involve substituting synthetic resources produced out-farm (i.e., fertilisers, insecticides, herbicides) for on-farm resources to achieve effective and efficient short-and-long term use of natural resources (Taylor et al., 1993). Some examples of on-farm resources are integrated pest management, crop rotations, green manures and cover crop (Taylor et al., 1993; Kleijn et al., 2019). The farm's sustainability level depends on how on-farm resources substitute out-farm resources. However, because SAPs include practices in different stages of farming production, the sustainability level at the farm is not bimodal, and ranges from "low sustainability" to "high unsustainability" (Taylor et al., 1993). In order to quantitively analyse the level of sustainability at farms, literature presents many sustainability indicators (Rigby et al., 2001; Bockstaller et al., 2008; Gómez-Limón and Sanchez-Fernandez, 2010; Waas et al., 2014). Based on the work of Rigby et al. (2001), we measure specifically the sustainability level of agricultural practices used by farmers. Rigby et al. (2001) measure SAPs by identifying five stages of vegetable production (i.e., seed source, soil, pest/disease control, weed control, crop management) which involve different agricultural practices such as the use of traditional seeds, synthetic fertilisers, organic fertilisers, green manure, wildflower strips, beetle banks, synthetic pesticides, organic herbicides, resistant varieties, intercropping and crop rotation.

4.3 Case study: The vegetable sector in Chile

In Chile, vegetable production is one of the main agricultural activities. In 2020 vegetable production occupied 77,000 hectares and encompassed 34,000 farmers, distributed all over the country. The sector mostly includes small-scale farmers (less than 5 hectares), with a much smaller number of large-scale farmers (exceeding 300 hectares). The largest concentration of vegetable production is located in the central zone of Chile, in the regions of Valparaiso, Metropolitana, O'Higgins and Maule. These regions span approximately 54,000 hectares of vegetable production and produce around 70% of all the country's vegetables (ODEPA 2020a). The main vegetables produced are sweet corn (*choclo*), onions, lettuce, tomatoes and beans.

Vegetable production in Chile is characterised by the intensive use of chemical inputs (e.g., fertilisers and pesticides) (Altieri and Rojas 1999; David et al. 2000), which negatively affects the environment (e.g., soil erosion, biodiversity loss and water pollution) (Riquelme-Garcés et al., 2013). Additionally, the use of inputs has negatively impacted human health in Chile, especially that of farmers exposed to pesticides and of consumers through the high levels of pesticide residues in vegetables (Corral et al. 2017). This is reflected in the low use of SAPs in vegetable production in Chile, where in 2017 less than 1% of the vegetables sold had an organic certificate (ODEPA, 2017) and only 1.4% of the farmers (circa 1,800 smallholders) self-recognised themselves as 'agroecological'. However, the latter group sells their products without any corresponding certificate (INDAP, 2017).

In Chile, vegetable production is mostly through spot market and informal contracts, with a share of 80%, and mainly catered to local demand and where the main buyers are wholesalers and intermediaries (Schwartz et al. 2013). Most spot market transactions and an important point of sales for wholesalers in the wholesale market in Santiago (capital city). Most informal contracts are concentrated in transactions at farm level, where the main buyers are intermediaries (Boitano 2011; Schwartz et al. 2013; Gaitán-Cremaschi et al. 2020). On the other hand, formal contracts with supermarkets and agro-industries have a 20% market share and meet local and international demand (Schwartz et al. 2013; Lakner et al., 2017; Gaitán-Cremaschi et al. 2020). However, not all the transactions with supermarkets and agro-industries are through formal contracts and there is a small percentage (4%) that is through informal contracts (ODEPA, 2020b). ODEPA (2020b) found that the use of formal contracts by supermarkets and agro-industries depends on the firms' strategies (supply and demand) and crop types. Some crops are mainly acquired through formal contracts (e.g., tomatoes, chili peppers, celery and broccoli); others are mainly acquired in spot markets (e.g. garlic, basil, sweet potatoes and mushroom); while others are acquired through formal contracts and spot markets (e.g., artichokes, onions, asparagus and peas).

4.4 Methods

4.4.1 Data collection

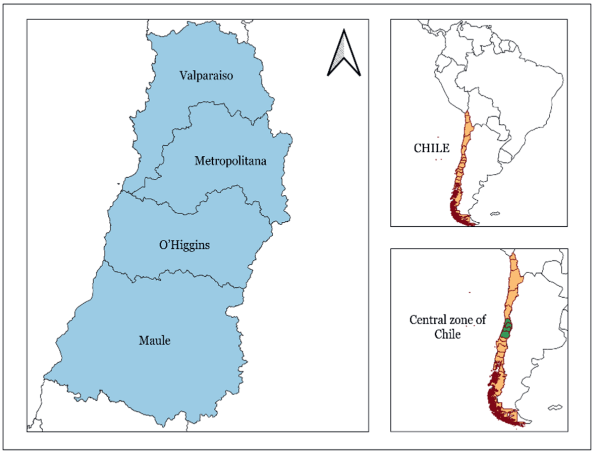
We collected the data for our study by conducting a face-to-face survey amongst 352 vegetable farmers in Chile. Each interview lasted 30 to 40 minutes with the farm holder. All the fieldwork was conducted in Chiles' official language Spanish. Most farmers were visited in the field and at their homes, and around 5% were visited at fairs. These farmers were selected randomly from contact lists provided by two main sources: organic organizations and private extension agricultural services[23] (this last included conventional and organic farmers). Most of the farmers surveyed were identified from the contact lists (70%), and the others were approached through snowball sampling (30%). During the day-to-day interview practices snowball sampling was used to complement the contact lists and achieve a sufficient number of observations per day. Farmers were asked to recommend other farmers who mainly produce vegetables and who might also be willing to participate in the survey. The rule used for the snowball sampling was that farmers had to be at least one km away from the farmer who advised the new respondent.

The surveys were carried out by the lead author and two enumerators. On average, each enumerator conducted between 2 and 3 surveys per day. Farmers were contacted by phone to schedule an appointment for the survey. Hence, the fieldwork was mainly executed according to farmers' predisposition to participate in the survey. We implemented the survey from October 2018 to April 2019 in four regions in Chile: Valparaiso, Metropolitana, O'Higgins and Maule (Figure 4.2). The sample is illustrative for the regions with the highest concentration of vegetable production in Chile, but not for

[23] The names of the organizations and extension agricultural services cannot be mentioned due to guarantee the protection of personal data and anonymity.

other regions due to the differences in agroecological and socio-economic conditions. Moreover, although the sample is not statistically representative of the population of the central region of Chile, our descriptive statistics related to age, gender, and land, among others, match the results of previous studies on the vegetable sector in the central regions of Chile (Boza et al., 2019).

Figure 4.2 Research area



The survey gathered information on six categories of data (details in Table 4.1): 1) type of buyers; 2) farmers' characteristics; 3) governance forms; 4) relationship attributes; 5) contractual provisions; and 6) levels of SAP adoption. We identified the different types of buyers (intermediaries, wholesalers and lead firms) from a literature review of studies carried out in Chile (Schwartz et al. 2013; Gaitán-Cremaschi et al. 2020; ODEPA 2020b). The type of buyer refers to farmers' main buyers, that is, the buyer who purchases the largest quantity of product from the farmer. Farmers' characteristics include information related to capital, education, gender among others (Leite et al., 2014), information about the link that farmers have with other individuals or other organizations (e.g., beneficiary of INDAP and membership in farmers' organizations) (Jara- Rojas et al., 2012), and whether farmers possess any organic certification (Baumgart-Getz et al., 2012). Governance forms indicates the type of governance between farmers and main buyers: spot market, informal contract, formal contract (Trienekens, 2011). Relationship attributes refer to the three terms used to measure relationships: trust, satisfaction and opportunism. We measured these three terms from a farmer's perspective on the relationships with the buyer using a Likert scale to qualify statements, ranging from 1 – "Totally disagree" to 7 "Totally agree". The statements in the questionnaire were derived from a literature review of papers measuring the same terms in other contexts e.g., fruit sector in Australia (Batt, 2003) vegetable sector in Philippines (Batt et al., 2006). Contractual provisions refer to the agreed-on conditions or standards that are included in the contract and that the farmers/buyers must comply with (e.g., price, volume and quality) and to other services that are provided or delivered but are not explicitly included in the contract, e.g. transportation to the point of sales (Bijman, 2008; Kersting and Wollni, 2012; Elder, 2016). Levels of SAP adoption measures the sustainability level of agricultural practices used by farmers. We base our measurement on Rigby et al.'s work (2001), which allows comparing diverse agricultural practices across four sustainability dimensions. Agricultural practices cover five production stages as mentioned above (seed sourcing, soil fertility, pest/disease control, weed control and crop management). The four sustainability dimensions are: the minimisation of off-farm inputs; the minimisation of non-renewable inputs; the maximisation of natural biological processes; and the promotion of local biodiversity. Each agricultural practice is scored according to each sustainability dimension, obtaining a sustainability level score per stage. The scores vary from -3 to +3, where ±3 indicates a strong negative/positive impact; ±2 indicates a medium negative/positive impact; ±1 is a moderate negative/positive impact; and a 0 implies no significant impact (Appendix 4.A). The complete procedure for measuring the sustainability level is detailed in Benitez-Altuna et al. (2021).

Table 4.1 Variable description

Category	Variable	Description	Unit
Type of buyers	Buyer-type	Who is your main buyer? Final consumer / intermediary / wholesaler / lead firms (supermarkets and agroindustry)	4 categories
Farmers' characteristics	Age	Head of household's age	years
	Experience	Head of household's years of experience in vegetable production	years
	Gender	Head of household's gender	female-male
	Education	Highest educational	7 categories
	Vegi-size (ha.)	Size of the land used for vegetable production	hectares
	Tenure	What is the ownership status of your land? rent / own / own + rent	3categories
	Crop-variety	Farmers with only vegetable crops or farmers with vegetable & other crops	yes-no
	Greenhouse	Use of greenhouse	yes-no
	Assets	Number of assets: tractor, truck, pick-up, car and motorcycle	no. of assets
	Income-farm	Income from the farm	percentage
	Income-total	Total monthly household income	8 categories
	INDAP	Household is beneficiary of INDAP*	yes-no
	Member-Farm	The household head is a member of a farmer organization	yes-no
	Member-Org	The household head is a member of a social organization	yes-no
	Contacts	Number of people they can reach out to in case of an urgent problem on the farm	no. of contacts
	Type certification	Do you have one of the following organic certificates for the vegetables you produce? Participatory certification, third-party certification, certification in process, no organic certification	4 categories
Governance forms	Governance	Which type of contract do you have with your main buyer? spot market / informal (verbal) contract / formal (written) contract	3 categories
Relationship attributes	Trust	- I trust my main buyer	Likert scale from 1 to 7
		- My main buyer is always honest	Likert scale from 1 to 7
		- My main buyer considers my interests	Likert scale from 1 to 7
		- I believe in the information provided by my main buyer	Likert scale from 1 to 7
	Satisfaction	- There is a good cooperation between my main buyer and myself	Likert scale from 1 to 7
		- My main buyer meets my expectations	Likert scale from 1 to 7
		- My main buyer is quick to handle complaints	Likert scale from 1 to 7
	Opportunism	- A deal with my main buyer is risky	Likert scale from 1 to 7
		- My main buyer acts opportunistically	Likert scale from 1 to 7
Contractual provisions	Contract term	What is the term of the contract (days)?	no. of days
	Payment	On average, how many days does it take your main buyer to pay you?	no. of days
	Contract provisions	How many clauses does the contract with your main buyer have? (e.g., quality, price, quantity, payment method, delivery frequency)	no. of clauses
	Out-service	Do you provide some kind of service (out of contract) to your main buyer (e.g., classification or packaging)?	no. of clauses
	In-service	Does your main buyer provide you with some kind of service (out of contract) (e.g., payment in advance, inputs or technical assistance)?	no. of clauses
Sustainability level of agricultural practices	Seed	Seed sourcing	numerical index
	Soil	Soil fertility	numerical index
	Pest	Pest/disease control	numerical index
	Weed	Weed control	numerical index
	Crop	Crop management	numerical index

* The Institute of Agricultural Development (INDAP), within the Chilean Ministry of Agriculture provides assistance to family farmers (INDAP, 2020).

** Likert scale 1 = totally disagree; 7 = totally agree

4.4.2 Farmers' characteristics related to buyer types

The farmers description according to each type of buyer was based on testing whether farmer characteristics, governance forms, relationship attributes and sustainability levels of agricultural practices differ statistically significant between types of buyers (i.e., intermediary, wholesaler, and lead firm). To do so, we separate the variables in two groups namely continuous and categorical variables. For each continuous variable we performed a non-parametric Kruskal-Wallis (or also called "one-way ANOVA on ranks") test and the Dunn test. The Kruskal-Wallis test allows to identify if there is a significant relationship between the variable and one or more types of buyer. The significant relationship is identified if the variable presents a p-value less than 0.05. To identify with which type of buyer the variables tested had significant relationships we conducted the Dunn test. For each categorical variable we performed a Pearson's Chi-squared and Fischer tests. These assess the independence between two categorical variables, in this case the variables tested and the type of buyer. Specifically, these tests compare the probability of trading with each type of buyer with respect to the probabilities of categorical variables to occur. A p-value less than 0.05 in the Pearson's Chi-square and Fisher tests indicates that the distribution of the buyers' types is related to the categorical variable to which it is compared. However, these tests do not identify in which type of buyer each variable had individual importance.

