Climate Change Risk and Farming Practices: Evidence from Small-scale Citrus Farmers in Indonesia

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Declaration

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Abstract

This thesis examines climate-related risk behaviours among small-scale citrus farmers and their decision to adoption certified seedlings and use of agrochemical inputs in East Java, Indonesia. The analysis is important for understanding citrus farmers' behaviours regarding climate change issues. Understanding farm households climate related behaviours is key to designing appropriate smallholder support and advisory services.

Given the importance of climate change to rural agricultural communities in developing countries, governments, NGOs and international development agencies continue to make substantial efforts to improve the ability of small-scale farmers to adapt. Yet, too often, national adaptation policies and programs ignore insights from existing smallholder adaptation practices. Previous studies show that behavioural insights are critical in developing an understanding of climate risk management by farmers.

An important aim of this thesis is to understanding climate-related influences on smallholders' decisions. The research objectives are to: (i) understand the extent of perceptions of risk among small-scale citrus farmers related to a range of climate change events and to identify the drivers of their risk perception at aggregated and disaggregated levels; (ii) provide analytical insights into the adoption of certified citrus seedlings by small-scale farmers by analysing the extent to which they value the certification of citrus seedlings and the role of this factor in influencing the adoption of higher-yielding, climate-risk resilient and disease-free citrus varieties; and (iii) explore the extent of use of chemical inputs and the role of risk preferences, intrahousehold dynamics and social networks on the household expenditure spent on chemical inputs. The research uses data from a household survey of 500 citrus farmers with interviews of both the male and female household heads. The first research objective was analysed by employing seemingly unrelated regression models (SUR) and ordered logistic regression models (OLM), the second objective was

estimated using a multinomial logit model, and the third objective employed joint modelling of risk, intrahousehold dynamics and spatial factors in a spatial regression model.

Among the key contributions of this thesis is integrating the research on complex patterns of risk behaviours, from both the economics and psychology literatures, into climate research on risk perceptions through a straight-forward extension of current approaches to the analysis of the risk perception index. An important result is the disadvantage of using only the aggregate approach in analysing risk perception because it could underestimate and simplify the complex representation of climate risk behaviours. This study also presents empirical support for the use of information and communication technology based extension as an efficient extension tool to reach more farmers than in traditional methods.

A second result highlights how farmers' beliefs about the yield and production risks of particular seedling types, along with risk preferences, were significantly related to farmers' intentions to adopt particular seedling types. This study also found the relationship between climate-related variables (i.e. climate information source and climate extension) and farmers' decisions to use certified seedlings.

Lastly, this thesis finds that more risk-averse households tend to have lower spending on insecticides and the use of this input is also significantly associated with higher profit variability. A wife's leadership could lead to a considerably lower expenditure for fungicides, but higher herbicide expenses; and a higher disagreement between spouses is associated with more insecticides and fungicides costs. The pattern of chemical inputs usage is spatially dependent on endogenous effects, while spatial disturbance effect existed for the use of chemical fertilisers and herbicides.

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List of Abbreviations

ACIAR	Australian Centre for International Agricultural Research
BPS	Badan Pusat Statistik (Statistics Indonesia)
CC	Certified - Certified
CU	Certified - Uncertified
GDP	Gross Domestic Products
GPS	Global Positioning System
HH	Household
ICHORD	Indonesian Centre for Horticultural Research and Development
ICT	Information and Communication Technology
IIA	Independence of Irrelevant Alternatives
KATAM	Kalender Tanam Terpadu (Integrated Cropping Calendar System)
MoA	Ministry of Agriculture
NPK	Nitrogen, Phosphorus, Kalium (Potassium)
RPI	Risk Perception Index
RPJMN	Rencana Pembangunan Jangka Menengah Nasional (National Medium Term Development Plan)
SAM	Spatial Autoregressive Model
SEM	Spatial Error Model
SUR	Seemingly Unrelated Regression
OLS	Ordinary Least Square
UC	Uncertified - Certified
UU	Uncertified - Uncertified
UNFCCC	United Nations Framework Convention on Climate Change

Chapter 1. Introduction

1.1 Background and motivation

Climate change impacts agriculture in unique and profound ways. Agricultural producers depend on weather-related inputs (sun, rainfall, temperature). Climate change alters weather-related inputs, directly affecting agricultural productivity (Nelson et al., 2014; Carraro, 2016). Examples include more extreme weather events, longer or shorter growing seasons, and more or less rainfall. The impacts are more profound in developing countries because these sectors are the main engine of economic growth (Timmer, 2002; Christiaensen et al., 2011) and an important source of sustenance and livelihood for a large portion of their rural populations (Lobell et al., 2008; Lybbert and Sumner, 2012).

Smallholder households, in particular, face unexpected challenges because of their reduced capacity to adapt to climate change and their lower resilience to shocks (Tol, 2009; Tripathi and Mishra, 2017). Smallholders experience distinct challenges in managing climate variables and extreme events for several reasons. Firstly, small-scale farmers are often dependent on rain-fed farming systems, which are susceptible to drought (Sidibé et al., 2018; Yesuf and Bluffstone, 2009). Secondly, they are mainly characterised by low incomes, low formal education levels, and inadequate managerial skills, restricting their ability to adapt to climate change risks (Tol, 2009; Tripathi and Mishra, 2017). Thirdly, their access to appropriate information, helpful technologies and supportive institutional services are limited (Lybbert and Sumner, 2012; Mulwa et al., 2017). Lastly, small-scale farm households tend to live in regions with poor infrastructure and with higher exposure to climate change-related weather events (Baettig et al., 2007; Seddon et al., 2016).

Given the importance of climate change to rural agricultural communities in developing countries, governments, NGOs and international development agencies continue to make substantial efforts to improve the ability of small-scale farmers to adapt (Bohensky et al., 2013; Crick et al., 2018). Yet, too often, national adaptation policies and programs ignore insights from existing smallholder adaptation practices (Rasmussen, 2018). Indeed, previous studies show that behavioural insights are critical in developing an understanding of climate risk management by farmers (Wheeler et al., 2013; Beckage et al., 2018; Fischer, 2018). These behaviours are closely related to how farmers perceive the risk arising from climate change (Fisher and Carr, 2015; Menapace et al., 2015).

Many studies confirm that farmers in developing countries with a higher perception of risk are more likely to adapt to climate change (e.g. Mumpower et al., 2016; Khanal et al., 2018). For example, Fisher and Carr (2015) find farmers' risk perceptions of drought positively influences the adoption of a drought-tolerant variety of maise in Uganda. However, existing literature on behaviours regarding risks from climate change in agriculture are often only focused on aggregated indexes of risk perception or general concerns over the issue (e.g. Frank et al., 2011; Le Dang et al., 2014; Frondel et al., 2017). These aggregated indexes typically combine farmers' concerns over impacts of climate change-induced events with respondents' beliefs about how climate change may lead to changes in the frequency of these events (e.g. Le Dang et al., 2014; van Winsen et al., 2014; Iqbal et al., 2016; Sullivan-Wiley and Gianotti, 2017). On the other hand, many risk studies have shown that the risks are potentially a complex combination of these factors (e.g. Kahneman and Tversky, 1979; Cohen, 2015; Just and Just, 2016; Gregg and Rolfe, 2017), so that both subjective beliefs and the impacts on utility can be important contributors to risk perception in complex and non-linear ways.

A substantial focus in recent times has been on the use of an aggregate index of climate risk perception, called the risk perception index (RPI). This may be insufficient in yielding deeper insight into risk behaviour and broader phenomena in climate change analysis. For example, a recent study by Sullivan-Wiley and Gianotti (2017) found a risk reduction program had inconsistent results in influencing farmers' responses to natural hazards, raising questions about the effectiveness of programs in regard to risk reduction policies. However, while the RPI is measured by the perceived likelihood and impact of particular hazards, there is a possibility that farmers respond to support services, such as extension ones, differently according to different perceptions about the likelihood and impact of hazards. It means that the RPI may not be comprehensive enough to explain the influence of policy interventions in generating beliefs concerning the likelihood and impact of particular hazards.

Beliefs generated by policy interventions are more likely to be closer to beliefs that facilitate rational adaptation to risks than is indicated by the RPI. On the other hand, the RPI could provide important information in understanding how farmers prioritise, or rank, the risk arising from each climatic event (MacKenzie, 2014). This ranking could provide information about farmers' priorities regarding climate events and lead to understanding how they allocate their scarce resources to minimise the negative impacts of different climatic risk events (Doss et al., 2008).

The allocation of resources in response to climate risk is more important and challenging for perennial crops farmers due to uncertainties inherent in this type of farming and the time-frames over which climate risks are manifest. The characteristics of perennial crops, which represent long-term investments and which have long gestation periods (Devadoss and Luckstead, 2010; Ouattara et al., 2019), mean farmers are more likely be more affected by the risks to future weather driven by climate change (Lobell and Field, 2011; Adamson et al., 2017; de Sousa et al., 2019). For example, farmers have less opportunity for switching crops, or varieties, to adapt to evolving climatic conditions because perennial crops have technological lock-in due to large irreversible, upfront investment costs (Gunathilaka et al., 2018). As a consequence, a comprehensive understanding of farmers' behaviours regarding the allocation of their resources as responses to climate change is needed, in relation to both long-term decisions [i.e. crop/variety/seedling choices, land allocation, etc.] and short-term strategies [i.e. input use, labour allocation, etc.] (Devadoss and Luckstead, 2010).

For long-term climate risk-reduction strategies, many studies recommend the use of improved varieties (e.g. Truelove et al., 2015; Holden and Quiggin, 2016; Burnham and Ma, 2018; Katengeza et al., 2019). These new varieties may encompass characteristics such as suitability in particular climatic situations, as well as improvements in productivity, quality and resistance to pests and diseases (Ellis, 1992; Doss and Morris, 2001). For a long-life perennial crop, these potential advantages could determine the long-term success of the farm business, which may only be attained by using high-quality seedlings. In developing countries, seedling quality often becomes a pressing issue so that governments establish certification as a quality assurance system to guarantee minimum standards for seedlings (Auriol and Schilizzi, 2015).

However, transparency issues and the unpreparedness of certification supporting systems have been a common problem for certification programs in developing countries (Tripp and Louwaars, 1997; Spielman and Kennedy, 2016). As a result, certified seedlings may not be trusted by farmers. Maredia et al. (2019) emphasise that a farmer's trust, reflected by how they value the quality of seedlings, will determine their willingness to adopt certified seedlings. In the context of low adoption of high-quality certified seedlings, one possible reason is that the seedlings may not be perceived as a profitable technology by farmers (Bold et al., 2017), or that certified seedlings do not meet farmers' needs (Kremer and Zwane, 2005; Macours, 2019). This study investigates to what extent farmers value certified and uncertified citrus seedlings and how these values influences farmers’ decisions in choosing certain types of citrus seedlings.

This study investigates seedling choices in the context of long-term decision-making by investigating farmers' behaviours in terms of the use of chemical inputs in citrus farming practices as a short-term farming decision. The changing climate could accelerate the loss of soil fertility and nutrition (Ramos and Martinez-Casasnovas, 2009; St.Clair and Lynch, 2010;

Grimm et al., 2013) and increase instances of damaging interactions between a plant and pests, diseases and weeds (Rosenzweig et al., 2001; Nelson et al., 2013; Delcour et al., 2015). The application of agro-chemical inputs is often considered a critical strategy to enhance farm productivity in the face of the decreasing environmental support (e.g. Minten and Barrett, 2008; Bezu et al., 2014; Arslan et al., 2017; Binswanger-Mkhize and Savastano, 2017).

As the expenses of chemical inputs may take a relatively large portion of small farm's household expenditure, the application of the input could be considered a costly input. As a result, the decision to allocate resources for the inputs may be driven by personal risk preferences (whether the input will be perceived to increase/decrease risk), intra-household dynamics in decision-making, as well as the effect of social networks. For example, a wife tends to have more responsibility for managing household expenditure in Indonesia, while husbands manage farm activities (Akter et al., 2017). As a consequence, the decision about household spending on agrochemical inputs should involve spouses in the decision-making process, not only a household head in a unitary model of households, as is frequently depicted in the literature (e.g. Marenya and Barrett, 2009; Aida, 2018; Chen et al., 2018).

Decisions about the application of chemical inputs also may be affected by social networks; farmers often refer to their neighbour's choices before they use a certain technology. This neighbour effect could result from information exchange or learning processes between farmers (Manski, 2000; Lapple and Kelley, 2014; Ward and Pede, 2015; Aida, 2018; Kubitza et al., 2018) or it may be correlated with the agro-environmental conditions (Hughes, 1996; Chen et al., 2020). This research attempts to examine these intra-household and social network effects on the pattern of agro-chemical inputs among small citrus farmers.

This thesis contributes to the literature on climate change and agricultural development in several ways. First, by using a survey-based approach, this study can integrate the research on complex patterns of risk behaviours, from both the economics and psychology literatures (e.g. Tversky and Kahneman, 1992), into climate research on risk perceptions through a straight-forward extension of current approaches to the analysis of the RPI. Based on evidence of the disadvantage of using the aggregate level of analysis for climate risk perception, this study suggests joint analysis for greater levels of detail and a better understanding of how extension or other policies affect the behaviours and perceptions of smallholder farmers.

Second, this study uses experiments to measure farmers' subjective beliefs about yield, which allows examination of how a quality signal regarding beliefs about yield can influence behaviour related to certified seedling adoption. This thesis also provides evidence that farmers' decisions to use certified citrus seedlings are related to their consideration of climate change adaptation strategies. Third, this study employed a joint analysis of individual factors, intra-household dynamics in decision-making and social networks, which allows a better understanding of small-scale farm household behaviour regarding the use of agro-chemical inputs (pesticides and fertilisers).

1.2 Climate change policies for agricultural development in Indonesia

The Indonesian economy is highly dependent on the agricultural sector. Between 2013-2017, agriculture contributed more than 13 per cent per year to the gross domestic product (GDP) (BPS, 2018b) and involved more than 27.6 million farm households in 2018 (BPS, 2018a). However, more than 58 per cent of the households can be categorised as smallholders because they hold less than 0.5 hectares of land. Considering the vulnerability of the agricultural sector and small-scale farmers to climate change and the importance of the agricultural sector to the Indonesian economy, the government should have a significant focus on climatic issues in the development of agricultural policy.

The Government of Indonesia has ratified the Paris Agreement of the United Nations Framework Convention on Climate Change (UNFCCC) which shows Indonesia's commitment to reduce carbon emissions and to address climate issues. In the National Medium Term Development Plan (RPJMN) 2015-2019, the government made sustainability and climate change as important strategies for agricultural development (Bappenas, 2014). Subsequently, as stated in the strategic plan 2015-2019 of the Ministry of Agriculture, the focus related to climate change in the agricultural sector was a mitigation strategy to anticipate the impact of natural disasters and climate change on food security (MoA, 2015; Rondhi et al., 2019).

For climate change adaptation, the strategies include: (i) adjusting farming systems to climate change; (ii) developing and applying climate-adaptive technology in farming systems; (iii) optimising the use of land, water and genetic resources; and (iv) strengthening the role of agricultural stakeholders through deliberations with farmers at the local level (i.e. to adopt the crops calendar to anticipate the changing climate). The government also promoted the adoption of improved varieties (high-yield, climate adaptive and efficient ones in relation to input use) by facilitating farmers' access to these varieties and by facilitating farm insurance to protect farmers from harvest failure caused by climate change.

However, to date, government approaches tend to focus on agricultural adaptation strategies for climate change and are limited to specific food crops. For example, the cropping calendar, known as the "Integrated Cropping Calendar System (KATAM)"[1], which is beneficial for farmers in minimising the negative impacts of climate variability (Anggarendra et al., 2016), is still focused on three leading food crops (rice, maise and soybean). This focus supports national food self-sufficiency which remains the government's top priority in agricultural development (MoA, 2015; Harahap et al., 2017). However, government resources are often insufficient to support the implementation of climate related program and policies (Yoseph-

[1] KATAM is an online application which provides information about recommended planting times, recommended varieties, and input dosage, including potential-climate hazard in sub-district levels

Paulus and Hindmarsh, 2018; Rondhi et al., 2019). Also, Kawanishi et al. (2016) identified that the Indonesian action plan for climate change adaptation still disregards non-climatic factors in the implementation of climate adaptation strategies. On the other hand, the government's strategies to adapt to climate change in horticulture are limited, even though this sub-sector is highly vulnerable. Hence, it is important to assess how the horticultural subsector manages climate risks, and particularly to understand how small-scale horticulture producers respond to programs, policies and projects the issue.

1.3 Citrus farming in Indonesia

Citrus has become a consumer favourite for dietary intake (Liu et al., 2012). In Indonesia, citrus has a high consumption rate, reaching 3.33 kg/capita/year in 2018 (Pusdatin, 2019). Even though the quantity of citrus production ranked second after bananas, achieving 2.5 million tonnes in 2018 (BPS, 2019), there was an increasing trend of importing citrus products to meet the expanding demand. In 2017, citrus imports reached 130 thousand tonnes (MoA, 2018). Considering this, Indonesia's Ministry of Agriculture includes citrus as one of its strategic commodities in agricultural development, especially given its capacity to substitute for imported products (MoA, 2015).

From 2013 through to 2018, citrus production grew almost 9 per cent a year, while the harvested area grew 2.25 per cent per year in the same period (MoA, 2018). These crops are cultivated in all of Indonesia's provinces (See Figure 1-1). East Java Province produced more than one-third of the total production and almost doubled its growth in the last five years. This growth is likely caused by the rapid adoption of this commodity, especially by small-scale farmers in rural areas. This points to the importance of citrus for rural development, especially in the production centres in East Java Province.

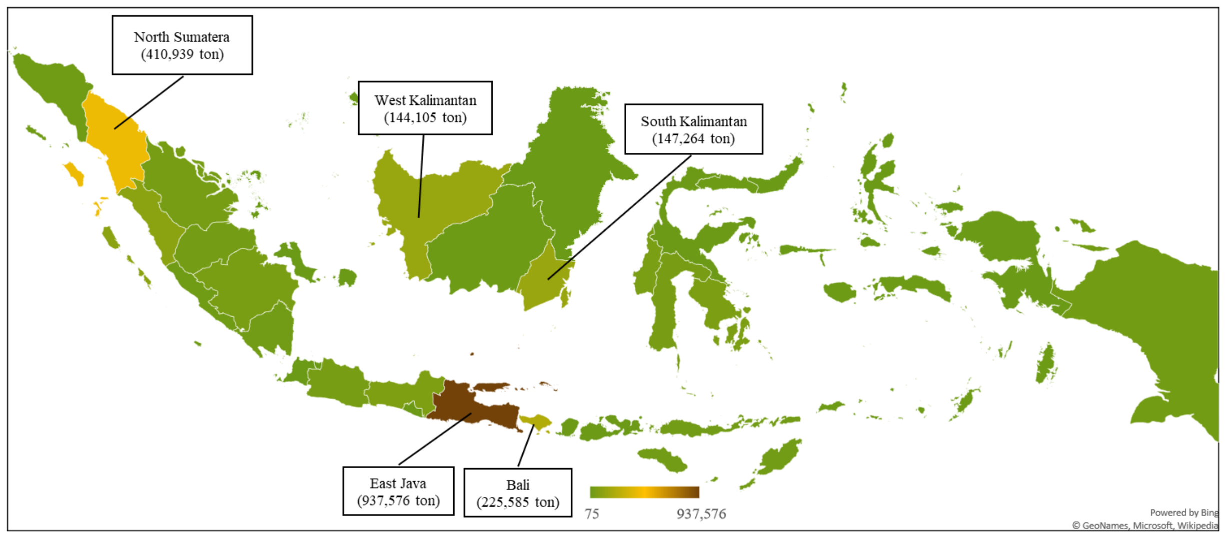

Figure 1-1. Citrus production by province in Indonesia, 2018
(Source: BPS, 2019)

Based on the agricultural census of 2013, total households (HH) that are involved in citrus farming numbered more than 554 thousand (BPS, 2013). However, the average tree ownership was relatively low, with only 129 trees or equivalent on 0.25 ha per HH. This indicates that small-scale farmers dominate citrus farming.

The consensus that small farm size is associated with low productivity (Fan and Chan-Kang, 2005), is likely relevant to citrus farming in Indonesia. The dominance of small-scale farmers seems to have a relationship with the large gap between the potential yield and farmers' actual productivity, because they mostly do not participate in the application of improved agricultural practices. In citrus farming in Indonesia, the application of integrated crop management is highly recommended, especially for five components, namely: (i) using disease-free certified seedlings; (ii) pests and disease control, especially that related to Huanglongbing disease; (iii) good orchard sanitation; (iv) optimal maintenance, such as fertilising, irrigation, etc; and (v) consolidation with other farmers (Ridwan et al., 2010; Nurhadi, 2015; Supriyanto et al., 2017). These recommendations were developed, however, as a response to Huanglongbing disease outbreaks, which caused significant losses in Indonesia's citrus industry. Nurhadi (2015) reports that this disease caused substantial damage in citrus plantations in the’80s and ’90s. For example, Huanglongbing disease caused 70 per cent of citrus trees in Bali to be eradicated.

The adoption rate of the most important improvement in technology in citrus farming— disease-free, certified citrus seedlings— is relatively low. Apart from farmers' willingness to use certified seedlings, the capacity of certified seedling producers to fulfil the demand for them is relatively low (Supriyanto et al., 2017) so that the use of uncertified seedlings is dominant in the citrus seedling market, with more than 80 per cent of the market share (Dwiastuti et al., 2019).

In regard to climate issues as the primary concern of this thesis, several studies have confirmed the effect of changes in climatic variables (rainfall, temperature, and humidity) on citrus farming (e.g. Rosenzweig et al., 1996; Sato, 2015; Simpson et al., 2015; Mesejo et al., 2016; Mufidah et al., 2016; Zouabi and Kadria, 2016). Citrus is highly dependent on water supply, so it requires accessible irrigation supplies (Zouabi and Kadria, 2016). Moreover, Lez-Altozano and Castel (1999) confirm that citrus in the flowering and fruit-set phases has a high sensitivity to water stress (causing a significant drop of reproductive organs). On the other hand, heavy and long period of rainfall can cause waterlogging, which negatively affects plant physiology and yield (Hossain et al., 2009). Citrus yield is also affected by increasing air temperature (Rosenzweig et al., 1996; Qin et al., 2016). Considering the vulnerability of citrus to pests and diseases (Berk, 2016), climatic variability might further increase susceptibility, because it could cause pests and diseases to be more destructive, unpredictable and harder to control (Muryati, 2007; Sutherst et al., 2011; Dixon, 2012). For example, Muryati (2007) finds that moth attacks increase during long rainy seasons.

1.4 Research objectives

This thesis examines climate-related risk behaviours among small-scale citrus farmers and their relationship with the adoption of certified seedlings and agrochemical inputs. The specific research objectives are to:

1. understand the extent of perceptions of risk among small-scale citrus farmers related to a range of climate change events and to identify the drivers of their risk perception at aggregated and disaggregated levels;
2. provide analytical insights into the adoption of certified citrus seedlings by small-scale farmers by analysing the extent to which they value the certification of citrus seedlings and the role of this factor in influencing the adoption of higher-yielding, climate-risk resilient and disease-free citrus varieties; and
3. explore the extent of use of chemical inputs and the role of risk preferences, intra-household dynamics and social networks on the household expenditure spent on chemical inputs.

1.5 Structure of the thesis

This thesis contains seven chapters. The analytical chapters, which address the objectives of this thesis, are presented in Chapters 4, 5 and 6. The following chapter explains the data collection methods, including questionnaire development, and sample selection process, as well as the management of data collection.

Chapter 3 presents the descriptive statistics. This chapter provides a brief overview of the socio-economic conditions of the sampled farmers. It includes household characteristics, citrus farming practices and their involvement in farmers' support systems. Given the heterogeneity between regions, the description of the characteristics are also presented using sub-samples at district levels.

Chapter 4 addresses the first research objective of this thesis. This chapter discusses farmers' risk perception of six climatic events and the drivers for these perceptions at aggregated and disaggregated levels. This chapter also attempts to understand how farmers' advisory services contribute to climate risk perception.

Chapter 5 addresses the second research objective. This chapter uses a series of experiments to measure farmers' beliefs about yield for certified and uncertified seedlings, risk and time preferences and then examines their association with farmers' choices to adopt certain types of citrus seedlings.

Chapter 6 explores the intensification of citrus farming, in terms of the pattern of chemical inputs (pesticides and fertilisers) usage. This chapter uses a spatial approach to focus on the role of individual-factors (i.e. risk preferences), dynamics in intra-household decision-making, and social-networks in influencing chemical inputs use.

Finally, Chapter 7 provides a summary and conclusion of the main findings obtained from the analytical chapters. This chapter also attempts to discuss the policy recommendations which could potentially be used by policymakers, or related industries, to design intervention program for climate-resilient citrus development.

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Chapter 2. Data collection

2.1 Introduction

This chapter presents the methods used for the development of the survey instruments, sample selection and data collection. The survey was a part of the Australian Centre for International Agricultural Research (ACIAR) 'Indohort' research project, "Improving market integration for high-value fruit and vegetable production systems in Indonesia" (AGB/2009/060).

2.2 Questionnaire development

As a part of a collaborative ACIAR research project, the survey for this study involved the University of Adelaide's Centre for Global Food and Resources, Bogor Agricultural University and the Indonesian Centre for Horticultural Research and Development (ICHORD). Hence, these three institutions actively contributed to the questionnaire development process. In the development of the questionnaire, a series of key informant interviews and focus group discussions were conducted with citrus researchers, extension workers, local government representatives, individuals from citrus nurseries, citrus traders and farmers to capture their point of view in relation to the study objectives.

Prior to the final version of the household survey, several iterations of the questionnaire were pilot tested and pre-tested to refine and nuance to the questions to ensure understanding by the male and female household head respondents. The research team tested the questionnaire draft to check the questions' flow and relevance and whether it was easy for respondents to understand. The feedback from the testing of each variable and question was used to build and refine the questionnaire. This step was repeated several times until the research team believed that the questionnaire worked well. In addition, extensive enumerator training was conducted to make sure the team clearly understood the purpose and intent of each question. During the training, the final pretesting took place.

The questionnaire had been approved and reviewed by the Low-Risk Human Research Ethics Review Group (Faculty of Arts and Faculty of the Professions, the University of Adelaide) and was deemed to meet the requirements of the National Statement on Ethical Conduct in Human Research (2007) involving no more than low risk for research participants (See Appendix 1).

The final questionnaire consisted of 12 modules (See Appendix 2 for the detailed questionnaire in Microsoft excel version), including information on spatial-administrative and geographical location such as respondents' addresses and GPS coordinates (latitude and longitude). The first module was household characteristics, used to collect general information on the household members. It included household composition, age, education levels, gender, and the main activities of household members. This study defined the household as a group of people who lived and ate together most of the time; each member recorded in the survey must have lived with the others for at least 6 months of the year. Furthermore, the head of the household was defined as the member who makes most of the economic decisions within the household.

The second module was on housing and assets. This collected information about current household and agricultural assets. It included information about communication technology-related equipment such as mobile phone, internet access and computers/laptops/tablets. This module also covered information about the source of drinking water, type of lighting, fuel for cooking and the main type of toilet used by the household as indicators of the household wealth.

Land tenure was captured in a different module from the asset module and collected information about the land owned, bought and sold in the 12 months prior to the survey. The questions covered land tenure arrangements, legal status of land ownership, irrigation support, soil type, access to the plot, the main crop grown and climate shocks (drought, flood and destructive winds) at the plot in the last five years.

The citrus plot module collected information about citrus production, seedling and cultivar choices. Citrus production in each plot was recorded for the 12 months prior to the survey. Regarding seedling choices, the questions covered farmers' reasons for choosing a certain type of seedling, procurement methods and sources, and seedling quality. This module also explored information about tree tenure (renting in or renting out), which differs in relation to with land tenure.

The citrus plots with the largest number of trees and the oldest and most productive ones were selected for the questions about input and labour use. The details of the inputs applied to the plot were recorded, including volume and value for each input type. However, if the farmer found it too challenging to specify the types and quantity of the inputs, such as pesticides, only information about the cost of the total inputs was recorded. This module also explored the labour used in the selected plot, including intra-household and hired labour for each activity in citrus farming.

The citrus marketing module gathered information about the marketing system of citrus products. It covered buyers, payment methods, and marketing arrangements in the 12 months before the survey conducted. This module also explored farmers' perceptions about the importance of citrus buyers' characteristics.

The social capital and accessibility module covered information about farmers' support systems in citrus farming, such as farmers' groups and cooperative membership, and use of extension and training services including those that related to climate change. The questions in this module also gathered information about farmer's access to citrus credit and insurance and whether the farmer had a connection to government authorities, such as extension workers, local agricultural departmental staff, or researchers, to seek information related to citrus production. In the next module, data on the main information source used in the last five years on citrus production methods, citrus prices and markets, and climate and weather were gathered.

Information about household income was collected using an income module. Fifteen categories of potential sources of household income were used to record the gross revenues and the business-related expenses of the last 12 months. Data on the relative importance of each income source over the past five years were also gathered.

Intra-household dynamics in the decision-making process were captured in the decision module. This module was designed to collect the information from husband and wife within the farm household about their involvement and responsibility in a series of citrus farming activities. In the data collection process, this module was asked of the husband and wife separately, so that they could not influence each other's answers.

Turning to the climate change module, this was designed to capture citrus farmers' knowledge, perception and adaptation strategies regarding climate change. The perception and adaptation strategies questions were specific to citrus farming. The knowledge and perception questions were also asked of the husband and wife separately.

Lastly, the experiments module gathered information about farmers risk and time preferences by using standard experimental procedures (See Appendix 3 for the detailed procedure). In this module, the experiments to measure subjective beliefs about the yield of certified and uncertified citrus seedlings were undertaken. The experiments used boards as visual aids to help the enumerators and respondents more easily understand the context of the games. Also, the experiments targeted the husband and wife within the household.

2.3 Sample selection

This citrus household survey used the Indonesian Statistic Agency (BPS) criteria of a citrus farmer, defined as a household which manages a minimum of 25 citrus trees (BPS, 2015). If a farmer owned more than 25 trees, but rented them out to others, the household was excluded from the sample. The total sample included in the survey was 500 citrus farmer households.

The sample selection was designed from scratch using a multistage random sampling process. East Java province was selected because in 2016 it was the largest citrus-producing province in Indonesia (MoA, 2016). Also, this province showed a high expansion of this crop in its rural areas so it might be important for rural development. Three districts— Banyuwangi, Jember and Malang districts—were purposely selected based on their number of citrus farming households and their rapid expansion of citrus farming. Further observation during the scoping study showed that these districts vary in terms of citrus farming methods, agro-ecosystems, socio-cultural factors, and infrastructure.

The selection of sub-districts to sample was based on the total citrus production in the selected district, where five per cent was used as a threshold. Nine sub-districts were chosen in Banyuwangi: Bangorejo; Purwoharjo; Tegaldlimo; Cluring; Pesanggaran; Siliragung, Gambiran; Tegalsari; and Muncar Sub Districts. Four sub-districts were chosen in Jember: Umbulsari; Semboro; Sumberbaru; and Jombang Sub Districts and two sub-districts in Malang: Dau and Poncokusumo Sub Districts.