4.4.3 Logit model

Logistic regression is formulated to predict and explain a binary categorical variable. The logistic regression is a common methodology in which the probability of a binary dependent variable (in this case, informal contract or formal contract) is a function of a set of explanatory independent variables such as trust and contract provisions. The logistic regression aims to identify the independent variables that impact membership in the governance forms or to classify observations into the defined groups namely informal and formal contracts (Hair, 2014). One of the advantages of the logit model is the easy incorporation of quantitative and qualitative independent variables. Moreover, logistic regression has some advantages over discriminant analysis. For example, logistic regression does not need to strictly face the assumptions of multivariate normality and equal variance-covariance matrices across groups, which are usually not met in real life analysis. In addition, logistic regression has straightforward statistical tests and a wide range of diagnostics (Hair, 2014). The present analysis aims to estimate the impact of independent variables on the probabilities of informal contract or formal contract by contractual provisions, relationships attributes and SAP adoption by farmers. The binary dependent variable is encoded with the values 1 (informal contract) and 0 (formal contract). The general model can be expressed as:

$$p\ (y=1) = \frac{1}{1+\ e^{-(\beta_0+\ \beta_{1xi}+\cdots+\beta_n X_{ni})}}$$

In this model, *p* is the probability that an individual responds to the first category of the dependent variable; while β is a vector of unknown parameters where the exogenous variables *X1, X2 … Xn* represent the responses of the *i* participant to each one of the *n* independent variables that may be either quantitative or qualitative. The coefficients for the independent variables are estimated using either the logit value (expressed in terms of logarithms) or the odd value (expressed in terms of exponentiated logarithms) as follows:

$$Logit_i = ln\left(\frac{prob_{event}}{1\ -\ prob_{event}}\right) =\ b_0 +\ b_1X_1 + \cdots +\ b_nX_n$$

or

$$Odds_i = ln\left(\frac{prob_{event}}{1\ -\ prob_{event}}\right) =\ e^{b_0+\ b_1X_1+\cdots+\ b_nX_n}$$

Both model formulations are equivalent and reflect the direction and magnitude of the relationship but are interpreted differently. The direction of the relationship (positive or negative) reflects the changes in the dependent variable (informal or formal contract) associated with changes in the independent variable. In the case of logit values, a positive coefficient means that an increase in the independent variable is associated with an increase in the predicted probability (informal contract = 1). On the other hand, exponential coefficients do not have negative values. Therefore, exponentiated coefficients above 1.0 reflect a positive relationship, and values below 1.0 represent a negative one (Hair, 2014). The magnitude of the coefficients answers the question: how much will the estimated probability change for each unit change in the independent variable? In this case, logit values are less useful because the unit logged odds is a unit of measure hard to understand, illustrating how much the probabilities change. On the other hand, exponentiated coefficients directly reflect the magnitude of the change. Their impact is multiplied for each unit of change in the independent variable. Moreover, the exponentiated coefficients are helpful in assessing an independent variable's impact and calculating the magnitude of the effects (Hair, 2014).

4.5 Results and discussion

The following section presents the results and discussion according to the order of the variables' categories presented in the methods section. Regarding the **type of buyers** trading in the vegetable sector in Chile, Table 4.2 shows that 22% of the farmer's main buyers in the sample were final consumers, 40% were intermediaries, 25% were wholesalers, only 9% were lead firms and the 4% others represented farmers' organizations, restaurants, and specialized stores.

Table 4.2 Type of buyers

Category	Variables	Min	Mean	Max
Type of buyers	Final consumer	0	0.22	1
	Intermediaries	0	0.4	1
	Wholesalers	0	0.25	1
	Lead firms	0	0.09	1
	Others	0	0.04	1

Table 4.3 presents the measurements in the different variable categories for farmers trading with each type of buyer, as well as the results of the test (ANOVA) on the statistical differences between these groups. Concerning **farmers' characteristics**, we did not find much difference between the age of farmers (average 52) and farming experience (average 29), although farmers trading with intermediaries seem to be a bit older and a bit more experienced. However, farmers trading with intermediaries have less financial capital, most farmers were INDAP beneficiaries (76%) and were members (50%) of other social organizations such as sports, water communities and neighborhood council. Considering farmers trading with lead firms, these have more female participation (14%) and higher education with a score of 5, which means that these farmers completed high school. They also have larger vegetable farms (15 ha.) and the highest percentage (65%) of land tenure. Moreover, farmers trading with lead firms have a higher percentage (24%) of other crops than vegetables (e.g., fruits and cereals), a greater number of assets (3) (e.g., tractors, trucks, pick-ups, cars and motorcycles), a larger total household income with a score of 4, which corresponds to 1'120,000 Chilean pesos (±1,300 USD) and more people (5) that they can reach out to in case of problems on the farm. Farmers trading with intermediaries presented the highest percentage (1%) of farmers whit organic participatory system certificates, farmers trading with lead firms presented the highest percentage (7%) of farmers with third party organic certificates and the highest percentage (10%) of farmers transitioning to organic certificates, and farmers trading with wholesalers presented the highest percentage (96%) of farmers without organic certificates. Although, differences measured between farmers trading with wholesalers and farmers trading with intermediaries were small, we can deduce some interesting characteristics of the two groups. Farmers supplying wholesalers often score

somewhere in the middle between farmers supplying intermediaries and lead firms. For example, farmers trading with wholesalers are a little bit older, have a little more experience and are more often INDAP beneficiaries compared to farmers supplying lead firms. On the other hand, farmers supplying wholesalers have a farm size a bit larger and a little more assets compared to farmers trading with intermediaries.

Regarding **governance forms**, we found that the transactions between farmers and intermediaries are mainly through informal or verbal contracts (78%), while farmers and wholesalers are mainly trading through spot markets (89%), and farmers and lead firms mostly use formal or written contracts (79%). Our findings indicate that governance forms may be linked to key characteristics of farmers. For example, as discussed above, our results show that farmers trading with lead firms are characterised by exploiting more land, more likely to be women, having higher education, owning and renting a higher percentage of land simultaneously, having a higher number of assets and higher household income. Taking one important indicator as an example, our data indicate that farmers trading with intermediaries can be categorised as small-scale farmers, mainly using informal contracts, while farmers trading with wholesalers are medium-scale, mainly using spot market transactions, and farmers trading with lead firms are large-scale, mainly using formal contracts.

Our findings support previous research that found that trading with lead firms is conditioned on farmers' financial capital and networking. Kariuki and Loy (2016) found that trading with lead firms is sensitive to production scale and networking in the case of vegetable production in Kenya. Similarly, Abdul-Rahaman and Abdulai (2017) found that one factor that affects participation in informal or formal contracts in the case of rice production in Ghana is membership in farmers' organizations. Moreover, Ton et al. (2018), who performed a meta-analysis of production contracts, found that farmers who participate in formal contracts have significantly larger lands and more assets than the average farmer in the region. Furthermore, our results support the findings of Kariuki and Loy (2016), who found that formal contracts contain a higher percentage of farmers with farm certifications. Our results regarding farmers trading through informal contracts and spot markets support evidence from Abdul-Rahaman and Abdulai (2017), who compared these groups of farmers on a number of indicators. For instance, they found a similar level of education. Further, although our results did not find significant differences in age between farmers participating in spot markets and informal contracts, we partially corroborate that older farmers are more likely to use informal contracts (Abdul-Rahaman and Abdulai, 2017).

Table 4.3 Descriptive statistics and farmers' description according to each type of buyer

Category	Variables	Min	Mean	Max	Intermediary (x)	Wholesaler (y)	Lead firm (z)	Comparison significance
	Number of farmers				142	89	29	
Farmers' characteristics	Age	24	52.68	91	53.27	53.1	52	E
	Experience	1	29.07	78	31.99	29.93	27.86	E
	Gender (Female)	0	0.21	1	7%	9%	14%	F
	Education	1	4.56	7	4.34	4.4	5.14	B
	Vegi-size	0.01	10.23	600	4.48	6.08	15.03	BC
	Tenure							
	- Rent	0	0.43	1	50%	47%	34%	F
	- Owner	0	0.44	1	41%	36%	31%	F
	- Owner + Rent	0	0.13	1	9%	17%	34%	F
	Crop-variety (yes)	0	0.3	1	18%	18%	24%	F
	Greenhouse (yes)	0	0.49	1	51%	47%	48%	E
	Assets	0	1.87	5	1.77	2.19	2.76	BC
	Income-farm	0	79.56	100	86%	87%	92%	E
	Income-total	1	2.95	8	2.89	2.81	4.81	BC
	INDAP (yes)	0	0.7	1	76%	72%	45%	F
	Member-farm (yes)	0	0.2	1	13%	17%	38%	F
	Member-org (yes)	0	0.5	1	50%	42%	48%	E
	Contacts	0	4.12	80	3.19	2.91	5.31	BC
	Type certification							
	- Participatory	0	0.04	1	1%	0%	0%	F
	- Third-party	0	0.02	1	1%	0%	7%	F
	- Transition	0	0.05	1	3%	4%	10%	F
	- None	0	0.89	1	95%	96%	83%	F
Governance forms	Governance							
	- Spot market	0	0.54	1	22%	89%	7%	F
	- Informal contract	0	0.39	1	78%	11%	14%	F
	- Formal contract	0	0.07	1	0%	0%	79%	F
Contractual provisions	Contract term	0	62.02	365	78.63	2.62	279.59	D
	Payment	0	5.72	120	3.74	0.39	42.88	D
	Contract provision	0	1.42	7	2.01	0.31	4.52	D
	Out-service	0	0.66	4	0.98	0.11	1.83	D
	In-service	0	0.41	5	0.64	0.07	1.21	AC
Relationship attributes	Trust	1	5.51	7	5.51	5.22	5.16	E
	Satisfaction	1	5.74	7	5.86	5.3	5.15	B
	Opportunism	1	3.43	7	3.35	4.08	3.77	E
Sustainability level of agricultural practices	Seed	0	0.2	1	0.07	0.09	0.18	E
	Soil	-3	-0.9	3	-1.42	-1.97	-1.46	E
	Pest	-3	-1.24	3	-1.76	-2.34	-1.07	C
	Weed	-3	-0.16	3	-0.35	-0.9	-0.72	E
	Crop	0	1.3	3	0.95	1.05	1.09	E

Note1: A= statistically significant difference between x and y; B= statistically significant difference between x and z; C= statistically significant difference between y and z; D= statistically significant difference between all buyers; E= non statistically significant difference between all buyers; F= statistically significant difference (Pearson's Chi-squared and Fischer tests)

Note 2: we acknowledge the existence of two schools of thought, one that considers the Likert scale as ordinal and the other that considers it as interval, for analysis purposes (Joshi et al., 2015). Moreover, there is evidence that parametric statistics can be used with Likert data without reducing the statistical power of the analysis (Norman, 2010).

Concerning contractual provisions, Table 4.3 shows considerable differences between farmers trading with each type of buyer. Farmers trading with intermediaries present a midpoint between contractual provisions in farmer-wholesaler spot market transactions and farmer-lead firm transactions through formal contracts. Transactions with lead firms presented the longer duration of contracts (243 days), the most prolonged period to pay farmers (42 days), a larger number of contract provisions (e.g., quality, price, volume, payment plan, delivery frequency and delivery place), larger number of services provided by farmers which are not explicated in the contract (e.g., product sorting, packaging and delivery) and a larger number of services provided by lead firms which are not explicated in the contract (e.g., technical support, payment in advance, input provision and transportation support for product delivery). In contrast, on average, transactions with wholesalers through spot markets did not show any contractual provisions.

The logit model (Table 4.4) with the binary dependent variable (governance forms) shows the relationships between type of contract and contractual provisions, relationships attributes and SAP variables. It is encoded with the values 1 - informal contract and 0 - formal contract. The model estimates the odds or probabilities of 1 or 0, where positive coefficients reflect a positive relationship with informal contracts and negative coefficients reflect a negative relationship with informal contracts. Table 4.4 shows that informal contracts are less likely to be long-term, take more days to pay farmers, have more contractual provisions and have more services from buyers than formal contracts. However, Table 4.4 also shows that in informal contracts, farmers are more likely to provide services.

These data on contractual provisions may have different explanations. Differences in contract term can be explained by lead firms having contracts encompassing the entire agricultural year, while informal contracts with intermediaries are only for the harvest season, representing a difference of around six months in duration between these contracts (Gaitán-Cremaschi et al., 2020; ODEPA, 2020b). The large number of days lead firms take to pay can be explained by the quantity of product traded, which implies much higher transaction costs for lead firms than for intermediaries or wholesalers, inducing a delay in payments by lead firms (Gaitán-Cremaschi et al., 2020; ODEPA, 2020b). Concerning contractual provisions, our results corroborate the findings of Ménard (2017), who found that informal contracts are mainly focused on price, quality and volume, while formal contracts or lead firms are more likely to work with less standardized products demanding more specificity. These results can also be explained by the fact that formal contracts have become increasingly the norm for lead firms in Latin America, especially for supermarkets (Reardon et al., 2019). In this way, lead firms can enforce quality (e.g., appearance and size) and safety (e.g., presence of pathogens and pesticide residues) standards on farmers to protect the consumers' health (Reardon and Berdegué, 2002; Cadilhon et al., 2012). Next, the low scores on out-services and in-services between farmers and wholesalers may be explained by the intermittent relationship between wholesalers and farmers, which impedes having more contract provisions or closer relationships which could trigger more collaboration (e.g., service interchange) (Anderson and Weitz, 1992; Ganesan, 1994).

Table 4.4 Comparing contractual provisions, relationship attributes and SAP adoption by informal and formal contracts

Category	Variables	Coefficient (odds %)		
Contractual provisions	Contract term	-0.018	(-2%)	**
	Payment	-0.178	(-16%)	***
	Contract provisions	-1.122	(-67%)	**
	Out-service	0.838	(70%)	
	In-service	-1.667	(-81%)	**
Relationship attributes	Trust	-2.058	(-87%)	**
	Satisfaction	2.982	(95%)	**
	Opportunism	0.453	(57%)	
Sustainability level of agricultural practices	Seed	-4.596	(-99%)	*
	Soil	0.352	(42%)	
	Pest	-0.815	(-56%)	***
	Weed	1.228	(77%)	**
	Crop	0.264	(30%)	
Mc Fadden pseudo R^2		0.800		

Significance: *P < 0.05, **P < 0.01, ***P < 0,001.

4

With respect to relationship attributes, Table 4.3 shows that farmers scored on average 5.51 in trust on a scale of 7, which means that most of the farmers “more or less agree” with the statement that they can trust in their main buyers. Farmers scored on average 5.74 in satisfaction, which means that most of the farmers “more or less agree” with the statement that they are satisfied with their main buyers. Farmers scored 3.43 in opportunism, which means that farmers “more or less disagree” with the statements that their main buyers behaved opportunistically. However, in general Table 4.3 does not show much differences in scores on trust, satisfaction and opportunism. However, on average, farmers trust more in intermediaries, are more satisfied trading with this type of buyer and perceive that intermediaries are less opportunistic. In contrast, farmers trading with lead firms show the lowest scores in trust and satisfaction, while farmers perceive wholesalers as more opportunistic than intermediaries and lead firms. In addition, the logit model (Table 4.4) shows that farmers trading through informal contracts are less likely to trust their buyers but are more likely to be satisfied with their buyers.

These results in Table 4.3 and Table 4.4 may be contradictory considering trust in intermediaries and trust in informal contracts. On the one hand, if we focus in our data on the type of buyer, our results corroborate the findings of Kariuki and Loy (2016), who found that informal contracts are supported by a high level of trust between farmers and intermediaries. On the other hand, if we focus in our data on the governance form, our results contradict the findings of Kariuki and Loy (2016), which can possibly be explained by the share of wholesalers having informal contracts, as our findings show that trust in wholesalers is on average significantly lower than trust in intermediaries.

The farmers' high likeliness of trusting their buyers through formal contracts can be explained by the fact that most of the buyers are lead firms and that trust is higher in more homogenous societies (e.g., similar ethnicity, economy, and social status) (Zak and Knack, 2001), which could be the case for transactions between large-scale farmers and lead firms. The higher level of trust between farmers and lead firms can also be explained by lead firms offering higher prices to farmers, which increases price satisfaction, and that, in turn, is an antecedent for trust (Susanty et al., 2017). Surprisingly, our outcome is contrary to that of Peppelenbos (2005) who found that formal contracts created a context of institutional distrust in Chile.

The higher satisfaction with intermediaries as buyers or with the use of informal contracts is in line with Schwartz et al. (2013) and Thorlakson (2018), who found that intermediaries have closer relationships with farmers, which may imply a higher level of satisfaction. Moreover, one element that may support farmers' satisfaction with intermediaries and informal contracts is the negotiation process to set product prices. In this case, both farmers and intermediaries start the negotiations with the same information. Nowadays, most farmers have a mobile phone and, before trading their products, they can call key informants to get pricing information. In this way, they have improved their bargaining power (Goyal and González-Velosa, 2013). The low levels of farmers' satisfaction with wholesalers compared to intermediaries can be explained by the stronger bargaining position of wholesalers as perceived by farmers (Benton and Maloni, 2005). Wholesaling is usually quite concentrated per product category and in time (Schwartz et al., 2013), often implying lower unit prices for farmers (Barrowclough et al., 2019; Cao and Mohiuddin, 2019). However, there is evidence that farmers continue to trade with wholesalers because they are the most profitable option when marketing expenses and management costs are considered (Barrowclough et al., 2019). The lower satisfaction with lead firms may be explained by lead firms having more power in the transaction with farmers. Elder & Dauvergne (2015) and Ruml & Qaim (2021) reported that farmers did not have sufficient information about contracts. Besides, Jiménez (2013) and Musara et al. (2018) reported that farmers usually have to accept payment delays without any compensation and that they are marginalised from decision-making processes.

Regarding opportunism, an explanation of why farmers supplying intermediaries through informal contracts perceive their buyers as less opportunistic than farmers supplying lead firms operating through formal contracts, can be that formal contracts are often so explicit, with little room for deviations, that the perception of farmers of opportunistic behaviour of these buyers is reinforced (Poppo and Zenger, 2002). Moreover, the higher levels of opportunism perceived by farmers trading with wholesalers compared with the other farmers can be explained by the low number of contacts these farmers have. According to McCarter and Northcraft (2007), individuals with more contacts will have more information; this information includes other individuals' reputations, which may lead to a more informed selection of business partners. Thus, partners with fewer contacts may perceive higher levels of opportunistic behaviour.

In the case of the sustainability level of agricultural practices Table 4.3 shows that the average scores of seed sourcing (Seed) and crop management (Crop) practices were positive (0.20 and 1.30, respectively), suggesting that the agricultural practices used in these stages have a moderate, although not significant, positive impact on the environment. On the other hand, we found that the average scores of fertiliser types (Soil), pests/disease control (Pest) and weed control (Weed) practices were negative (-0.90, -1.24 and -0.16, respectively), suggesting that the practices used in these stages have a moderate negative impact on the environment. Although our results do not present a significant relation between sustainable practices and type of buyer, farmers trading with intermediaries presented the highest sustainability scores in soil and weed control, while farmers supplying lead firms presented the highest sustainability scores in the categories seed, pest and crop. On average, farmers trading with wholesalers presented the lowest sustainability scores. Moreover, Table 4.4 shows that farmers trading through informal contracts are more likely to use sustainable practices in weed control as well as practices in the categories soil and crop; however, the latter two are not statistically significant. Besides, Table 4.4 shows that farmers trading through informal contracts are less likely to use more sustainable practices in seed and pest.

These differences between sustainability level of agricultural practices may have diverse explanations. The greater level of sustainable practices in weed control of farmers supplying through informal contracts can be explained by most buyers trading with informal contracts being intermediaries who are mainly supplied by small-scale farmers. Usually, small-scale farmers control weeds manually without using synthetic products in order to save money (Gaitán-Cremaschi et al., 2020). In this case, SAP adoption is not an objective of farmers; it is more a consequence of the farm management choices. An explanation for the use of organic seeds by farmers trading with lead firms is that lead firms operating through formal contracts in Chile have a larger percentage of suppliers with organic certification, which implies the use of organic seeds (SAG, 2020), Moreover, according to ODEPA (2020b), Chilean lead firms mainly use formal contracts to promote SAP adoption. However, SAP adoption, as required by these contracts, mainly focuses on reducing pesticide residue in vegetables to safeguard the final consumers' health, it is not related to other environmental goals, such as increasing biodiversity or improving soil quality. Moreover, the requirements applied by lead firms to farmers regarding pest/disease control contribute to ensuring the safety standards required by the Agricultural and Livestock Service of Chile (SAG), standards that SAG inspects mainly in medium-to-large scale farmers (Gaitán-Cremaschi et al., 2020).

4.6 Conclusions

Our study aimed to explore how different farmer-buyer relationships relate to different levels of the adoption of SAPs in the vegetable sector in Chile. To this end, we characterised farmers related to each type of buyer, we explored the governance forms used for buyer-farmer transactions and we investigated whether there is a relationship between the contract governance form (formal or informal) and (a) provisions in the contract (e.g., quality, quantity and the provision of services); (b) attributes of the relationship between farmer and buyer (i.e., trust, satisfaction and opportunism); and (c) level of SAP adoption. This study aimed to contribute to the literature on sustainable food supply chains by including intermediaries and wholesalers in the analysis. It also gave insight into whether and how contractual provisions, relationship attributes, and SAP adoption are related. Moreover, it aimed to contribute insights into the potential role of intermediaries, wholesalers, and lead firms in the farmers' adoption of SAPs.

We found that farmers trading with intermediaries through informal contracts are less likely to adopt SAPs. However, according to Thorlakson (2018), intermediaries may be interested in marketing sustainable products because of the overall low margins on regular products for these buyers. FAO-INRAE (2021) presents cases where close relationships between intermediaries and smallholders lead to adoption of SAPs. The main characteristics of these cases in India and the Republic of Korea are a transparent flow of information between farmers and intermediaries regarding price and sales and an associativity of either the producers or the intermediaries. Moreover, these authors find that participatory guarantee systems with the active participation of farmers, intermediaries and consumers can be a mechanism to support the trade of sustainable products. In addition, we found that farmers trading through informal contracts (mostly with intermediaries) are more likely to be satisfied with the relationship, Tewari et al. (2018) and Grabs and Carodenuto (2021) found that close relationships between intermediaries and farmers build collaboration and encourage them to mutually commit to pursuing SAP adoption.

In the case of farmer trading with wholesalers, we found that these actors are less likely to engage in contracting. In the case of farmer and wholesaler using informal contracts, the farmer is less likely to adopt SAPs. A possibility to increase the adoption of SAPs in the farmer-wholesaler relationship is the application of an auction system in public wholesale markets. Johnson et al. (2016) found that the auction system in wholesale markets in Canada promotes the adoption of SAPs by farmers. On the one hand, an auction system could accredit the sustainability of wholesalers' operations, while on the other hand it would accredit the operations of farmers adopting SAPs. For example, such a system could require the progressive adoption of SAPs, starting with basic practices (e.g., minimum pesticide residues in crops) and moving up to organic certifications. Thereby, accredited wholesalers could demonstrate the quality of the product acquired and accredited farmers would be informed about the quality (through SAP adoption) and price of their products. This could also improve trust in the farmer-buyer relationship.

We found that farmers trading with lead firms are more likely to adopt SAPs. Lead firms support this through formal contracts and/or certification schemes. SAP adoption related to lead firms focuses mainly on using organic seeds and sustainable practices to control pests and diseases. This limited scope of SAP adoption may be related to traditional international certification schemes that mainly focus on improving the products' intrinsic quality but not on environmental impact as such (Achabou et al., 2017). Moreover, we found that farmers are more likely to have lower satisfaction levels when trading through formal contracts and/or with lead firms. According to Ruml and Qaim (2021), even when farmers reported benefits from their relationships with lead firms, they were dissatisfied. However, Sahara and Gyau (2014) and Ruml and Qaim (2021) suggest that some ways to improve farmers' satisfaction include reducing information asymmetries regarding contractual provisions, reducing the number of days before payment and providing quicker response to farmers' concerns. In this way, farmers might perceive a more balanced relationship and conversely be willing to be involved in contracts that include the adoption of SAPs.

Our research has also aimed to raise questions and to open areas for further research focused on intermediary- and wholesaler-farmer supply chains as sustainable alternatives for the lead firm-farmer supply chain. Certainly, the promotion of intermediary- and wholesaler-supply chains offers an opportunity to preserve local and regional supply chains and farmer diversity (Tewari et al., 2018; Clapp and Moseley, 2020). This also means that local and regional supply chains may become necessary in providing access to sustainable food for vulnerable populations (Clapp and Moseley, 2020). Furthermore, this research brings forward the idea of considering alternative supply chains, including intermediaries and wholesalers, when developing strategies supporting the adoption of SAPs in fresh-food supply chains.

Notwithstanding the relatively limited findings of this research, this work offers valuable insights, which although not conclusive, should be further researched.