Considering their heterogeneity in relation to agro-ecosystems, socio-cultural factors, and infrastructure, similar-sized samples were taken from each district: 168 households in Banyuwangi, 166 households in Jember and 166 households in Malang. An even number of 14 villages was randomly drawn from each district and they represented all pre-selected sub-districts within each district. At first, in each district, these 14 villages were distributed evenly to fit the number of pre-selected sub-districts. If, however, there were leftovers, the remaining villages were assigned to sub-districts with larger production levels (Appendix 4). At the household level, within each village, a population list of citrus farmers was collected from and verified by local village authorities. From this population, 12 citrus farmers were randomly selected from each village.

2.4 Data collection and management

The final questionnaire was constructed using a Commcare application; a platform for electronic mobile data collection. This application allowed us to collect and track the data over time so that the data cleaning could be done from the beginning of data collection, while also providing flexibility for offline data collection (Dimagi, 2020). Thus, the data collection process used paperless tablet instruments. All instruments for data collection used Bahasa Indonesia.

Data collection was conducted from September - October 2017, included13 professional enumerators and three senior enumerators responsible for supervision. All the enumerators had extensive field survey experience, including with mobile-electronic based questionnaires. The enumerators interviewed the selected samples in the farmer’s house or their farm’s field. The enumerator might visit two or three times, depending on the farmer and the spouse’s availability.

Data collected from each respondent had to be checked by the field supervisor and uploaded to the server on a daily basis. The research team could verify the uploaded data and confirm any data needing clarification with the enumerator. If the research team needed further information, the enumerators had to follow-up with the respondent. The specific method used for data analysis is explained in each analytical chapter.

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Chapter 3. Descriptive statistics

3.1 Introduction

This chapter describes the characteristics of the sampled citrus farmer's households (HH) to provide an overview of farmers' socio-economic conditions. This section also presents information on the use of agro-chemical inputs, labour force input and marketing methods to obtain a broader picture of the level of the citrus farming systems employed by the respondents. In order to capture the geographical variation, the analysis is broken down into district levels because the geographical context could influence spatially-based differences in agricultural environments, infrastructure readiness, accessibility to supporting systems, and other factors which lead to differences in farming behaviour (see. Lee et al., 2015; Abid et al., 2016). This study includes the heads of HHs and spouses' characteristics as 'the head of household representative' since many decisions in rural agricultural HHs arise from discussion between family members, especially the 'household heads', which typically refers to a husband and wife pair (e.g. Adesina et al., 2000; Fisher and Kandiwa, 2014; Anderson et al., 2017).

3.2 Household characteristics

There are an enormous number of studies regarding the importance of HH characteristics on smallholders' farming behaviours, such as age, education, gender, farming experience, household labour, income and other factors (e.g. Wollni and Zeller, 2007; Deressa et al., 2009; Läpple and Rensburg, 2011; Rao et al., 2012; Abebaw and Haile, 2013; Grabowski et al., 2016). Table 3-1 presents the citrus farmers HH descriptive statistics derived from the survey sample.

Male HH heads dominated our sample; only 2.6% of them were female. Our respondents had a wide age range; from 28 to 87 years old, with an average of 53 years. The average age was higher in Banyuwangi than in Jember and Malang; 54.3, 53.3 and 52.5 years old, respectively. Spouses were typically younger than the male household heads, the average being 46.5 years old. In Banyuwangi, the average age of spouses was 47.5 years, while it was 47.0 years in Jember and 44.8 in Malang. However, the age of farmers did not align with their experience in citrus farming. The age of the head of HH was slightly different between districts, but the HH head's experience in citrus farming in Jember was the highest with an average 19.6 years, followed by Banyuwangi (14.1 years) and Malang (11.3 years). Interestingly, even though Malang is well known as a citrus producer in the past couple of decades, farmers in this district had the lowest levels of experience. This is probably due to many of our sample, in one of the subdistricts in Malang (Poncokusumo), having only started to plant citrus in the last couple of years.

Regarding formal education completed, the male head of HHs seemed less highly educated than their spouses; 7.55 years for the head of the HH and 7.64 years for their spouses. The education level in Banyuwangi and Jember was higher than the average; 7.82 and 8.10 years for the heads of the HH, and 8.02 and 8.12 for the spouses, respectively. In Malang, the education level was the lowest, with only 6.73 years for the head of the HH and 6.79 for spouses.

The mean HH size was less than four persons, whereas in Malang it was more than four persons. This HH size is in line with the number of HH members who are involved in citrus farming, which involves an average of two persons (in Malang it was more than two persons), indicating that it is mainly the HH head and spouse who participate in citrus farming. This finding is also supported by the fact that the mean of the age and education of HH members who are involved in citrus farming was 47.86 years of age and with 7.97 years of education, which aligns very closely with the HH head and spouses' characteristics. Since the survey data were obtained in Java, the majority of the HH heads and spouses are Javanese, with the exception being in Jember where 15 per cent of the HH heads and spouses are Maduranese.

Table 3-1. Household characteristics

No	Variables	Overall	Banyuwangi	Jember	Malang
1	Age of the head of household (years)	53.35	54.27	53.30	52.48
2	Age of the spouse (years)	46.53	47.51	46.98	44.83
3	Experience in citrus farming of the head of HH (years)	15.01	14.09	19.60	11.35
4	Formal education completed by the head of HH (years)	7.55	7.82	8.10	6.73
5	Formal education completed by the spouse (years)	7.64	8.02	8.12	6.79
6	Percentage of Heads of HH involved in citrus farming	0.97	0.99	0.99	0.94
7	Percentage of spouses involved in citrus farming	0.73	0.74	0.70	0.75
8	Household size (persons)	3.87	3.63	3.81	4.17
9	Household size involved in citrus farming (persons)	2.01	1.98	1.92	2.14
10	Average age of HH members involved in citrus farming	47.86	49.05	49.11	45.40
11	Average education of HH members involved in citrus farming	7.97	8.20	8.46	7.24
12	Percentage of ethnicity of the heads of HH				
	– Javanese	94.60%	99.40%	84.94%	99.40%
	– Maduranese	5.20%	-	15.06%	0.60%
	– Osing	0.20%	0.60%	-	-
	– Others	-	-	-	-
13	Percentage ethnicity of spouses (percent)				
	– Javanese	93.64%	100.00%	82.24%	98.70%
	– Maduranese	5.48%	-	15.79%	0.65%
	– Osing	-	-	-	-
	– Others	0.88%	-	1.97%	0.65%

Table 3-2 presents citrus farmers’ agricultural assets. Our respondents reported that the average area of agricultural land owned and managed was 1.08 hectares. This size of land ownership is much higher than for the majority of farmers in East Java, especially in Jember and Malang. Based on the 2013 agricultural census data, 76 per cent of farmers in these areas owned less than 0.5 ha land (BPS, 2013b). This study defined a citrus farmer as a household which owned and managed a minimum of 25 citrus trees, the minimum number of citrus trees owned was 47, the maximum was 4500, and the average was 393 trees. The average ownership in Malang was the highest among the 3 districts (428 trees), followed by Jember (398 trees) and Banyuwangi (353 trees). However, this ownership is still higher than the census data available for these regions, which indicate an average of 307 trees (BPS, 2013a).

The housing area of our sample was relatively large, with an average of 600 m^2, including the home yard. The average area in Malang contrasted very strongly with two other districts where the area was less than half than that of Banyuwangi and Jember, at only 342.14

m^2. However, based on the owners' valuations, the value of the houses in Malang, including the yard, was the highest of the three districts. This might be due to the sample in Malang being primarily located in the countryside and an agrotourism area.

Table 3-2. Household assets

No	Variables	Overall	Banyuwangi	Jember	Malang
1	Agricultural land (hectares)	1.08	0.72	1.20	1.31
2	Average citrus ownership (trees)	393.62	353.74	398.92	428.69
3	Housing area including home yard (m2)	600.06	709.67	747.04	342.14
4	Self-estimated housing value (million IDR)	343.03	293.47	309.04	425.97
5	Percentage of HH which own a bicycle	65.60%	72.62%	85.54%	38.55%
6	Percentage of HH which own a motor cycle	96.60%	95.83%	96.99%	96.99%
7	Percentage of HH which own a car	24.80%	20.24%	24.10%	30.12%
8	Percentage of HH which own a generator	10.00%	6.55%	15.06%	8.43%
9	Percentage of HH which own a water pump	30.20%	33.93%	45.18%	11.45%
10	Percentage of HH which own a manual sprayer	75.20%	69.05%	75.90%	80.72%
11	Percentage of HH which own a power sprayer	61.80%	78.57%	45.78%	60.84%
12	Percentage of HH which own cattle	22.00%	10.71%	13.86%	41.57%
13	Percentage of HH which own a goat	19.20%	26.19%	13.25%	18.07%
14	Percentage of HH which own poultry	61.20%	58.33%	59.64%	65.66%
15	Percentage of HH which own a mobile phone	94.00%	94.05%	96.39%	91.57%
16	Percentage of HH which had internet access	64.80%	60.71%	63.86%	69.88%
17	Percentage of HH which own a computer/laptop	23.60%	23.21%	23.49%	24.10%

Regarding the ownership of mode of transportation, farmers in Malang had the lowest level of bicycle ownership, but the highest car ownership. The ownership of motorcycles was very similar among the three districts, with an average of 96.6 per cent of households owning motorcycles in all three districts. The high level of motorcycle ownership was probably due to the popularity of this vehicle in Indonesia. Previous research shows that Indonesia is the third-largest user of motorcycles in the world after China and India (Pinch and Reimer, 2012; Susilo et al., 2015).

Water pumps and generators are important tools used by farmers to water their citrus farms during the dry season. The level of generator ownership was 10 per cent. About 15 per cent of the citrus farmers in Jember used a generator and less than 10 per cent did in Banyuwangi and Malang. In relation to water pumps, about 30 per cent of all respondents owned water pumps, whereas 33.93 per cent did in Banyuwangi, 45.18 per cent in Jember, while only 11.45 per cent owned pumps in Malang. Our fieldwork revealed that it was common for farmers to rent a generator to water their farm in dry seasons. Moreover, the relatively high level of ownership of these two types of equipment in Jember implies that this region probably had lower irrigation infrastructure support or that farmers might face more issues regarding water availability during the dry season.

Since sprayers (manual and powered) are the most important equipment for pest and disease control, the majority of farmers owned this equipment, with averages of 75.20 and 61.80 per cent, respectively. In relation to power sprayers, farmers could also rent this equipment or use the sprayer service available in their village.

Livestock has been an integral part of the farming system in Indonesia, especially in Java. Mixed farming, with integration of crops and animals, is acknowledged to provide a better livelihood for small-scale farmers (Paris, 2002; Priyanti et al., 2015). Another important benefit from the crop-animal farming system is the generation of high-quality manure—compost from the livestock is an important aid in the crop production system (Tanner et al., 2001; Thorne and Tanner, 2002).

Many respondents reported that they used a large amount of manure for citrus farming and that ownership of livestock plays an important role in supporting the availability of manure. Twenty-two per cent of our sample reported that they have cattle or buffalo, but this reaches more than 41 per cent in Malang. Farmers in Banyuwangi likely preferred medium-sized ruminants, such as goat or sheep, in preference to cattle or buffalo. This district had the highest proportion of goat/sheep ownership (26.19 per cent), but the lowest ownership of cattle/buffalo (10.71 per cent). In relation to poultry, the majority of the farmers in the 3 districts owned this livestock, with an average of 61.20 per cent of households owning poultry.

3.3 Farmers' livelihoods

Citrus is one of the high-value horticultural commodities (Naidoo and Iwamura, 2007) and has been an important source of farmers' livelihoods in East Java Province, especially in Banyuwangi, Jember and Malang, which are citrus production centres. This is reflected in the proportion of household income generated by citrus farming, as presented in Table 3-3. The average citrus income was IDR 17.26 million[2] and was relatively similar among the three districts.

Table 3-3. Income sources and main activities

No	Variables	Overall	Banyuwangi	Jember	Malang
1	Income from citrus farming (million IDR/year)	17.26	18.34	16.98	16.45
2	Share of citrus in HH income (per cent)	25.77%	30.39%	30.66%	16.20%
3	Income from agricultural activities (million IDR/year)	34.30	31.55	27.55	43.82
4	Income from non-agricultural activities (million IDR/year)	28.86	22.23	32.62	31.81
5	Total income (million IDR/year)	63.16	53.78	60.17	75.63
6	Share of agricultural related activities for HH income (per cent)	60.49%	62.12%	57.28%	62.06%
7	Percentage of the main activity of the head of HH				
	Farmer	76.20%	81.55%	74.70%	72.29%
	Government officer (icl. Military/Police/Pensioner, etc.)	2.60%	3.57%	1.20%	3.01%
	Professional worker (Non-government)	0.60%	-	0.60%	1.20%
	Self-employed trader	5.60%	4.17%	8.43%	4.22%
	Self-employed-other	2.40%	0.60%	2.41%	4.22%
	Agricultural wage labour	4.40%	4.76%	4.82%	3.61%
	Other wage labour	6.20%	3.57%	7.23%	7.83%
	Unpaid housework	0.40%	-	-	1.20%
	Others	-	-	-	-
	None	1.60%	1.79%	0.60%	2.41%
8	Percentage of the main activity of spouse				
	Farmer	35.16%	42.67%	24.34%	38.56%
	Government officer (icl. Military/Police/Pensioner, etc.)	0.66%	1.33%	0.66%	-
	Professional worker (Non-government)	1.98%	2.00%	2.63%	1.31%
	Self-employed trader	15.82%	16.67%	17.11%	13.73%
	Self-employed-other	2.20%	0.67%	3.95%	1.96%
	Agricultural wage labour	2.42%	1.33%	1.97%	3.92%
	Other wage labour	3.52%	4.00%	1.32%	5.23%
	Unpaid housework	37.58%	30.67%	48.03%	33.99%
	Others	0.22%	-	-	1.30%
	None	0.44%	0.67%	-	-

[2] As a comparison, the average of exchange rate during the survey (September – October 2017) was IDR 13,422.87 per USD (Data from Bank Indonesia)

Total income obtained from agricultural activities and agricultural related activities (i.e. agricultural product trading) for farmers in Malang was much higher than for the other two districts. On the other hand, Banyuwangi had the lowest income from non-agricultural activities compared with two other districts; only IDR 22.23 million a year. Thus, the yearly income of our respondents in Banyuwangi was the lowest, followed by Jember and Malang, with IDR 53.78, 60.17 and 75.63 million, respectively. While income from citrus differs only slightly between the three districts, the share of citrus related income in Malang is the lowest (16.20 per cent). In Banyuwangi and Jember, the income generated by citrus farming was more important for the HH income (30.39 and 30.66 per cent, respectively). The average share of income from agricultural related activities to the HH income was more than double the share of citrus income, implying that our respondents did not only focus on citrus farming but had a diversified HH income portfolio.

The large share of agricultural related activities in HH income is also reflected by the main activity of the head of HH and spouse (Table 3-3). More than three-quarters of the HHs and one-third of the spouse's main activity was as a farmer. Also, more than one-third of the spouses also reported that their main activity was unpaid housework. This was more prevalent in Jember, where it reached 48.03 per cent.

3.4 Citrus farming practices

3.4.1 Citrus cultivars and seedlings

Ladaniya (2008) states that there are at least 15 citrus cultivars that are commercially produced for the fresh fruit market. In Indonesia, Mandarin (locally known as Siam) dominates national production (Ladaniya, 2008; Hassan et al., 2014), followed by the Tangerine cultivar (locally known as Keprok) (Morey, 2007; Pusdatin, 2015). This is reflected by the majority of our sample (72.62 per cent) which plant Siam, while only 16.40 and 9.22 per cent grow Keprok and

Sweet Orange, respectively (Table 3-4). However, the composition differed between the three districts. In Malang, which is located in a highland area, only 42 per cent of the farmers grew Siam, more than 36 per cent grew Keprok and almost 20 per cent planted Sweet Orange. However, in Banyuwangi and Jember where citrus is mostly planted in areas of low-lying land, the Siam cultivar was dominant, with 92.43 and 83.03 per cent, respectively.

Table 3-4. Citrus cultivar and seedling use

No	Variables	Overall	Banyuwangi	Jember	Malang
1	Percentage of plots that plant Siam cultivar	72.62%	92.43%	83.03%	42.16%
2	Percentage of plots that plant Keprok cultivar	16.40%	1.33%	11.71%	36.34%
3	Percentage of plots that plant Sweet orange cultivar	9.22%	3.77%	4.06%	19.90%
4	Percentage of HHs that use certified seedlings	24.60%	13.10%	7.23%	53.61%
5	Certified seedlings at plot level (1 if yes)	18.79%	7.45%	6.46%	45.51%
6	Percentage of HHs which plan to use certified seedlings in the next planting period	41.80%	42.26%	36.75%	46.39%
7	The reasons for using certified seedlings				
	- Availability	15.22%	12.50%	4.35%	17.52%
	- Cheapest price	11.41%	-	13.04%	13.14%
	- Easy to access	9.24%	4.17%	-	11.68%
	- Better performance	66.30%	83.33%	60.87%	64.23%
	- Following other farmers	16.85%	4.17%	21.74%	18.25%
	- Longer production period	8.15%	16.67%	21.74%	4.38%
	- Adaptive to climate situation	2.17%	8.33%	0.00%	1.46%
8	The reason for using uncertified seedlings				
	- Availability	40.00%	34.23%	43.24%	43.90%
	- Cheapest price	39.75%	47.32%	41.14%	23.17%
	- Easy to access	36.23%	40.94%	40.24%	19.51%
	- Better performance	18.49%	23.15%	18.02%	10.98%
	- Following other farmers	21.01%	20.13%	21.32%	21.95%
	- Longer production period	0.63%	1.01%	0.30%	0.61%
	- Adaptive to climate situation	2.89%	2.01%	3.60%	3.05%
9	Source of certified seedlings				
	- Seedling producer	20.11%	20.83%	4.35%	22.63%
	- Seedling big trader	21.74%	70.83%	73.91%	4.38%
	- Seedling retailer	-	-	-	-
	- Local market	0.54%	-	4.35%	-
	- Government assistant	25.54%	-	4.35%	33.58%
	- Research institute	30.98%	4.17%	13.04%	38.69%
	- Own production	-	-	-	-
	- Other farmers	1.09%	4.17%	-	0.73%
10	Source of uncertified seedlings				
	- Seedling producer	29.69%	18.46%	32.73%	43.90%
	- Seedling big trader	52.20%	71.48%	41.44%	39.02%
	- Seedling retailer	3.14%	0.67%	5.11%	3.66%
	- Local market	9.18%	8.72%	14.11%	-
	- Government assistant	0.00%	-	-	-
	- Research institute	0.38%	-	-	1.83%
	- Own production	0.25%	-	0.60%	-
	- Other farmers	3.52%	0.34%	2.40%	11.59%
	- Other sources	1.64%	0.34%	3.60%	-

The use of certified seedlings is one the most important issues in Indonesia's citrus development (Ridwan et al., 2008; Ridwan et al., 2010; Nurhadi, 2015; Supriyanto et al., 2017). The adoption of these types of seedlings is a vital component of citrus as an agribusiness because high-quality seedlings, which are free from systemic disease, have varieties with high purity levels, have high yield and high quality and have a long production period (Ridwan et al., 2008). However, less than a quarter of our sample used certified seedlings and only 18.79 per cent of the citrus plots were planted with these kinds of seedlings in plot levels.

Jember had the lowest adoption rate; only 7.23 per cent. By contrast, more than half of the citrus farmers in Malang adopted these types of seedlings. This high adoption rate might be influenced by support from the citrus research institute located in this region. Even though farmers had a meagre adoption rate, more than 40 per cent of them reported that they would use certified seedlings in the next planting period. Farmer's main reason for using certified seedlings was the better performance of the citrus plants generated by these seedlings, including their higher yield and quality. Farmers obtained these seedlings mainly from research institutes, through government assistance, or from seedling producers and traders. It implies that the use of certified seedlings still depends on government support. On the other hand, the reasons for farmers' using uncertified seedlings are mostly related to lower price, more accessibility and consistent availability. Producers and traders of uncertified seedlings emphasized these three factors to encourage farmers to use these types of seedlings.

3.4.2 Input use

Citrus farmers in East Java were likely to utilize an intensive farming system, indicated by the application of fertilisers and pesticides, as shown in Table 3-5. Of 500 respondents, only three reported not using a chemical fertiliser; one farmer in Jember and two in Malang. The main type of chemical fertilisers used by farmers were NPK Phonska (79 per cent), ZA (74.20 per cent), Urea (55.80 per cent), SP-36 (53.20 per cent), and NPK Mutiara (46.40 per cent). However, the use of these types varied among the districts. For example, Urea was less popular in Malang, with only 27 per cent of the farmers using this fertiliser. In relation to NPK fertiliser, NPK Mutiara was more popular in Malang, while NPK Phonska was preferred in Banyuwangi and Jember.

Table 3-5. The using of fertiliser and pesticide in the main citrus plot

No	Variables	Overall	Banyuwangi	Jember	Malang
1	Used at least one chemical fertiliser	99.40%	100%	99.40%	98.80%
2	Used Urea	55.80%	69.05%	71.08%	27.11%
3	Used SP-36	53.20%	66.07%	41.57%	51.81%
4	Used ZA	74.20%	66.07%	87.95%	68.67%
5	Used ZK	2.40%	0.00%	1.81%	5.42%
6	Used NPK Mutiara	46.40%	45.24%	34.34%	59.64%
7	Used NPK	2.80%	0.60%	3.61%	4.22%
8	Used NPK Phonska	79.00%	89.29%	84.94%	62.65%
9	Used KCl	7.40%	10.12%	7.23%	4.82%
10	Used organic fertiliser/manure	41.60%	16.07%	14.46%	94.58%
11	Used liquid fertiliser	6.00%	6.55%	8.43%	3.01%
12	Used leaves fertiliser	54.20%	67.26%	57.23%	37.95%
13	Used branded organic fertiliser	37.00%	35.71%	58.43%	16.87%
14	Used flowering hormone	33.80%	35.71%	45.78%	19.88%
15	Used chemical pesticide	98.00%	100.00%	97.59%	96.39%
16	Used bio pesticide	1.80%	0.00%	0.60%	4.82%
17	Used fungicide	67.40%	76.19%	71.08%	54.82%
18	Used herbicide	47.20%	62.50%	63.25%	15.66%
19	Used flower adhesive	27.60%	22.62%	29.52%	30.72%
20	Used yellow trap	4.60%	3.57%	1.81%	8.43%
21	Paid for irrigation	55.60%	81.55%	59.04%	25.90%
22	Chemical pesticides expenses per tree (IDR/yr)	9,688.89	6,443.48	7,740.94	14,921.35
23	Plant protection expenses per tree (IDR/yr)	12,961.70	9,651.63	10,823.14	18,450.22
24	Organic fertilisers expenses per tree (IDR/yr)	3,076.22	1,985.37	1,646.62	5,609.81
25	Chemical fertilisers expense per tree (IDR/yr)	15,811.03	17,703.31	18,335.50	11,371.49
26	Total input cost per tree (IDR/yr)	37,893.60	36,047.71	36,918.53	40,736.81

Overall, more than 40 per cent of farmers reported that they used organic/manure fertiliser. However, the application of this fertiliser was dominated by farmers in Malang with 95 per cent use it, while it was used by only about 15 per cent in Banyuwangi and Jember. Interestingly, there was a tendency for farmers in Banyuwangi and Jember to use branded organic fertilisers, which are not as popular in Malang. A similar pattern was also shown by the use of leaves fertiliser and flowering hormone. As a consequence, the total expenses for fertiliser use in Banyuwangi and Jember was much higher than that in Malang, implying that fertiliser use in these two districts was more intensive (see Table 3-5). On the other hand, the high rate of organic fertiliser used by farmers in Malang may reduce their fertiliser costs.

Whilst farmers in Banyuwangi and Jember districts were much more intensive in their use of fertiliser, farmers in Malang were more intensive in their application of pesticides. Total expenses for plant protection (including insecticides, herbicides, fungicides and biopesticides) in Malang reached IDR 18,450 per tree. This amount was almost double that of farmer's plant protection expenses in Banyuwangi and Jember. However, only 15 per cent of the farmers used herbicides in Malang, which was much lower than Banyuwangi and Jember, where it reached 62.50 and 63.25 per cent, respectively.

Citrus is a crop which is highly dependent on water supply, it needs accessible irrigation to optimise yields, especially during dry seasons (Lez-Altozano and Castel, 1999; Zouabi and Kadria, 2016). The importance of irrigation supply is indicated by the finding that more than half of our respondents reported paying for irrigation. However, only a quarter of our sample reported paying for irrigation in Malang, while it was almost 60 per cent in Jember, and more than 80 per cent in Banyuwangi. The fact that farmers are willing to pay for irrigation services shows their awareness of the importance of irrigation supports in order to adapt to climatic situations.

3.4.3 Labour

Overall, the head of the household dominated labour on citrus farms (Table 3-6). Their spouses contributed only one-third of the head of HH participation levels. In Jember, the involvement of spouses was very low, only averaging 40 days a year. Farmers in Malang obtained more support from other HH members, reaching 53 days a year on average. Citrus farmers in Malang were also more intensive in their use of labour, using both internal HH labour and hired (fixed and daily) labour. The use of hired labour in Malang was relatively higher than other districts, especially for fixed labour and female hired labour. This might be one of the consequences of the low-rate of Malang's application of herbicides for weed management (only 15 per cent), entailing greater use of manual weeding, which is labour intensive.

Table 3-6. The use of labour in the main citrus plot

No	Variables	Overall	Banyuwangi	Jember	Malang
1	Head of household's work in the plot (days/yr)	179.43	176.69	168.80	192.83
2	Spouse's work in the plot (days/yr)	55.99	60.72	39.28	67.95
3	Other HH members (>18syr) work in the plot days/yr)	31.14	21.86	18.21	53.46
4	Used fixed labour in the plot	11.40%	2.98%	9.64%	21.69%
5	Total fixed labour per tree (day)	0.10	0.01	0.08	0.21
6	Total paid male labour in the plot (day)	13.66	6.24	17.77	17.08
7	Total paid male labour per tree (day)	0.06	0.03	0.09	0.07
8	Total paid female labour in the plot (day)	2.66	0.10	0.25	7.65
9	Total paid female labour per tree (day)	0.01	0.00	0.00	0.02
10	Total children labour in the plot (day)	0.35	0.14	0.64	0.26
11	Total children labour per tree (day)	0.00	0.00	0.01	0.00

3.4.4 Marketing

In contexts where farmers can use more than one method, citrus farmers used various marketing methods to sell their products. Firstly, farmers harvested the fruit on their own, or by using hired labour, and then sold it to traders. Almost 15 per cent of our respondents used this method. However, farmers in Malang seemed to prefer to use this method more than farmers in other districts (Table 3-7). With this method, farmers can decide the criteria of the fruit to be harvested, such as size and maturity, and supervise the harvesting process to ensure proper care of trees by labour. However, the availability of harvest labour seems likely to become a precondition for farmers to use this method; farmers in Malang have more fixed and hired labour (Table 3-6). Moreover, farmers using this method could face difficulty in finding buyers who offer a competitive price, especially if the volume for sale is too small. Farmers used this method mainly because they have a small harvest, such as occurs in the early stage of the harvesting period, or it is used by big farmers who have fixed labour on in their farms.

A second method involves traders harvesting the citrus fruit and paying the farmers based on the volume harvested (the local term for this method is "*kilo*"). This was the dominant marketing method in Banyuwangi and Jember (with 85.12 and 83.13 per cent, respectively), while only about one-third of Malang's farmers used this approach. With this method, the harvesting process was done by the trader's workers and using the trader's criteria for the harvested fruit. Some farmers reported that the trader's workers did not take care of the trees during the harvesting process and often wasted too much fruit.

Table 3-7. The marketing method used by the citrus farmers

No	Variables	Overall	Banyuwangi	Jember	Malang
1	Self-harvesting	14.20%	8.33%	10.24%	24.10%
2	Harvested by traders and sold by volume (kilo)	69.00%	85.12%	83.13%	38.55%
3	Tebas	5.40%	3.57%	8.43%	4.22%
4	Renting out	9.40%	13.10%	12.05%	3.01%
5	No harvest	16.80%	7.14%	6.63%	36.75%
6	Combination 1 + 2	3.00%	1.79%	4.22%	3.01%
7	Combination 1 + 3	1.20%	1.19%	1.81%	0.60%
8	Combination 1 + 4	1.00%	1.79%	-	1.20%
9	Combination 2 + 3	1.80%	1.19%	4.22%	-
10	Combination 2 + 4	7.40%	11.31%	10.84%	-
11	Combination 3 + 4	0.80%	1.19%	1.20%	-
12	Combination 1 + 2 + 3	0.60%	-	1.81%	-
13	Combination 1 + 2 + 4	10.80%	13.10%	15.06%	4.22%
14	Combination 1 + 3 + 4	0.20%	0.60%	-	-
15	Combination 2 + 3 + 4	0.20%	-	0.60%	-

A third method was *tebas*, where farmers sell the fruit to traders during the early stage of the fruit's development. The traders and farmers negotiate the price based on their calculation of the possible volume of the fruits. However, this method seems to put farmers in a weaker position. Most farmers reported that they had stopped using this method and only about 5 per cent of our respondents still used it. This method was more popular in Jember; twice as many used using this method compared with farmers in the other districts.

A final method was renting out the citrus plot to traders for a certain period, usually for a minimum of five years. Farmers used this method for many reasons, but mainly because they needed a large amount of money instantly, for example, to build or renovate their houses. Farmers and traders mostly had a contractual agreement that explained the terms and conditions, such as price, contract period, rights and obligations[3]. During the contract period, traders had responsibility for all aspects of farm management and farmers do not have access to their farm. In this method, farmers reported that traders tended to boost citrus production during the contract period by applying “super-intensive” farming[4]. Table 3-7 shows that this method was more popular for farmers in Banyuwangi and Jember. Suryanata (1994) found that this practice was begun in the early 1980s on apple farms in the highland of East Java, where the typical arrangement mainly involved capital-rich farmers renting trees from capital-poor landowning farmers.

It was also common for farmers to combine their marketing methods, both at household and/or plot levels. At household level, farmers could rent out a citrus plot and manage the other plots for their monthly income, using other marketing methods. At plot level, a combination of marketing methods was possible for different harvesting periods. As shown in Table 3-7, the combination of self-harvest, *kilo* and renting-out (combination 1 + 2 + 4) was the most popular, especially in Jember and Banyuwangi where more than 13 per cent of farmers in Banyuwangi, and 15 per cent in Jember used this combination. The combination of *kilo* and renting out

[3] In order to legalise the position of the contract, farmers and traders sometimes use Notary Public services.
[4] Farmers in Banyuwangi and Jember reported that renters tended to use more than the normal dosage of fertilisers and pesticides in the citrus farms during the contract to boost the yield. By the end of the contract, the citrus trees were damaged, so that farmers were faced with replanting.

(combination 2 + 4) was also popular in these districts, with 11.31 and 10.84 per cent, respectively.