4.7 Limitations and future research

While the quantitative empirical approach adopted in this study can be considered a contribution to research on the relation between contracts, relationship attributes and SAP adoption by farmers in developing countries and emerging economies, it can also be a limitation due to the lack of specific insights and depth of latent variables such as trust or satisfaction. Moreover, a limitation regarding the quantitative approach is the sample size, which limits the statistical power of the analysis. The farmer perspective adopted in this research can be seen as a contribution because most farmer-buyer relationship analyses focused only on buyers and their perspective. In contrast, farmers' perspectives can also be seen as a limitation for not including the buyers' perspective in the analysis. In addition, we acknowledge that other variables not currently considered (e.g., political/economic power and commitment) may also provide insights on the relationship attributes between farmers and buyers.

Future studies analysing relationship attributes could implement in-depth interviews with farmers and buyers to go beyond the relations showed in this study. Finally, in the context of Latin America and developing countries, where most of the transactions in fresh-food supply chains are through wholesalers and intermediaries, researchers should focus more on the (potential) role of these actors in the adoption of SAPs. There is a lack of insight on how to include wholesalers and intermediaries in sustainable food systems (Beninger and Shapiro, 2019).

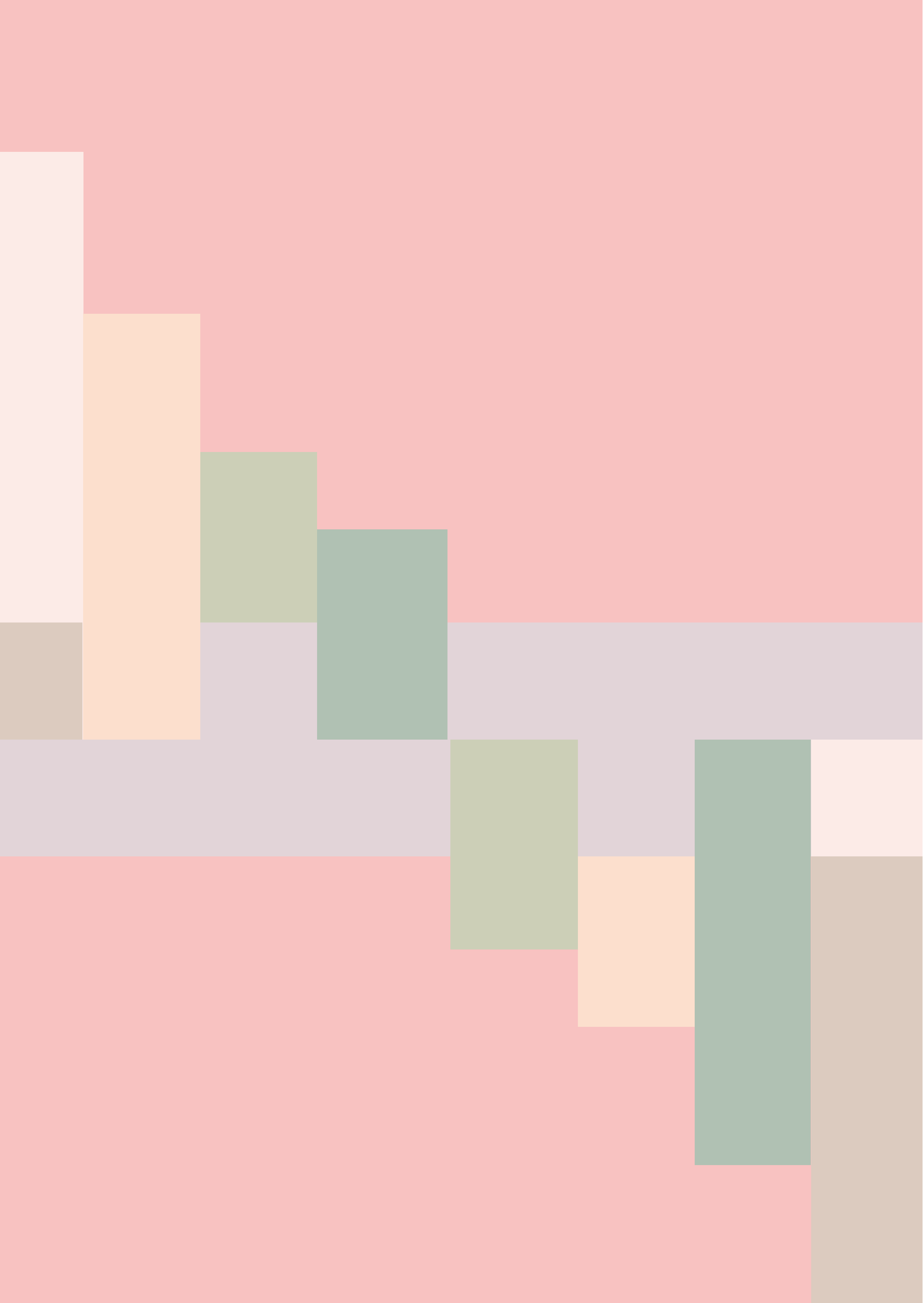
APPENDICES

Appendix 4.A

The table below shows the scores for each agricultural practice in relationship to the four sustainability dimensions based on the work of Rigby et al. (2001).

Production stage		Sustainability dimensions				TOTAL
		Minimises off-farm inputs	**Minimises non-renewable inputs**	**Maximises natural biological processes**	**Promotes local biodiversity**	
Seed sourcing						
1	Conventional seed					0
2	Organic seed		1			1
3	Reused	1				1
4	Traditional	1				1
Soil fertility						
1	Conventional synthetic	-1	-1	-1		-3
2	Organic fertiliser purchased		1	1		2
3	Prepared organic fertiliser	2	2	1	3	8
Pest/disease control						
1	Chemical pesticides	-1	-1	-3	-3	-8
2	Organic pesticide purchased		1	1		2
3	Prepared organic pesticide	1	1	1	1	4
4	Preventive practices without chemicals	2	2	2	2	8
Weed control						
1	Chemical herbicides	-1	-1	-1	-1	-4
2	Organic herbicides purchased		1	1		2
3	Mechanic control	1	0.5	1	0.5	3
4	Preventive practices without chemicals	1	1	1	1	4
Crop management						
1	Crop rotation	0.5	0.5	1		2
2	Intercropping	1	1	1	1	4
3	Crop rotation + intercropping	1.5	1.5	2	1	6

Source: Based on Rigby et al. (2001)



CHAPTER 5

Discussion and conclusions

5.1 Introduction

Climate change is evident, and today's food production systems are contributing to this climate emergency. Crop production through Agricultural Intensification (AI) techniques is one of the main contributors to climate change (Poore and Nemecek, 2018). Most of the field crops around the world are produced through AI practises (FAO, 2021b), characterised by the intensive use of inorganic inputs (e.g., fertilisers and pesticides) and the production of monocrops (Perkins and Jamison, 2008; Tscharntke et al., 2005). AI has resulted in the environment's contamination, threatening human health and biodiversity around the world (Townsend and Howarth, 2010; Carvalho, 2017). One alternative to counter the negative effects of AI is adopting sustainable agricultural practices (SAPs) (Bommarco et al., 2013). However, despite the potential benefits of SAPs, their rate of use in developed and developing countries is still low (Pannell et al. 2006; Tey et al. 2017).

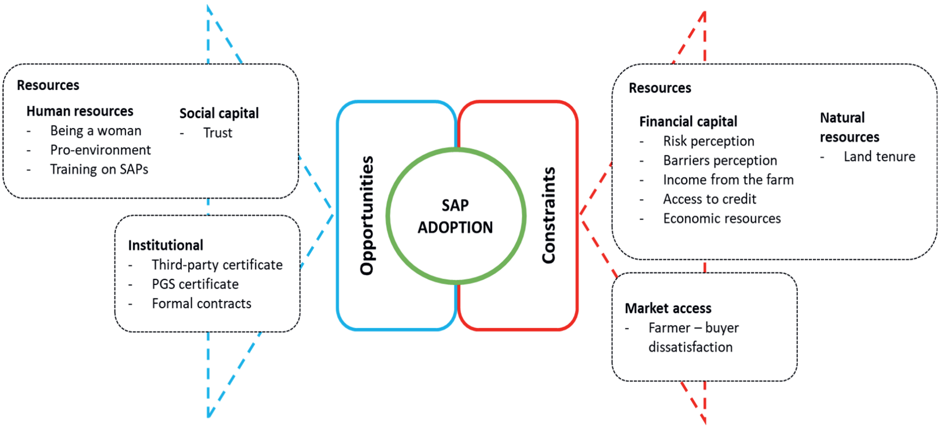
Vegetable production in Chile is no exception, with low SAP adoption rates, for example only 2% organic production, including organic farmers with certifications and non-certified agroecological farmers (INDAP, 2017). Vegetable production in Chile is characterised by the improper and excessive use of inorganic inputs, resulting in environmental pollution and increasing human health risks (Elgueta et al., 2020; Calderon et al., 2022). Therefore, there is a need to improve the SAP adoption rate. However, the literature is not conclusive on the factors that explain SAP adoption, factors which may differ according to the production context (Dessart et al., 2019; Anibaldi et al., 2021). Factors that are related to SAP adoption include socio-economic (e.g., land tenure, education and farm size), biophysical (e.g., water and soil quality), institutional (e.g., governmental policies and consumer organisations) and farmer perception factors (e.g., risk, barriers, trust and attitude towards sustainable practices) (Knowler and Bradshaw, 2007; Baumgart-Getz et al., 2012; Tey et al., 2017; Anibaldi et al., 2021).

This thesis contributes to existing literature by further exploring SAP adoption. Empirically, the research identifies how vegetable value chain characteristics such as farmer characteristics, market channels, contract characteristics and farmer-buyer relationships impact SAP adoption amongst farmers in Chile. It also provides new insights on how different factors correlated to SAP adoption interact, how farming system traits align with SAP adoption and how farmer-buyer relationships can support SAP adoption. Consequently, this thesis generates information to support SAP adoption in Chile in the frame of the HortEco project and contributes with insights to further the transition to more sustainable fresh-food value chains. The following sections will detail our findings.

5.2 SAP adoption constraints and opportunities

To position this thesis in the broader area of value chain literature, the results are organised around three major groups of opportunities and constraints (i.e., resources, market access and orientation, farmer-buyer relationships and institutional voids) of value chain upgrading. We do not aim to provide an in-depth explanation of each of these; rather, we strive to provide valuable insights regarding the elements analysed in previous chapters which mainly focus on how farmer and farm characteristics are correlated to SAP adoption, farming typologies including farm and farmer characteristics and market channels related to SAPs, and how farmer-buyer relationships are related to SAP adoption. Figure 5.1 summarises the key results.

Figure 5.1 Main results



5.2.1 Resources

As mentioned in the Introduction, resources are classified into various types: human resources, capital, natural resources and technology. In this section, we focus on resources included in this study, primarily described in Chapter 2, that is, how farmer and farm characteristics are correlated to SAP adoption. Our results show that key resources positively related to SAP adoption are:

Human resources. include the following decisive elements: (a) the farmer's gender, in particular, being a woman; (b) considering it easy to take actions to preserve the environment (pro-environment) and (c) training in programmes related to SAPs. (a) According to our research, being a woman in this context is linked to educated individuals who know how to farm sustainably[24] and are aware of the latter's benefits. This finding is consistent with other studies in Latin America that found that women are key SAP adoption promoters (Hillenkamp, 2020; Mestmacher and Braun, 2020; Trevilla et al., 2021). I will discuss women and SAPs in-depth in section 5.2.4 below.

(b) Considering it easy to take actions to preserve the environment is positively related to SAP adoption. This finding is in line with Koger and Winter (2011) and Kothe et al. (2019) who found that individuals who seek to minimise their negative impact on the environment are more inclined to engage in actions to reduce environmental impact. However, according to Kothe et al. (2019), this behaviour mainly emerges when facing a threatening event, thus corroborating the findings of Bopp et al. (2019), who found that adopting soil conservation practices in annual crops in Chile depends on the farmers' awareness of soil deterioration.

(c) Lastly, our results indicate that training programs related to SAPs are directly correlated to the adoption of SAPs; they are also indirectly related to perceiving low levels of risk and barriers to adopting SAPs. Training increases farmers' environmental knowledge (Kollmuss and Agyeman, 2002), that is, making them aware of the causes behind environmental degradation and its possible solutions and thus potentially leading to SAP adoption (O'Connor et al., 1999). Furthermore, according to Tverskky and Kahneman (1974) and Knight et al. (2003), an individual with more knowledge about a topic will be able to estimate the risks of his/her actions more objectively. In keeping with these results, Grothmann and Patt (2005) and García de Jalón et al. (2015) found that lack of knowledge is a key obstacle for the adoption of new practices or technologies.

Capital. is another key resource, which can be subdivided into financial and social capital. Related to financial capital we have identified the following factors: (a) risk perception; (b) barrier perception; (c) a higher percentage of income from farming activities; (d) better access to credit; and (e) economic resources.

(a) In terms of financial capital, we found that high levels of perceived risk is less likely related to the adoption of SAPs. This result is in line with Salazar and Rand (2016) who found that adopting modern irrigation technology by small-scale farmers in Chile is hindered by these farmers' perceived risks. These

[24] Throughout this section I use the term "sustainable" to refer to any product, practice or farming technique that implies using sustainable agricultural practices.

risks are related to lower crop production volumes or quality, resulting in less profit. Thus, farmers do not adopt SAPs due to perceived risk of not generating sufficient economic gains.

(b) We found that high levels of perceived barriers (i.e., the unavailability of or difficult access to organic inputs and the time/effort required to adopt SAPs) are less likely correlated to SAP adoption. These perceived barriers are related to a lack of financial resources, i.e., to be able to buy organic inputs and maintain a viable household/farm during the transition to SAPs.

(c) Another key finding of our study is the negative correlation of farmers earning a higher percentage of their income from farming practices. We found that this is less likely related to SAP adoption, contrasting with Baumgart-Getz et al.'s (2012) findings. This may be explained by the fact that Chilean farmers who earn a higher percentage of income from their farming activities are more risk-averse due to their economic dependency on farm income.

(d) We found that better access to credit also has a negative correlation to SAP adoption. This result is contrary to Jara-Rojas et al. (2012) who found that access to credit has a positive correlation to water conservation practices in Chile amongst small-scale farmers. A possible explanation for these contradictory results may be that Jara-Rojas et al. (2012) focus on adopting specific water irrigation technologies (e.g., drip irrigation), whereas this thesis focuses on the transformation of the overall farm production system. However, another explanation may be that farmers who adopt sustainable practices do not have access to credit, as credit providers cater to conventional farmers who they perceive to have a lower risk of failure.

(e) Lastly, the economic resources construct comprises three variables: the size of land under production; the number of assets; and total household income. We found that this construct is indirectly correlated to SAP adoption, as it is directly related to perceiving high levels of risk and barriers. This may be explained by the fact that individuals whose wealth status is sufficiently high will prefer to maintain the status quo given that the process of changing production processes implies transition costs (Tversky and Kahneman, 1973). Moreover, the willingness to maintain this status quo may be accentuated by the local (Chilean) context, where the sustainable production of vegetables for the local market is considered less competitive and is not supported by the Chilean government or the financial sector. Finally, on the one hand, the lack of financial capital is negatively related to SAP adoption, and, on the other hand, having sufficient financial capital is also negatively related to SAP adoption. A possible explanation for these contradictory findings can be found in Chapter 3, where we explore different farming typologies. Farmers included in types III (traditional farming) and IV (conventional small-scale farming) belong to the group where a lack of financial resources is a factor negatively correlated to SAP adoption. Type-V farms (conventional medium-scale farming) include those with sufficiently high income. However, these farmers seem reluctant to change the status quo and maintain conventional production techniques. Future research is needed to provide more insights on this point.

With respect to social capital resources, we have identified two factors related to SAP adoption: (a) trust; and (b) relationship attributes (Chapter 4). (a) The trust construct reflects farmers' trust in other people (e.g., farm labourers, input suppliers and neighbours); we found that low levels of trust in others are indirectly negatively correlated to adopting SAPs because low levels of trust are more likely related to perceiving high levels of risk and barriers. This finding is consistent with Engler et al. (2016) and Hunecke et al. (2017) who found that trust in the farmers' networks is an element that affects their perception of risks related to the adoption of new technologies in Chile. Relatedly, other studies in Chile suggest that efforts to encourage SAP adoption should extend beyond technical aspects to include social network-building to thus promote the adoption of new practices and technologies (Roco et al., 2014; Hunecke et al., 2017). In general, we found that Chilean farmers had little trust in others, which might be related to the low rates of farmer organisational activities found in the field.

(b) With respect to relationship attributes, we found that farmers trust more in intermediaries, are more satisfied trading with this type of buyer and perceive that intermediaries are less opportunistic. However, these results contradict our findings that farmers trading through informal contracts are less likely to trust their buyers (mainly operated by intermediaries). These findings could be explained by the share of wholesalers having informal contracts, as our findings show that trust in wholesalers is, on average, significantly lower than trust in intermediaries. However, further research should be undertaken to investigate in-depth informal contracts and farmers' relationships with intermediaries and wholesalers. In addition, although we found that farmers trading through informal contracts are less likely to trust their buyers, they are more likely to be satisfied with their buyers. So, here we find that there is both satisfaction with buyers who trade with informal contracts and with intermediaries. Regarding the relationships of farmers with intermediaries, these results contradict the popular belief that intermediaries are 'exploitative' (Schoonhoven-Speijer et al., 2017). Moreover, other studies have also shown that intermediaries provide diverse services to small-scale farmers in developing countries, such as interest-free credit and technical support (Volrey et al., 2012; Bailey et al., 2016). However, our findings do not determine whether farmers' satisfaction with intermediaries enables or hinders the adoption of

SAPs. Further research might explore the potential inclusion of intermediaries to promote sustainability schemes. Finally, our results confirm previous studies that formal contracts are associated with high levels of trust (Bergh and Öhrvall, 2018; Mao et al., 2022) and that high levels of trust are related to the adoption of SAPs (Cobo-Reyes et al., 2017; Joffre et al., 2020).

Natural resources.[25] In this thesis, this resource primarily refers to land tenure. In Chapter 2, we discussed how land tenure is not a significant factor in terms of SAP adoption, although, our findings in Chapter 3 illustrate that farming types whose land tenure is below 50%, namely, types III, IV and V (traditional, conventional small-scale and conventional medium-scale farming types, respectively), are less likely to adopt SAPs. Moreover, Chapter 4 indicates, although not statistically significant, that farmers owning and renting a higher percentage of land simultaneously usually are more likely to adopt SAPs. This is consistent with Roco et al. (2014) who found that land tenure is positively related to adaptation practices for climate change in Chile. According to the literature, farmers who do not own the land they work on do not have incentives to adopt long-term strategies such as SAPs given that their main objective is to produce as much as they can over the short term (Tey et al., 2017).

5.2.2 Market access and orientation

In this section, we examine market access as a constraint to SAP adoption and focus on describing the market channels found in the vegetable value chain in Chile. Although we do not address market orientation specifically, we provide a description of how lead firms entice farmers to participate in sustainable markets and how farmers can opt to enter these markets.

Our research did not find that market access was a barrier to SAP adoption, even though this option was included in the survey carried out amongst farmers (Chapter 2). Most of the farmers surveyed in this study did not identify market access as a constraint regarding the adoption of SAPs. This finding may be explained by the demand for sustainable products being greater than the still scant supply of those products (von Meyer-Höfer et al., 2015; Gaitán-Cremaschi et al., 2020). Relatedly, according to Adasme-Berríos et al. (2015), the consumption of sustainable products in Chile has great potential for growth,

[25] Although I do not mention water in this thesis as a limiting resource, I acknowledge that farmers in Chile's Mediterranean and semi-arid regions face water scarcity due to the intensive production of agricultural crops (i.e., avocado) and the management of water as a private resource (Muñoz et al., 2020). During my fieldwork, I observed that many farmers changed from using irrigation channels to water wells due to reduced water flows. Water scarcity may threaten agriculture activities in the short term in the central region of Chile.

illustrated by more than half of the sample in their study still being unfamiliar with the organic product concept.

In Chapter 3 and 4 we provide insights on the sustainable product market. We found two market channels[26] for sustainably produced vegetables: large-scale farmers working with lead firms and small-scale farmers selling their products in street markets. Both channels provide farmers access to markets that recognise specific product attributes, pay higher prices and ensure sales. Moreover, both market channels are related to the production of sustainable products through certification schemes. A variety of studies have analysed the first market channel, that is large-scale farmers who sell their products to lead firms (usually supermarkets) (Elder et al., 2014; Achabou et al., 2017; Thorlakson et al., 2018). Our results are consistent with the literature that found that producing organic agricultural products is mainly driven by lead firms (Elder and Dauvergne, 2015; Thorlakson et al., 2018). Many lead firms recognise consumer needs and engage with corporate social responsibility issues related to sustainability (Achabou et al., 2017). To achieve sustainability goals, lead firms pass on these requirements to farmers through formal contracts where they specify the organic standards farmers have to comply with or the certificates that farmers have to acquire (mainly issued by third-party certification agencies) (Elder and Dauvergne, 2015; Thorlakson et al., 2018). Formal contracts which include contractual provisions related to organic standards reduce uncertainty for both partners, as predicted by transaction cost economics (Bijman, 2008). Although this relationship between farmers and lead firms is positively related to SAP adoption, in Chapter 4, we discuss how most farmers are not satisfied when trading with these lead firms, putting pressure on this business relationship. This result is in line with Elder and Dauvergne (2015) and Ruml and Qaim (2020) who found that farmers have feelings of dissatisfaction with lead firms. However, further research is needed to determine whether farmers' perceptions are affected by the terms and provisions of the contracts or if these feelings have other origins.

The second market channel, small-scale farmers selling products in street markets, is mainly driven by farmers themselves who recognise the need to offer a better product to consumers. In this market, farmers organise themselves to obtain organic certifications through a participatory guarantee system (PGS). Previous studies have already indicated that alternative certification systems were first created in Latin America (Hruschka et al., 2021). Farmers using this channel organise and manage street markets, usually called ecofairs, where they sell their products directly to end consumers and obtain premium

[26] This thesis uses the term "market channel" to refer to the people or organisations and activities needed to transfer products from farmers to the end consumers (Pelton et al., 2014).

prices (Gaitán-Cremaschi et al. 2020). The inception of this market channel concurs with literature on short food chains. The latter have emerged to overcome the agricultural intensification model by improving consumer awareness about the environment and related health issues, consumer trust in food systems, product origin and the quality of food produced through sustainable practices (Cruz et al., 2021; Thomé et al., 2021).

In addition to these two market channels, we also discuss an additional outlet comprising (non-certified) agroecological farmers in street markets. This market channel is driven by small-scale farmers selling their sustainable products directly to end consumers who value the quality of the products. These farmers are not necessarily looking for a higher price (Gaitán-Cremaschi et al. 2020). They produce sustainable products because, in keeping with their values, they believe this is the correct way to do so. This is consistent with previous literature on farming in Latin America that argues that agroecology “carries ecological and social ethics with the goal of creating nature-friendly and socially just production systems” (Altieri and Nicholls, 2017, p. 236). In this channel, farmers have the opportunity to explain to consumers how they farm and why, which is a highly effective instrument to build trust (Cruz et al., 2021). Moreover, these farmers question why sustainable products have to be certified, because the certification process implies higher prices, thus making sustainable products inaccessible for most consumers. A possible policy to cope with this challenge is presented by Lamine and Dawson (2018) who found that, in Brazil, public food procurement programmes pay premium prices to associations of agroecological farmers without certifications while delivering food to low-income families and children in schools. However, this Brazilian case is rare because supporting agroecological farmers and simultaneously providing consumers with fewer economic resources access to sustainable food is a major challenge.

In Chapters 3 and 4, we point out that extant literature does not consider intermediaries and wholesalers as being involved in sustainable production practices. Food value chain literature mainly assumes that lead firms are the only channels that can support SAP adoption (Achabou et al., 2017; Freidberg, 2020), overlooking the fact that intermediaries and wholesalers handle most of the local production of fresh food in developing and emerging economies. In Chapter 4, we found that farmers’ satisfaction is more likely related to trading with intermediaries. Our results are in line with previous studies that found that intermediaries have closer relationships with farmers (Schwartz et al., 2013; Thorlakson, 2018). According to Tewari et al. (2018) and Grabs and Carodenuto (2021), high levels of farmer satisfaction with intermediaries have the potential to encourage a mutual commitment to pursue the adoption of SAPs. Moreover, if emerging and developing countries want to improve SAP adoption, they also have to consider new ways to supply food. In this respect, intermediaries and wholesalers may play a social and economic role in supplying food to the local market (Dirven and Faiguenbaum, 2008; Schoonhoven-Speijer et al., 2017).

5.2.3 Institutional voids

This section focuses on the barriers to SAP adoption which governmental policies could potentially eliminate. Further, this section describes how organic certification schemes and formal and informal contracts help to fill institutional voids. Although we do not include an analysis of the direct impact that governmental policies have on SAP adoption, this section provides an overview of the formal and informal guidelines that may support the adoption of SAPs.

In Chapter 2, we found that one barrier farmers perceived regarding their adoption of SAPs was the fact that they are surrounded by other farmers using conventional production techniques. Specifically, inorganic inputs (e.g., herbicides and pesticides) used by neighbouring conventional farms might contaminate their crops. This perception is accentuated in a context where governments and other private institutions (e.g., banks and media) focus their support on large-scale conventional farmers (Rosset and Martínez, 2015). Moreover, despite the fact that Chile has norms regarding the use of inorganic inputs, the Chilean government does not adequately supervise and control their use (Muñoz-Quezada et al. 2016; Gaitán-Cremaschi et al. 2020). In Chapter 4, we explain how the safety standards required by lead firms are supported by the Agricultural and Livestock Service of Chile (SAG), which controls pesticide/herbicide application and disposal amongst medium-large-scale farmers. Although the control SAG exercises may be more common or frequent amongst medium-large-scale farmers, overall, its control is still limited due to the large dispersion of farms across Chile (Muñoz-Quezada et al. 2016; Gaitán-Cremaschi et al. 2020).