3.5 Farmer support systems

Small-scale farmers in developing countries are usually highly dependent on government assistance for agricultural development, through means such as subsidies, extension and institutional support, and infrastructure development. However, the Indonesian government still focuses on food crops (Simatupang and Timmer, 2008) and the attention and support for citrus development is relatively low. It is indicated by the low proportion (only 5.6 per cent) of citrus farmers who obtained citrus training in the five years prior to the survey.

In Banyuwangi, less than 2 per cent of citrus farmers obtained this training. The involvement of farmers in citrus extension activities was also very low, with only 21.20 per cent being involved. In Malang, the involvement was much higher (27 per cent), but in Banyuwangi it was only 15 per cent (see Table 3-8). On the other hand, three-fourths of the respondents used other farmers, or their neighbouring farmers (farmer-to-farmer extension), as their main source of information on citrus technology, while only 6 per cent of them obtained information on citrus technology from government officers, such as extension workers or researchers. Since citrus extension and training is very important in improving farmer's knowledge and capacity, especially that related to the recent citrus technology innovation, the formal support systems for citrus farmers need to be enhanced.

As an agricultural crop, citrus is very sensitive to climatic/weather condition, so climate change will affect citrus farming. Thus, it is important to increase farmers' knowledge about climate change issues in order to improve their resilience, capacity and capability to adapt to climate change. However, our survey showed that only 5 per cent of the respondents had been involved in a climate extension and/or training program in the 10 years prior to the survey. It was only 3.57 per cent in Banyuwangi, 4.22 per cent in Jember and 8.43 per cent in Malang (Table 3-8). This indicates that participation in climate-related campaigns in agriculture was still very low. However, citrus farmers reported that more than 60 per cent of farmers did not use any source to update their uptake of climate information.

Table 3-8. Extension system and information sources

No	Variables	Overall	Banyuwangi	Jember	Malang
1	Percentage of HH which obtained citrus training in the last 5 years	5.60%	1.79%	4.82%	10.24%
2	Percentage of HH which obtained citrus extension in the last 5 years	21.20%	15.48%	20.48%	27.71%
3	Percentage of HH which obtained a climate extension in the last 10 years	5.40%	3.57%	4.22%	8.43%
4	Percentage of HH who were a member of the farmers' group	16.00%	8.33%	12.05%	27.71%
5	Percentage of HH who were cooperative members	5.60%	4.76%	7.23%	4.82%
6	Percentage of HH who have direct access to gov. authority	21.80%	23.21%	22.29%	19.88%
7	Percentage of HH who use citrus credit	26.60%	18.45%	32.53%	28.92%
8	Percentage of HH who use other farmers as citrus technology information source	75.00%	88.10%	68.67%	68.07%
9	Percentage of HH who use gov. officers as citrus technology information source	6.20%	2.38%	7.83%	8.43%
10	Percentage of HH who use citrus trader as citrus price information source	62.40%	67.86%	67.47%	51.81%
11	Percentage of HH who use other farmers as citrus price information source	32.60%	30.36%	30.12%	37.35%
12	Percentage of HH without source of climate information	61.40%	64.29%	57.83%	62.05%

That institutional support for citrus farmers is also relatively low is indicated by the membership of farmers in farmers' groups and cooperatives. In Malang, more than a quarter of the respondents were members of farmers' groups, but in Jember only 12 per cent were members and membership was less than 10 per cent in Banyuwangi (Table 3-8). The level of farmers' participation in cooperative development was slightly higher in Jember than the other two districts, but overall participation was still very low. Only 7.23 per cent of the citrus farmers in Jember reported being a cooperative member compared to 4.76 per cent in Banyuwangi and 4.82 per cent in Malang.

3.6 Summary and conclusion

This chapter presents a detailed picture of citrus farmers' profiles in East Java. With regard to the authority of local government to execute the national government policies and programs in their region, as the result of regional autonomy policies, we break down the farmers' profiles to district levels. Moreover, local governments generally have more engagement with farmers in their regions, so the findings from this study could help them to design policies or build programs for citrus and agricultural development.

There are variations between districts, so we describe the level of citrus farming system in each district. Firstly, Malang district has more variation in term of citrus cultivars, which implies that the citrus development in this region should not be focused on a certain cultivar of citrus but needs to be diversified because they have better access to the consumer market and to agro-tourism. This district also has advantages in term of its access to the citrus research institute located in this region, so farmers and local government workers can much more easily access the recent technologies, as well as certified seedlings, produced by the institute. As a result, the majority of the citrus farmers in this district have used certified seedlings, which are still barely used in the other two districts.

Even though this study does not have evidence about the availability of agricultural labour, the Malang district seems likely to have a better supply, indicated by its higher use of hired labour, its herbicide use and use of a harvesting method that involve more labour. Even though it is not clear whether the level of fertiliser and pesticide use follows recommendations or not, the cost of fertiliser per tree in this area is the lowest, but is highest for use of pesticides. The cost of organic fertiliser in this district was more than double that of other districts. Regarding farmers support systems', farmers in Malang seem to have better support for extension, training and farmers institution developments such as farmers groups.

Secondly, the Jember district mostly planted the *Siam* cultivar. However, there were a relatively large number of farmers that plant *Keprok*. This district is one of the biggest producers of uncertified seedlings, which might affect the proportion of the farmers who use certified seedlings; it has the lowest rate of certified seedling use of the three districts in our survey. The average cost of fertiliser and pesticides was slightly higher than Banyuwangi, so the cost of fertiliser per tree in this region was the highest among the three districts. The use of hired labour for citrus farming was much higher than for Banyuwangi but was still lower than Malang. Another interesting finding is that marketing via *tebas* was more popular in this district. Moreover, farmers in Jember are likely to have better access to credit, which shown by the relatively high proportion of farmers who use credit for their citrus farming.

Lastly, the *Siam* cultivar was very dominant in Banyuwangi which implies that this district has specialised as the production centre for this type of citrus. The using of certified seedling was much higher than in Jember and this may be due to the growth of certified seedling producers in this area. Farmers in Banyuwangi also showed interest in using certified seedlings for their next planting period, so this initiative needs to be supported by the government and related stakeholders. As the largest citrus producer in East Java, the availability of certified seedlings to meet farmers' needs is very important and needs to be addressed. Our respondents in this district reported the lowest cost for plant protection. However, it is not clear whether this area has lower pest and disease infestation or whether more of them prioritise the application of fertiliser. Another important finding that needs serious attention from policymakers is the proportion of farmers who use other farmers as their primary source of information about citrus technology (almost 90 per cent did). This finding implies a lack of government extension support, on the one hand, but is also indicates the opportunity for developing farmer-to-farmer extension, on the other hand. Compared with the other two districts, it is clear that the farmers in Banyuwangi have the lowest extension and training supports, as well as farmers' institutional development. Hence, the opportunity to develop a farmer-to- farmer extension system needs to be considered, by preparing to influence farmers to increase their knowledge and their ability to disseminate citrus technology information. This pattern might also be effective in Jember because the proportion of the farmers who use other farmers as their main information source about citrus technology is also relatively very high.

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Chapter 4. Statement of Authorship

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Contribution to the Paper	Contributed to designing the research, preparation of primary survey and data collection, data cleaning, data analysis and interpretation, and writing and revised the manuscript.		
Overall percentage (per cent)	70 per cent		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	20/07/2020

Co-Author Contributions

By signing the Statements of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);
ii. permission is granted for the candidate in include the publication in the thesis; and
iii. the sum of all co-author is equal to 100 per cent less than the candidate's stated contribution.

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Chapter 4. Accounting for diverse risk attitudes in measures of risk perceptions: A case study of climate change risk for small-scale citrus farmers in Indonesia[5]

Abstract

Climate change is likely to generate severe impacts on smallholder farmers in developing countries. As key drivers of adaptation, climate risk perceptions are highly heterogeneous, varying both across people and context, and are complex, being defined as behaviour which varies across both impact and likelihood dimensions in non-linear ways. Yet most studies examining risk perceptions are unable to disentangle the role of perceptions regarding impacts from those regarding the likelihood of climate-related events taking place. This paper presents a decomposition and associated analysis of survey-based 'risk perception' measures. The decomposition we apply allows independent accounting for perceptions over frequencies and impacts linking to behavioural patterns of risk attitude. The approach presented here draws on a detailed 2017 survey of 500 farmers in rural Indonesia to generate insights into the relationship between risk perceptions and extension services, accessibility of information, and other factors. Results show that risk perceptions are generated from complex interaction between perceived future frequencies and outcomes of climate events and indicate differential impacts of extension services across these perceptions. This paper also presents empirical support for the use of information and communication technology based extension as an efficient extension tool to reach more farmers than in traditional methods.

Keywords: climate change; risk perception; likelihood; impact; small farmers.

[5] Earlier version of this paper was presented at the 62nd AARES 2018 Annual Conference, 6 - 9 February 2018, Adelaide Convention Centre, Adelaide, South Australia.

4.1 Introduction

Climate change impacts agriculture predominantly by altering weather-related inputs directly affecting agricultural productivity (Nelson et al., 2014; Carraro, 2016). Examples include more extreme weather events, longer or shorter growing seasons, and more or less rainfall. The resulting negative impacts range from increasing food security risks of low-income populations (Lobell et al., 2008; Lybbert and Sumner, 2012) to weakening the many contributions the agricultural sector makes to economic growth and development (Timmer, 2002; Christiaensen et al., 2011). Whilst climate change presents major risks to agriculture in general (Godfray et al., 2010; Dillon et al., 2015; Seddon et al., 2016; Tripathi et al., 2016), it is particularly of concern for smallholder farm households with low capacity to absorb shocks or to actively adapt to changing weather patterns and the risks from severe weather events (Deressa et al., 2009; Berger et al., 2017; Hannah et al., 2017; Mulwa et al., 2017; Fahad and Wang, 2018).

Adaptation behaviour, in particular, is an important component of farmers' climate risk management strategies and is closely linked to risk perceptions arising from climate change (Bohensky et al., 2013; Menapace et al., 2015; Woods et al., 2017; Khanal et al., 2018). Understanding how climate change risk perceptions link to adaptation practices is complex, combining behavioural elements across belief formation and outcome assessments arising from actions and weather events (van der Linden, 2017). Existing literature on behaviour with respect to risks arising from climate change in agriculture, however, often focuses only on aggregate indexes of risk perception or general concerns (e.g. Frank et al., 2011; Le Dang et al., 2014). These indexes, a prime of example of which is the Risk Perception Index or RPI (e.g. Sullivan-Wiley and Gianotti, 2017), typically aggregate farmers' concern over impacts of climate change-induced events with their beliefs over how climate change may lead to changes in the frequency of these events (e.g. Iqbal et al., 2016; Sullivan-Wiley and Gianotti, 2017).

However, studies demonstrate that risks are potentially a complex (i.e. nonlinear) combination of beliefs over likelihood and impact factors (e.g. Kahneman and Tversky, 1979; Cohen, 2015; Gregg and Rolfe, 2017), so that both subjective beliefs and impacts on income can be important, independent contributors to risk perception. Tversky and Kahneman (1992) term these types of divergent risk behaviours the four-fold pattern of risk attitudes (Tversky and Kahneman, 1992, p. 306) acknowledging that household member choices may be driven in different directions by optimism or pessimism combined with risk-aversion or risk-loving (Ward and Singh, 2015; Just and Just, 2016; Sidibé et al., 2018). In the case of climate change, in which probabilities of events are highly uncertain (i.e. there is considerable ambiguity around their likelihood of occurrence) and in which extension plays a role in reducing or framing that uncertainty there is more importance regarding disaggregation of perceptions of risks between outcomes and probabilities. Using these insights, we apply the RPI and "unpack" the index for a range of climate events to obtain a more comprehensive understanding of farmers climate risk perception in relation to factors such as access to extension services, experience with information-communication technologies (ICT), use of improved varieties and more.

The focus of the study is on small-scale citrus farmers in rural areas of East Java Province, Indonesia: an area thought to be considerably affected by climate change in the future (Aldrian and Djamil, 2008; Rodysill et al., 2011). Like other permanent crops, citrus farmers are particularly susceptible to climate risks due to the relatively long planning time-frames regarding variety choice decisions, relatively high start-up investment costs and a lengthy waiting period for the initial harvest (Gunathilaka et al., 2018; Ouattara et al., 2019). The study data are derived from a survey undertaken with 500 households across 42 villages in 2017.

This chapter contributes to the literature on climate risk perception in three main ways. First, the study provides a survey-based approach to integrating research on complex patterns of risk behaviour from economics and psychology literature (e.g. Tversky and Kahneman, 1992) into climate research on risk perceptions through a straight-forward extension of current approaches to the analysis of the RPI. Second, the chapter provides evidence about the disadvantages of aggregate level analysis and suggests joint analysis approaches using the RPI as an approach which integrates clear insights from general patterns of risk perceptions with a greater level of detail on how extension or other policies affect behaviour and perceptions of smallholder farmers. Finally, contrasting with previous literature which emphasised a "traditional extension model", we find that the use of ICT-based extension is linked to a greater perception of climate risk associated with a more realistic view of those risks and thus may be an efficient approach to improving adaptation amongst rural farming communities.

This chapter begins with a conceptual framework about the RPI with its construction out of perceptions over frequencies of events and event impacts arising from climate change issues (Section 4.2). In Section 4.3, the survey method and summary statistics of the data are presented. The methodology is presented in Section 4.4 including the calculation of the climate risk perception index and the econometric approach. Results are presented in Section 4.5 and followed by a short discussion in Section 4.6. Finally, we present the conclusions in Section 4.7.

4.2 Conceptual framework

Several approaches are used to understand climate risk perceptions in the literature. Amongst studies focusing on climate risk perceptions, the RPI is widely used (e.g. Iqbal et al., 2016; Sullivan-Wiley and Gianotti, 2017). The RPI is a metric or index that is constructed as the combination of probability or likelihood of risk events and the severity of consequences arising from risk events (Aven, 2016; Li et al., 2018). Since the risk perception is different from real or objective risk (Freudenburg, 1988; Slovic, 1999; Sjöberg, 2000; Aven and Renn, 2009;

Sullivan-Wiley and Gianotti, 2017), data in risk perception studies are mainly obtained by asking agent's perceptions regarding risks using ordered qualitative scales where they can express their subjective views on probability and incidence of climate risk, and also their concern regarding magnitude of the gain/loss caused by the risk rather than a detail measurement of probability or consequences (e.g. Weber et al., 2002; Abbott-Chapman et al., 2008; Ogurtsov et al., 2008; Duijm, 2015; Frondel et al., 2017; Cullen et al., 2018). For the construction of the RPI, the combination of the two elements are expressed as a multiplicative function (e.g. van Winsen et al., 2014), an additive (e.g. Iqbal et al., 2016) or the combination of multiplication and addition (e.g. Sullivan-Wiley and Gianotti, 2017). As the risk is often defined by expected value, the multiplicative version is more common in the risk assessment literature (Aven and Renn, 2009). Also, Duijm (2015) points out that subjective risk perception should follow the multiplicative relationship as it could show the logical compatibility with the quantitative approach.

The resulting RPI from is then often used as a dependent variable in regression analyses, or correlational studies, regarding policy/environmental variables which might be related to an increasing or decreasing risk perception. The typical aim in these studies is to understand the relationship between extension, education levels, policy and other factors in order to generate information on which policies or interventions might assist farmers to improve adaptation to risks[6] (e.g. Le Dang et al., 2014; Iqbal et al., 2016; Sullivan-Wiley and Gianotti, 2017).

As outlined earlier, the RPI is constructed from two sources of risk: (1) the perceived impact that climate events might have on a household, and; (2) the perceived likelihood that climate events might occur. The literature shows that these considerations are often vastly different with Tversky and Kahneman (1992) outlining a four-fold pattern of risk behaviours

[6] The study of climate risk perception are also widely used to identify or measure the threat component on the basis of protection motivation theory and its direct linkage to a protective response or behavioural change toward climate change issues (e.g. Bubeck et al., 2012; Grothmann and Patt, 2005).

which allows for different perceptions over both outcome (impact) and likelihood (probability) aspects (See Figure 4-1).

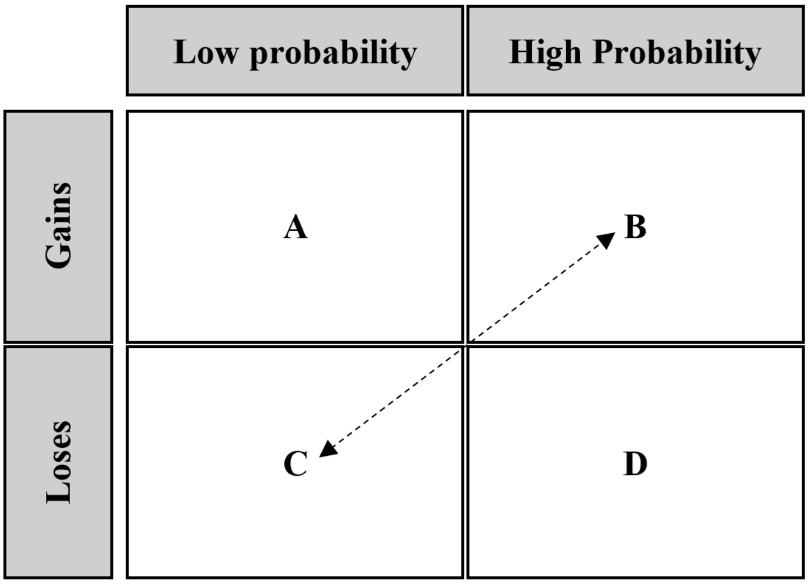

Figure 4-1. Fourfold pattern of risk

(Adapted from Bosch-Domènech and Silvestre (2006); Tversky and Kahneman (1992))

Considering that the climate change events could have both positive and negative effects on agricultural production (Parry et al., 2004; Ludwig and Asseng, 2006; Challinor et al., 2014), farmers' risk behaviours should be ably explained by the four-fold pattern as shown in Figure 4-1. However, the standard approach to the RPI is only able to assess the risk situation in the main diagonal of the fourfold matrix (quadrant B or C). As a result, consideration of risk perceptions as an aggregate of impacts and likelihoods (e.g. Frank et al., 2011; Sullivan-Wiley and Gianotti, 2017), as studies using the RPI currently do (e.g. Le Dang et al., 2014; Iqbal et al., 2016; Sullivan-Wiley and Gianotti, 2017), means that only relations which affect both factors in the same direction are identified– i.e. allowing only for a two-fold pattern of risk perceptions. When the farmers have a different perception of likelihood and impact, these two components moderate each other in of the aggregate RPI formulation (Bosch-Domènech and Silvestre, 2006), so it cannot explain risk attitudes in quadrants A and D.

This limitation, however, can be avoided by analysis of perceived likelihood and perceived impact separately (i.e. a disaggregated analysis). Specifically, by redefining the RPI as being based on separate functions it is possible to allow for a more complex representation of risk behaviours. Here RPI is defined as:

$$RPI = I(x) \times L(x) \quad (4\text{-}1)$$

$Where$:

$I(x) = function\ representing\ perceived\ impact\ of\ event$

$L(x) = function\ representing\ perceived\ likelihood\ of\ event$

This approach encompasses the standard approach but allows finer analysis of the relationship of variables of interest independently to perceptions of event impact and to perceptions of event likelihood. Hence, this study highlights the different influence and direction of each explanatory variables (x) on both the RPI and the elements which derive to the analysis of how the variables could affect the RPI and its elements in different ways. Another major aspect of this study is to elaborate on how influencing factors, especially intervention variables could shape the understanding of the climate risk perception in aggregate and disaggregate levels.

4.3 Data

This study uses data obtained from a survey of 500 citrus farming[7] households in East Java, Indonesia, from September - October 2017. Households included in the sample using a

[7] A citrus farmer is defined as a household who manage more than 25 citrus trees, following the minimum business unit of citrus farming used by National Statistic Agency (BPS) to define a citrus farmer (BPS, 2015).

multistage random sampling process. Three districts: Banyuwangi, Jember and Malang districts (Figure 4-2) were purposely chosen as they were the largest citrus production districts in East Java province based on 2015 data. Similar sized samples were taken from each district: 168 households in Banyuwangi, 166 households in Jember and 166 households in Malang. The sample includes 12 randomly selected households from 42 randomly selected villages. The survey collected information at the plot level.

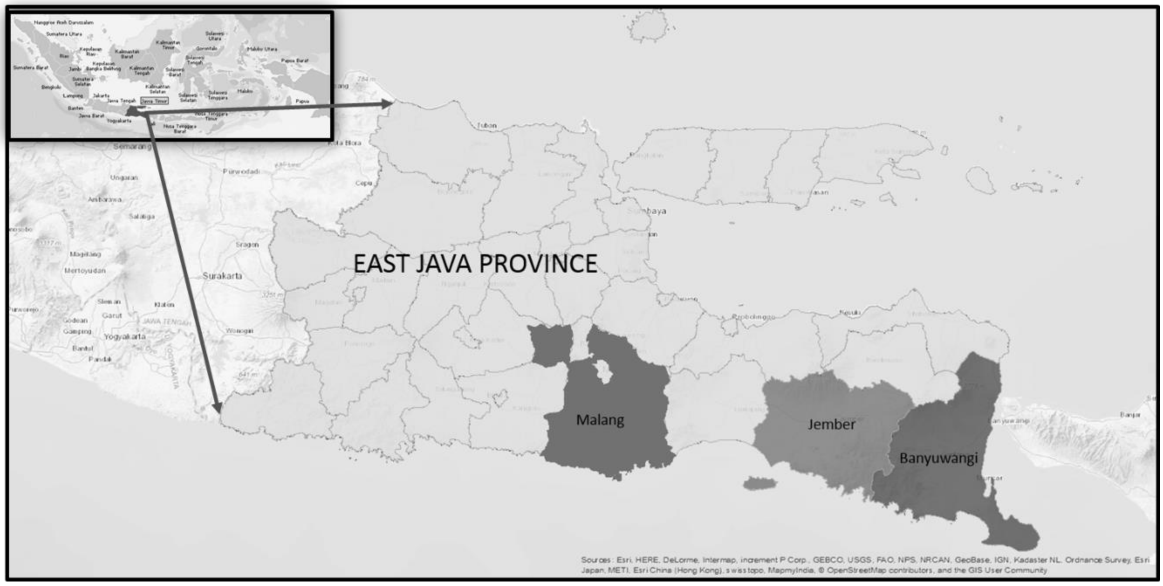

Figure 4-2. Survey site

Table 4-1 presents the demographic and socioeconomic characteristics of the citrus farmer sample as well as other variables used in the econometric analysis. Compared with the 2013 agricultural census, the average ownership of citrus trees from the survey is slightly higher than the census which was 374 trees per household (BPS, 2013, 2015). However, the median ownership based on the survey is 293 trees.

Table 4-1. Descriptive statistics

Variables	Description	Mean	Std.dev	Min.	Max
Household Characteristics					
Gender	Dummy: 1 if head of household is male	0.97	0.16	0.00	1.00
Age	Age of the head of household (year)	53.35	11.12	28.00	87.00
Experience	Experience in citrus farming (year)	15.01	10.22	0.00	47.00
Education	Formal education completed (year)	7.55	4.04	0.00	18.00
Ethnicity	Dummy: 1 if the ethnic group is Javanese	0.95	0.23	0.00	1.00
HH size	Number of household member (person)	3.87	1.48	1.00	15.00
Citrus income	Income from citrus farming in a year (million IDR)	17.26	34.13	-35.15	287.30
Total income	Total income in a year (million IDR)	63.16	68.68	-40.40	417.34
Agricultural assets					
Land	Ownership of agricultural land (hectare)	1.08	2.37	0.05	30.04
Citrus	Ownership of citrus (trees)	393.62	403.18	47.00	4500.00
Generator	Ownership of generator (unit)	0.10	0.31	0.00	2.00
Cattle	Ownership cattle (unit)	0.49	1.35	0.00	20.00
External factors					
Mobile-phone	Ownership of mobile-phone in HH (unit)	2.19	1.19	0.00	7.00
Internet	Dummy: 1 if had access to internet	0.65	0.48	0.00	1.00
Training	Citrus training attended in last 5 years (number)	0.26	1.62	0.00	20.00
Extension	Citrus extension attended in last 5 years (number)	1.76	8.05	0.00	120.00
Climate	Climate extension attended in last 10 years (number)	0.29	2.50	0.00	50.00
Farmers group	Dummy: 1 if part of citrus farmers group	0.16	0.37	0.00	1.00
Cooperative	Dummy: 1 if part of cooperative	0.06	0.23	0.00	1.00
Direct access	Dummy: 1 if had direct access to gov. authority to ask about citrus	0.22	0.41	0.00	1.00
Citrus credit	Dummy: 1 if had citrus credit	0.27	0.44	0.00	1.00
Citrus info	Dummy: 1 if citrus technology information source was other farmers	0.75	0.43	0.00	1.00
Climate info	Dummy: 1 if farmers had no climate information source	0.61	0.49	0.00	1.00

4.4 Method

4.4.1 Risk perception index elicitation

As outlined earlier in Eq. 4-1, the RPI is a multiplication function of the perceived likelihood and perceived impact of a certain climate event. The structured questionnaire is designed so that the farmers could express their responses to the statements of representation of the two elements for each climate event types based on a five-point Likert scale (*0 = strongly disagree; 1 = disagree; 2 = no likelihood/no negative impact, 3 = agree; and 4 = strongly agree*). The statements are expressed as follows: (a) "*In my opinion, there is a likelihood of increasing* ***climate events*** *in the future*"; and (b) "*The increasing of* ***climate events*** *has a negative impact on my citrus farming*". These two statements were delivered after the farmers give their response to the following statement "*In my experience, there have been increasing* ***climate events*** *in the last ten years*". The perception for six climate events are measured, namely (a) increasing air temperature, (b) increasing dry season period; (c) increasing excessive rainfall; (d) increasing rainy season period; (e) increasing flood; and (f) increasing destructive wind. The events were decided based on literature review, field works and a series of in-depth interviews with citrus farmers, extension workers, citrus seed producers, citrus traders and local agricultural departments. A focus group discussion with citrus researchers obtained broader and deeper understanding of the importance of climate change issues on citrus farming.

4.4.2 Econometric methods

Concerns about risks from different sources may be correlated with each other, in addition to being explained independently by observable variables. Given that the RPI is elicited for 6 types of climate events, this information is incorpated through a system of regression equations.

The resultant climate RPI model is a set of linear equations for each climate change event *j* which are individually represented as:

$$y_{ij} = \alpha_j V_i + \beta_j W_i + \gamma_j Z_i + u_{ij} \tag{4-2}$$

where y_{ij} and u_{ij} represent the outcome variable and white noise error term respectively with $cor(u_j, u_k) = \sigma_{jk}$. V_i is an $(M\ x\ 1)$ vector of farmers characteristics, W_i is an $(S\ x\ 1)$ vector of agricultural asset variables, and Z_i is an $(L\ x\ 1)$ vector of extension and advisory service variables. Stacking all *j* equations we obtain:

$$\begin{cases} y_{i1} = \alpha_1 V_i + \beta_1 W_i + \gamma_1 Z_i + u_{i1} \\ y_{i2} = \alpha_2 V_i + \beta_2 W_i + \gamma_2 Z_i + u_{i2} \\ y_{i3} = \alpha_3 V_i + \beta_3 W_i + \gamma_3 Z_i + u_{i3} \\ y_{i4} = \alpha_4 V_i + \beta_4 W_i + \gamma_4 Z_i + u_{i4} \\ y_{i5} = \alpha_5 V_i + \beta_5 W_i + \gamma_5 Z_i + u_{i5} \\ y_{i6} = \alpha_6 V_i + \beta_6 W_i + \gamma_6 Z_i + u_{i6} \end{cases} \tag{4-3}$$

Equation (4-3) can be expressed in matrix notation as:

$$\boldsymbol{Y} = \boldsymbol{\alpha V} + \boldsymbol{\beta W} + \boldsymbol{\gamma Z} + \boldsymbol{\Sigma} \tag{4-4}$$

Given prior expectations regarding correlation between the RPI for different climate events, we estimated the Seemingly Unrelated Regression (SUR) model (Zellner, 1962) which accounts for cross-equation correlation. The model was estimated using the systemfit package (Henningsen and Hamann, 2007) in the R statistical program (R Core Team, 2018).

To conduct the disaggregated analysis, we employed the ordered logistic regression model (OLM) as suggested by Hoffmann (2016) for Likert scale data as each disaggregated index can take integer values from 0 to 4 (inclusive) only. Following Frondel et al. (2017), we applied the standard OLM for the perceived likelihood and outcome of climate events, as follows:

$$y_{ij}^{*} = \delta_j V_i + \theta_j W_i + \tau_j Z_i + \varepsilon_j \quad (4\text{-}5)$$

where y_{ij}^{*} denotes the perceived likelihood of climate event j or perceived negative impact of climate event j by the respondent i. The OLM model was analysed using the rms package in the R statistical program (Harrell Jr, 2018). In order to make a direct comparison between the aggregate approach (examining the RPI using the SUR model) and the disaggregate approach, we calculated both the disaggregate marginal effects (ME) for each independent variable (k) and the aggregate effect.

4.5 Results

4.5.1 Climate risk perception index

The RPI was calculated for six climate change events which represents the individual's risk perception of climate change events where the value varies from zero to sixteen. The mean of RPI values for all respondents ranges from 3.66 (increasing flood) to 6.12 (increasing rainy season period) (Table 4-2). Based on t-test, the RPI of increasing rainy season period is significantly higher than other events (Table 4-2). From the six climate change events, citrus farmers categorised floods and increasing destructive wind as low risks (mean of RPI < 4), and these two events do not statistically different. Table 4-2 also shows that there is a high variation of the RPI between respondents indicated by high standard deviation, which imply the large differences in the risk perception of climate events between the citrus farmers.

Table 4-2. Risk perception index of climate change events

Climate events	Mean	Std.dev	Min	Max
Increasing air temperature	5.78	3.37	0	16
Increasing dry season period	5.36	3.15	0	16
Increasing rainy season period	6.12	2.97	0	16
Increasing excessive rainfall	5.29	3.05	0	16
Increasing flood	3.66	2.65	0	12
Increasing destructive wind	3.85	2.62	0	12

4.5.2 Econometric estimation

The estimated cross-equation correlations from the regression equations for the aggregate RPI are presented in Table 4-3. The climate events have a statistically significant correlation, indicating that SUR model is more efficient than an equation-by-equation OLS approach (which assumes independence between equations). With respect to the farmers' priority regarding climate events, we focus on the three most important climate events: increasing air temperature, increasing dry season period and increasing rainy season period for further analysis[8].

The estimation results for the RPI and its elements with the focus on extension system for the three climate events is presented in Table 4-4. We find a larger number of external factor variables which significantly influence the perception than internal (socio-demographic) factor variables, such as household characteristics and assets.

[8] We provide the estimation regression result for all six climate events, both for RPI and elements in the Appendix 5 (See Table A4-1 – A4-6).

Table 4-3. Residual correlation of RPI for six climate events

	Increasing air temperature	Increasing dry season period	Increasing rainy season period	Increasing excessive rainfall	Increasing flood	Increasing destructive wind
Increasing air temperature	1	0.407***	0.137***	0.212***	0.136***	0.093***
Increasing dry season period		1	0.180***	0.308***	0.033*	0.097***
Increasing rainy season period			1	0.329***	0.091***	0.052
Increasing excessive rainfall				1	0.147***	0.049*
Increasing flood					1	0.368***
Increasing destructive wind						1

Note: '*', '**', '***' significant at 10%, 5%, and 1% levels, respectively

First, for the event of increasing air temperature, mobile-phone ownership, attendance in climate-related training or extension, and climate/weather information source is negatively related to RPI, while for internet access and access to credit the relationship is positive. When the farmers do not use any information source for the climate or weather, the probability of perceiving a negative likelihood of increasing air temperature is lower. In contrast, when farm household members have access to the internet, the probability is higher. There are some variables that significantly relate with the perceived likelihood and/or perceived negative impact arising from increasing air temperature, but statistically not significant to influence the RPI. For example, cooperative membership is associated with a decrease in the perceived negative impact of the event on citrus farms.

Table 4-4. Seemingly unrelated regression and ordered logit model estimation for risk perception index, perceived likelihood and perceived impact of increasing air temperature, increasing dry season period and increasing rainy season period

Variables	Increasing air temperature			Increasing dry season period			Increasing rainy season period		
	RPI	Perceived likelihood	Perceived impact	RPI	Perceived likelihood	Perceived impact	RPI	Perceived likelihood	Perceived impact
Model:	SUR	OLM	OLM	SUR	OLM	OLM	SUR	OLM	OLM
Mobile-phone (unit)	-0.327 **	-0.301 ***	-0.063	-0.184	-0.202 **	0.040	-0.387 ***	-0.172 *	-0.260 **
	(0.157)	(0.097)	(0.102)	(0.153)	(0.096)	(0.103)	(0.141)	(0.097)	(0.110)
Internet access (1 if yes)	0.707 *	0.708 ***	-0.103	0.560	0.629 ***	-0.027	1.044 ***	0.381 *	0.729 ***
	(0.369)	(0.229)	(0.238)	(0.360)	(0.230)	(0.244)	(0.332)	(0.231)	(0.266)
Citrus training (number)	-0.042	-0.073	0.040	-0.126	-0.051	-0.067	-0.094	-0.052	-0.070
	(0.093)	(0.059)	(0.058)	(0.090)	(0.056)	(0.064)	(0.083)	(0.059)	(0.061)
Citrus extension (number)	0.004	0.002	-0.003	-0.024	-0.007	-0.029 **	-0.023	-0.018	-0.015
	(0.019)	(0.010)	(0.012)	(0.018)	(0.012)	(0.013)	(0.017)	(0.012)	(0.013)
Climate extension (number)	-0.099 *	-0.028	-0.078 **	0.053	0.012	0.104	-0.001	-0.013	0.004
	(0.058)	(0.031)	(0.038)	(0.056)	(0.031)	(0.071)	(0.052)	(0.032)	(0.041)
Farmers group membership (1 if yes)	-0.149	-0.077	0.024	0.054	0.112	0.021	-0.060	0.066	-0.287
	(0.456)	(0.283)	(0.286)	(0.446)	(0.279)	(0.296)	(0.409)	(0.276)	(0.319)
Cooperative membership (1 if yes)	-0.623	0.409	-0.948 **	-0.195	0.199	-0.242	0.569	0.409	0.610
	(0.685)	(0.447)	(0.441)	(0.665)	(0.428)	(0.481)	(0.612)	(0.441)	(0.502)
Direct access to government authority (1 if yes)	0.258	0.037	0.219	0.204	-0.058	0.320	-0.922 ***	-0.458 **	-0.576 **
	(0.356)	(0.224)	(0.231)	(0.347)	(0.218)	(0.231)	(0.320)	(0.221)	(0.249)
Citrus credit (1 if yes)	0.651	0.394 *	0.150	0.111	-0.021	-0.039	0.249	0.223	0.076
	(0.332)	(0.212)	(0.213)	(0.323)	(0.201)	(0.215)	(0.299)	(0.206)	(0.234)
Citrus technology information source (1 if other farmers)	-0.108	-0.447 **	0.364 *	0.030	0.046	0.138	0.344	0.489 **	-0.160
	(0.344)	(0.215)	(0.219)	(0.336)	(0.213)	(0.223)	(0.309)	(0.210)	(0.242)
Climate information source (1 if none)	-0.651 **	-0.624 ***	-0.086	-0.059	0.120	-0.086	-0.387	-0.380 **	0.080
	(0.301)	(0.191)	(0.193)	(0.293)	(0.185)	(0.197)	(0.270)	(0.189)	(0.214)

Note: Standard error in parentheses.

'*', '**', '***' significant at 10%, 5%, and 1% probability level, respectively

Second, for increasing dry season period, none of the external factors has a statistically significant relationship to the RPI. However, even though there is no significant influence on the RPI, mobile-phone ownership and internet access have a significant relationship to the farmer's perception of the likelihood of the events in the future, where the mobile phone has a negative effect and access to the internet is positive. Also, more attendance in citrus extension could decrease the probability of perceiving the negative impact of increasing dry season period on citrus farming.

Last, increasing rainy season period is related to external factors. Mobile-phone ownership and direct connection to government authority to ask about citrus technology have a negative relationship to the RPI, whilst internet access variable had a positive relationship. Mobile-phone ownership variable is also associated with a lower probability of perceived likelihood and perceived negative impact of the events on citrus farming. In contrast, access to the internet is associated with a higher perception of negative impact. The source of climate information has a consistent relationship associated with a lower perception of the likelihood of the event in the future. It is similar with the source of citrus technology information variable where farmers without climate information sources tend to have a lower probability of perceived likelihood of increasing rainy season period.

Our results also support an important finding associated with the limitation of typical analysis of the RPI regarding the relationship between final risk perceptions and interventional variables, especially when the variables affect the two risk elements in different direction. For example, the main source of citrus technology information (farmer to farmer’s extension) has different directions for its relationship with the risk elements of increasing air temperature (Table 4-4 and 4-5). This variable is negatively associated with the perceived likelihood of increasing air temperature on one hand (P-value = 0.037), and positively associated with the perceived negative impact of this event on citrus farming on the other hand (P-value = 0.096).

As a result, this variable does not significantly influence the RPI of increasing air temperature (P-value = 0.754). This finding confirms the hypothesis that the different direction of the effect on the risk elements could eliminate the role of its combination in the form of RPI.

Table 4-5. Marginal effects resulting from OLM of perceived likelihood and perceived impact

	RPI	Perceived likelihood					Perceived impact				
		Y = 0	Y = 1	Y = 2	Y = 3	Y = 4	Y = 0	Y = 1	Y = 2	Y = 3	Y = 4
1. Increasing air temperature											
Mobile-phone (unit)	-0.327**	0.000	0.046***	0.028***	-0.070***	-0.004**	0.000	0.009	0.005	-0.010	-0.004
	0.157	0.000	0.015	0.010	0.023	0.002	0.000	0.015	0.007	0.017	0.006
Internet access (1 if yes)	0.707*	-0.001	-0.114***	-0.055***	0.161***	0.010**	0.000	0.015	0.007	-0.016	-0.007
	3.688	0.001	0.039	0.017	0.051	0.004	0.001	0.035	0.017	0.038	0.015
Citrus training (number)	-0.042	0.000	0.011	0.007	-0.017	-0.001	0.000	-0.006	-0.003	0.007	0.003
	0.093	0.000	0.009	0.006	0.014	0.001	0.000	0.009	0.004	0.009	0.004
Citrus extension (number)	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.019	0.000	0.002	0.001	0.002	0.000	0.000	0.002	0.001	0.002	0.001
Climate extension (number)	-0.099*	0.000	0.004	0.003	-0.006	0.000	0.000	0.012**	0.006**	-0.013**	-0.005**
	0.058	0.000	0.005	0.003	0.007	0.000	0.000	0.006	0.003	0.006	0.002
Farmers group membership	-0.149	0.000	0.012	0.007	-0.018	-0.001	0.000	-0.004	-0.002	0.004	0.002
(1 if yes)	0.456	0.000	0.044	0.025	0.065	0.004	0.001	0.042	0.021	0.046	0.018
Cooperative membership (1	-0.623	0.000	-0.055	-0.046	0.094	0.007	0.006	0.175*	0.048***	-0.187**	-0.042***
if yes)	0.685	0.001	0.053	0.058	0.102	0.010	0.006	0.096	0.012	0.095	0.014
Direct access to government	0.258	0.000	-0.006	-0.004	0.009	0.001	-0.001	-0.031	-0.016	0.034	0.015
authority (1 if yes)	0.356	0.000	0.034	0.022	0.052	0.006	0.001	0.032	0.017	0.034	0.016
Citrus credit (1 if yes)	0.651*	0.000	-0.056**	-0.041*	0.091*	0.003	-0.001	-0.022	-0.011	0.024	0.010
	0.332	0.001	0.029	0.025	0.049	0.004	0.001	0.030	0.016	0.033	0.014
Citrus information source (1	-0.108	0.001	0.063**	0.047*	-0.103**	-0.008	-0.002	-0.057	-0.025*	0.062	0.021*
if other farmers)	0.344	0.001	0.028	0.026	0.049	0.005	0.001	0.036	0.015	0.040	0.012
Climate information source	-0.651**	0.001	0.091***	0.063***	-0.144***	-0.010**	0.000	0.013	0.006	-0.014	-0.005
(1 if none)	0.301	0.001	0.027	0.022	0.044	0.004	0.001	0.028	0.014	0.031	0.012
2. Increasing dry season period											
Mobile-phone (unit)	-0.184	0.001	0.041**	0.001	-0.040**	-0.003*	0.000	-0.006	-0.002	0.005	0.003
	0.153	0.001	0.019	0.003	0.019	0.001	0.000	0.015	0.006	0.013	0.008
Internet access (1 if yes)	0.560	-0.003	-0.130**	0.007	0.119***	0.007**	0.000	0.004	0.001	-0.003	-0.002
	0.360	0.002	0.049	0.011	0.042	0.004	0.000	0.035	0.014	0.030	0.019
Citrus training (number)	-0.126	0.000	0.010	0.000	-0.010	-0.001	0.000	0.010	0.004	-0.008	-0.005
	0.090	0.000	0.011	0.001	0.011	0.001	0.000	0.009	0.004	0.008	0.005
Citrus extension (number)	-0.024	0.000	0.001	0.000	-0.001	0.000	0.000	0.004**	0.002**	-0.004**	-0.002**
	0.018	0.000	0.002	0.000	0.002	0.000	0.000	0.002	0.001	0.002	0.001
Climate extension (number)	0.053	0.000	-0.002	0.000	0.002	0.000	0.000	-0.015	-0.006	0.013	0.008
	0.056	0.000	0.006	0.000	0.006	0.000	0.000	0.010	0.004	0.009	0.005
Farmers group membership	0.054	0.000	-0.022	-0.001	0.022	0.001	0.000	-0.003	-0.001	0.003	0.002
(1 if yes)	0.446	0.001	0.054	0.005	0.056	0.004	0.000	0.042	0.016	0.037	0.023
Cooperative membership (1	-0.195	-0.001	-0.038	-0.004	0.040	0.003	0.000	0.037	0.013	-0.034	-0.017
if yes)	0.665	0.002	0.079	0.015	0.089	0.007	0.001	0.079	0.025	0.075	0.030
Direct access to government	0.204	0.000	0.012	0.000	-0.011	-0.001	0.000	-0.044	-0.018	0.036	0.026
authority (1 if yes)	0.347	0.001	0.044	0.001	0.042	0.003	0.001	0.030	0.013	0.023	0.020
Citrus credit (1 if yes)	0.111	0.000	0.004	0.000	-0.004	0.000	0.000	0.006	0.002	-0.005	-0.003
	0.323	0.001	0.040	0.001	0.039	0.003	0.000	0.031	0.012	0.028	0.016
Citrus information source (1	0.030	0.000	-0.009	0.000	0.009	0.001	0.000	-0.020	-0.008	0.018	0.010
if other farmers)	0.336	0.001	0.043	0.001	0.042	0.003	0.000	0.034	0.012	0.030	0.016
Climate information source	-0.059	-0.001	-0.024	0.000	0.023	0.002	0.000	0.012	0.005	-0.011	-0.007
(1 if none)	0.293	0.001	0.038	0.002	0.036	0.002	0.000	0.028	0.011	0.024	0.015
3. Increasing rainy season period											
Mobile-phone (unit)	-0.387***	0.000	0.025*	0.015*	-0.039*	-0.001	0.000	0.023**	0.015**	-0.021**	-0.017**
	0.141	0.000	0.014	0.009	0.022	0.001	0.000	0.010	0.007	0.010	0.007
Internet access (1 if yes)	1.044***	-0.001	-0.057	-0.030*	0.085*	0.002	-0.001	-0.070**	-0.043**	0.071**	0.043***
	0.332	0.001	0.036	0.017	0.051	0.002	0.001	0.028	0.017	0.032	0.015
Citrus training (number)	-0.094	0.000	0.007	0.005	-0.012	0.000	0.000	0.006	0.004	-0.006	-0.004
	0.083	0.000	0.008	0.005	0.013	0.000	0.000	0.005	0.004	0.005	0.004
Citrus extension (number)	-0.023	0.000	0.003	0.002	-0.004	0.000	0.000	0.001	0.001	-0.001	-0.001
	0.017	0.000	0.002	0.001	0.003	0.000	0.000	0.001	0.001	0.001	0.001
Climate extension (number)	-0.001	0.000	0.002	0.001	-0.003	0.000	0.000	0.000	0.000	0.000	0.000
	0.052	0.000	0.005	0.003	0.007	0.000	0.000	0.004	0.002	0.003	0.003
Farmers group membership	-0.060	0.000	-0.009	-0.006	0.015	0.000	0.000	0.027	0.017	-0.028	-0.017
(1 if yes)	0.409	0.000	0.038	0.026	0.063	0.002	0.001	0.033	0.020	0.036	0.017
Cooperative membership (1	0.569	0.000	-0.052	-0.046	0.096	0.003	-0.001	-0.043	-0.031	0.025***	0.049
if yes)	0.612	0.001	0.049	0.060	0.106	0.004	0.001	0.028	0.022	0.009	0.050
Direct access to government	-0.922***	0.001	0.071*	0.030**	-0.100**	-0.002	0.001	0.057**	0.035**	-0.061*	-0.032**
authority (1 if yes)	0.320	0.001	0.037	0.012	0.046	0.002	0.001	0.028	0.016	0.033	0.013
Citrus credit (1 if yes)	0.249	0.000	-0.031	-0.021	0.051	0.001	0.000	-0.007	-0.004	0.006	0.005
	0.299	0.000	0.028	0.021	0.048	0.001	0.000	0.020	0.013	0.018	0.015
Citrus information source (1	0.344	-0.001	-0.076**	-0.033***	0.107**	0.003	0.000	0.014	0.009	-0.012	-0.011
if other farmers)	0.309	0.001	0.035	0.012	0.044	0.002	0.000	0.020	0.013	0.017	0.017
Climate information source	-0.387	0.001	0.053**	0.036*	-0.087**	-0.002	0.000	-0.007	-0.005	0.007	0.005
(1 if none)	0.270	0.001	0.026	0.020	0.043	0.002	0.000	0.019	0.012	0.018	0.013

Note: Standard error in parentheses. '*', '**', '***' significant at 10%, 5%, and 1% probability level, respectively

4.6 Discussion

4.6.1 Farmers' priority of climate events based on risk perception index

Starting with the discussion of farmers' priority of climate change events based on the RPI, we find that citrus farmers consider an increasing rainy season period event as the primary concern, followed by an increasing air temperature and so on (see. Table 4-2). The results imply that farmers are more likely to prioritise their resources to address the climate issues based on those priorities which need to be considered in the related policy design or decision-making process (Nigussie et al., 2018; Rasmussen, 2018). However, as the perception might be biased as the availability of heuristics (Tversky and Kahneman, 1974), government or related stakeholders might need to assess these farmers perception and comparing with the scientific information in order to provide more accurate climate-resiliency support systems which acceptable by the farmers.

The wide range variation of RPI for each climate event implies that citrus farmers might have heterogeneous perceptions of risk arising from climate events (See Table 4-2) which could be associated with the variation in socio-demographic and external factors (See Appendix 5: Table A4-1 – A4-6). This finding is in line with the literature showing that the different perceptions at the individual or household levels reflect the influence of social economic characteristics and individual risk-aversion (see Frondel et al., 2017; Sullivan-Wiley and Gianotti, 2017). We also find variation of RPIs across the districts which implies that the farmers' perception might be affected by agro-ecosystems or geographical aspects. This is a common phenomenon since the geographical context could cause the spatial heterogeneity of risks for leading to the different risk perception of the farmers (Bobojonov and Aw-Hassan, 2014; Bonatti et al., 2016; Woods et al., 2017).

Whilst our study was not designed to investigate why the citrus farmers perceived some climate events to be greater risks than others, we suggest an explanation for three RPIs, especially in terms of the negative impact of the events on citrus farming. First, the increasing rainy season period was perceived as the highest RPI because, based on their experience, farmers believed that a long rainy season period could disturb the flowering and fruit setting phase, which diminishes the yield (e.g. Hossain et al., 2009; Mesejo et al., 2016). A longer rainy season may also increase pest, disease and weed infestations (Atanackovic et al., 2015) and reduce the effectiveness of pest, disease and weed controlling through the reducing of toxicity of the chemical control (Boina and Bloomquist, 2015). Second, increasing air temperatures could disturb pollination ecosystems as citrus production strongly depends on pollination services (Maia et al., 2018). High temperatures during certain stages of fruit growth could also cause losses as a physiological response to the environmental condition (Qin et al., 2016). With higher air temperatures, citrus pests and diseases are likely also to be destructive, unpredictable and harder to control in these areas (Sutherst et al., 2011; Dixon, 2012). Finally, citrus is highly dependent on water supply, so that farming in the dry season requires accessible irrigation supplies (Zouabi and Kadria, 2016). However, this event was perceived to have a lower RPI than increasing rainy season period and air temperature. A possible reason is the better availability of irrigation infrastructure in the survey site (Hussain et al., 2006), though this relationship requires further analysis in order to draw causal inferences. Also, the survey showed that most of the citrus trees are grown on land which was previously planted with food crops (rice, maize, and others) which have better irrigation support (Simatupang and Timmer, 2008). Consequently, it might be easier for the citrus farmers to deal with increasing dry season period events, so they might perceive this event to have a lower RPI.

4.6.2 Role of advisory and extension services in shaping risk perception

Considering the importance of extension system in order to address the climate-related issues, our analysis reveals the opportunity for the use of the progressive development and spreading of information and communication technology (ICT) in order to shape the farmer's climate risk perception. ICT extension tools could provide better access to information and utilise social networking to increase the efficiency of extension efforts (Aker, 2011; Fu and Akter, 2016; Tripathi and Mishra, 2017). However, the regression results showed a different relationship between mobile-phone and internet access with the RPI and with the disaggregated analysis of the RPI. Specifically, households with mobile phones tended to have a lower perception of the likelihood of climate events and their impacts whilst those with internet access perceived climate events as more likely and of higher impact. These differences indicate the importance of the appropriate use of new technologies in extension. Whilst mobile phones improve social networks and can be used to communicate with households they are somewhat limited as information sharing tools. In contrast, access to the internet provides households with potentially huge amounts of information but also allows household members to avoid accessing information that they may not like (e.g. which indicates recent choices may have been risky). Extension programmes can benefit from enhanced access to the internet but should also seek to instill information-accessing behaviours which promote a rational formation of beliefs and to guide household members in accessing weather and climate related information from the internet.

Direct access to a government authority is a part of farmer's connection to obtain formal and informal support (Wossen et al., 2015) related to citrus farming. Our regression results showed that this variable has an association with a reduced farmer's perception of risks associated with an increasing rainy season period, both on the RPI and individual elements. Whilst this result may seem at odds with initial considerations, the RPI for increasing rainy season period is the highest of all events considered in this study on average. In this context, it may be that direct contact with extension officers serves to moderate extreme beliefs.

Regarding climate information sources, farmers without a source of climate/weather information seemed likely to have a lower perception of the negative impact of climate events (increasing air temperature and rainy season period) on citrus farming. Pidgeon and Fischhoff (2011) point out that it is rational for a well-informed individual to not react to the climate information they have if they do not have the information about viable actions to deal with the climate situations indicating the importance of an effective climate extension programme in this region, and more broadly.

Farmers in developing countries often have a high dependency on government for information provision. However, our results showed that alternative approaches to accessing information were more strongly associated with the risk perception than access to traditional sources of information (e.g. in-person extension or participation in a farmers group). In line with previous studies (e.g. Anderson and Feder, 2004; Brown et al., 2018; Moyo and Salawu, 2018; Ragasa and Mazunda, 2018) we find that government extension programs should seek to complement existing sources of information including physical social networks accessed directly or through modern technologies (i.e. mobile phones) and the internet. A failure to modernise in this way may lead to farmers generating wayward beliefs or marginalise the importance of the government research and extension programme as a key plank of agrarian development. This latter aspect is particularly pertinent given our survey data shows that the proportion farmers who are involved in citrus extension, citrus training, or climate extension and farmers groups are only 21.2, 5.6, 5.4 and 16 per cent, respectively. On the other hand, the proportion of farmers who have mobile-phone and internet access are 94 and 64.8 per cent, respectively.

4.7 Conclusion

The complexity of climate-related risk behaviour means research needs to account for a diverse array of risk attitudes in order to obtain better insight into a wide range of views on its existence, impact and incidence. In this paper, we considered farmers' climate risk perceptions using a disaggregated approach to analysis of the Risk Perception Index, or RPI (Sullivan-Wiley and Gianotti 2017), allowing representation of a four-fold pattern of risk attitudes as outlined by Tversky and Kahneman (1992). Our results provide a conceptual framework and empirical evidence of the limitation of aggregate-level analysis of RPI in explaining endogenous variable to influence the perception, which could be explained better by the analysis in disaggregate levels.

Our analysis results in several findings that can be used by government or related industries to design the intervention program and policies. First, government or related industries could provide the supporting system to the citrus farmers based on the RPI ranking, especially adaptation and mitigation strategies regarding those climate events. Also, understanding the RPI and its components in aggregate and disaggregate levels could inform the policymakers whether the citrus farmers have had an accurate information regarding climate change issues or not, which is important to for a better climate resiliency campaign, such as improving the farmers understanding of future climate risk or providing the precision climate adaptation strategies. Second, we find that farmers' information access methods (mobile-phone ownership, access to the internet, and connection to government authority) have a stronger influence for the farmers' perception than conventional extension systems, such as extension and training meetings, and farmers groups (farmers group and cooperative). The use of ICT should be embraced by extension programmes which can seek to complement farmers' independent sourcing of information through training on self-learning and rational information seeking behaviours along with traditional extension approaches (i.e. direct information provision and training).

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Overall percentage (per cent)	70 per cent		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
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Co-Author Contributions

By signing the Statements of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);
ii. permission is granted for the candidate in include the publication in the thesis; and
iii. the sum of all co-author is equal to 100 per cent less than the candidate's stated contribution.

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Chapter 5. The role of certification, risk, and time preferences in promoting adoption of climate-resilient citrus varieties in Indonesia[9]

Abstract

The adoption rate of certified climate-resilient crop seedling varieties in developing countries is generally low, impacting on the ability of smallholder perennial crop farmers to adapt to climate change. Given the long-lived nature of perennial crop investments and the high level of uncertainty regarding both the quality of the seedlings and the climate to which they will be exposed as mature trees, there are clear linkages to farmers' subjective beliefs regarding yield differentials between certified and uncertified seedlings, risk behaviours, and time preferences. We consider these aspects using a recently developed survey-based tool for measuring risk and time preferences and link those to stated preferences and observations on the adoption of certified seedlings. Results show that farmers' beliefs regarding yield and variance of yields of certified and uncertified seedling along with the risk attitudes are significant correlates with seedling choice behaviours. Our results also indicate that information asymmetries in the certified seedling market may play a role in limiting the benefits of certification programs both due to cheating and due to lower levels of adoption.

Keywords: subjective belief; risk behaviours; seedling certification; perennial crop; climate risk

[9] Earlier version of this chapter was presented as a contributed paper at the 93rd Annual Conference of the Agricultural Economics Society, University of Warwick, England, 15 - 17 April 2019.

5.1 Introduction

Farmers in both high-income and emerging economies face similar sources of agricultural risk. However, *ex-ante* responses to risk and *ex-post* coping strategies can differ greatly. Smallholder farmers in emerging economies are relatively more vulnerable to a range of human health, food security, financial, price, production and climate-related shocks. Smallholders *ex-ante* risk management strategies include diversifying crops, seeking off-farm work, limiting experimentation with new technologies, accumulating assets and engaging with social networks for credit access (Cervantes-Godoy et al., 2013). Over the past decades, much of the literature examining how risk influences crop choices focuses on seasonal or annual cropping systems (Wening Sarwosri and Mußhoff, 2019). Whilst a wide range of literature focuses on risk management and beliefs for annual cropping systems, fewer studies consider the joint impacts of risk preferences, time preferences, and subjective beliefs for the more severe cases of smallholder investment in long-lived perennial crops.

Risk management concerns are exacerbated when farmers make production and variety choices about perennial crops due to the long time periods typically needed to establish positive returns and the potential for climate change impacts to impact on expected returns over that time period. Perennial tree crops require substantial lead-in times and involve technological lock-in due to longer depreciation times before earning revenue (Lobell and Field, 2011; Gunathilaka et al., 2016; de Sousa et al., 2019). When combined with a greater level of uncertainty over climate change impacts for increasingly distant future climatic states, the risks associated with investments in perennial crops are more severe as compared to annual/seasonal crops. However, it is not just risks that matter in these cases: the long time periods to returns indicate that time preferences will play a role in investment decisions whilst the deep uncertainty and limited information over climate change projections available to smallholder farmers also means that subjective beliefs are likely to play a role in the formulation of risk management strategies in these contexts. A range of adaptation strategies are potentially available to farmers facing climate change risks. Common examples include adopting new varieties, shifting management practices, modifying agronomic systems, and investing in physical or human capital (Huang et al., 2015; Moniruzzaman, 2015; Chavas, 2019). The use of improved varieties is one of the most commonly suggested climate change risk-reducing management strategies (e.g. Fisher et al., 2015; Holden and Quiggin, 2016; Katengeza et al., 2019). New varieties are developed to offer important advantages in term of higher productivity, better quality, greater resistance to pests and diseases and more resilience to particular climate shocks (Ellis, 1992; Doss and Morris, 2001). In most cases, the advantages of these new varieties and their specific performance attributes are linked to seed/seedling certification systems used as a quality control assurance system[10].

Programs to generate improved varieties, and programs that focus on certification of seedlings have different objectives, and thus seek to address different problems. Genetic improvement associated with improved varieties focuses purely on the physical attributes of crop varieties in order to improve their performance across a range of domains including yield, resilience to environmental pressures, taste, processing characteristics and more. In contrast, certification programs are derived from acknowledgement that most genetic improvements are 'credence attributes'. Credence attributes of products are unobservable by consumers through reasonable efforts or through direct consumption/use (Baron, 2011). Certification programs seek to generate trust in the minimum quality (i.e. yield/produce quality) and maximum sensitivity to environmental conditions (e.g. climate, diseases, pests) (Auriol and Schilizzi, 2015). Whilst the theory around resolution of credence attributes concerns is well-known (i.e.

[10] In this study, we differentiate the term of improved variety and certified seedling. Improved variety is a crop variety which has resulted from scientific breeding research programs. Certified seedling embody the attributes of 'improved varieties' but in addition embody institutional aspects that seek to provide a guarantee over particular genetic, production, yield, and/or resilience traits. This guarantee is typically through certification by a recognised seed supervisory authority (McDonald, 1998; van Gastel et al., 2002).

establish a credible certification program), effective implementation is inhibited by poor governance, inadequate funding, conflicts of interest (by private providers), and quality assurance failures amongst others (e.g. Auriol and Schilizzi, 2015).

Tripp and Louwaars (1997) identify several common problems with seed/seedling certification programs in developing countries. First, many government programs tend to be inadequately funded, resulting in long delays before seeds are released and presenting inconclusive results. Second, certification standards are often set too high for the government's organisational capacity and too often inappropriate for the existing technologies and farming systems. Third, certification processes often neglect the participation of the local community, even though 'social certification' could produce a better quality reputation outcome (Kansiime and Mastenbroek, 2016). Lastly, a lack of transparency in the certification process results in buyers questioning whether certified seedlings truly embody the genetic heritage claimed by sellers, especially when the certification is a mandatory regulation (Tripp and Louwaars, 1997; Spielman and Kennedy, 2016).

Indonesia makes it mandatory to plant only certified citrus seedlings, a result of the Huanglongbing disease[11] outbreak (Ditjen Hortikultura, 2016). The certified citrus seedlings are labelled as disease-free (Nurhadi, 2015; Supriyanto et al., 2017). Whilst the use of certified seeds in this context in Indonesia is mandatory, monitoring of seed supply chains and farmer planting activities is limited meaning that uncertified seedlings are widely available for citrus farmers. In addition, there are a range of factors that may mean farmers have a preference for uncertified seedlings over certified seedlings (Fuglie et al., 2006; Cavatassi et al., 2011; Larsen, 2019). One key factor is the role of negative/positive externalities from neighbouring plantings of uncertified/certified seedlings. A citrus orchard planted with certified disease-free seedlings

[11] Huanglongbing is degenerative disease which causes decreasing citrus productivity and even plant death. This disease is spread by an insect vector and also carried over in the seedling, so in the controlling strategies, the collective plant management is very important (see. Nurhadi, 2015; Supriyanto et al., 2017).

is not guaranteed to be safe from the Huanglongbing disease since the seedling is not a disease-resistant variety (it is only guaranteed to be disease-free at the time of planting). If a surrounding orchard is infected by the disease, neighbouring orchards with certified plants could be affected. As a result, citrus farmers may lack an incentive to buy and plant certified seedlings if their neighbouring farmers use uncertified seedlings. The relative use of uncertified seedlings over certified seedlings may be increased if farmers perceive that there is uncertainty in the quality of certified seedling due to concerns over seed production systems (Maredia et al., 2019).

Being free from disease is not the only attribute of the certified citrus seedlings. The certified seedlings also meet specific criteria for genetic purity, and physical and physiological qualities (McDonald, 1998; van Gastel et al., 2002; Bishaw et al., 2007; Supriyanto et al., 2017). The combination of these attributes provides better adaptability to biotic and abiotic stresses such as those caused by climate change, as well as increasing productivity (Bishaw et al., 2007). It is unclear whether farmers value these additional attributes of certified seedlings, or whether they view certified seedlings as being substantively the same as uncertified seedlings.

The purpose of this study is to provide analytical insights into the adoption behaviour of certified citrus seedlings with a focus on subjective beliefs on yields of certified/uncertified citrus seedlings and their interactions with risk and time preferences. A survey tool was developed and implemented to (i) measure farmers' yield beliefs[12] about citrus seedlings; (ii) analyse the extent to which farmers' value certified citrus seedlings; and (iii) examine the

[12] In the remainder of the paper, the terms of 'subjective belief of yield' and 'expected yield' are used for the same purpose to explain the farmers' belief or trust regarding of the potential yield of the certified/uncertified citrus seedlings.

extent to which certification influences adoption of higher-yielding, climate-risk resilient and disease-free citrus varieties.