In Chapter 3, we explored how organic certification standards (third-party and participatory guarantee systems) fill institutional voids related to sustainable production. As mentioned in the previous section, farmers with certifications have better access to organic vegetable markets. The participatory guarantee system (PGS) emerged due to the necessity of farmers to reduce their costs and revitalise organic networks, providing benefits such as the exchange of knowledge and farmer empowerment (Hruschka et al., 2021). The PGS represents a hybrid structure that combines formal and informal institutions and is mainly recognised in the national market. To create a PGS, farmers have to create a farmer organisation (informal institution) first and then petition SAG (formal institution) for permission to use the PGS and the

Chilean organic label. However, according to Hruschka et al. (2021), the PGS' hybrid nature may prevent the massification of its use due to the lack of expertise amongst its members, the distance between these and the required time investment.

As mentioned in Chapter 4, we show that farmers' trust is more likely related to trade through formal contracts, but it also shows that farmer's satisfaction is more likely related to informal contracts. The higher levels of trust of farmers trading through formal contracts can be explained by lead firms offering higher prices to farmers, which increases price satisfaction, and that, in turn, is an antecedent for trust (Susanty et al., 2017). Moreover, the low levels of satisfaction with formal contracts may be due to flawed design of the terms and provisions of the contracts between farmers and lead firms or by the lack of communication between the two (Musara et al., 2018; Ruml and Qaim, 2021). The low levels of trust among farmers using informal contracts, in which intermediaries mainly operate, are contradictory with literature pointing at high levels of trust between farmers and buyers being vital to maintain informal contracts (Bijman, 2008; Escobal et al., 2015). Further, the high levels of satisfaction of farmers operating through informal contracts can be explained by the fact that in this type of contract, contractual provisions are specified according to the needs of farmers and buyers (Beninger and Shapiro, 2019).

5.2.4 Women and agroecology

In Chapters 2 and 3, we found that being a woman positively correlates with the use of SAPs. In Chapter 2, we explore evidence that reveals that being a woman is a key predictor of SAP adoption, while the discussion in Chapter 3 demonstrates that women are the majority in the Type II-Ecological farmers. These findings are in line with Mestmacher and Braun (2021), who found that women in Chile play a central role as promoters of agroecological principles. Moreover, the results of this thesis are also consistent with evidence from other studies dedicated to farming practices in Latin America, indicating that women are the promoters of social movements at both local and national levels in support of transitioning to more sustainable food systems (Hillenkamp, 2020; Trevilla et al., 2021). Karami and Mansoorabadi (2008) explain the link between women and agroecology based on the gender-based division of labour. Women have traditionally been largely responsible for their households, providing quality and safe food for their families. However, due to the lack of access to economic resources, women have had to make use of common resources to provide food. This has resulted in women acquiring knowledge on how to use natural resources without external inputs and developing stronger attitudes towards conserving the environment.

On the other hand, the recognition of women is also context-dependent. In territories characterised by patriarchal relationships and capitalist pressures, women's roles in agroecology tend to be underestimated and undervalued (Schwendler and Thompson, 2017). In these contexts, women have been forced to cede or have been excluded from decision-making regarding their land, limiting the growth of agroecological movements (Trevilla et al., 2021; Zaremba et al., 2021). A way to support agroecology in rural areas is through extension programs based on gender-oriented pedagogy, empowering both women and men to break from the traditional gender-based division of labour as described by a case study in Brazil carried out by Schwendler and Thompson (2017).

5.3 Contribution to the literature

This thesis contributes to SAP adoption literature by applying the value chain approach, analysing the diverse factors that are correlated to constraints and opportunities of SAP adoption. The use of social capital (SC) theory permits understanding the role that trust and networks play and how these can affect farmers' perceptions towards SAP adoption. Moreover, the use of SC theory allows to understand how trust, satisfaction and non-opportunistic behaviour affect farmer-buyer relationships establishing closer ties or agreements with business partners. Similarly, the transaction cost economics (TCE) lens enables understanding how the perception of risks and barriers related to the possible costs involved in adopting SAPs can hinder their adoption. Furthermore, SC theory and TCE consider how governance mechanisms affect farmers-buyer relationships in different market channels and how contracts can help promote (or demand) the adoption of SAPs.

5.3.1 Factors affecting SAP adoption

Most of the literature on SAP adoption refers to a 'yes or no' decision and focuses on implementing a single farm practice (e.g., conservation tillage, the use of cover crops and compost) (Tey et al., 2017). Moreover, most studies focus on a single production stage (e.g., planting, manuring or weeding) (Kassie et al., 2013), without considering that some agricultural practices have to be interconnected at different production stages to be effective. The measurement of SAP adoption employed in this thesis, considering different sustainability levels of different farming practices in different production stages, provides more useful insights to analyse complex SAP adoption processes.

Further, SAP adoption literature usually presents single factors or a single category of factors that affect the adoption (Baumgart-Getz et al., 2012; Tey et al., 2017). These studies are criticised for considering agriculture as a perfect engineering product in which cause-effect relations are linear (Darnhofer, 2021). These approaches underestimate the possible interactions between natural, technological and social factors and their effects on farmers' adoption decisions (Kassie et al., 2013; Darnhofer, 2021). There are few studies on how factors interact and how they jointly impact SAP adoption. In this thesis, we have attempted to fill this knowledge gap, exploring the interactions between these factors. In our view, the insights gained enrich the understanding of the fundamental factors that either enable or hinder SAP adoption. In general, the results of this thesis show that being a woman, receiving training on SAPs and being pro-environment are positively correlated to the adoption of SAPs. Contrarily, the perception of risks and barriers, better access to credit and higher income from farm activities are negatively correlated to SAP adoption. Regarding the interaction between factors, we have identified that economic resources, trust and training are indirectly related to the adoption of SAPs through the perception of risks and barriers.

5.3.2 Categorising the sustainability of farming systems

Although the study of farming types is not a new phenomenon (Tittonell et al., 2005; Alvarez et al., 2018), little research has been conducted to date on the sustainability levels of different agricultural practices (Teixeira et al., 2018). Usually, farming types in studies focused on environmental issues include indicators such as soil quality and technology adoption as 'yes or no' indicators for SAP adoption (Sierra et al., 2017; Goswami et al., 2014; Teixeira et al., 2018). However, 'yes or no' indicators prevent identifying the heterogeneity of farms and their use of different SAPs. Moreover, according to Lam et al. (2020), research has to provide more insights on how farmer and farm characteristics impact the pursuit of sustainability. Chapter 3 in this thesis contributes to the farming typology literature by including farmer and farm traits and by incorporating additional indicators, namely, the sustainability levels of agricultural practices and market channel characteristics such as type of buyers (e.g., lead firms, intermediaries and wholesalers) and type of agreements (e.g., spot market, informal contract and formal contract). The insights gained by incorporating these indicators, in our view, provide a broader understanding of farmers' heterogeneity and the different pathways towards sustainability that fit each farming type. We have identified five farming types: (1) Large dual farming; (2) ecological farming; (3) traditional farming; (4) conventional small-scale farming; and (5) conventional medium-scale farming. These farming types reveal how the sustainability of different agricultural practices interconnects with socio-economic, farm structure and market channel characteristics. We demonstrate that the transition to sustainable agriculture can have different starting points and, although that transition may imply contradictory pathways, they can coexist.

Moreover, identifying these farming system traits can contribute to designing more focused agricultural policies that favour SAP adoption.

5.3.3 Farmer-buyer relationship and SAPs

Most of the literature on food chains and farmer-buyer relationships focuses on the role of lead firms (Prowse, 2012; Grabs and Carodenuto, 2021). This literature examines how governance forms between farmers and lead firms stimulate (or not) economic development, higher yields, crop diversity, access to new technology and SAP adoption (Bellemare and Lim, 2018; Ton et al., 2018; Meemken and Bellemare, 2020). However, even though a major part of the fresh food chains operates with intermediaries and wholesalers in developing and emerging economies, little research has been carried out on their roles and functions (Thorlakson, 2018; Mariyono et al., 2020; Grabs and Carodenuto, 2021). Extant literature usually assumes that these buyers hamper market access for farmers (Schoonhoven-Speijer et al., 2017). Moreover, farmers working with intermediaries and wholesalers receive even less attention when studies focus on SAP adoption (Thorlakson, 2018; Grabs and Carodenuto, 2021). By exploring the link between governance forms and contractual provisions, attributes of farmer-buyer relationships and level of SAP adoption by farmers, this thesis provides insights on the actual role of intermediaries, wholesalers and lead firms related to SAP adoption amongst farmers. We found that formal contracts between lead firms and farmers are related to the adoption of SAPs.

Although, our results show limited applications of sustainable practices by farmers trading with intermediaries and wholesalers, our research does discern potential for future developments in this direction as discussed in Chapter 4. For example, our results show that farmers trading through informal contracts (mainly operated by intermediaries) are more likely to be satisfied with their buyers, which can encourage the mutual commitment to adopt SAPs (Tewari et al., 2018; Grabs and Carodenuto, 2021). Moreover, auction systems in wholesale markets may support SAP adoption by farmers supplying to wholesalers. Thus, this thesis' incorporation of intermediaries and wholesalers highlights the potential role these actors can play in supporting SAP adoption in fresh food chains.

5.4 Implications for practitioners and policymakers

Each chapter of this thesis provides a different perspective on the adoption of SAPs. Chapter 2 shows that the study of their adoption cannot focus only on one sustainable practice or one production stage. SAP adoption in farms has to be approached as a system in which agricultural practices interconnect. Chapter 2 thus identifies which factors are important for adopting SAPs and how these factors interact with each other. Understanding how factors interact provides insights for both practitioners and policymakers to prioritise their efforts in more structured strategies. For example, we found that being a woman, having training programmes related to SAPs and barriers such as the time needed to transition to SAPs were key factors related to their adoption. Given these results, policymakers could focus on three policies: a) offering training programmes related to SAPs, enabling farmers to see these practices as a way to reduce input costs and increase their independence; b) offering training programmes specifically focused on women and agroecology, providing spaces for them to build agroecological networks; and c) providing financial support for farmers with few resources during their transition to SAPs.

Chapter 3 provides insights regarding policies that provide financial support and other strategies linked to the farmers' production scales and farming systems (e.g., organic or conventional) and their adoption of SAPs. In that chapter we identify different pathways to adapt farming systems, from AI practices to hybrid systems and agroecological production methods. The insights provided in this chapter into the different market channels and the types of trade agreements used by farmers according to the sustainable level of their agricultural practices, could be an input for policymakers to support the development of “green” market channels. First, as intensified agricultural systems are linked to medium-large-scale farmers, policymakers could design financial support programs focused on providing tax reductions for organic inputs, crop insurance, greening payments or subsidies to encourage these farmers to adopt SAPs. Second, as hybrid systems are linked to small-scale farmers who do not own the land they work, Chile’s Agricultural and Livestock Development Institute (INDAP) could prioritise a land tenure regularisation programme for farmers who are willing to adopt SAPs. Due to farmers' lack of financial resources and their dependency on farm income, we also suggest the Chilean government focus on providing technical assistance regarding SAPs to help farmers make use of the resources they have at hand and provide them financial support during the transition to SAPs to incentivise their adoption. Third, as agroecological systems are linked to small-scale farmers who do not need incentives to adopt SAPs, these farmers do however need support with the provision of spaces to market their products. Moreover, these farmers need spaces where they can exchange experiences and knowledge in order to improve their agricultural practices. Finally, the transition to SAPs should not focus only on farmers; relevant policies also have to include current and future value chain actors in strategies that support SAP adoption.

Chapter 4 explores how different farmer-buyer relationships are linked to different levels of SAP adoption. We found that formal contracts between farmers and lead firms are more likely to adopt SAPs. However, we also found that farmers supplying lead firms through formal contracts are more likely to present low satisfaction levels. In this sense, practitioners and policymakers could monitor and control formal contracts in order to include farmers in the design of the contracts and to prevent farmers from feeling dissatisfied or lessening their commitment and thus support the adoption of SAPs. Moreover, authorities could support public wholesale markets by implementing auction schemes focused on sustainable products. Wholesalers and other public entities could also support and promote the sales of sustainable food through such schemes. Finally, bearing in mind that farmers are more likely to be satisfied supplying through informal contracts mainly to intermediaries, policymakers could use this social capital to involve intermediaries as spokespeople to promote the benefits of SAP adoption amongst farmers and to build new sustainable market channels.