This study contributes to the literature in several ways. Firstly, as a key element of investment, subjective beliefs regarding the potential returns relative to a base case are the primary element on which risk and time preferences operate. We use choice tasks embedded in a questionnaire designed on principels of experimental approaches (i.e. Falk et al., 2016) to generate information on risk and time preferences and on a measure of relative quality as perceived by respondents. This approach allows us to examine how the quality signal regarding the belief of yield could impact adoption behaviour for certified seedlings. Second, we extend the adoption literature on how risk and time preferences and climate risk perception contribute to the seedling choices of long-lived perennial tree crops. Third, climate-related variables are examined to understand their relationship with farmers' decisions to plant certified seedlings and the role of certified seedling as a climate adaptation tool. Fourth, we present evidence that asymmetric information about the seedling quality attributes is a key constraint limiting adoption of certified seedlings indicating that improvements in governance and transparency may be critical to improving trust amongst farmers in certification programs for inputs.

The remainder of this article is structured as follows: we next provide the case study background. In section 5.3, we explain the experiments for belief and risk behaviours. Section 5.4 provides the survey data and Section 5.5 the econometric specifications. We present the key findings and discuss further explanation in Section 5.6 and 5.7. Section 5.8 presents the conclusions and policy implications.

5.2 Background: Citrus seedling certification policy in Indonesia

As a consequence of increasing demand for horticultural products in middle-income countries such as Indonesia (e.g., Mergenthaler et al., 2009; Reardon et al., 2009; Minot et al., 2015), developing countries are experiencing an increase in the area and intensity of plantings of horticultural crops (Weinberger and Lumpkin, 2007; Van den Broeck and Maertens, 2016). Horticultural producers generate increased farm income contributing to greater economic growth and development of rural communities relative to subsistence crops (Weinberger and Lumpkin, 2007; Van den Broeck and Maertens, 2016).

In Indonesia, citrus is a rapidly expanding crop among smallholders and is credited with making significant contributions to rural development. The main production issue for citrus development in Indonesia is low productivity, caused primarily by pests and diseases (Nurhadi, 2015; Supriyanto et al., 2017). These pests and diseases are expected to become more prominent under climate change (Muryati, 2007; Sutherst et al., 2011; Dixon, 2012). As citrus seedlings are produced mainly by vegetative multiplication methods (Supriyanto et al., 2017), all systemic pathogens could be accumulating in the propagation materials (Fuglie et al., 2006; Vapnek, 2009). Hence, plant breeders highly recommend disease-free stock seedlings for citrus development (Nurhadi, 2015; Supriyanto et al., 2017; Dwiastuti et al., 2019).

Indonesia's Agriculture Ministry outlines a series of procedures (as stated in the Decree of Minister of Agriculture No. 201/2016 (Ditjen Hortikultura, 2016)) to protect farmers from low-quality citrus seedlings. The procedures aim to ensure certified citrus seedlings sold to farmers are free from disease/pathogen contamination. However, even though seedling certification is mandatory and recommended multiplication blocks have established in 29 out of 34 provinces in Indonesia (Supriyanto et al., 2017), uncertified citrus seedlings dominate the market with reports of up to 80% of citrus seedlings being sold being uncertified (Dwiastuti et al., 2019).

5.3 Methods

5.3.1 Citrus seedling games

Farmers' decisions to adopt a certain type of technology, such as certified seedlings, can be explained by their expectations about the outcomes of the seedlings and the relevant preference framework (i.e. risk preferences alone in a static decision framework, or risk and time preferences together for a dynamic framework) (Bellemare, 2009; Delavande et al., 2011). Whilst risk and time preferences are theoretically dependent in typical economic choice frameworks (via the elasticity of substitution), a key assumption of economic models of decision making is that subjective beliefs over outcomes of different state-choice combinations are independent of preference-related aspects (i.e. risk and time preferences). In this study, we sought to separately elicit these three elements (subjective beliefs, risk preferences and time preferences) in order to describe their independent, and potential joint, relationships to adoption of certified citrus seed varieties.

To generate information on subjective yield expectations, we developed seedling games to elicit the farmers' belief of yield or expected yield of both certified and uncertified citrus seedlings. We modified the Vargas Hill (2009) methods used to capture farmer's beliefs or expectations about the future price and yield of coffee in Uganda and as well as the Menapace et al. (2013) study to measure apple growers' subjective beliefs about crop loses in Italy. In addition, we introduced visual aids as recommended by Delavande et al. (2011) to overcome the difficulties associated with asking directly for a probability or per cent of chance.

In the games, we show the farmer a board which display nine different boxes depicting different yield levels for 100 citrus trees obtained from the certified and uncertified seedlings (0 – 2 ton, 3 – 4 ton, 5 – 6 ton, …, 17 – 18 ton) (See Figure 5-1). Then, we gave the respondent ten tokens. The farmer allocated their ten tokens among the boxes based on how much chance they believe in getting the yield expected from the seedling. The farmers could put all of the tokens in one box or distribute them among several boxes based on their belief (See supplementary materials for more details). Farmers played the game twice, once for uncertified seedlings and once for certified seedlings.

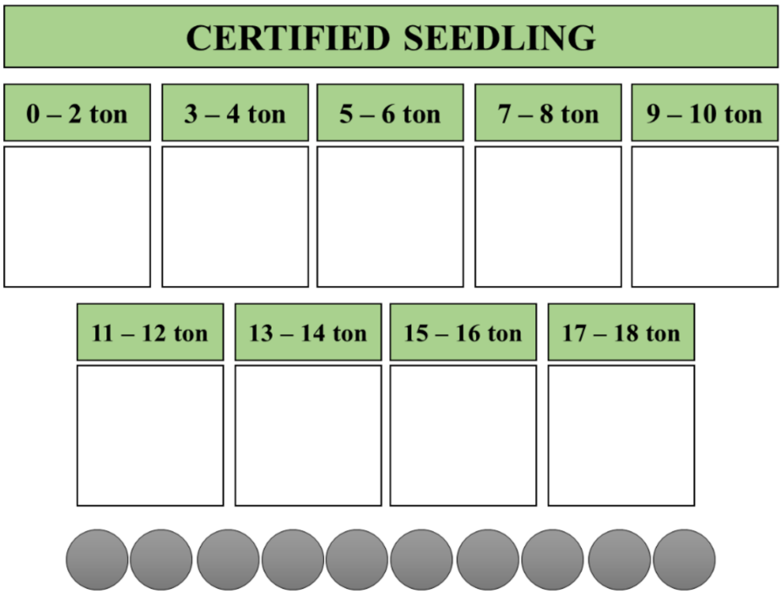

Figure 5-1. Board for certified seedling games

The mean and variance of the subjective expected yield for each seedling type were calculated for each farmer as follows:

$$Mean\ EY_x = \sum_{j=1}^{9} x_j * T_j 0.1 \tag{5-1}$$

$$Variance\ EY_x = \sum_{j=1}^{9} T_j 0.1 * (x_j - Mean\ EY_x)^2 \tag{5-2}$$

where EY_x is farmer’s expected yield for seedling x, x_j is the midpoint value of yield category j (9 categories), and $T_j$is the number of tokens placed in yield category j.

5.3.2 Behavioural preferences

To understand the behavioural traits of individual farmer’s seedling choices, we measure each farmers’ risk and time preferences using experiments and survey tools. These tools were developed using a modified version of Falk et al. (2016).[13] The experiments use hypothetical multiple price lists (MPL) and the survey items use eleven-scales of qualitative self-assessments (willingness to take risks and willingness to give up something today). The MPL uses the staircase method in which respondents only needed to choose five sequential lottery options. The staircase method is calibrated for lower literacy respondents to better capture their risk/time preferences via research reported in Falk *et al*. (2016).

For the risk preferences, farmers first chose between a hypothetical risky lottery versus a hypothetical safe payment. If the respondents chose the safe option, the amount of money in the next subsequent safe option is smaller. However, if the respondent preferred the lottery, then the next subsequent safe option was increased. This procedure[14] was iterated five times to provide a reasonably precise interval for the coefficient of risk aversion.

For time preferences or time discounting, respondents had to choose between a hypothetical immediate payment or a hypothetical delayed payment, with the value of money for the delayed payment higher than the immediate payment. If a respondent chose the immediate payment, the next subsequent delayed payment was increased. If the respondents chose the delayed payment, the delayed payment for the next subsequent choice was decreased. This procedure was iterated five times to provide a reasonably precise interval for the coefficient of impatience (see Appendix 3 for more details).

As the experiments and qualitative survey items are complementary in explaining behavioural preferences, risk and time preferences are calculated based on a weighted sum of MPL and self-assessment choices based on the calibrations undertaken in Falk et al. (2018) and Falk and Hermle (2018). The weighted-values of experiment and survey items in constructing

[13] In the real experiment, following Miyata (2003) and Falk, Becker et al. (2016), we avoided to use the "lottery" term because gambling activities is illegal and prohibited in the most culture and religious affiliation in the survey site. Practically, our enumerators explained to the respondents that the experiments are the scientific method to elicit the behavioural toward risk.

[14] See Appendix 3 for more details

risk and time preferences were obtained by computed z-scores of self-assessments in individual level, then weighting the z-scores with the regression coefficients of observed choices in the experiment with the respective survey item. The calculated risk preferences, representing relative risk aversion, and time preferences, representing patients for more beneficial future outcomes are given by:

$$\text{Risk preferences} = 0.5630 \times \text{Staircase risk} + 0.4370 \times \text{Willingness to take risks} \quad (5\text{-}3)$$

$$\text{Time preferences} = 0.6532 \times \text{Staircase time} + 0.3468 \times \text{Willingness to give up something today} \quad (5\text{-}4)$$

To better understand the role of climate risk perception on the seedling choices, we also surveyed the farmer's perception of likelihood climate change events (increasing air temperature, dry season period and rainy season period) and their impact on citrus farming. The respondent gave their responses on five scales of Likert. We calculated the risk perception index (RPI) for each climate event as a multiplicative function of perceived likelihood and impact on a citrus farm (see. Hasibuan et al., 2020).

5.4 Data

We use primary data from a citrus farming household survey and experiments in three purposively selected citrus-producing districts in East Java Province (Banyuwangi, Jember and Malang). East Java is a major citrus production centre for Indonesia and is experiencing rapid growth in the area planted for citrus. In addition, it is largely populated by smallholder farmers who are capital and information-constrained and rely on improving farm income to achieve development outcomes (Pusdatin, 2015). The survey and experiments were undertaken with 500 citrus households from September - October 2017. The sample was drawn from 42 randomly selected villages (14 villages from each district) and 12 households randomly selected from each village.

Among the 500 citrus households, 24.6 per cent (123 farmers) had adopted certified citrus seedling. Respondents were also asked whether they plan to use certified seedlings for the next planting period with 41.8 per cent of the respondents indicating an intention to adopt certified seedlings. However, only 37.14 per cent of non-adopters planned to use the certified seedling. On the other hand, 43.9 per cent of the adopters did not intend to use the certified seedling in their next planting periods (Figure 5-2).

		CURRENT	
		Certified	**Uncertified**
FUTURE	**Certified**	69 (13.80 %)	140 (28.00 %)
	Uncertified	54 (10.80 %)	237 (47.40 %)

Figure 5-2. Farmers' planning to use the type of seedling

For the seedling games, 12 respondents did not participate in the games due to a lack of knowledge about the seedling types available and the seedling types planted on their plots. For risk and time preferences experiments, four respondents refused to participate in the experiments for religious reasons, a situation not uncommon in such studies, such as an example in Uganda (Ubfal, 2016) and in Indonesia (Miyata, 2003; Goldbach and Schlüter, 2018). After these removals, 486 respondents were included in subsequent analysis. Table 5-1 provides the descriptive statistics of explanatory variables for all respondents and each choice category.

Table 5-1. Descriptive statistics of seedling choice groups

Variables	Total		CC		CU		UC		UU	
	Mean	SD	Mean	SD.	Mean	SD	Mean	SD	Mean	SD
Number of observations (HH)	486		69		53		137		227	
Household characteristics										
Gender of the head of HH (1 if male)	0.97	0.16	0.99	0.12	1.00	-	0.99	0.12	0.96	0.21
Age of the head of HH (year)	53.24	11.07	53.75	11.20	53.08	12.31	51.03	10.11	54.45	11.16
Experience of the head of HH (year)	15.10	10.24	11.41	9.49	13.79	11.51	14.85	9.91	16.68	10.06
Education of the head of HH (year)	7.56	4.00	7.97	4.32	6.45	3.82	8.45	3.86	7.15	3.93
HH size (person)	3.88	1.48	4.39	1.51	3.79	1.41	3.82	1.27	3.79	1.58
Citrus income (million IDR)	17.52	34.43	23.38	38.29	19.75	40.67	17.60	32.67	15.18	32.60
Non-agricultural income (million IDR)	29.02	42.33	33.11	44.06	25.79	33.36	29.40	40.92	28.30	44.61
Agricultural assets										
Agricultural land (hectare)	1.09	2.40	1.02	1.03	1.11	2.09	1.02	2.63	1.15	2.63
Citrus ownership (trees)	397.30	407.28	452.83	359.03	440.38	343.36	363.42	378.23	390.81	449.30
Farmer's support systems										
Mobile-phone (unit)	2.20	1.18	2.42	1.17	1.75	1.02	2.38	1.13	2.12	1.22
Internet (1 if yes)	0.65	0.48	0.72	0.45	0.66	0.48	0.66	0.47	0.61	0.49
Citrus training (1 if yes)	0.06	0.23	0.16	0.37	0.08	0.27	0.06	0.24	0.02	0.13
Citrus extension (1 if yes)	0.22	0.41	0.33	0.47	0.34	0.48	0.18	0.39	0.17	0.38
Climate extension (1 if yes)	0.05	0.23	0.10	0.30	0.09	0.30	0.08	0.27	0.01	0.11
Farmers group membership (1 if yes)	0.16	0.37	0.33	0.47	0.26	0.45	0.12	0.33	0.11	0.32
Cooperative membership (1 if yes)	0.06	0.23	0.10	0.30	0.04	0.19	0.07	0.25	0.04	0.21
Direct access to gov authority (1 if yes)	0.22	0.41	0.20	0.41	0.19	0.39	0.23	0.42	0.22	0.42
Credit access (1 if yes)	0.27	0.44	0.25	0.43	0.28	0.45	0.25	0.43	0.28	0.45
Citrus technology information source (1 if other farmers)	0.75	0.43	0.64	0.48	0.62	0.49	0.80	0.40	0.79	0.41
Climate information source (1 if none)	0.61	0.49	0.48	0.50	0.64	0.48	0.49	0.50	0.72	0.45

Note: CC: certified-certified; CU: certified-uncertified; UC: uncertified-certified; UU: uncertified-uncertified

5.5 Empirical strategy

To understand the correlates associated with seedling choice categories of respondents we use the multinomial logit model (Läpple and Rensburg, 2011; Andersson et al., 2015). In our analysis, farmer i is categorised as being in one of four mutually exclusive alternatives (j) associated with their most recent type of seedling planting choice and their future intentions for planting seedlings: (1) certified-certified (CC), (2) certified-uncertified (CU), (3) uncertified-certified (UC), and (4) uncertified-uncertified (UU). Whilst a farmer can only be in one of these categories, it is possible (and potentially insightful) to relate the frequency of farmers in each category to variables observable for analysis. This approach provides both a description of the ex-ante probability that each farmer will be in any of the four categories based on observable individual-level variables, and of the correlation between observable variables and the probability of a farmer being in each of the four categories. The latter is of primary interest for considering the relationship of risk preferences, time preferences and subjective beliefs to adoption patterns for certified citrus seedlings.

Formally, the probability of farmer i chosing alternatives $(P_{ij})\ for\ j \in (CC, CU, UC, CC)$ is given by the Logit model as:

$$Pr\ (y_i = j) = \frac{e^{x_i' \beta_j}}{\sum_{j=1}^{4} e^{x_i' \beta_j}}, \qquad j\ =\ 1, \dots, 4 \tag{5-5}$$

We use the first category ($j = 1$ indicating CC farmers) as the base outcome so that the determinant associated with each category can be compared with CC. The coefficients resulting from the model are interpreted as being associated with the relative probability of a farmer being in either CU, UC or UU relative to being in category CC (Läpple and Rensburg, 2011; Andersson et al., 2015).

$$\frac{Pr_{(y\ =\ j)}}{Pr_{(y\ =\ 1)}}\ =\ e^{x_i' \beta_j},\quad for\ j\ > 1 \tag{5-6}$$

A key assumption in the theory underpinning the use of categorical models as indicative of underlying decision frameworks is the Independence of Irrelevant Alternatives (IIA). It is now well-known that the multinomial logit model (i.e. a logit model with 3 or more alternatives/categories) is susceptible to non-independence of irrelevant alternatives due to the mathematical formulation of the decision problem. However, this is only a concern in the case that an irrelevant alternative/category exists. This might occur, for example, in the case that CC farmers were (arbitrarily) split into two cohorts – those who purchased certified seedlings on an odd day of the week versus those who purchased on an even day of the week. However, In the case that no irrelevant alternatives are present the multinomial logit model is a preferred alternative to others, such as the multinomial probit, due to the latter relying on simulated maximum likelihood approaches that become problematic for larger numbers of alternatives/categories. In this study, each category is a logical exclusion from the others based on considerable behavioural differences regarding the adoption of (or not) of a potentially costly technology (certified seedlings). Thus, there are unlikely to be any concerns regarding the IIA assumption with respect to the choice of the multinomial logit model as the key statistical methodology underpinning this study. As a safeguard we also conducted a series of tests to consider the failure of the IIA assumption following Nguyen-Van et al. (2017). No indications of the failure of the IIA assumption were found.

5.6 Results and discussion

5.6.1 Expected yields

We first consider the existence of differences in the subjective beliefs of the mean and variance for yields between certified and uncertified seedlings by differentiating between those farmers that have purchased certified seedlings and those that have not. The results in Figure 5-3 indicate that the overall mean expected yield for certified seedlings is significantly higher than for uncertified seedlings (P-value = 0.000). However, this result is driven by those farmers who intend to continue their use of certified seedlings (CC, n = 69) or who intend to use certified seedlings in the next planting period (UC, n = 137). For citrus farmers who have used certified seedlings but were not intending to use them again (CU, n = 53), the difference in the mean yield of certified versus uncertified seedlings is lower and significant at only the 10% level, (paired t-test P-value = 0.076). For those households that do not have or intend to use certified seedlings (UU, n = 227), the mean yield is not statistically different (paired t-test P-value = 0.122).

These results indicate that the adoption, or not, of certified citrus seedlings by farmers in this sample are tied to beliefs regarding the relative yield performance of certified citrus seedlings. Specifically, the categories of farmers showing continued adoption (disadoption) also show the strongest yield advantage (disadvantage) for certified citrus seedlings.

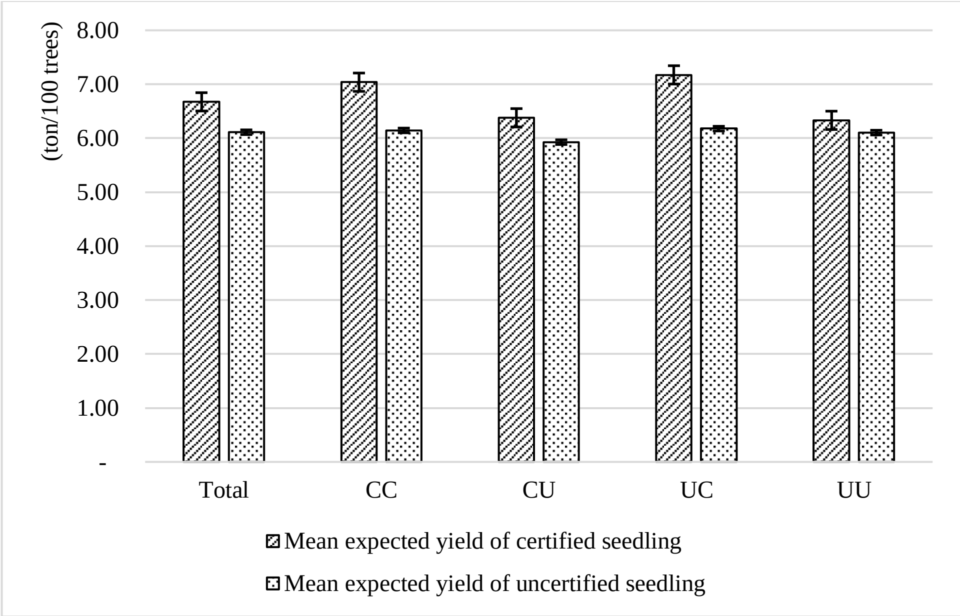

Figure 5-3. Mean of expected yield of certified and uncertified citrus seedlings

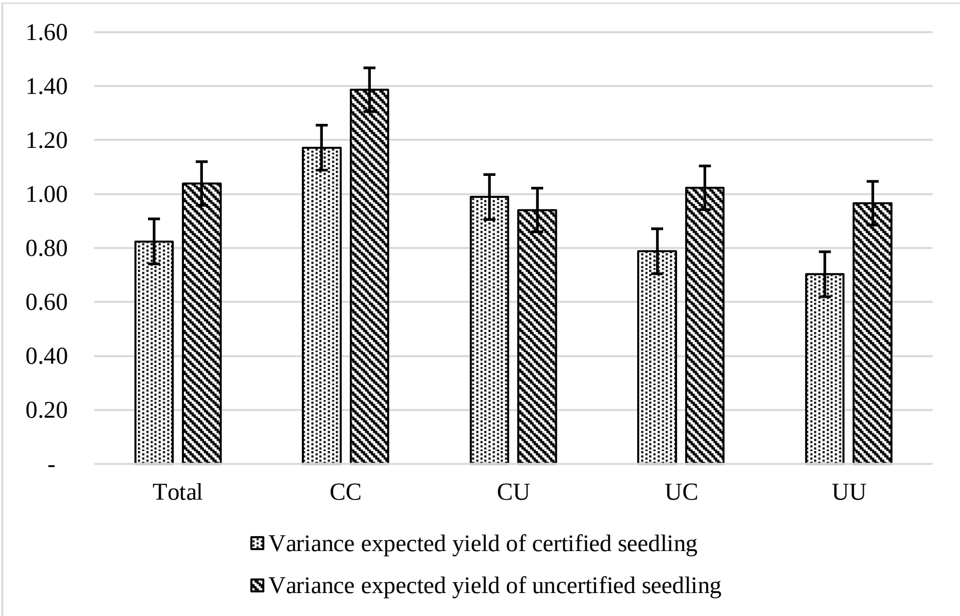

Figure 5-4. Variance of expected yield of certified and uncertified seedlings

In contrast to the results shown in Figure 5-3, those shown in Figure 5-4 regarding subjective beliefs over the variance of yields for certified versus uncertified seedlings indicate a more general expectation of lower variance for certified relative to uncertified citrus seedlings. Excepting the CU group, there was a general expectation that certified seedlings had a lower yield variance than uncertified seedlings (paired t-test P-value of CC, CU, UC and UU respectively are: 0.039; 0.596; 0.000; and 0.000).

5.6.2 Risk and time preferences

Table 5-2 shows the risk and time preferences calculated from responses to the survey methods outlined in Section 5.3.2. The risk scores represent a combination of constant relative risk aversion and self-qualitative assessment of risk preferences with lower values indicating more risk-aversion and vice versa with risk neutrality indicated by a score of 5.563. Observed risk preference scores range between 0.563 to 10.563 (Table 5-2). In line with previous studies (e.g., Gong et al., 2016; Fischer and Wollni, 2018), we find that the majority of the respondent farmers could be categorised as risk-averse. We also find no difference in risk preferences between groups of farmers based on adoption category (Table 5-3).

Table 5-2. Expected yields and behavioural preferences of seedling choice groups

Variables	Total		CC		CU		UC		UU	
	Mean	SD	Mean	SD.	Mean	SD	Mean	SD	Mean	SD
Risk preference	3.59	2.36	3.68	2.50	3.63	2.54	3.48	2.21	3.62	2.37
Time preference	3.39	2.42	3.81	2.74	3.34	2.19	3.39	2.52	3.28	2.52
RPI of increasing temperature	5.77	3.38	6.39	3.64	5.85	3.25	5.55	3.41	5.69	3.31
RPI of increasing dry season period	5.35	3.17	5.77	3.80	5.74	3.05	5.07	3.20	5.29	2.95
RPI of increasing rainy season period	6.11	2.97	5.94	2.83	5.09	3.18	6.43	3.21	6.20	2.78

Time preferences, indicated by patience scores, represent the combination of discount factor preferences and self-qualitative assessment for farmers' willingness to give up something today in order to benefit more in the future. The lowest level of time preferences indicates the lowest patience levels of the farmers for delayed payment and vice versa. The patience scores range between 0 and 10.653 with the average being 3.393 (Table 5-2). Thus, in line with previous studies (e.g. Goldbach and Schlüter, 2018), most of our respondents could be categorised as having low patience for future payments, implying a high rate of time discounting. However, there is no difference in time preferences between groups (Table 5-3).

Table 5-3. Mean comparison of characteristics between groups

Variables	CC vs CU	CC vs UC	CC vs UU	CU vs UC	CU vs UU	UC vs UU
Household Characteristics						
Gender (1 if male)	-0.014	0.000	0.030	0.015	0.044	0.029
Age (year)	0.678	2.724*	-0.696	2.046	-1.374	-3.420***
Experience (year)	-2.387	-3.441**	-5.277***	-1.054	-2.890**	-1.836**
Education (year)	1.518**	-0.474	0.817*	-1.992***	-0.701	1.291***
HH size (person)	0.599**	0.574***	0.603***	-0.025	0.004	0.029
Citrus income (million IDR)	3.622	5.774	8.201**	2.152	4.579	2.427
Total income (million IDR)	11.416	14.798*	20.864**	3.382	9.449	6.066
Agricultural assets						
Land (hectare)	-0.089	0.001	-0.125	0.091	-0.036	-0.126
Citrus (trees)	12.449	89.403*	62.016	76.954*	49.567	-27.387
Farmers support systems						
Mobile-phone (unit)	0.666**	0.041	0.301**	-0.625***	-0.364**	0.261**
Internet (1 if yes)	0.064	0.060	0.112*	-0.004	0.048	0.052
Citrus training (1 if yes)	0.084*	0.101**	0.142***	0.017	0.058**	0.041**
Citrus extension (1 if yes)	-0.006	0.151**	0.162***	0.157**	0.168***	0.011
Climate extension (1 if yes)	0.007	0.021	0.088***	0.014	0.081***	0.067 ***
Farmers group membership (1 if yes)	0.069	0.209**	0.219***	0.140**	0.150***	0.010
Cooperative membership (1 if yes)	0.064	0.036	0.057*	-0.028	-0.006	0.006
Direct access to gov authority (1 if yes)	-0.037	-0.002	-0.036	0.035	0.001	-0.034
Credit access (1 if yes)	0.014	-0.023	-0.022	-0.038	-0.036	-0.002
Citrus technology information source (1 if other farmers)	0.015	-0.158**	-0.155***	-0.173**	-0.170***	0.003
Climate information source (1 if none)	-0.163*	-0.011	-0.244***	0.152*	-0.081	-0.233***
Beliefs and risk behaviours						
Mean expected yield of certified seedling	0.660	-0.136	0.707*	-0.795**	0.047	0.843***
Mean expected yield of uncertified seedling	0.217	-0.033	0.040	-0.251	-0.177	0.074
Variance expected yield of certified seedling	0.183	0.384**	0.469***	0.201	0.286**	0.085
Variance expected yield of uncertified seedling	0.446**	0.364**	0.421***	-0.082	-0.025	0.057
Risk preference	0.045	0.196	0.055	0.151	0.010	-0.141
Time preference	0.465	0.419	0.525	-0.046	0.060	0.106
RPI of increasing temperature	0.542	0.837*	0.704*	0.294	0.162	-0.132
RPI of increasing dry season period	0.032	0.695*	0.477	0.663*	0.445	-0.218
RPI of increasing rainy season period	0.848*	-0.489	-0.256	-1.336**	-1.104***	0.232

Note: '*', '**', '***' significant at 10%, 5%, and 1% probability level, respectively, computed by a two-sided *t*-test for continuous variables and Mann-Whitney (Wilcoxon) test for dummy variables. The coefficient is mean difference. For example, if the coefficient of CC vs CU positive, it means that the mean of CC is higher than CU, vice versa.

Regarding the climate risk perception indices (RPI), citrus farmers perceived an increasing rainy season period as the highest risk, followed by increasing air temperature and increasing dry season period. However, this pattern is different among the four adoption cohorts. For the farmers who currently use certified seedlings (CC and CU), increasing air temperature is perceived as the highest risk. However, for the non-adopter groups (UC and UU), increasing rainy season period has the highest RPI compared with the other climate events (See Table 5-2 and 5-3).

5.6.3 Comparison of characteristics between seedling choice groups

Table 5-3 presents a comparison of differences in characteristics between the four groups. The statistically significant differences are highlighted. Among the household characteristics, the mean years of education for CC and UC groups are significantly higher than the farmers not planning on using certified seedling in the next planting period (CU and UU). The CC farmers have less citrus cultivation experience than UC and UU farmers. In terms of their engagement with advisory services, the UU farmers are less likely to receive agricultural support from formal sources. Compared with the CC group, UU citrus farmers have less access to extension and training, lower participation in farmers' groups and cooperatives, more reliance on neighbouring farmers for their citrus technology information and no access to a climate information source. For the non-adopter farmers, we find lower participation of UU farmers in extension, training and farmers group compared with CU farmers.

The source of climate information is also significantly different amongst the adoption cohorts. Specifically, the proportion of farmers without access to a climate information source is significantly higher for farmers who plan to use uncertified seedlings (CU and UU) than for those farmers who plan to use certified seedlings (CC and UC).

An assessment of risk behaviours reveals no difference between groups in term of risk, time preferences and mean expected yield of the uncertified seedlings indicating that differences in subjective yields between certified and uncertified seedlings arise from the differences in subjective beliefs for the former rather than the latter. Indeed, results show that farmers in CC and UC cohorts have a higher mean expected yield for certified seedlings compared with UU. CC also has the highest expectation to the yield variances of uncertified seedlings, implying this group of farmers believe that uncertified seedlings are riskier than certified seedlings. The RPI of an 'increasing rainy season period' for CU is lower than CC and UC, suggesting that the higher risk perception of 'increasing rainy season period' influences farmers in both of these two cohorts: farmers who plan on using certified seedling in future planting periods.

5.6.4 Multinomial logit estimation

The estimation of the multinomial logit model uses the CC farmer group as a base category. The Hausman-McFadden test for IIA failed to reject the null hypothesis that the multinomial logit model is appropriate for the analysis of the dynamic choice of the citrus seedlings. Table 5-4 presents the estimation results for the multinomial logit model.

In terms of household characteristics, more years of citrus experience and smaller households are associated with a greater probability of being in the CU, UC and UU cohorts. Income variables do not have a significant relationship with the probability of being in the CU, UC and UU categories compared with CC.

We find that beliefs and risk behaviours play significant roles in the farmers' choice of citrus seedling. Expected yield significantly contributes to increases or decreases in the probability of being in CU, UC or UU compared with CC (Table 5-4), while risk and time preferences do not show a significant association when considered alone. However, the interaction of risk preferences and mean/variance of expected yield of the certified/uncertified seedling show different results. For example, farmers with a stronger preference for risk and with a higher variance of expected yield of certified seedlings have a lower probability of being UC and UU. More risk-taking (risk-averse) farmers, with a higher belief in the variance of expected yield of certified (uncertified) seedlings is associated with a lower (higher) probability of being UC and UU. Also, the higher value of the interaction between risk preferences and mean expected yield of certified seedlings increases the probability being in UU, but the higher value of the interaction between risk preferences and mean of uncertified seedlings decreases the probability being in CU and UU. The variance of expected yield also has a significant relationship. The higher variance of expected yield for certified seedlings increases the probability of moving from being an adopter of certified seedlings to a dis-adopter.

Table 5-4. Estimation result of multinomial logit model

	CU	UC	UU
(Intercept)	**5.583***** **(0.868)**	**3.897***** **(0.850)**	**3.659***** **(0.755)**
Age (year)	**-0.041**** **(0.017)**	**-0.049***** **(0.014)**	**-0.030**** **(0.013)**
Citrus farming experience (year)	**0.049**** **(0.023)**	**0.070***** **(0.019)**	**0.082***** **(0.019)**
Education (year)	-0.096 (0.060)	-0.000 (0.048)	-0.045 (0.047)
HH size (person)	**-0.284**** **(0.126)**	**-0.320***** **(0.122)**	**-0.252**** **(0.109)**
Citrus income (IDR million)	-0.003 (0.006)	0.002 (0.005)	-0.002 (0.005)
Non-agricultural income (IDR million)	0.002 (0.006)	0.001 (0.004)	0.002 (0.004)
Land (hectare)	0.056 (0.133)	0.077 (0.119)	0.094 (0.115)
Citrus tree (number)	0.000 (0.001)	**-0.001*** **(0.001)**	-0.000 (0.000)
Generator (unit)	-0.958 (0.653)	-0.754 (0.475)	**-0.886*** **(0.460)**
Mobile phone (unit)	**-0.564**** **(0.236)**	0.089 (0.182)	-0.126 (0.174)
Internet access (1 if yes)	0.841 (0.541)	-0.235 (0.449)	-0.080 (0.430)
Citrus training (1 if yes)	-1.246 (0.759)	-0.572 (0.629)	**-2.007***** **(0.735)**
Citrus extension (1 if yes)	0.446 (0.591)	-0.342 (0.511)	0.063 (0.487)
Climate extension (1 if yes)	0.310 (0.783)	0.550 (0.662)	-1.349 (0.834)
Farmers group membership (1 if yes)	-0.727 (0.614)	**-0.955*** **(0.520)**	**-0.986**** **(0.497)**
Cooperative membership (1 if yes)	-0.621 (0.665)	-0.593 (0.529)	**-0.886*** **(0.533)**
Citrus credit (1 if yes)	0.662 (0.506)	0.422 (0.421)	**0.792*** **(0.408)**
Direct access to gov authority (1 if yes)	0.183 (0.529)	0.393 (0.429)	0.467 (0.420)
Citrus technology information source (1 if other farmers)	0.129 (0.466)	**0.733*** **(0.408)**	**0.689*** **(0.386)**
Climate information source (1 if none)	0.389 (0.452)	-0.078 (0.357)	0.534 (0.346)
Risk perception index of increasing air temperature	-0.032 (0.070)	-0.076 (0.056)	-0.033 (0.054)
Risk perception index of increasing dry season period	0.064 (0.075)	-0.055 (0.057)	-0.021 (0.057)
Risk perception index of increasing rainy season period	**-0.148**** **(0.074)**	0.064 (0.060)	0.021 (0.058)
Mean expected yield of certified seedling (ton/100 trees/yr)	**-0.417*** **(0.236)**	0.073 (0.184)	**-0.480***** **(0.185)**
Mean expected yield of uncertified seedling (ton/100 trees/yr)	**0.413*** **(0.234)**	0.053 (0.184)	**0.531***** **(0.185)**
Variance expected yield of certified seedling	**0.809*** **(0.420)**	0.651 (0.411)	0.655 (0.401)
Variance expected yield of uncertified seedling	**-1.699***** **(0.574)**	**-0.751*** **(0.445)**	**-0.946**** **(0.440)**
Risk preferences	-0.122 (0.213)	0.109 (0.182)	0.043 (0.172)
Time preferences	-0.110 (0.094)	-0.099 (0.071)	-0.098 (0.068)
Risk preference : Mean expected yield of certified seedling	0.059 (0.049)	-0.012 (0.041)	**0.068*** **(0.040)**
Risk preference : Mean expected yield of uncertified seedling	-0.075 (0.048)	-0.016 (0.042)	**-0.089**** **(0.040)**
Risk preference : Variance expected yield of certified seedling	-0.127 (0.077)	**-0.161*** **(0.091)**	**-0.158*** **(0.082)**
Risk preference : Variance expected yield of uncertified seedling	**0.319**** **(0.127)**	0.152 (0.108)	**0.212**** **(0.101)**

Note: Certified – certified (CC) is the comparison group. The standard error in parentheses. *', '**', '***' significant at 10%, 5%, and 1% probability level. Please see Appendix 6 (Table A5-1) for the estimation of the model without interaction.

Whilst subjective beliefs over yields are strongly tied to intentions and actions, there are stronger indications that yield stability is a more universally-valued attribute of certified seedlings. Results show that higher variance of expected yield of uncertified seedlings associated with a lower probability of being CU, UC and UU cohorts. This finding could help explaining why large numbers of adopter farmers (43.9 per cent) do not plan on using certified seedlings. Their dis-adoption behaviours might be related to their beliefs about seedling riskiness where certified seedlings is risker than uncertified seedlings (see Fig. 5-4). The possible explanation for this finding is that there is a possibility that the CU farmers planted "low quality certified seedlings" as the implementation of procedures and regulations in the certification process is not strict, resulting in lower quality seedlings being claimed and sold as high-quality certified seedlings (see. van Gastel et al., 2002; Maredia et al., 2019).

Higher RPI of increasing rainy season period decreases the probability of being CU. It indicates that farmers with higher RPI of this event tend to stay with the certified seedling in their future planting season. Having a higher RPI has been associated with a greater likelihood to adapt to the respective climate issue (see. Mumpower et al., 2016; Khanal et al., 2018), as a result, the certified seedling may be perceived as a risk coping strategy for the increasing rainy season period issue.

Table 5-5 shows the average marginal effect of farmer advisory services. Mobile-phone ownership is associated with a lower probability of being in CU and a higher probability of being in UC. On the other hand, internet access is associated with a higher probability of being in CU. Participation in citrus training has a positive relationship with the probability of being in CC and is associated with a decrease in the probability of being in UU.

Climate-related extension is associated with a higher probability of being in UC and a lower probability of being in UU. In contrast, farmers who lack access to a climate information source are much more likely to be non-adopters of certified seeds. These results support other studies demonstrating the importance of providing formal climate information services to farmers studies (e.g. Tall et al., 2018).

Table 5-5. The average marginal effect of farmers' advisory services

Variables	CC	CU	UC	UU
Mobile phone (unit)	0.011	**-0.044*** **	**0.043** **	-0.010
	(0.016)	**(0.017)**	**(0.022)**	(0.024)
Internet access (1 if yes)	-0.001	**0.081** **	-0.051	-0.029
	(0.039)	**(0.036)**	(0.051)	(0.055)
Citrus training (1 if yes)	**0.130** **	0.001	0.160	**-0.290** **
	(0.059)	(0.064)	(0.106)	**(0.135)**
Citrus extension (1 if yes)	0.003	0.043	-0.078	0.032
	(0.047)	(0.040)	(0.064)	(0.068)
Climate extension (1 if yes)	0.034	0.077	**0.245** **	**-0.357** **
	(0.061)	(0.059)	**(0.104)**	**(0.141)**
Farmers group membership (1 if yes)	**0.091** **	0.006	-0.038	-0.059
	(0.045)	(0.042)	(0.069)	(0.074)
Cooperative membership (1 if yes)	0.071	0.002	0.012	-0.086
	(0.064)	(0.073)	(0.096)	(0.110)
Citrus credit (1 if yes)	-0.061	0.010	-0.032	**0.084***
	(0.037)	(0.032)	(0.047)	**(0.050)**
Direct access to gov authority (1 if yes)	-0.038	-0.015	0.011	0.043
	(0.038)	(0.036)	(0.050)	(0.055)
Citrus technology information source (1 if other farmers)	**-0.060***	-0.038	0.046	0.052
	(0.035)	(0.031)	(0.050)	(0.053)
Climate information source (1 if none)	-0.027	0.010	**-0.084** **	**0.101** **
	(0.032)	(0.031)	**(0.041)**	**(0.046)**

Note: The standard error in parentheses. *', '**', '***' significant at 10%, 5%, and 1% probability levels

A range of social/network variables have a significant association with adoption status of farmers in this sample. Farmer group membership, cooperative membership, and receiving formal citrus training are all associated with a greater probability of being in the CC cohort compared to the UU cohort (and also in a citrus farmers' group is also associated with an increase in the probability of being in CC. In contrast, farmer-to-farmer extension is associated with a greater chance of being in the UU cohort (relative to the CC cohort). A pattern in which more community-oriented information provision/extension is associated with greater adoption of certified varieties whilst personal (e.g. farmer-to-farmer) forms of information gathering is associated with lower adoption of certified varieties may be associated with a pro-social element in which group-based training generates a stronger commitment to adoption of technologies that have positive externalities for the community of farmers overall.

Finally, our results suggest that access to credit is associated with an increase in the probability of being in UU. Hence, the higher price of certified seedlings compared with uncertified seedling might not constrain choices. Other studies find that new technologies, including climate adaptation systems often require financial support (see. Cavatassi et al., 2011; Pan et al., 2018).

5.7 Discussion

The key results revealed in Section 5-6 relate to significant differences in subjective beliefs between adoption cohorts and in the way that interactions between risk preferences interact and subjective beliefs relate to the probability of being in each of the four adoption categories. In line with previous studies (e.g. Vargas Hill, 2009; Menapace et al., 2013; Holden and Quiggin, 2016), these findings indicate that beliefs and preferences, particularly risk preferences, are key determinants of adoption patterns in the context of this study. Thus, at a minimum these results point toward the importance of effective extension programs as a mechanism to enhance adoption of certified inputs such as seedlings through influencing beliefs around private returns to adoption. However, we may explore these results further focusing on the patterns of risk preference and subjective beliefs across cohorts. Results from estimation of the multinomial logit model (Table 5-4) show that the interactions of risk preferences and subjective beliefs are significant predictors of adoption cohort membership, examination of the data show that subjective beliefs over mean and variance of yields differ substantially between adoption cohorts. On the other hand, the average risk preferences of adoption cohort members are the same (statistically) across all four adoption cohorts. Thus, whilst risk preferences are related to adoption, they are only related to adoption when considered as a reflection on differences in subjective beliefs over yields and variance for certified/uncertified citrus seed varieties. The key differences in adoption behaviour, then, relate more to subjective beliefs than to deep behavioural elements that are difficult to change (e.g. risk/time preferences). This indicates that a key element of extension programs in the context of adoption of 'credence' agricultural technologies then is to shift the subjective beliefs of farmers regarding the positive (yield, resilience, input requirements) and negative (lack of resilience, cost) attributes of the technology.

Results on extension/network related phenomena suggest particular approaches to extension may generate changes in adoption. Multinomial logit model results (Table 5-5) show that group-based networking/extension activities are associated with a stronger association with being in an adoption cohort (CC or UC) whilst farmer-to-farmer information gathering activities are more associated with being in a non-adoption cohort (UU). The similar pattern is also found in the context of hybrid seed adoption in India (Matuschke and Qaim, 2009). We suggest that group-based extension/networking activities may involve pro-social pressures and a greater airing of viewpoints that allow the moderation of incorrect information (Maertens and Barrett, 2013). Peer-to-peer activities, on the other hand, are necessarily more limited, and are more likely to be associated with confirmation bias through seeking out of like-minded individuals. Whilst this aspect should be the object of deeper explorations in order to refine extension methodologies, it points to a focus of extension activities on group-based interactions and, potentially, the creation of structured information sharing activities that seek to provide a platform for information sharing amongst disparate farming networks (see. Taylor and Bhasme, 2018).

Whilst the key results point to changing subjective beliefs as a key element of improving adoption of certified varieties, the literature on credence goods, reviewed briefly in the introduction to this paper, shows that shifting beliefs around credence attributes is not trivial (Baron, 2011; Auriol and Schilizzi, 2015). Certification programs operated to 'certify' credence attributes are prone to failure either in an absolute sense (they admit unacceptably high numbers of goods that would actually fail a test to ascertain whether they meet the certification criteria) or in a perceived sense (they are not trusted by consumers to provide goods that meet the certification criteria). The former of course will lead to the latter if it occurs at a high enough level. However, the latter may occur even if the certification program is effective in an absolute sense. Perceptions of compromise can be generated from conflicts of interest, perceptions of regulatory/monitoring failures, and from perceptions of a lack of competence. For example, conflicts of interest occur when certification agencies are also the producers of the product but can also occur when government programs are promoting production of specific crops and varieties to meet national production targets (see. Nyoka et al., 2015). Past research in Indonesia documents fake certified citrus seedlings in the market (Sutopo, 2012) indicating that a key constraint may remain for increasing adoption of certified citrus seedlings (and more broadly for inputs with credence attributes in Indonesia) may relate to the governance around Government-led certification programs.

5.8 Conclusion and policy implications

In this study, we analyse the role of farmers' belief of citrus yield and their risk behaviours on the choices regarding the adoption of certified citrus seedlings in Indonesia. A low-level of adoption of certified seedlings is one of the critical issues in citrus development in Indonesia (Supriyanto et al., 2017).

In this study we focus on behavioural elements related to adoption: namely subjective beliefs over yields and the variance of yields for 'certified' and 'uncertified' citrus seed varieties, and regarding risk and time preferences of citrus farmers. Results show that, whilst risk preferences are important predictors of adoption practices, they are only important as a reflection on subjective beliefs over yields and the variance of yields for the two seed varieties.

Time preferences as measured in this study were not found to be important. Our results indicate two policy implications.

First, the significant role of farmers' subjective beliefs of yields suggests the need to properly inform farmers about the full range of benefits certified seedlings provide. We take this common refrain further by showing that group-based extension services are strongly associated with adoption of certified varieties whilst peer-to-peer information gathering activities are more strongly associated with non-adoption. These results indicate that changing beliefs regarding the private returns to certified varieties is a key driver of adoption, but that the pathway to do so may be through greater and more effective usage of structured group-based networking/information sharing programs with a focus on creating groups with mixed prior beliefs in order to avoid confirmation bias/'group think'.

Second, in this case study area, the past experiences amongst respondents with "*low quality certified seedling*" suggest concerns around the ability of the Government to provide a robust and trusted certification process for citrus seedlings. Certification programs are inherently difficult to operate due to the need to maintain trust in the program by customers – customers who typically cannot easily assess the quality of the goods they are purchasing (in terms of the attributes being certified), even through usage. These results suggest it may be prudent for the agricultural ministry to review its seedling certification process with an aim to increase the transparency and to address farmer concerns around effectiveness, robustness and the management of conflicts of interest.

In addition, our results reveal significant relationships between adoption behaviour and climate-related variables, including a climate risk perception index, climate extension services and climate information sources. These results suggest that farmers' choice to use of certified citrus seedling may be expected as an adaptation tool for climate change issues.

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Chapter 6. Statement of Authorship

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Name of Principal Author (Candidate)	Abdul Muis Hasibuan		
Contribution to the Paper	Contributed to preparation of primary survey and data collection, data cleaning, data analysis and interpretation, and writing the manuscript.		
Overall percentage (per cent)	70 per cent		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
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Co-Author Contributions

By signing the Statements of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);
ii. permission is granted for the candidate in include the publication in the thesis; and
iii. the sum of all co-author is equal to 100 per cent less than the candidate's stated contribution.

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Chapter 6. Risk preferences, intra-household dynamics and spatial effects on chemical inputs use: Case of small-scale citrus farmers in Indonesia[15]

Abstract

The use of chemical fertilisers and pesticides is rapidly increasing in developing countries. If used appropriately, these inputs are key approaches to enhancing farm productivity including mitigating potential damage caused by climate change. Yet there is also an increasingly concerning trade-off between chemical input applications and environmental externalities in communities of smallholder farmers. Furthermore, fertilisers and pesticides account for a high proportion of farm input expenses, especially for high-value horticultural crops, impacting on the risks facing farmers and potentially limiting other household needs for cash-constrained households. Given the potential impacts of chemical input purchases on household expenditures and the joint roles of male and female spouses in farming activities in Indonesia, these input purchase decisions may involve complex intra-household dynamics between spouses. Moreover, small-scale farmers in rural areas often refer to their neighbour farmers in managing their farm. In this paper, we consider the independent and joint roles that risk, intra-household dynamics, and extra-household (spatial) dynamics play in decisions regarding household expenditure on chemical fertilisers and pesticides. Using spatial regression models, we find that all factors are associated with household expenditures on chemical inputs. Results show that wife leadership and disagreement across farm activities contribute to the level of the chemical pesticides expenditure. The results also indicate the importance of social networking in the decision of chemical pesticides and fertilisers usage.

Keywords: chemical input, intra-household dynamics, agricultural expenditure, neighbour effect

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6.1 Introduction

Agricultural production is substantially affected by climate change (Wheeler and von Braun, 2013; FAO, 2016). Crop growth dependency on climate parameters, increasing temperature and uncertainty in precipitation, generates increased risks to agricultural production (Ramos and Martinez-Casasnovas, 2009; St.Clair and Lynch, 2010; Grimm et al., 2013), particularly for smallholders making a decision involving substantial payback periods such activities like orchards coffee and cocoa. Intensification of agricultural activities may be a strategy to cope with diminishing ecosystem support as a result of climate change on the one hand, and doubling food demand, on the other hand.

Using costly inputs to enhance production in a risky environment can be risk-increasing, creating a disincentive for investment in intensification for risk-averse producers. The potential role of input-intensification is thus an important one for rural smallholder farmers in developing countries, linked as it is to the potential for improvements or safeguarding of livelihoods, but at potentially substantial risk. Furthermore, given the social nature of many adoption decisions (e.g. Matuschke and Qaim, 2009; Maertens and Barrett, 2013; Ward and Pede, 2015) these are likely to be linked substantially to intra-household and social dynamics. This chapter presents an analysis of how spatial dynamics and intra-household bargaining factors affect the pattern of the chemical input usage among small-scale citrus farmers in Indonesia.

Promoting intensification of agricultural practices, for instance, by increasing agrochemical input intensity, is a common focus of governments and development organisations to increase farm productivity and food security (e.g. Minten and Barrett, 2008; Bezu et al., 2014; Arslan et al., 2017; Binswanger-Mkhize and Savastano, 2017). As small-scale farmers have lower capability to apply these practices, a common policy tool used by many governments is input subsidies (e.g. Xu et al., 2009; Rada et al., 2011; Jayne and Rashid, 2013; Warr and Yusuf, 2014). As a result, there is a tendency toward increasing farmers dependency on the use of chemical inputs (see. Schreinemachers et al., 2012; Nelles and Visetnoi, 2016; Qanti et al., 2017; Lambrecht et al., 2018).

Increasing expenditures on inputs can severely impact other household expenditures, such as food, health or education. Furthermore, these decisions may be associated with conflict in the household whereby male and female household heads compete for scarce cash resources. In the context of farm households in Indonesia, wives tend to have greater authority to control money for household expenditures (Colfer et al., 2015; Akter et al., 2017) whilst the husbands typically have relatively greater authority over expenses related to farming activities. This may generate conflicts over trade-offs between the objectives of male household heads in investing in agriculture to maximise (risky) farm income and those of the female household heads in ensuring the household is well-provisioned, and children are sent to school.

Such divisions are not well-represented by the classical unitary-household model often used in the literature (e.g. Marenya and Barrett, 2009; Aida, 2018; Chen et al., 2018). Even though a husband may have a stronger power in many household decisions (Carlsson et al., 2012), the wife often has a role in influencing the decision (Basu, 2006; Fisher and Carr, 2015). As a consequence, decisions regarding chemical inputs expenditure could result from negotiation between the husband and wife through a dynamic decision-making process within the farm household or via a non-cooperative outcome associated with disagreement between the spouses.

Examples of social factors are thought to affect decisions regarding the application of chemical inputs include peer effects associated with the choices or perceptions of neighbours in the village, or more distantly through patterns of adoption in other villages (Manski, 2000; Wydick et al., 2011; Wollni and Andersson, 2014). These aspects may be enhanced or moderated by environmental factors across geographic areas such as soil type and fertility, pest, disease and weed infestations, and environmental shocks such as climate-related factors (Hughes, 1996; Vigani and Kathage, 2019; Chen et al., 2020). As a result, farmers' patterns in the use of chemical inputs could depend on farm location and on input usage within and between villages.

The influence of social factors depends on interactions between farmers creating awareness of differences in farm management or of social norms, and defining the opportunities for and costs of information exchange (Lapple and Kelley, 2014; Haensch et al., 2019). For example, control efforts against some citrus diseases, like Huanglongbing disease in East Java, that spread by a highly mobile insect vector require collective action of the farmers at large spatial scales (Milne et al., 2018; Singerman and Useche, 2019). Information exchange about the benefit of collective action against the insect vector could increase the farmers' willingness to participate by creating pressure associated with conformity to an emergent social norm. Also, considering the importance of coordinating spraying times between farmers, the farmers' involvement could be influenced by regulations, leading to pressure on farmers to participate in collective action efforts (Singerman and Useche, 2019).

Individual preferences also play an important role. Chemical inputs are costly inputs for small-scale farmers, and have yield-effects related to environmental factors (i.e. temperature, rainfall, extreme weather events) meaning the application of these inputs is potentially risk-increasing (Dercon and Christiaensen, 2011). As a consequence, the decisions regarding the use of chemical inputs are also related to risk preferences as they affect the distribution of returns under any environmental state.

For example, the chemical fertiliser could contribute to increasing the variance of profit (risk-increasing inputs) despite tending to increase the yield in most states of nature. On the other hand, pesticide applications are thought to be risk-reducing inputs despite being costly as they tend to reduce variance in yields and revenues (Just and Zilberman, 1983). An extensive literature exists analysing the association of risk preferences with the use of chemical inputs indicates that risk preferences may be important components of decisions regarding their application (e.g. Pannell, 1991; Liu and Huang, 2013; Gong et al., 2016; Burke et al., 2019; Hou et al., 2020).

To date, limited studies analyse this relationship simultaneously with social (spatial-neighbour), geographic (spatial-environmental) and household bargaining considerations. Considering that small-scale farmers are highly budget constrained for chemical input procurement and the possibility of different characteristics of the inputs regarding risk exposure, the farmers' risk preferences may provide a better explanation of the farmers' tendency to use more chemical pesticides or fertilisers than social, environmental or household bargaining factors.

This chapter presents an analysis of the adoption of chemical inputs in the context of citrus production by smallholders in East Java Province in Indonesia. Using well-established risk preference measures, novel approaches to measuring household bargaining in relation to farm decision-making, and spatially econometric models, the analysis considers the simultaneous relationship of social, environmental, intra-household dynamics and risk preferences factors to the use of chemical inputs in a setting in which low levels of application may be limiting profitability.

This chapter contributes to the literature in several ways. First, indices of the dynamic of intra-household leadership in farm decision–making the study is developed, allowing a detailed understanding of the dynamic in household leadership and its relationship with household expenditure for farm chemical inputs. Second, these insights are combined with extra-household factors associated with social networks and geographic patterns of adoption and with intra-household factors related to the examination of decision-making and leadership of male and female spouses regarding chemical inputs expenditure choices. Third, with more focus on farmers risk preferences, intra-household factors and social and network effects, the aim is to provide empirical evidence for the pathways to behavioural change in terms of the usage of chemical pesticides and fertilisers, with the case of small-scale citrus farmers in Indonesia.

The following section presents the conceptual framework, followed by a brief description of the survey site and selected samples characteristics. In section 6.4, the spatial model to estimate the role of risk preferences, intra-household dynamics and neighbourhood effects on chemical inputs use is presented. The results are shown in Section 6.5, presenting the level of chemical input expenses, intra-household dynamic in farming decision-making leadership and the estimation results. The paper discusses the implications of potential policy and program interventions in Section 6.6 and the conclusion in Section 6.7.

6.2 Conceptual frameworks – intra-personal, intra-household and network models

Within a given region, adoption and usage of chemical inputs are driven by factors that occur across three main levels: the personal level (‘intra-personal’) defined by preferences; the household-unit level (‘intra-household’) defined by the relationships between decision-makers in the households, and; the community level (‘extra-household’) wherein information sharing and peer effects can generate localised differences in usage patterns. These are outlined conceptually in the following with a focus on particular elements that we sought to measure in this chapter, respectively: risk preferences; intra-household bargaining and disagreement, and; network effects. The association of these variables with the chemical inputs use can be conceptualised in a reduced form input demand function (see. Lin, 1994), as:

$$x_j = f(z, Risk, HH, SN) \qquad (6\text{-}1)$$

where x_j is chemical input j, z is a vector of household and plot characteristics, $Risk$ is risk preferences, HH is intra-household dynamics in decision-making, and SN is social networks. In the remainder of this section we detail the individual elements in Eq. (6-1) with a focus on their linkage to input usage decisions for smallholder agricultural households.

6.2.1 Riskiness and risk preferences

The intensity of the application of chemical inputs such as fertilisers and pesticides is associated with both changes to the expected yield and with changes to the variance of expected yields. As a result, choices over the application of chemical inputs have implications for the risks that face farmers and so are a function of farmers' risk preferences (Just and Zilberman, 1983). For example, pesticide applications are often considered a risk reduction strategy, so that risk-averse farmers tend to apply more pesticide to stabilise the farm yield or profit (Just and Pope, 1978). However, other studies highlight that pesticide applications in some contexts can increase risk (e.g. Pannell, 1991; Salazar and Rand, 2020) or even have different risk implications within a context but with the application of different types of pesticides (Möhring et al. (2020). Similarly, the relationship between risks and fertiliser is an empirical question with research showing both risk-increasing and risk decreasing outcomes in different contexts (e.g. Gandorfer et al., 2011).

The risk profile of inputs, that is whether they are risk-decreasing, risk-neutral, or risk-increasing, influences choices on input utilisation through the risk preferences of the decision-maker. Specifically, risk-averse (loving) producers prefer mean preserving spread decreases (increases) over increases (decreases). Taking risk-neutrality as a base case, this means the risk-averse (loving) producers will tend to utilise less (more) of risk-increasing inputs and more (less) of risk decreasing inputs relative to a risk-neutral producer.

6.2.2 *Intra-household bargaining and disagreement*

The assumption of the unitary household model used in many studies does not account for intra-household processes that involve differing preferences of key household decision-makers, for example the male and female household heads (Udry, 1996; Doss and Quisumbing, 2020). This is particularly relevant for extension-based approaches to shifting the intensity of chemical input usage with differences in attendance to extension schools and membership of farming groups. Disagreements can also influence final input use choices of households meaning that different approaches to targeting behavioural change may be important.

Cultural institutions, not efficiency or effectiveness, are a prime factor in determining women's roles in agricultural households in Indonesia. These cultural norms mean that men tend to take the lead in farming engagement activities and to place significant demands on women's time associated with domestic duties (Akter et al., 2017). Extension programs typically target men, and it is men who are expected to represent their households in formal village activities (van de Fliert, 1999; Wijers, 2019). This all might suggest that the unitary model is appropriate as a decision model in this context. Yet women play important roles in a range of key farming activities such as planting, harvesting and marketing (Seymour, 2017). In addition, women in smallholder farming households typically take the lead in managing household income and expenditures (Colfer et al., 2015; Akter et al., 2017). Women, then, are likely to hold important roles in decision-making and may be able to sway decisions to their own preferences in cases of disagreements.

The non-cooperative model is gaining traction as an alternative decision model for households in which the household heads hold different preferences and do not always achieve a resolution to disagreements. For example, different responses between husband and wife regarding leadership in decision-making over particular activities implies a disagreement and provides insights into the underlying power of relative leadership in the decision-making process between husband and wife (Seymour and Peterman, 2018). This disagreement between the spouses can be a source of inefficiency or efficiency in the household. In cases that inefficiency drives duplication or ignorance of key activities, disagreements generate inefficiency. However, in cases that disagreements are associated with one spouse rejecting poor choices of the other spouse, improved efficiency may be achieved. For example, Robinson (2012) shows that women tend to prefer to spend greater portions of household income on items/services that support overall household welfare whilst men tend to seek to direct household income to expenditures that are more associated with private (own) utility. This is associated with household (in)efficiency when women(men) can hide income from their spouse in a non-cooperative setting (e.g. see evidence for income hiding by both men and women in Castilla and Walker (2013)). The key driver in these outcomes is the presence of disagreement over norms of behaviour in the household, in particular regarding key decisions that are associated with household activities. Identifying the sources of these disagreements, and describing both their key elements and their impacts on decision outcomes can contribute to understanding approaches to guiding household decisions in the future. Whilst a considerable research effort has been placed on establishing the primacy of the non-cooperative model, through the use of field experiments to observe the tendency for household heads to make (costly) use of asymmetric information (e.g. Castilla and Walker, 2013; Ashraf et al., 2014), there are few studies that seek to describe the sources of disagreements and their relationships to household decisions for smallholder farming households.

6.2.3 Social network

The relationship of social networks (SN) to chemical input usage decisions can be related to three main network effects (Manski, 2000). Firstly, endogenous interactions describe the case wherein farmers' behaviour emerges from the bulk of behaviours within their peer groups.

Secondly, contextual interactions occur where farmers' behaviour is associated with exogenous group characteristics. Lastly, correlated effects occur where institutional conditions are similar between groups driving correlations between those groups – for example, between villages that may be geographically isolated but institutionally similar.

The endogenous effect typically assumes that a farmer might learn or imitate their peers' experimentation or behaviours (Wydick et al., 2011; Maertens and Barrett, 2013). This means that farmers within a network may learn from each other, and that there may be a tendency toward homogenisation of practices over time (Ward and Pede, 2015). Contextual interactions occur when farmers face relatively identical conditions or environment resulting in similar activities. Spatial interactions based on environmental concerns can also involve feedback processes wherein positive or negative externalities of particular activities (e.g. efforts to control Huanglongbing disease by some farmers) affect the activities of others (e.g. freeriding by non-controlling farmers that can impact effectiveness of regional control of the Huanglongbing disease) (Milne et al., 2018; Singerman and Useche, 2019). Spatial effects can then provide improved insights into patterns of farming activities which may be otherwise ignored by studies that do not account explicitly for these effects.