5.5 Limitations and further research

This thesis provides useful insights on the correlation that farmer and farm characteristics, farming system typologies and farmer-buyer relationships have on SAP adoption. However, we acknowledge that other elements in the value chain should be considered in future studies. Although we studied resources related to the adoption of SAPs, an in-depth view of sustainable farmer organisation operations and the impact of technology and ecosystem services available for farmers is also needed. Moreover, in terms of market access and market orientation, further research should focus on the farmer-consumer relationship in short food chains, as well as home delivery schemes providing sustainable groceries and the value-added distribution between lead firms and farmers. Regarding institutional voids, further research should focus on the impact agricultural policies have on SAP adoption and how specific policies designed to support that adoption actually impact the rate of SAP adoption.

This thesis uses a survey approach with vegetables growers. While the quantitative approach adopted can be seen as a contribution to the research on SAP adoption and farmer-buyer relationships in large samples, it also can be a limitation due to a lack of detail and depth regarding latent variables. Similarly, while the farmer perspective adopted in this thesis provides detailed information to help understand factors affecting SAP adoption at the farm level, it can also be a limitation due to the lack of information regarding other key chain actors such as buyers and consumers. Although the sample is only from the central zone of Chile, we believe that the sample size, jointly with the insights gained from previous experiences and workshops, makes this thesis an illustrative case for assessing sustainable agricultural practices from a value chain perspective. We acknowledge that the use of contact lists and snowball sampling has limitations and could imply some bias. Additionally, focusing only on the main buyer of the farmer does not present a complete overview of farmers' transactions and, as such, is a limitation of this study. In terms of questionnaire design, the order of the questions impacts the quality of the data collected. From our experience, it is not advisable to start with a question about beliefs or values such as environmental awareness. Regarding limitations of how the survey was performed, we believe that surveys carried out at fairs provide less precise information than those carried out at the farm or at home because at fairs farmers are focused on selling their products and the enumerators do not get a good insight of the farm.

With respect to the farm-level index used to measure the sustainability of agricultural practices based on the work of Rigby et al. (2001), we acknowledge some limitations. For example, Janvier et al. (2007) indicated the lack of specificity of the indicators, for example the measurement of microbial communities in the soil. Dale and Polasky (2007) highlighted the limitation of not embracing a broader perspective considering the spatial context of agricultural lands. Likewise, Gómez-Limón & Sanchez-Fernandez (2010) pointed out the difficulty of interpreting the combination of indicators. However, literature also mentioned some advantages of the index. For example, Gómez-Limón & Sanchez-Fernandez (2010) and Waas et al. (2014) argued that this index allows ranking agricultural practices from best to worst, expressing negative and positive effects. Moreover, Bockstaller et al. (2008) stressed the usefulness of this index for interpreting results by aggregation of the indicators in stages (e.g., seed sourcing, soil fertility pest and disease control). Moreover, according to Rigby et al. (2001), this index supports detailed comparative assessments of large samples, where it is possible to exclude and include components (e.g., use of technology, type of irrigation systems) or modify the weighting of the components.

In Chapter 2, we found that training programmes related to SAPs were a key factor correlated to their adoption. However, more insights are needed, and future studies should focus further on what motivates farmers to attend these programmes and what are the most effective ways to deliver relevant information to farmers. Despite that the use of SEM allows to conduct complex and multidimensional yet precise analyses of empirical data, there is no full literature consensus on the goodness of fit indices; thus, the theoretical models developed by the researcher should be tested in different contexts (Xiong et al., 2015; Tarka, 2018). In Chapter 3, we apply a multivariate analysis methodology which focuses on grouping similarities between farmers, thus identifying different farming types. However, during this process, “atypical” farmers are “lost”, that is, farmers that do not completely fit into any one type. For example, farmers can be categorised as Type V-Conventional medium-scale farmers even if they have an organic certificate, meaning that their average values correspond to Type V, but their way of farming does not align with this farming type’s main characteristics. Thus, future studies should identify and understand the rationale of these ''atypical'' farmers. Chapter 4 provides insights on farmer-buyer relationships, adopting the farmers' perspective and applying a quantitative approach. However, more research using in-depth interviews with buyers, especially intermediaries and wholesalers, is needed. Lastly, more insights on the work carried out by these two types of buyers and how they manage logistics and relationships with small-medium-scale farmers and consumers is needed. This type of research could thus contribute to identify the potential role of these buyers in encouraging SAP adoption amongst farmers and in making the food the latter produce more available.

5.6 Main conclusions

This thesis analyses how vegetable value chain characteristics are related to Chilean farmers' adoption of SAPs. The thesis' broad perspective, including different farming practices and production stages as the basis for the quantitative analysis carried out, provides valuable insights on complex SAP adoption processes. Chapter 2 serves to identify which factors are important and how these factors interact with each other, contributing to the debate on what policymakers and scholars need to focus on in order to increase the rate of SAP adoption. This research shows that the main enablers of SAP adoption are being a woman, receiving specific training on SAPs and being pro-environment. The main constraints are the perception of risk and barriers, better access to credit and higher income from farm activities. Moreover, we found that economic resources, trust and training are significant factors that are indirectly correlated to SAP adoption by being directly correlated to the perception of risk and barriers.

Chapter 3 provides insights on how the sustainability of agricultural practices is interconnected with socio-economic, farm structure and market channel characteristics. We successfully identify five farming system types, suggesting that SAP adoption may imply different pathways (e.g., organic versus agroecology) and that farmers are at distinct starting points on the path towards SAPs adoption. We provided insights into the different market channels and the types of trade agreements used by farmers according to the sustainable level of their agricultural practices. Therefore, the different farming system types provide insights allowing governments to tailor public strategies to fit rural realities and encourage SAP adoption.

Chapter 4 explores how different farmer-buyer relationships relate to different levels of the adoption of SAPs. The insights gained from this chapter suggest that close farmer-buyer relationships could support the adoption of SAPs and that formal contracts are related with the adoption of SAPS. Moreover, the research suggests that excluding actors such as intermediaries and wholesalers in SAP-related policies programmes can potentially threaten the more vulnerable population's access to sustainable food. Finally, increasing support for and research on trading schemes involving intermediaries and wholesalers may have a positive impact on the adoption rate of SAPs.

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SUMMARY

Climate change is evident and the actual food systems are contributing to this. One of the main agricultural sectors contributing to climate change is crop production (Poore and Nemecek, 2018). Most of the field crops around the world are driven by agricultural intensification (AI) (FAO, 2021b), characterized by the intensive use of inorganic inputs (e.g., fertilisers and pesticides) and monocrops (Perkins and Jamison, 2008; Tscharntke et al., 2005). AI has caused the contamination of the environment, threatening human health and biodiversity around the world (Townsend and Howarth, 2010; Carvalho, 2017). Moreover, AI has contributed with the transformation of food value chains (Reardon et al., 2019), increasing vertical coordination of farm production with lead firms (Balsevich et al., 2003; Reardon et al., 2009). However, the transformation of food value chains has accentuated the negative impact of AI on environment (Pullman et al., 2009; Lehtinen, 2017). One alternative to counter adverse the negative effects of AI is the adoption of sustainable agricultural practices (SAPs) (Bommarco et al., 2013).

The vegetable value chain in Chile is not an exception, with the adoption of SAPs rate of around 2% of the farmers, including organic certified farmers and agroecological farmers, without certificate (INDAP, 2017). The vegetable value chain in Chile is characterized by improper and excessive use of inorganic inputs, resulting in environmental pollution and increasing human health risks (Elgueta et al., 2020; Calderon et al., 2022). Therefore, in Chile, there is a need to improve the SAPs adoption rate. The literature has identified that the use of SAPs by farmers in food value chains is context-specific. Food value chains' constraints for the use of SAPs are related to lack of governmental support, knowledge gaps regarding the implementation of SAPs, farmers farmer-buyer relationship characteristics among others (Beske et al., 2014; Dania et al., 2018; Jia et al., 2018).

This thesis aims to empirically identify how vegetable value chain characteristics are related to the farmer's use of sustainable agricultural practices (SAPs) in Chile. This general aim is addressed by exploring three groups of factors related to the adoption of SAPs: farm and farmer characteristics; farming systems; and farmer-buyer relationships.

RQ1: What farmer and farm characteristics are related to SAP adoption and how do these factors interact in affecting SAP adoption?

Chapter 2 empirically analyses what factors are related to the simultaneous adoption of various SAPs by farmers in different vegetable crop production stages. Further, since the literature on SAP adoption mainly analyses these factors as separate from each other, this chapter explores the interaction between factors

and how these jointly are correlated to the application of SAPs. We identify which factors are related to SAPs adoption through multiple linear regression. Then, based on the results of this step, we carry out a literature review to see how the factors correlated to the adoption of SAPs interact. This analysis is performed using structural equation modelling (SEM). We identified that, the significance of factors on the adoption of SAPs depends on the production stage. For example, awareness of the impact agrochemicals have on the environment only is positively correlated to the use of organic pesticides. However, in general our results show that being a woman, receiving training on SAPs, and being pro-environment are positively correlated to the adoption of SAPs. Contrarily, risk perception, barriers perception, better access to credit and higher income from farm activities are negatively correlated to the adoption of SAPs. Regarding the interaction of the identified factors, we found that economic resources, trust and training are indirectly correlated to the adoption of SAPs through perceived risks and barriers of the adoption of SAPs. Moreover, through analysing the interaction between factors, we provide more insights into the complex processes of SAPs adoption.

RQ2: What types of farming systems are related to the adoption of SAPs?

Chapter 3 characterises heterogeneity of farmers and their initial starting point in the transition to SAPs. Specifically, this chapter classifies farming systems, with elements including the sustainability level of agricultural practices and market channel characteristics, in combination with socio-economic and farm characteristics. The chapter applies a farming typology approach and conducts an empirical analysis to unravel the diversity of co-existing farming systems in the vegetable sector. We developed the typology using multivariate analysis techniques including principal component analysis (PCA) and hierarchical clustering (CA). Our results show five farming-system types: (1) Large dual farming, (2) ecological farming, (3) traditional farming, (4) conventional small-scale farming, and (5) conventional medium-scale farming. These farming typologies unravel how the sustainability of agricultural practices is interconnected with socio-economic, farm structure and market channel characteristics. The study shows that the transition to sustainable agriculture can have different starting points, and, although the transition to sustainable agriculture may imply contradictory pathways, these can coexist. Moreover, this study provides insights into the different market channels and the types of trade agreements used by farmers according to the sustainable level of their agricultural practices. Moreover, the unravelling of these farming system characteristics contributes to designing more narrowed agricultural policies towards the adoption of SAPs.

RQ3: How do different farmer-buyer relationships link to different levels of SAP adoption?

Chapter 4 explores how different farmer-buyer relationships relate to different levels of the adoption of SAPs in the vegetable sector. The focus is on what farmer characteristics are related to each type of buyer, what governance form (spot market, informal contract, formal contract) is used for buyer farmer transactions and whether there is a relationship between the contract governance form (formal or informal) and (a) provisions in contracts with farmers (e.g., quality, quantity and the provision of services); (b) attributes of relationships with the farmer (i.e., trust, satisfaction and opportunism); and (c) level of SAP adoption by farmers. This analysis is performed using ANOVA and logit modelling. We found that formal contracts between lead firms and farmers support the adoption of SAPs. However, we also found that farmers trading through formal contracts, supplying mainly to lead firms, are more likely to show low satisfaction levels. Moreover, our results show that regardless wholesalers and intermediaries do not use formal contracts, the sustainability level of agricultural practices concerning the three types of buyers does not differ significantly. Another finding is that farmers trading through informal contracts supplying mainly to intermediaries are more likely to be satisfied. The analysis of intermediaries and wholesalers seeks to pose the potential role of these actors to support the adoption of SAPs in fresh food supply chains and for future research to determine the contribution of these actors to support the availability of sustainably produced food to a vulnerable population.

In sum, the three research questions have contributed to understanding how value chain characteristics are related to the use of SAPs. The broad perspective of this thesis, including different farming practices and production stages as a base for the quantitative analysis, allowed us to contribute insights into the complex processes of adopting SAPs. This thesis identified how farmer and farm characteristics are related to the adoption of SAPs, how knowledge of farming system typologies can support the adoption of SAPs, and how farmer-buyer relationships are related to the adoption of SAPs.

Several implications can be drawn for this thesis. First, women and extension programs related to SAPs could be key to increase the adoption rate of SAPs. Second, it is necessary to realize the starting points of farmers in order to tailor public strategies to fit rural realities towards the adoption of SAPs. Third, it is necessary to include intermediaries and wholesalers in sustainability schemes. Qualitative research should complement these findings, both with farmers and buyers.

Further research into the rationale of farmers to choose sustainable practices is needed, including attention to the operations of sustainable farmers organizations, the value-added distribution between lead firms and farmers, the farmer-consumer relationship in short supply chains and the effect of public

policies. Moreover, more research is needed on the potential role of wholesalers and intermediaries in stimulating farmer adoption of SAPs.