6.3 Methods

6.3.1 Risk preferences

Risk preferences were calculated using survey-based experimental methods that were posed as hypothetical multiple price lists (MPL) in addition to questions that involved qualitative self-assessments for willingness to take risks. The questions were derived from the survey-based risk assessment methods of Falk et al. (2016)[16] that have been calibrated to a wide range of

[16] As gambling activities is illegal in Indonesia and considering cultural and religious affiliation in survey site, we did not use the "lottery" term. Practically, our enumerators emphasised to the respondents that the experiments are the scientific method to elicit the risk behaviours.

respondents including to the low literacy in developing countries as reported in Falk *et al*. (2016). Using staircase procedures, farmers were first asked to choose between a hypothetical risky lottery versus a hypothetical safe payment. If they prefer the safe option, the farmer then faced a question with a reduced safe payment but with the same lottery option. In the case that the farmer chose the lottery option, the next question they faced involved a higher safe payment option with the same lottery option. This was iterated five times for each respondent providing large coverage of the range of risk attitudes and reasonably high fidelity for non-boundary risk preferences (i.e. highly risk-averse or highly risk-loving)[17]. The final risk preference value was calculated using combinations of the respondents' choices in the staircase hypothetical risk assessment task and the responses to the subjective self-assessment questions based on the procedure of Falk *et al*. (2018). The weighted-values of experiment and survey items in constructing risk preferences were obtained by computed z-scores of self-assessments in individual level, then weighting the z-scores with the regression coefficients of observed choices in the experiment with the respective survey item. The calculated risk preferences, representing relative risk-aversion, is given by:

$$RISK = (0.5630 \times Staircase\ risk) + (0.4370 \times Willingness\ to\ take\ risks) \quad (6\text{-}2)$$

6.3.2 Riskiness of inputs

In order to understand the chemical inputs risk profiles in terms of whether they increase or decrease risk in the context of citrus farming in Indonesia, we estimated a Just and Pope production function (Just and Pope, 1978, 1979). The Just and Pope (1978) production function allows inputs to affect both the mean yield function (the production function) and to be associated with changes in the expected variance of that yield. In this context, a productive factor that generates an increase in the variance of the yield is thought to be risk-increasing

[17] See Appendix 3 for more details

whilst one that generates a decrease in the variance of the yield is risk-decreasing. The conceptual form of the Just and Pope production function is:

$$y_i = f(x_i; \alpha) + h^{\frac{1}{2}}(x_i; \beta)\varepsilon \qquad (6\text{-}3)$$

where: y_i is a yield/output measure for citrus; $f(x_i; \alpha)$ reflects the effect of the inputs on the mean of citrus yield, $E(y_i|x_i)$, and; $h(x_i; \beta) = var(y_i|x_i)$ is the variance of yield or risk function indicating how the chemical inputs increase or decrease the output risk.

In practice, a functional form is required to estimate this model using standard parametric approaches. We tested the model in alternative functional forms such as trans-log, interactions and quadratic (Hicks Neutral), as used in the previous studies (e.g. Quisumbing, 1996; Gregg and Rolfe, 2016; Seymour, 2017) and included household and plot characteristics such as HH size, citrus age and irrigation.

Profit was used as the outcome variable since the application of chemical inputs will affect the quantity and quality of citrus yield (see. Möhring et al., 2020). The variance of the profit is not only affected by the variance in yield (quantity), but also the variance in price (quality) (Pannell, 1991), so profit-risk might be better to capture the risk profile of the inputs, as the farmers are assumed to maximise profit. Since input variables were containing zero-valued observations, we used inverse hyperbolic sine transformation (Burbidge et al., 1988; Bellemare and Wichman, 2019).

6.3.3 Intra-household dynamic indices

Two main aspects of household interactions were considered in this analysis: wife's leaderships and disagreement between the spouses on leadership statements. Indices to describe these factors were developed following the approach of Sayekti et al. (2020). These indices involve the identification of wife's leadership statements and the disagreement in leadership statements between male and female spouses across k=15 citrus farming activities: (1) land preparation; (2) buying farm equipment; (3) buying farm input (fertilisers, pesticides, etc.); (4) choosing and buying seedling; (5) planting; (6) fertilisers application; (7) pesticides application; (8) weeding; (9) watering, irrigation & drainage maintenance; (10) pruning; (11) harvesting; (12) deciding marketing method; (13) negotiating with buyer/trader; (14) looking for hired labour; and (15) attending extension activities.

For each activity, the husband and wife were both asked (separately and independently) to indicate whether they led the activity, whether their spouse led the activity, or whether they jointly led the activity.

Let $WWL_{ik} = 1$ for the case that the female spouse in household i stated she led activity k and $= 0$ otherwise. From this definition, a wife's leadership index (WWL) was calculated as:

$$WWL_i = \sum_{k=1}^{K} WWL_{ik} \qquad (6\text{-}4)$$

Disagreements regarding the wife's leadership statement could take the form of positive disagreement (male spouse states the female spouse leads the activity whilst the female spouse states she does not) or negative disagreement (male spouse states the female spouse does not lead the activity whilst the female spouse states she does). Let $HWL_{ik} = 1$ represent the case that the husband stated his wife led activity k in household i and $= 0$ otherwise. Measures of positive and negative disagreement are then given by:

$$POS_{ik} = \begin{cases} 1 \ if \ WWL_{ik} = 0 \ and \ HWL_{ik} = 1 \\ 0 \ otherwise \end{cases} \qquad (6\text{-}5)$$

$$NEG_{ik} = \begin{cases} 1 \ if\ WWL_{ik} = 1\ and\ HWL_{ik} = 0 \\ 0\ otherwise \end{cases} \quad (6\text{-}6)$$

The final disagreement index was indicated by the sum of negative and positive disagreements:

$$DIS_i = \sum_{k=1}^{K} NEG_{ik} + \sum_{k=1}^{K} POS_{ik} \quad (6\text{-}7)$$

6.3.4 Spatial factors

In the case that farmers' behaviours in chemical inputs use are generated by spatial dependence processes, spatial regression models are efficient approaches to modelling these processes (e.g. Ward and Pede, 2015; Aida, 2018). The estimation strategies can be specified as the combination of spatial autoregressive (SAR) and spatial error model (SEM), known as SAC or SARAR model as follows:

$$\boldsymbol{X}_{ij} = \rho W \boldsymbol{X}_{ij} + \alpha_j \boldsymbol{Z}_i + e_j \quad (6\text{-}8a)$$

$$e_j = \lambda W e_{\text{j}} + u_j \quad (6\text{-}8b)$$

where W is a $n\ x\ n$ spatial-weight matrix, $W\boldsymbol{X}$ represents the endogenous interaction effects of dependent variables for farmer i and network members n, We is the interaction effect among disturbance terms, $\boldsymbol{Z}$ is a vector of explanatory variables, ρ is the coefficient of spatial autoregressive, and λ is the coefficient spatial autocorrelation. If ρ and $\lambda \neq 0$, it means that the social networks cause the farmers to behave in the same way as they have similar unobserved conditions related to the chemical inputs decision.

We chose to use a 2.5 km threshold, based on household GPS coordinates, to analyse the spatial effect in order to incorporate regional concerns regarding the Huanglongbing disease[18]. This threshold extends beyond the village administrative region (the maximum sample in a village is 12 households), with the average number of the neighbours is 17.6 in the spatial model. We estimated the Moran's I statistic within the threshold to test if the data potentially has a spatial dependence and the spatial models are relevant for the analysis.

6.3.5 Joint modelling of risk, intra-household dynamics and spatial factors

The estimated regression model for chemical inputs use (CI) that incorporated aspects related to household risk preferences, household leadership and bargaining dynamics, and spatial processes were:

$$CI_{ij} = \rho\, WCI_{ij} + \beta_{1j} z_i + \beta_{2j} WWL_i + \beta_3 DIS_i + \beta_4 RISK_i + e_j \quad (6\text{-}9a)$$

$$e_j = \lambda W e_{\mathrm{j}} + u_j \quad (6\text{-}9b)$$

Wife's leadership and disagreement indices as outlined in Section 6.3.3. are denoted as *WWL* and *DIS*, respectively. Risk preferences calculated as outlined in Section 6.3.1 are denoted as *RISK*. The riskiness of inputs, estimated from Section 6.3.2 are not included in the regression but provide required context for the hypotheses regarding the interaction of risk preferences with input usage choices. Spatial factors are as outlined in Section 6.3.4. Finally, other plots and household characteristics (z) were included as controlling factors.

6.4 Data

This study use data obtained from a field survey that was conducted from September to October 2017 in East Java Province in Indonesia, covered three districts, namely Banyuwangi, Jember

[18] Huanglongbing is citrus greening disease, the most destructive disease in citrus farming worldwide (Rawat et al., 2017). The Asian citrus psyllid (*Diaphorina citri* Kuwayama), the insect vector for the Huanglongbing disease, can disperse up to 2 - 2.4 km (Lewis-Rosenblum et al., 2015).

and Malang. These districts are the main producers of citrus which have a high growth among small-scale farmers in rural areas so that it is important for rural development. The changing in climate also impacts the regions, especially rainfall pattern and increasing temperature (Aldrian and Djamil, 2008; Rodysill et al., 2011). Household surveys were carried out with 500 citrus farmers households in 42 villages (14 villages from each district). After removing non-responses and incomplete responses, 422 of the households remained available for analysis. Respondent locations for spatial analysis were generated using the GPS coordinates of the farmer's house (Figure 6-1).

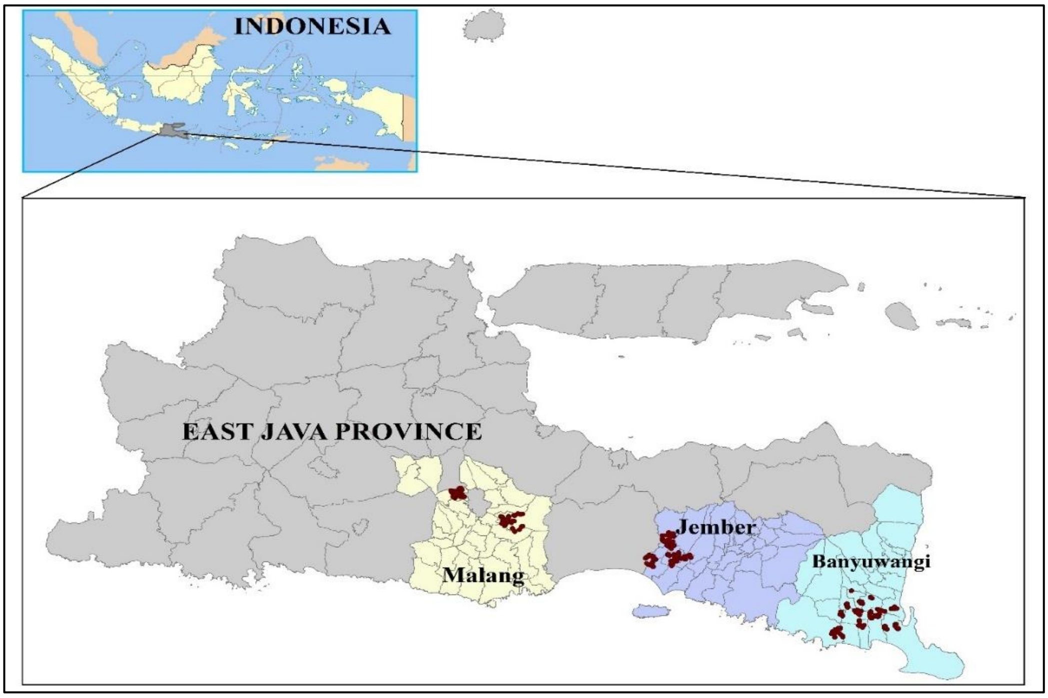

Figure 6-1. Survey site and respondents GPS location

Both the male and female household heads were interviewed, independently and separated from each other by enumerators. Responses to questions were not shared with spouses and were recorded digitally ensuring no paper records on responses were generated.

We defined a household as a citrus farmer if they manage more than 25 citrus trees, including those rented from other farmers[19]. The input usage was captured at farm plot levels and aggregated up to a farm level. The average size of the surveyed plot is 0.3 ha. Since the plot size often could not describe the actual citrus farm size, especially if a farmer used a poly-culture system, we use the number of citrus trees in the surveyed plot for the analysis, the average of which is 210.66 trees (Table 6-1). The adoption rate of certified seedling in the surveyed plot is on average 20 per cent and, on average for our sample, 10 per cent of the plot is rented in from another farmer.

Table 6-1. Respondent characteristics

Variables	No. obs	Mean	Median	Std.dev	Min	Max
Household-level characteristics						
Household size (number)	422	3.92	4.00	1.47	2.00	15.00
Citrus age (years)	422	4.74	4.00	3.56	0.00	27.00
Certified seedling (1 if yes)	422	0.20	0.00	0.40	0.00	1.00
Total citrus tree in the plot (number)	422	210.66	150.00	161.58	25.00	1900.00
Rented in (1 if yes)	422	0.10	0.00	0.30	0.00	1.00
Cooperative (1 if yes)	422	0.05	0.00	0.23	0.00	1.00
Citrus credit (1 if yes)	422	0.26	0.00	0.44	0.00	1.00
Citrus extension (1 if yes)	422	0.22	0.00	0.41	0.00	1.00
Citrus training (1 if yes)	422	0.06	0.00	0.24	0.00	1.00
Climate extension (1 if yes)	422	0.05	0.00	0.23	0.00	1.00
Citrus income (million IDR)	422	16.09	5.80	33.09	-35.15	287.30
Non-agricultural income (million IDR)	422	28.29	12.10	40.64	-2.00	300.00
Wife characteristics						
Age of wife (years)	422	46.44	46.00	10.18	23.00	86.00
Education of wife (years)	422	7.63	6.00	3.52	0.00	16.00
Risk preferences of wife	422	2.96	3.11	2.06	0.47	10.47
Husband characteristics						
Age of husband (years)	422	53.02	52.00	10.94	28.00	87.00
Education of husband (years)	422	7.55	6.00	4.00	0.00	18.00
Risk preferences of husband	422	3.72	3.58	2.30	0.47	10.47

6.5 Results

6.5.1 Chemical input use

We find that 98.82 per cent of the respondents apply chemical pesticides in their citrus orchard and almost all of our respondent (99.76 per cent) used chemical fertilisers. Since the farmers used many types of pesticides and fertilisers, we used the cost-value (IDR per tree) rather than

[19] We follow the National Statistic Agency (BPS) definition of a citrus farmer, based on the minimum business unit criteria (BPS, 2015).

the volume. The average cost for chemical pesticides was IDR 13.37 thousand or USD 1 per tree [20], dominated by insecticides, followed by fungicides and herbicides. The average expenses for chemical fertilisers was IDR 16.81 thousand per tree (Table 6-2). Based on paired t-test, the cost of chemical fertilisers is significantly higher than the total chemical pesticides (P-value = 0.000). However, for the plot with the certified seedling, the total cost for total pesticides was higher than chemical fertilisers (P-value = 0.093).

Table 6-2. Cost of chemical pesticides and fertilisers (IDR per tree)

	Total (n = 422)	Certified Seedling (n = 85)	Uncertified Seedling (n = 337)	t value	P-value
Insecticides	9959.39	13436.66	9082.33	2.666	0.008
	(13551.68)	(21570.50)	(10485.93)		
Fungicides	2867.46	4043.90	2570.73	2.198	0.029
	(5548.36)	(8432.75)	(4511.73)		
Herbicides	538.72	373.41	580.42	-1.846	0.066
	(926.77)	(835.77)	(944.94)		
Chemical fertilisers	16808.71	13329.14	17686.35	-2.425	0.016
	(14891.42)	(10134.50)	(15758.82)		

Note: Standard deviations are in parenthesis. P-value is calculated based on the mean difference between certified and uncertified seedlings

6.5.2 Intra-household dynamics

Table 6-3 presents the husband and wife responses regarding their involvement and statement of leadership for 15 citrus farm activities. The rate of stated husband participation and leadership is much higher than the wife for all of the activities. The husband participation is relatively low in pruning, harvesting, deciding marketing method, negotiating with buyer/trader, looking for hired labour, attending training or extension activities compared to other activities. In contrast, the wife participation in most of those activities was relatively high. It might imply the specialisation of those activities which relative more suitable for women and can substitute the husband involvement. In terms of the low participation of the husband and

[20] The average exchange rate during the survey (September – October 2017) was IDR 13,422.87 per USD (Data from Bank Indonesia)

wife in attending extension and training activities, this fact might be the result of the low availability of farmers' support system for citrus farming.

Table 6-3. Husband and wife participation and leadership in citrus farm activities (per cent)

Farm activities (k)	Participation		Leadership statement					
	Husband	Wife	HHL	WWL	HJL	WJL	HWL	WHL
1. Land preparation	0.99	0.30	0.81	0.01	0.17	0.12	0.00	0.17
2. Buying farm equipment	0.99	0.24	0.86	0.02	0.11	0.09	0.01	0.13
3. Buying farm input (Fertiliser, pesticide, etc.)	0.99	0.35	0.84	0.05	0.12	0.11	0.03	0.18
4. Choosing and buying seedling	0.99	0.32	0.81	0.02	0.17	0.16	0.00	0.14
5. Planting	0.99	0.42	0.83	0.01	0.16	0.18	0.00	0.23
6. Fertilisers application	0.99	0.37	0.83	0.02	0.14	0.13	0.01	0.23
7. Pesticides application	0.98	0.13	0.92	0.01	0.06	0.04	0.00	0.08
8. Weeding	0.92	0.44	0.71	0.04	0.19	0.18	0.02	0.21
9. Watering - irrigation/drainage maintenance	0.83	0.13	0.78	0.01	0.05	0.05	0.00	0.06
10. Pruning	0.73	0.14	0.67	0.01	0.06	0.07	0.00	0.06
11. Harvesting	0.57	0.27	0.40	0.02	0.15	0.12	0.01	0.14
12. Deciding the marketing method	0.86	0.54	0.52	0.06	0.31	0.29	0.03	0.19
13. Negotiating with buyer/trader	0.84	0.39	0.61	0.06	0.19	0.20	0.04	0.13
14. Looking for hired labour	0.61	0.27	0.48	0.05	0.12	0.13	0.02	0.10
15. Attending training or extension activities	0.21	0.01	0.21	0.00	0.00	0.01	0.00	0.01

Note: HHL = husband's statement of his leadership; WWL = wife's statement of her leadership; HJL = husband statement of joint leadership; WJL = wife's statement of joint leadership; HWL = husband's statement of his wife leadership; WHL = wife's statement of her husband leadership.

We also find that husbands and wives were more likely to state the husband leadership in the farm activities ($HHL_k > HWL_k, WHL_k > WWL_k$). This finding implies that the wives less likely to claim sole responsibility and tend to acknowledge the husband's leadership. As shown in Table 6-3, we also find that husbands and wives' statement of joint leadership was relatively similar ($HJL_k \approx WJL_k$).

In terms of the intra-household dynamic, about 13.5 per cent of wives stated that they lead at least one of the farm activities ($WWL \geq 1$). The range of WWL is 0 to 14, with the mean is 0.388 and the variance is 2.029. We also found that more than 37 per cent of the household had at least one negative disagreement ($NEG\_DIS \geq 1$) and 53 per cent had at least one positive-disagreement ($POS\_DIS \geq 1$). As a result, more than 65 per cent of the households had at least one disagreement ($DIS \geq 1$). The range of DIS is 0 to 18, with the mean is 2.943 and the variance is 12.419. This finding implies that the decision-making in citrus farm household is very dynamic where husband and wife do not always agree with what their spouse claim in term of their role in farm activities.

6.5.3 Chemical inputs, profit and risk

The average citrus productivity was 18.79 kg per tree with 76 of the observations (18 per cent) having zero yield due to trees being immature. Test for the functional form of the profit function using OLS estimation with the restrictions of the Trans-log form suggests the use of Quadratic (Hicks-neutral) form, which has relatively stronger support based on the AIC statistics (Table 6-4). The main estimation results are presented in Table 6-5[21]. The results show that insecticides and fungicides positively increase citrus farm profit. In term of risk, insecticides and herbicides application could increase the risk, means that these inputs tend to increase the profit variability.

Table 6-4. The test result for the alternative functional forms based on OLS estimation

Criteria	Cobb-Douglas	Translog	Interaction	Quadratic (Hicks-neutral)
DF	15	43	36	22
Log Likelihood	-1239.4	-1216.7**	-1226.0***	-1227.0
AIC	2508.8	2519.4	2524.0	2498.1
BIC	2566.5	2684.8	2662.5	2582.7

Note: '***', '**', and '*' significant at 0.01, 0.05 and 0.1 levels, respectively

Table 6-5. Effect of chemical inputs on profit and risk using Quadratic (Hicks-neutral) specification

	Profit	Profit Risk
Insecticides	**2.175***	**0.308***
	(1.288)	**(0.168)**
Fungicides	**1.417****	-0.011
	(0.638)	(0.050)
Herbicides	0.554	**0.099***
	(0.935)	**(0.055)**
Fertilisers	-1.799	-0.266
	(1.558)	(0.209)

Note: Standard errors are in parenthesis; '***', '**', and '*' significant at 0.01, 0.05 and 0.1 levels, respectively

[21] The full estimation results are presented in Appendix 6 Table A6-1

6.5.4 Spatial estimation results

We tested the spatial correlation in chemical fertilisers, and pesticides use based on Moran-I statistic test. The results show that the spatial correlation is significant for all of the chemical inputs (see Appendix 6: Table A6-2, Figure A6-1). Given this evidence of the existence of spatial correlation, we accounted for applying the joint estimation of the spatial regression model as specified in Eq. (6-9). The estimation results are presented in Table 6-6.

General findings are in-line with expectations regarding the role of specialisation in citrus production. For example, the total number of citrus in the plot has a significant negative sign for all of the model, indicating that a lower scale of economic of citrus farming contributes substantially to the increasing use of chemical pesticides and fertilisers. Farmers that rented in the citrus orchard from others, tend to spend significantly more money on the insecticides and fertilisers. Higher citrus income also contributes to a higher expenditure for insecticides, fungicides and fertilisers, and higher non-agricultural incomes is associated with a higher expense for herbicides. The certified seedling adoption and citrus age are positively associated with the use of insecticides and fungicides, while the availability of irrigation in the plot has a negative relationship with this input. Farmers who involve in an extension tend to have higher expenditure on insecticides, fungicides and fertilisers, in contrast for those who involve in a citrus training, the use of insecticides and fertilisers is significantly decreasing. Finally, access to credit and a membership in cooperative associated with a higher level of fertiliser use.

a. Risk preferences

Considering that the use of chemical inputs as a risk strategy, we test the association between spousal risk behaviours and the chemical inputs expenditure. Our results show that more risk-averse households tend to have lower spending on insecticides. This finding implies a perception that the insecticide application is a risk-increasing activity despite the evidence that it is risk decreasing, or at least risk-neutral. This finding is consistent with the risk function estimation, where insecticides contribute significantly to increase profit-risk (see Table 6-5).

An increasing the expense for insecticides by one per cent could increase profit variability by 0.308 per cent.

Table 6-6. Estimation results of the use of chemical inputs (IDR 000/tree)[22]

	Insecticides	**Fungicides**	**Herbicides**	**Fertilisers**
(Intercept)	5.740	0.519	**0.770***	**24.185*****
	(5.276)	(2.125)	**(0.393)**	**(7.076)**
Age of wife (year)	0.121	0.048	0.007	**0.260***
	(0.126)	(0.053)	(0.009)	**(0.138)**
Education of wife (year)	-0.232	-0.053	-0.008	0.182
	(0.235)	(0.099)	(0.016)	(0.255)
Age of husband (year)	-0.128	-0.039	-0.006	**-0.274****
	(0.120)	(0.051)	(0.008)	**(0.129)**
Education of husband (year)	-0.231	0.072	0.016	-0.237
	(0.204)	(0.085)	(0.014)	(0.218)
Household size	0.098	0.046	-0.008	0.650
	(0.397)	(0.167)	(0.027)	(0.432)
Citrus age (year)	**0.736*****	0.086	0.006	0.227
	(0.178)	(0.072)	(0.013)	(0.199)
Certified seedling (1 if yes)	**3.410****	**1.245***	0.108	-1.276
	(1.551)	**(0.641)**	(0.116)	(1.807)
Irrigated plot (1 if yes)	**-3.795*****	-0.335	-0.008	0.376
	(1.414)	(0.560)	(0.117)	(1.782)
Total citrus tree in the plot	**-0.015*****	**-0.004****	**-0.000***	**-0.025*****
	(0.004)	**(0.002)**	**(0.000)**	**(0.004)**
Rented in (1 if yes)	**6.069*****	0.441	**-0.278****	**5.724*****
	(1.964)	(0.831)	**(0.136)**	**(2.152)**
Cooperative (1 if yes)	2.356	0.435	-0.018	**6.132****
	(2.682)	(1.132)	(0.184)	**(2.904)**
Citrus credit (1 if yes)	0.922	0.090	0.091	**3.939*****
	(1.349)	(0.570)	(0.093)	**(1.475)**
Citrus extension (1 if yes)	0.321	0.249	0.176	**3.730****
	(1.610)	(0.667)	(0.115)	**(1.805)**
Citrus training (1 if yes)	**-4.870***	-1.867	-0.126	**-8.355*****
	(2.709)	(1.136)	(0.190)	**(2.988)**
Climate extension (1 if yes)	**7.176*****	**3.521*****	-0.101	3.423
	(2.669)	**(1.129)**	(0.187)	(2.932)
Citrus income (million IDR)	**0.059*****	**0.030*****	-0.001	**0.120*****
	(0.019)	**(0.008)**	(0.001)	**(0.021)**
Non-agricultural income (million IDR)	-0.012	**-0.011***	**0.003*****	0.007
	(0.015)	**(0.006)**	**(0.001)**	(0.017)
Risk preferences of husband	**0.760*****	0.037	0.022	0.075
	(0.259)	(0.109)	(0.018)	(0.282)
Risk preferences of wife	**0.506***	-0.035	-0.007	0.161
	(0.287)	(0.120)	(0.020)	(0.315)
Wife-wife leadership	-0.183	**-0.301***	**0.053***	0.242
	(0.412)	**(0.173)**	**(0.029)**	(0.457)
Disagreement	**0.475*****	**0.131***	-0.011	0.066
	(0.169)	**(0.071)**	(0.012)	(0.185)
Hired labour	0.027	0.046	**0.017*****	0.140
	(0.085)	(0.036)	**(0.006)**	(0.096)
Rho (spatial lag)	**0.308****	**0.518*****	**-0.782*****	**-0.523****
	(0.156)	**(0.138)**	**(0.209)**	**(0.254)**
Lambda (Spatial error)	-0.042	-0.155	**0.718*****	**0.576*****
	(0.240)	(0.286)	**(0.062)**	**(0.110)**

Note: Standard errors are in parenthesis; '***', '**', and '*' significant at 0.01, 0.05 and 0.1 levels, respectively

[22] We also provide the estimation results for the chemical inputs use where intra-household dynamics indices are predicted using confirmatory factor analysis (CFA) (See Appendix 6: Table A6-3 – A6-5 for the estimation of spatial model, CFA and goodness of fit for the CFA). Since, the correlation of WWL and DIS resulted from sum and CFA are relatively high, 0.71 and 0.78 respectively, it is not surprising that the estimation results for spatial model between the two versions of WWL and DIS are not much different.

b. Social network effects

Table 6-6 shows the existence of spatial-neighbour effects on the use of chemical pesticides and fertilisers. For chemical pesticides use, the endogenous effect is significant for the three types of pesticides, where for the insecticides and fungicides the signs are positive. It means that the pattern of insecticides and fungicides are positively correlated to their neighbour farmers. However, the spatial lag is negatively significant for the use of the herbicide and fertilisers, implies the negative relationship between the inputs use with the neighbour farmers. The spatial disturbances are correlated with the expenditure for herbicides and chemical fertilisers. It suggests a similarity in agro-ecosystem can influence the pattern use of chemical fertilisers and herbicides.

c. Husband – wife leadership and risk preferences

Our results suggest that wife statement of her leadership (WWL) has a negative association with the use of fungicides. In contrast with the herbicides, this variable has a positive relationship. Moreover, the different perception of the leadership between husband and wife within the household (DIS) contributes to a higher level of insecticides and fungicides use.

6.6 Discussion

Since the main problem of citrus development in Indonesia is pests and diseases attacks (Muryati, 2007; Albrigo et al., 2009; Supriyanto et al., 2017), it is expected that farmers would spend more money for the pesticides. However, the results highlight that citrus farmers' expenses for chemical fertilisers are relatively higher than pesticides. Moreover, FAO (2005) reported that fertilisers use for perennial farming systems in Indonesia is relatively low as small farmers tend to prioritise fertiliser use on food crops. Also, the Government of Indonesia provides fertiliser subsidies for small-scale farmers (Warr and Yusuf, 2014; MoA, 2016a), but not for pesticides. Two reasons for this result include: (i) there is a tendency for high-value crop farmers in Java to apply large amounts of additional nutrients to maintain the level of production (Suryanata, 1994); and (ii) Perdana et al. (2018) find that preferences towards fertiliser use in Java is changing as farmers begin to use more expensive and higher quality imported fertilisers, especially for their high-value horticultural crops.

That the citrus farmers prioritise fertilisers is also indicated by the significant contribution of credit access and cooperative membership to chemical fertilisers expenses, but not for the chemical pesticides (see. Table 6-6). Credit availability and cooperative services[23] tend to be used by the farmers for fertiliser procurement rather than pesticides. This finding also means that farmers may seek financial support because they perceive the application of fertiliser more important for their farm. Moreover, the importance of credit access, cooperative membership as well as income's role on the fertiliser use implies that liquidity issues are considerable constraints for the application of this input, as also reported in the previous studies (e.g. Moser and Mußhoff, 2016; Haider et al., 2018).

The analysis suggests that citrus tree renting behaviour influences chemical input use. The data demonstrates that citrus tree leasing behaviours are practiced in the survey area as landholders with citrus trees on their plots, rent out the citrus trees to other farmers or traders for a specific period (normally more than 5 years). In the survey, 10 per cent of the plots with citrus trees are rented (Table 6-1). Renting trees contributes significantly to increased insecticides and fertilisers use (Table 6-6). Even though it is associated with a lower herbicides' expenditure, the exceptionally high coefficient for the insecticides and fertilisers implies the renting tenure status strongly influence the intensification behaviours. Suryanata (1994)

[23] We also found that by the farmers' reasons to be a cooperative member which are financial service (credit and saving) (87 per cent), and input procurement (26 per cent).

concludes that the tree renters are mainly capital-rich farmers so that they greater resources for the citrus farm intensification. Moreover, during the fieldwork, key informant and focus group interviews stated that the citrus tree renters tend to 'force' the citrus production during the renting period by introducing a '*super-intensive*' farming system. As a result, the citrus trees are often damaged and need to be replanted after the contract finished.

6.6.1 Social networks effects on chemical inputs expenditure

Our results suggest several findings regarding the neighbour effects on the chemical inputs use. First, the endogenous interaction effect is significant for the use of all chemical inputs (insecticides, fungicides, herbicides and fertilisers). However, the sign of the endogenous effect for insecticides and fungicides are positive, while the herbicides and fertilisers are negative. Aida (2018) argues that spatial endogenous effect of pesticides can be positive or negative. If the neighbour application can reduce the pest and disease infestation in the region, the neighbour effect should be negative. However, if the pesticide application kills the predator insects or natural enemies more than pests, the pests' infestation could increase in the surrounding orchard, lead to the increased use of pesticides. Apart from Aida (2018) arguments, the positive neighbour effects in our study might also be associated with the information exchange among the farmers within the regions. For example, a large number of available pesticides in the market could make it more difficult to know which is most appropriate. Thus, farmers rely on neighbouring farm households for information. Based on the data of Indonesian Ministry of Agriculture, there were 3207 registered brands of pesticides in 2016 in Indonesia, and more than 100 of them are suitable to use for the citrus farm (MoA, 2016b).