RESUMEN

El cambio climático es evidente y los sistemas alimentarios actuales son parte del problema. Uno de los principales sectores que contribuye al cambio climático es la producción de agrícola (Poore and Nemecek, 2018). La mayoría de cultivos alrededor del mundo son manejados mediante agricultura intensiva (AI) (FAO, 2021b), la cual se caracteriza por el uso intensivo de insumos inorgánicos (p.ej. fertilizantes y pesticidas) y monocultivos (Perkins and Jamison, 2008; Tscharntke et al., 2005). La AI ha causado la contaminación del medioambiente, amenazando la salud humana y la biodiversidad alrededor del mundo (Townsend and Howarth, 2010; Carvalho, 2017). Además, la AI ha contribuido con la transformación de las cadenas de valor alimentarias (Reardon et al., 2019), incrementando la coordinación vertical entre explotaciones agrícolas y empresas comerciales nacionales e internacionales (Balsevich et al., 2003; Reardon et al., 2009). Sin embargo, la transformación de las cadenas de valor alimentarias ha acentuado el impacto negativo de la AI en el medioambiente (Pullman et al., 2009; Lehtinen, 2017). Una alternativa para contrarrestar los efectos negativos de la AI es la adopción de prácticas agrícolas sostenibles (PAS) (Bommarco et al., 2013).

La cadena de valor de hortalizas en Chile es un caso del uso de AI, en la cual solo alrededor del 2% de los agricultores ha adoptado PAS, incluyendo a agricultores con certificación orgánica y agricultores agroecológicos sin certificación (INDAP, 2017). La cadena de valor de hortalizas en Chile se caracteriza por el uso inapropiado y excesivo de insumos inorgánicos, lo que acrecienta la contaminación ambiental y el riesgo a enfermedades humanas (Elgueta et al., 2020; Calderon et al., 2022). Por lo cual se busca que el sector hortícola en Chile incremente la tasa de adopción de PAS. La literatura en cadenas de valor alimentarias ha identificado que el uso de PAS por parte de los agricultores depende de la especificidad de cada contexto. Las barreras en las cadenas de valor alimentarias para el uso de PAS están relacionadas con: la falta de apoyo gubernamental, la falta de conocimientos relacionados con la implementación de PAS, la relación entre agricultores-comerciantes entre otras (Beske et al., 2014; Dania et al., 2018; Jia et al., 2018).

Esta tesis tiene como objetivo, identificar empíricamente cómo las características de la cadena de valor de hortalizas en Chile están relacionadas con el uso de prácticas agrícolas sostenibles (PAS) por parte de los agricultores. Este objetivo general se desarrolla mediante la exploración de tres grupos de factores que están relacionas a la adopción de PAS: características del agricultor y la granja, sistemas agrícolas y las relaciones entre agricultores y comerciantes.

Pregunta de investigación 1: ¿Qué características del agricultor y de la granja están relacionadas a la adopción de PAS y cómo estos factores interactúan en la adopción de PAS?

El Capítulo 2 analiza empíricamente que factores están relacionados con la adopción simultánea de varias PAS por agricultores hortícolas en las diferentes fases de producción agrícola. Además, ya que la literatura en PAS principalmente analiza estos factores por separado, este capítulo explora la interacción entre factores y cómo la interacciones entre éstos pueden estar correlacionadas con el uso de PAS. Se identificó los factores que están relacionados con la adopción de PAS a través de múltiples regresiones lineares. Después, con base en los resultados previos, se realizó una revisión bibliográfica para identificar cómo los factores relacionados con la adopción de PAS podrían interactuar. Con esta información, se realizó un modelo de ecuaciones estructurales (MES). Se identificó que la significancia de los factores depende de la fase de producción agrícola. Por ejemplo, ser consciente del impacto de agroquímicos en el medioambiente esta sólo positivamente correlacionado con la fertilidad del suelo, en donde los agricultores optan por el uso de pesticidas orgánicos. Sin embargo, en general nuestros resultados indican que ser mujer, recibir capacitación en PAS y estar a favor del medioambiente están positivamente correlacionados con la adopción de PAS. Caso contrario, la percepción de riesgo, la percepción de barreras, mejor acceso a créditos y mayores ingresos económicos provenientes de la franja están negativamente correlacionados con la adopción de PAS. Con respecto a la interacción entre estos factores, se encontró que los recursos económicos, confianza y capacitación en PAS están indirectamente correlacionados con la adopción de PAS a través de la percepción de riesgo y barreras para la adopción de PAS. Adicionalmente, a través del análisis de la interacción entre factores, este estudio provee nuevas perspectivas hacia el complejo proceso de adopción de PAS.

Pregunta de investigación 2: ¿Qué tipos de sistemas agrícolas están relacionados con la adopción de PAS?

El Capítulo 3 caracteriza la heterogeneidad de los agricultores y su punto de partida hacia la transición de PAS. Específicamente, este capítulo clasifica los sistemas agrícolas, mediante componentes que incluyen el nivel de sostenibilidad de las prácticas agrícolas y las características de los canales de comercialización, en combinación con las características socioeconómicas de los agricultores y las características de la granja. Este capítulo aplica un enfoque de tipología agrícola y conduce un análisis empírico para descifrar la diversidad de sistemas agrícolas que coexisten en el sector hortícola. La tipología se desarrolló usando técnicas de análisis multivariado incluyendo análisis de componente principal (ACP) y agrupamiento jerárquico (AJ). Se encontraron cinco tipos de sistemas agrícolas: (1) Agricultura extensiva dual, (2) agricultura ecológica, (3) agricultura tradicional, (4) pequeña escala de agricultura convencional, (5) mediana escala de agricultura convencional. Estas tipologías agrícolas descifran cómo la sostenibilidad de las prácticas agrícolas está interconectada con características socioeconómicas, características estructurales de la granja y características de los canales de comercialización. El estudio muestra que la transición hacia la agricultura sostenible puede tener diferentes puntos de partida y a pesar de que las transiciones hacia la agricultura sostenible pueden implicar caminos contradictorios, estos pueden coexistir. Además, este estudio proporciona perspectivas de los diferentes canales de comercialización y los diferentes acuerdos de comercialización usados por agricultores de acuerdo con el nivel de sostenibilidad de sus prácticas agrícolas. Asimismo, al descifrar las características de estos sistemas agrícolas se contribuye con información para el diseño de políticas agrícolas más precisas hacia la adopción de PAS.

Pregunta de investigación 3: ¿Cómo las diferentes relaciones agricultor-comerciante están relacionadas con los diferentes niveles de adopción de PAS?

El Capítulo 4 explora cómo las diferentes relaciones entre agricultor-comerciante se relacionan con los diferentes niveles de adopción de PAS en el sector hortícola. El estudio se enfocó en determinar cuáles características del agricultor se relacionan con cada tipo de comerciante (es decir empresas comerciales, intermediarios y mayoristas), qué formas de gobernanza (mercado al contado, contratos informales, contratos formales) son usadas en las transacciones agricultor-comerciante y si existe alguna relación entre los contratos y (a) las cláusulas contractuales (p.ej. calidad, cantidad y servicios ofrecidos); (b) atributos en las relaciones agricultor-comerciante (es decir confianza, satisfacción y oportunismo); and (c) nivel de adopción de PAS. Este análisis se realizó mediante ANOVA y un modelo Logit. Se encontró que los contratos formales entre empresas comerciales y agricultores favorecen la adopción de PAS. Sin embargo, también se encontró que los agricultores comercializando a través de contratos formales, que abastecen principalmente a empresas comerciales, son más propensos a mostrar bajos niveles de satisfacción. Además, los resultados muestran que a pesar de que los comerciantes mayoristas e intermediarios no utilizan contratos formales, el nivel de sostenibilidad de las prácticas agrícolas entre los tres tipos de comerciantes no difieren significativamente. Otro hallazgo es que los agricultores que comercializan mediante contratos informales, que abastecen principalmente a comerciantes intermediarios son más propensos a estar satisfechos. El enfoque en comerciantes intermediarios y mayoristas busca plantear el potencial rol de estos actores en la transición hacia PAS en la cadena de suministro de alimentos frescos. Además, busca que futuras investigaciones se enfoquen en determinar la contribución de estos actores en el aseguramiento de la disponibilidad de alimentos sostenibles para poblaciones vulnerables.

En resumen, las tres preguntas de investigación contribuyen a entender cómo las características de las cadenas de valor están relacionadas con el uso de PAS. El amplio panorama de esta tesis, que incluye las diferentes prácticas agrícolas y fases de producción agrícola, permite contribuir con diferentes perspectivas dentro del complejo proceso de adopción de PAS. Esta tesis identifica como las características del agricultor y de la granja están relacionadas con la adopción de PAS, como el conocimiento de los tipos de sistemas agrícolas apoya la adopción de PAS y como las relaciones entre agricultor-comerciante están relacionadas con la adopción de PAS.

Se pueden extraer varias implicaciones de esta tesis. Primero, las mujeres y la capacitación relacionada a las PAS pueden ser clave para incrementar la tasa de adopción de PAS. Segundo, es necesario identificar los diferentes puntos de partida de los agricultores para adecuar las estrategias públicas a las realidades rurales a fin de apoyar la adopción de los PAE. Tercero, es necesario incluir comerciantes intermediarios y mayoristas a los esquemas de comercialización de productos sostenibles, lo cual se debe complementar mediante estudios cualitativos tanto en agricultores como en comerciantes.

Futuras investigaciones deben enfocarse en: el proceso de toma de decisiones de los agricultores a la hora de escoger prácticas sostenibles, el manejo de las organizaciones de agricultores sostenibles, la distribución del valor agregado entre el agricultor y la empresa comercial, la relación agricultor-consumidor en los circuitos cortos de comercialización y los efectos de las políticas públicas. Además, se necesita más investigación en el potencial rol de comerciantes intermediarios y mayoristas para impulsar la adopción de PAS entre los agricultores.

Author´s Note

To conclude this thesis, I would like to pose some reflections:

From my perspective, many factors can affect the adoption of SAPs, but I will summarize the main motivations for the adoption of SAPs by identifying three types of farmers. The first type, these farmers were "born-green", which means that they only know sustainable agriculture due to beliefs, tradition or common sense. The second type, farmers motivated by health issues, these farmers have had severe health problems using inorganic inputs, and they changed radically to sustainable agriculture. The third type, farmers motivated by economic incentives, usually large-medium scale farmers who were pulled by lead firms to produce sustainable products, which usually turn out in organic conventionalization. These three types of farmers do not need extra motivation to adopt SAPs and more or less are convinced of the benefits of SAPs. However, how to motivate conventional farmers? With conventional farmers, I refer to the farmers in the "limbo" or with the back against the wall, not to the large-scale farmers producing conventionally. I refer to the farmers socially disadvantaged, who lack access to economic resources and education. The ones that are pushed to use inorganic inputs in an agricultural market where the price rules. I believe that the government should support these farmers. Despite that government proclaim the execution of sustainable policies, for me is not clear if governments are really supporting the adoption of SAPs. It seems that the strategies implemented for the adoption of SAPs, which are patronate-based, providing small subsidies or free equipment to farmers, are preventing more radical changes. Moreover, the contradictory policies, on one side supporting the agri-export neoliberalist model and on the other "supporting" agroecology, do not have the same weight, by this, I mean that agroecology policy requirements are always after conventional requirements, leaving agroecology at the end of the list to do. Should we expect something else from the government? Should we exert more pressure on governments? Or we are resourceful enough to create our path towards agroecology?

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Francisco Benítez

Wageningen, The Netherlands

December 2022

Francisco Javier Benítez Altuna
Wageningen School of Social Sciences (WASS)
Completed Training and Supervision Plan

Name of the learning activity	Department/Institute	Year	ECTS*
A) Project related competences			
A1 Managing a research project			
WASS Introduction Course	WASS	2017	1
Systematic approaches to reviewing literature	WASS	2017	4
Writing research proposal	WUR	2018	6
Scientific writing	Wageningen in'to Languages	2018	1.8
The essentials of scientific writing and presenting	Wageningen in'to Languages	2019	1.2
A2 Integrating research in the corresponding discipline			
Food value chain research: Understanding inter-organizational relationships	WASS	2017	1.5
Economic of Innovation	University of Oslo	2018	8
Introduction to R for statistical analysis	PE&RC	2019	0.6
Theories for business decisions	WASS	2020	2
B) General research related competences			
B1 Placing research in a broader scientific context			
Quantitative data analysis: Multivariate Techniques	WUR	2019	2
Academic publication and presentation in the social science	WASS	2021	4
B2 Placing research in a societal context			
The young scholars workshop on cooperatives	WUR and COOP	2018	0.5
"Horizontal and vertical vegetable value chain collaboration towards the adoption of sustainable practices"	HortEco – Challenges and opportunities for organic certification in vegetable production, Chile	2018	1
"Factors affecting the adoption of sustainable practices: A case study in Chile"	HortEco – First workshop of Organizations of Ecological Farmers, Uruguay	2019	1
C) Career related competences/personal development			
C1 Employing transferable skills in different domains/careers			
Educational tasks, lectures	WUR	2018-2019	1
Competence assessment	WGS	2018	0.3
Active bystander training	WIMEK	2020	0.1
Total			**36**

*One credit according to ECTS is on average equivalent to 28 hours of study load

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