In the case of herbicides, we argue that the herbicides use is correlated with labour availability and wage costs for weeding. Labour becomes scarcer as more and more farmers employ workers, making herbicide use more practical for weed control. The negative endogenous effect on fertilisers use is most likely related to the distribution system of the fertilisers. The availability of the fertilisers, especially those subsidised by the government, are often scarce at the time most needed by farmers (Flor et al., 2016; Perdana et al., 2018). Hence, those farmers gaining access to the fertilisers, reduce access for other citrus farmers. On the other hand, if the neighbour farmers have good cash liquidity, they can buy imported fertiliser, which is more expensive.

Second, the results show that the spatial error is significant both for herbicides and fertilisers expenditure, reflecting similar behaviour in the expenditure of the two inputs as farmers face relatively homogenous unobserved environments. For herbicides, the unobserved spatial disturbance can be considered as the similarity in weeds infestation within a specific region (Aida, 2018). The significant spatial error for chemical fertilisers also could be arising from the common unobservable agro-environment condition, such as soil quality, rainfall pattern, etc. (Nakano et al., 2018) which might influence the farmers' decision on the use of chemical fertilisers.

6.6.2 Intra-household decision-making

There are a growing number of studies considering the relevance of the collective household model for the farmers behaviour in developing countries which extend the literature in gender or intra-household decision-making (e.g. Ashraf, 2009; Carlsson et al., 2012; Anderson et al., 2017; Lecoutere and Jassogne, 2019). In this study, we use the intra-household dynamics approach with the focus on the relationship of the sole leadership's claim by wife (WWL) and different perceptions of leadership between husband and wife (DIS) on the level of chemical input use. A DIS implies the existence of wife leadership in farm activities, even though it may not have an acknowledgement from their spouse.

Our findings confirm that the leadership in citrus farming activities is very dynamic, and not a unitary decision-making process by a household head as used in many studies. Our estimations also show that WWL and DIS are associated with the level of pesticides use (See Table 6-6). This finding confirms that the decision for the application pesticides might be related to the cultural as intra-household dynamics intertwine with economic consideration (see. Luna, 2020). The wife's leadership in citrus farming activities can contribute to the farm household expenses for pesticides (insecticides and fungicides). This finding is also strengthened by the significant effect of husbands' and wives' risk preferences on the use of the insecticides. The significant relationship of spousal preferences with insecticides use is in line with Magnan et al. (2020)'s finding which supports the importance of accounting husbands and wives' behavioural in understanding agricultural technology adoption. Considering increasing concerns among communities about pesticide health and safety issues, providing extension and educational services on safe application methods, storage and handling to females within the household is a key lesson to be applied.

6.7 Conclusions and policy implication

Using data from citrus farm household in East Java, Indonesia, the results in this chapter show the extent to which farmers use agrochemical inputs and how the dynamics within and beyond the household contribute to the input intensification. The analysis finds that chemical inputs use among citrus farm households exhibits spatial correlation. The significant relationship of the spatial lag for chemical inputs shows the influence neighbouring farmers have on citrus decision behaviour, highlighting the importance of social networks and social communication in farmers decision-making. It also emphasises the existence of farmer to farmer extension practices regarding the chemical pesticides choice among the citrus farmers.

One important program design implication is that farmer to farmer extension can provide a highly useful complement to formal extension systems in the effort to control or to promote the proper or sustainable use of chemical pesticides. Using, upgrading and promoting collective action initiatives among farmers within a region to control insect vectors of Huanglongbing disease is highly recommended (see. Nurhadi, 2015; Milne et al., 2018; Singerman and Useche, 2019). Moreover, the usage of chemical fertilisers and herbicides were dependent on unobserved spatial characteristics suggesting that citrus extension program focusing on appropriate chemical input use can be based at a larger regional level rather than smaller administrative levels such as villages or subdistricts.

The empirical evidence shows how the intra-household dynamics and spousal risk preferences associated with household expenditure for insecticides. Hence, considering the conventional agricultural policies or program which only targeted the head of households, this finding suggests changing this paradigm by involving the spousal-household heads as targets in agricultural supporting services programs. For example, the policymakers or related citrus value chain industries need to consider the farmers' advisory services designed in a women-friendly environment.

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Chapter 7. Summary, conclusion and policy implications

7.1 Summary and conclusions

The dependency of agricultural activities on weather and evolving climatic conditions means that climate change issues are likely to cause 'unprecedentedly large, complex and uncertain' economic impacts in many developing countries. Smallholder households, in particular, tend to be relatively more impacted than most due to their low resilience to these shocks because they have lower capability, capacity and institutional support to adapt to climate change.

Many adaptation strategies have been proposed and implemented in various government policies and programs to increase small-scale farmers' resilience to climate shocks. In Indonesia, for example, the government ranks sustainability and climate change issues as important strategies for development in the agricultural sector, as stated in the National Medium-Term Development Plan (RPJMN) 2015-2019. However, as annunciated in previous studies (e.g. Nigussie et al., 2018; Rasmussen, 2018), many policies and programs exclude the insights of farmers themselves and the voices of local wisdom, leading to the ineffectiveness of many climate-related policies or programs. In light of this concern, previous studies have shown that farmers' behaviours regarding their response to climatic situations are closely associated with their perception of climatic risks (e.g. Fisher and Carr, 2015; Menapace et al., 2015). Hence, it may be necessary to consider and incorporate farmers' perspectives to facilitate the success of climate adaptation and mitigation policies.

The influence of climate risk on agricultural production is, however, highly variable and heterogeneous, depending on crop-type, as well as farmers' characteristics, agro-environmental conditions, infrastructure readiness and institutions, amongst other factors. Hence, to identify more specific strategies, this thesis focuses on small-scale citrus farming, a high-value horticultural crop in Indonesia. Citrus is a rapidly expanding crop among smallholders and is credited with making a significant contribution to rural development. Also, as a perennial crop, which is characterised by high-upfront investment costs and substantial technological lock-in associated with choice of citrus variety, citrus farming is highly affected by changing climate variables.

Using a household survey and behavioural experiments, this thesis examines the climate risk perceptions and risk preferences of small-scale citrus farmers and how these risk behaviours are associated with climate risk adaptation, especially in their choice of citrus seedling types and intensification of farming practice. The behavioural experiments involved husbands and wives in order to obtain a broader view of the behaviour of farm households, rather than only considering a single household head in a unitary model of households.

This thesis makes three main contributions to the literature. First, it provides a methodological improvement by using a survey-based approach in measuring climate risk perception, which integrates the complex patterns of risk behaviours by drawing on literature from economics and psychology. This approach encompasses the standard aggregate risk perception index used in the literature and allows for better understanding of climate change risk perception. Second, this research used choice task experiments to measure relative seedling quality as perceived by farmers, which can provide a better explanation of how subjective beliefs constitute a key element of farmers' investments and which could positively influence farmers' adoption of high-quality citrus seedlings. Third, this research combines individual, intra-household dynamics and social factors and considers their association with the pattern of farm intensification in rural areas. This contributes to an extension of the empirical evidence concerning the effects of household models and spatial-social networks.

This thesis has three specific objectives. The first objective, addressed in Chapter 4, is to understand the extent of small-scale citrus farmers' risk perceptions of a range of climate change events, and to identify the drivers of their risk perception at aggregated and disaggregated levels. The second objective, addressed in Chapter 5, is to provide analytical insights into the adoption behaviour of small-scale farmers in relation to certified citrus seedlings by analysing the extent to which they value the certification of citrus seedlings and the role this plays in influencing the adoption of higher-yielding, climate-risk resilient and disease-free citrus varieties. The third objective, addressed in Chapter 6, is to explore the level of use of chemical inputs and the role of individual, household and spatial-social network factors on household expenditure on chemical inputs.

This thesis used data from a 2017 household survey of 500 small-scale citrus farmers across three districts, 15 subdistricts and 42 villages in East Java Province, Indonesia. District and sub-district levels were selected purposively, based on the levels of citrus production, while villages and farm household levels were chosen randomly. The survey was conducted by 13 professional enumerators, and three senior enumerators acting as supervisors in the field to address any issues.

Chapter 4 explores the disadvantages of an aggregated approach in analysing risk perception by presenting a decomposition analysis of standard 'risk perception' that accounts separately for perceptions of frequencies and impacts. Considering the representation of a four-fold pattern of risk attitudes, as outlined by Tversky and Kahneman (1992), the aggregate risk perception index (RPI), commonly used in the literature (e.g. Iqbal et al., 2016; Sullivan-Wiley and Gianotti, 2017), is only able to identify relationships which affect both perceived likelihood and perceived impact in the same direction – i.e. allowing only for a two-fold pattern of risk perception. By decomposing the analysis of perceived likelihood and perceived impact separately (i.e. a disaggregated analysis), it is possible to present a more complex representation of risk behaviours.

This chapter provides empirical evidence on the importance of disaggregated analysis of climate risk perception among small-scale citrus farmers in relation to six climatic events.

Using a seemingly unrelated regression (SUR) model and an ordered probit model, this study found that an interventional variable (e.g. farmer-to-farmer extension) potentially has a different relationship with farmers' perceived likelihood of a climatic event and its perceived impact of a climatic event on citrus farming. As a result of this analysis, it is demonstrated that there is no significant relationship between the interventional variable and the RPI of the particular climate event; this may obscure the importance of the variable in shaping farmers' perceptions.

The aggregated RPI, however, can contribute to a better understanding of climate risk by providing an index-based ranking for a range of climatic events. Based on the RPI score, citrus farmers perceived the increasingly long rainy seasons period as their primary concern, followed by increasing air temperature, increasingly long dry seasons, increasingly excessive rainfall, increasingly destructive winds and increasing floods. These results imply that farmers are more likely to prioritise coping strategies for climatic issues based on these priorities.

This thesis also attempted to understand the factors determining risk perception, at both aggregate and disaggregate levels. This is an important finding suggesting that information and technology-based extension methods give sampled farmers greater opportunities compared with a traditional extension model in that farmers exposed to these innovative methods tend to more strongly perceive the risk of climatic events, which may indicate a greater willingness to adapt.

Chapter 5 assessed the drivers of the adoption of certified citrus seedlings. This analysis was based on the high level of concern about the low adoption rate of disease-free certified citrus seedlings. This low rate of adoption is predicted to contribute to low productivity and is associated with concern about the spread of systemic diseases, especially Huanglongbing disease, where the use of unhealthy seedlings potentially disperses the disease. Considering the long-life of citrus as a perennial crop and the technological lock-in associated with variety choice, investment decisions regarding seedling choices will be crucial. Using a series of experiments, this chapter explored the extent of farmers' beliefs about the yield of certified and uncertified seedlings and their risk and time preferences. The experiments to measure farmers' beliefs about the yield employed a modified version of the method used by Vargas Hill (2009) and Menapace et al. (2013). While, for the measurement of risk and time preferences, this study used a recent procedure outlined by Falk et al. (2016).

Based on the belief experiments, this study found that the mean yield for certified seedlings is significantly higher than for uncertified seedlings. However, for the farmers who have not yet adopted, or do not intend to use, certified seedlings, beliefs about yield of the two types of seedling are not statistically different. In relation to yield stability, the sampled farmers believe that uncertified seedlings have a higher yield variance, implying that certified seedlings are less risky than uncertified ones. However, farmers who have adopted certified seedlings, but who did not plan to use them again, expressed a belief that there was no difference in yield variance between the two seedling types.

Applying a multinomial logit model, this chapter examined the association of beliefs and risk behaviours with the dynamics of seedling choices in relation to current and future adoption behaviour. The results showed that belief about yield and production risks of particular seedling types was significantly related to farmers' intentions to adopt particular seedling types. The regression results also showed a significant relationship of the interaction between risk preferences and yield beliefs with seedling choices. This finding implies that yield level and yield stability are important quality signals in attracting citrus farmers to adopt certified seedlings as well as pointing to the role of risk preferences on farmers' seedling choices. This chapter also provided interesting findings on the strong relationship between climate-related variables and farmers' decisions to use certified seedlings, suggesting that certified seedlings may be expected to be adopted as a climate adaptation strategy. However, this study uses the farmers planning/intention to use certified or uncertified seedling to examine the dynamic use of the seedlings, which may illustrate the farmers' interest in a certain type of seedling which potentially different from real behaviours. Thus, it suggests using the panel survey to obtain the real dynamic of the seedling use, even though it might be difficult since citrus farming has a long life cycle (10 – 25 years).

Finally, Chapter 6 examined farming intensification practices among small-scale citrus farmers. This is indicated by the level use of agrochemical inputs, especially chemical pesticides and fertilisers. Using a joint spatial model, this chapter focused on the role of risk preferences, the dynamics of intra-household decision-making in citrus farm activities, as well as social networks, on the use of chemical inputs. In order to develop the hypothesis about risk preferences, this study estimated the risk characteristics of each input by employing the Just and Pope production function.

This study finds that almost all of the respondents applied chemical pesticides and fertiliser in their citrus orchards. However, the cost of chemical fertilisers was significantly higher than the total cost of chemical pesticides. Insecticides and herbicides are the inputs that are associated with higher variability in farm profits. Particularly in relation to insecticides, this finding is consistent with the estimation results of the joint model where risk-loving farmers tend to have higher expenses for this input.

Husbands' participation in, and leadership of, citrus farming activities are dominant compared to that of their wives. However, there are indications of wives' specialisation in relation to several activities and this demonstrates a decrease in husbands' participation and leadership, on the one hand, and increasing leadership by wives, on the other hand. Wives tended to acknowledge their husband's leadership and were less likely to claim sole responsibility for farm activities. Moreover, this study found that more than half of the sampled households had at least one disagreement, implying the existence of wives' leadership activity in citrus farming being under-acknowledged. The regression results show that the wives' claim of sole responsibility and disagreement between spouses significantly contributed to the level of household expenses for pesticides (insecticides, fungicides and herbicides).

The pattern of chemical input use is associated with endogenous effects, which implies that farmers' behaviours in relation to chemical pesticides and fertilisers are, to some extent, dependent on the behaviour of neighbouring farmers. This study found the existence of spatial disturbance effects on the use of chemical fertilisers and herbicides, suggesting that similarity in the use of inputs correlated with homogeneity in agro-ecosystems. Finally, this study cannot conclude whether the fertilisers and pesticides applications were overuse or underuse, however, the results of this chapter suggested the opportunity for policymakers to control, or regulate, the proper and sustainable use of chemical inputs through formal extension systems and informal farmer-to-farmer extension (farmers' social networks).

7.2 Methodological insights

RPI has been used extensively to understand how people perceive risk exposure. In the context of climate change, the association of risk perception with farmers' tendency to adapt to climate change has been confirmed in many developing countries (e.g. Mumpower et al., 2016; Hou et al., 2017; Mase et al., 2017; Khanal et al., 2018). Thus, to develop adaptation strategies for small-scale farmers, understanding their climate risk perception becomes crucial. However, many studies use an aggregate index, which typically combines farmers' concerns over impacts of climate change-induced events with respondents' beliefs over their frequency (e.g. Le Dang et al., 2014; van Winsen et al., 2014; Iqbal et al., 2016; Sullivan-Wiley and Gianotti, 2017). On the other hand, the two elements potentially combine in complex ways to form concept of risk (e.g. Kahneman and Tversky, 1979; Quiggin, 1982; Botzen et al., 2013; Cohen, 2015; Just and

Just, 2016; Gregg and Rolfe, 2017), so that both perceived likelihood and impact can be different in the contribution they make to risk perception.

Therefore, Chapter 4 provided a conceptual framework about, and empirical evidence of, the limitation of aggregate-level analysis of RPI in explaining how endogenous variables influence the perception of risk. This chapter tested the explanatory variables associated with the RPI and its elements separately for six climate change events. By using the SUR model and ordered logit models, the estimation results showed that some explanatory variables have a different relationship (the sign of significant coefficient in regression estimation results) with perceived likelihood and perceived impact in the ordered logit model. However, the variables do not have a significant relationship with the RPI in the SUR model. Thus, this study suggests that risk perception could be explained better by analysis at disaggregated levels.

7.3 Policy implications

This thesis provides empirical pieces of evidence which may be useful for policymakers to design programs related to climate change in agriculture generally, or specifically to the development of citrus production. Considering that climate change studies in Indonesia mainly focus on technical aspects in order to provide adaptative technology to address climate issues, this study enriches the topic by providing insights from farmers' perspectives, which may be important in shaping the success of climate-related programs implemented by policymakers.

Using citrus farming as a case study, this thesis attempts to answer some critical questions in citrus development in Indonesia, especially related to the low adoption level of disease-free certified citrus seedlings and the increasing concern about the food safety of horticultural products, as well as sustainability issues which are associated with the application of agrochemical inputs. Thus, the findings from this study have several useful policy implications that may be useful for policymakers and related industries, or to be developed with further discussion and analysis.

7.3.1 Prioritising climate change events

The concept of risk perception was developed to understand people's judgement of hazards and which can be used to understand and predict their responses to particular risks (Slovic et al., 1982; Freudenburg, 1988; Sjöberg, 2000). Thus, understanding how farmers perceive climate events could be helpful in understanding their perspectives on climate change issues even though they might have misperceived climate risks.

As explained in Chapter 4, citrus farmers perceived that increasingly long rainy seasons posed the greatest risk among climate events, followed by increasing air temperature, increasing dry season periods, increasingly excessive rainfall, increasingly destructive winds and increasing floods. This finding implies that citrus farmers might prioritise their scarce resources to adapt to climate events based on their level of risk perception. However, this risk perception results from farmers' subjective judgements that could be biased as the availability of heuristics (Tversky and Kahneman, 1974). Thus, policymakers might need to assess the perception of both perceived likelihood and perceived impact of climatic events on citrus farming and compare it with available scientific or objective information. It is important to provide more accurate climate-resilience support systems, on the one hand, but they must be accepted by farmers, on the other hand.

The findings from Chapter 4 demonstrated that farmers' methods of accessing information (mobile-phone ownership, access to the internet, and connection to government authority) have a stronger influence on their perception than conventional extension systems, such as extension and training meetings, and 'farmers' groups' (farmers' groups and cooperatives). As a consequence, the use of information and communication technologies (ICT) could be incorporated into formal extension programs, which can seek to complement farmers' independent sourcing of information through training about self-learning and rational information-seeking, along with traditional extension approaches (i.e. direct information provision and training).

7.3.2 Increasing certified seedling adoption

Typically, certified citrus seedlings are promoted as disease-free seedlings, especially in relation to Huanglongbing disease, which devastated citrus farming in Indonesia a few decades ago. The reason is that Indonesia did not have any disease-resistant citrus varieties which could have helped control the disease outbreaks. The vegetative multiplication method, mostly used in citrus seedling propagation, potentially contains systemic pathogens, so that when planted in an orchard, it can spread the disease into the region in which it is planted. Hence, the disease-free attributes of seedlings is expected to be able to attract farmers to adopt certified seedlings to reduce the possibility of disease outbreaks in citrus production regions. However, as found in this study, less than a quarter of the sample adopted certified seedlings and more than half of the respondents did not plan to use them in their future planting period. This thesis identified several strategies that decision-makers, or related industries, could potentially use to promote the use of certified seedlings.

First, this thesis found that yield ability and stability from certified seedlings were perceived as attributes that could influence farmers to use certified seedlings. Even though certified and uncertified seedlings could be produced from the same citrus variety, certified seedlings should have the advantage in yield potential since the certification process will guarantee the genetic purity of improved citrus varieties generated by the seedlings. Hence, the yield potential of certified seedlings can be used in promotion strategies rather than only emphasizing the disease-free attributes.

Second, this study confirmed that climate-related variables, such as climate risk perception, climate extension and climate information sources, have an association with farmers' decisions to use certified seedlings in their future replanting. It implies that farmers use certified seedlings because they might be expected to have better performance in the particular climatic conditions they face. Even though the adaptability to climatic conditions has not been a consideration in citrus seedling certification policies, certified seedlings also have advantages in physical and physiological qualities (as required in the certification process) which are very important for adaptation to climate variability. Hence, promoting the better performance of certified seedlings in various climatic situations, as a result of better physical and physiological attributes, could encourage farmers to use certified seedlings. Moreover, improving climate information systems and providing climate extension and training more extensively are highly recommended to increase farmers' concern about the issue of climate change in order to enhance the probability of farmers using certified seedlings.

Third, the literature on the adoption of agricultural technology in developing countries often relates the low-level adoption by small-scale farmers to financial issues, such as income and access to credit (see. Cavatassi et al., 2011; Pan et al., 2018). However, this study found that this issue might not be relevant in the context of certified citrus seedling adoption. The higher price of certified seedlings, compared with uncertified seedlings, is often hypothesised as a constraint to their adoption, but the cost seems tolerable for farmers. Thus, the policy for enabling access to agricultural credit to enhance the use of certified seedling does not seem too urgent.

Finally, this study found potential dis-adoption behaviours; a relatively high rate of farmers who currently use certified seedlings but who do not plan to use similar seedlings in future planting periods. This behaviour might be caused by their belief about the quality of certified seedlings. A possible explanation for this situation is the farmers probably used "low quality certified seedling", as a result of the loosening of the regulations related to the implementation of certification procedures, which should adhere strictly to regulations. Compromising the quality assurance system means low-quality seedlings are certified and are passed off as high-quality seedlings in the seedling market. Hence, it is highly recommended that policymakers strictly apply regulation to the certification process and enhance law enforcement of "fake certified seedlings", so that certified seedlings available in the market are high-quality ones, not "lemon seedlings".

Moreover, there is also the possibility that farmers' doubts about the quality of certified seedlings leads to potential dis-adoption behaviour due to inflated expectations about certified seedlings. For example, if the planting of certified seedlings does not follow recommended farming practices, it may not significantly increase the yield or reduce the production risks. High-quality seedlings might not demonstrate best performance in the context of poor management practices, so the less-than-expected performance of certified seedlings could be caused by low-quality seedlings or poor farm management (Auriol and Schilizzi, 2015). This study encourages involving and educating farmers in implementing recommended agricultural practices as part of certified seedling marketing so that farmers have comprehensive information about good agricultural practices for citrus.

7.3.3 Understanding the drivers of the use of agrochemical inputs

Small-scale farmers and governments in developing countries, including Indonesia, often face a paradox regarding the application of agrochemical inputs. For farmers, there is increasing dependency of farming systems on chemical inputs to maintain farm productivity as a response to decreasing environmental supports, such as diminishing soil fertility, or pests and disease outbreaks. On the other hand, small-scale farmers are mostly constrained by limited resources in the application of chemical inputs. For governments, there is pressure to enhance food production to fulfil the doubling of population food demand, as well to respond to the increasing concern about food safety and environmental sustainability. With the focus on intensification practices in citrus farming, this thesis provides insights into the drivers of chemical inputs use. These insights can support policymakers, extension workers and related industries in developing support systems for proper/sustainable chemical input application among small-scale farmers.

The findings from this thesis highlight the spatial dependence on chemical inputs use among small-scale farmers, more specifically, the spatial-endogenous correlation for all of the chemical inputs and spatial disturbance dependence for herbicides and fertilisers. The existence of endogenous effects on the pattern of the use of chemical pesticides indicates that farmer behaviours are positively correlated with the influence of neighbouring farmers. In terms of developing farmers' support systems in citrus pest and disease management, this finding can be directed to the opportunity for collective action among neighbouring farmers to address pest and disease control.

Even though there is no evidence of spatial disturbance dependency on the use of insecticides and fungicides, which might be taken to imply homogeneity in pest and disease infestation, collective action in the development of integrated pest and disease management frameworks remains an important and necessary development. For example, coordination between farmers in order to control the spread of the insect vector of citrus Huanglongbing disease is very critical in preventing the spread of this dangerous disease (Milne et al., 2018; Singerman and Useche, 2019). Thus, this finding could be good news for the implementation of integrated pest and disease management in the citrus farming system.

The significant endogenous effects noted in this study also means that information exchange between farmers is very effective in spreading the technology on pest and disease control. In this case, the extensive information exchange could lead to farmer-to-farmer extension among neighbouring farmers. This pattern of information dissemination can also be seen as a very low-cost learning process. Hence, policymakers could foster this pattern by injecting more appropriate and sustainable technology and information about pest and disease control in citrus farming.

The spatial disturbance effect was found to be significant for the use of fertilisers, which suggests that farmers might employ a similar pattern of chemical fertiliser use if they face homogenous environments, which could, for instance, relate to soil fertility or climatic conditions. This finding implies that programs related to this input use should be developed with a regional focus, beyond administrative borders, such as village boundaries.

In term of the decision-making process within households and its relationship with pesticides expenses, this study finds that household dynamics are relatively important in decision-making for farming household behaviours in relation to chemical inputs use. As a consequence, it could be meaningful to involve wives in the campaign for the proper and sustainable use of chemical inputs, rather than only targeting a household head, which is typically a husband. Moreover, farmers' advisory services, such as extension or training programs, need to be designed to create a women-friendly environment.

Regarding extension and training activities, this study found that these two types of advisory services have a different relationship to the pattern of chemical inputs use, with the extensions tending to cause a higher level of the use of inputs, and vice versa for the training. Since citrus training is assumed to have more intensive activity and to involve more expert facilitators in the field, the knowledge obtained by the farmers from the training should be more accurate and relevant in comparison to extension programs. Moreover, extension workers in

Indonesia are mainly concerned with food crops so that their knowledge of other crops is often limited. For example, in the case of coffee farming, Neilson (2008) found that farmers found it difficult to access a credible government extension service. Based on this assumption, the finding of this study suggests that extension workers in citrus production centre need to have "knowledge upgrading" provided by experts in citrus. Connecting the significant role of training and farmer-to-farmer extension, it is important to build a system that allows for knowledge diffusion from trained farmers to their neighbour farmers; also suggested by Feder et al. (2004).

An interesting finding from Chapter 6 is tree tenure or tree leasing behaviours. This study found that there were a relatively large number of farmers who rent out their citrus trees to other farmers for certain periods of time to get cash earlier than they otherwise would from their citrus farming. Suryanata (1994) state that this practice is common for high-value tree crops and typically involves capital-rich farmers renting in trees from capital-poor farmers. However, there are indications of exploitation, or rent-seeking behaviours, from "rich-capital-tenants" because they tend to apply over-intensive farming methods to boost yields during the lease period. This practice potentially disadvantages the poor-capital landholders because they often find their plants damaged by the end of the lease period. Thus, this study encourages policymakers to address these practices so that poorer, small-small scale farmers can receive greater benefit from the high-value citrus chain system which also important.

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Appendices

Appendix 1. Low risk human ethic approval

THE UNIVERSITY of ADELAIDE

RESEARCH SERVICES
OFFICE OF RESEARCH ETHICS, COMPLIANCE AND INTEGRITY
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CRICOS Provider Number 00123M

5 May 2017

Professor Stringer
The Centre for Global Food and Resources

Dear Professor Stringer

ETHICS APPROVAL No: **H-2017-072**

PROJECT TITLE: **Technology adoption among small-scale citrus farmers under climate risks in Indonesia**

The ethics application for the above project has been reviewed by the Low Risk Human Research Ethics Review Group (Faculty of Arts and Faculty of the Professions) and is deemed to meet the requirements of the *National Statement on Ethical Conduct in Human Research (2007)* involving no more than low risk for research participants. You are authorised to commence your research on **05 May 2017**.

Ethics approval is granted for three years and is subject to satisfactory annual reporting. The form titled *Annual Report on Project Status* is to be used when reporting annual progress and project completion and can be downloaded at http://www.adelaide.edu.au/research-services/oreci/human/reporting/. Prior to expiry, ethics approval may be extended for a further period.

Participants in the study are to be given a copy of the Information Sheet and the signed Consent Form to retain. It is also a condition of approval that you **immediately report** anything which might warrant review of ethical approval including:

- serious or unexpected adverse effects on participants,
- previously unforeseen events which might affect continued ethical acceptability of the project,
- proposed changes to the protocol; and
- the project is discontinued before the expected date of completion.

Please refer to the following ethics approval document for any additional conditions that may apply to this project.

Yours sincerely

DR JOHN TIBBY
Co-Convenor
Low Risk Human Research Ethics Review Group (Faculty of Arts and Faculty of the Professions)

DR ANNA OLIJNK
Co-Convenor
Low Risk Human Research Ethics Review Group (Faculty of Arts and Faculty of the Professions)

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CRICOS Provider Number 00123M

Applicant:	**Professor R Stringer**
School:	**The Centre for Global Food and Resources**
Project Title:	**Technology adoption among small-scale citrus farmers under climate risks in Indonesia**

The University of Adelaide Human Research Ethics Committee
Low Risk Human Research Ethics Review Group (Faculty of Arts and Faculty of the Professions)

ETHICS APPROVAL No: **H-2017-072** App. No.: 0000022328

APPROVED for the period: **05 May 2017 to 31 May 2020**

Thank you for your response, dated 05.05.17, to the matters raised. It is also noted that this project involves PhD student Abdul Muis Hasibuan.

DR JOHN TIBBY
Co-Convenor
Low Risk Human Research Ethics Review Group
(Faculty of Arts and Faculty of the Professions)

DR ANNA OLIJNK
Co-Convenor
Low Risk Human Research Ethics Review Group
(Faculty of Arts and Faculty of the Professions)

Appendix 2. Citrus questionnaire

SURVEY OF CITRUS GROWERS IN EAST JAVA

September - October 2017

UNIVERSITY OF ADELAIDE - ICHORD - IPB

Objectiv : The purpose of this survey is to obtain better understanding of citrus farmers behaviours under climate change risks

Use of data : The data collected as part of this survey are for research purposes ONLY.
Household-level data will not be shared with non-research organizations. Only summary results will be included in published report.

Household ID number						Enumerator	

Name of head of household	
Name of respondent	
Address/location	
Phone	
Village	
Sub-district	
District	
Latitude	
Longitude	
Altitude	

Do you manage the citrus plot more than 25 trees?

Yes	
No	

Note:

If citrus farmers rent out all of the citrus plot, please exclude from the respondent list

	Date			Name	Sign
	Day	Month	Year		
Interview			2017		
Field check			2017		
Check supervisor			2017		
Send data			2017		

Research funded by a grant from the Australian Centre for International Agricultural Research (ACIAR)

Version: 18 September 2017

A. CHARACTERISTICS OF MEMBERS OF THE HOUSEHOLD

	Name	What is the relationship between [name] and the head of household? *1 Head* *2 Spouse* *3 Son/daughter* *4 Son/daughter in law* *5 Grandchild* *6 Parent or in-law* *7 Other related* *8 Other unrelated*	Is [name] a male or female? *1 Male* *2 Female*	How old is [name]? [age at last birthday, use 0 for < 1 yr] *(Year)*	How many years of schooling has [name] completed? *(Year)*	What is the ethnic group? *1 Javanese* *2 Maduranese* *3 Balinese* *4 Osing* *5 Minang* *6 Others*	Ask tthese questions only for members What is the marital status of [name]? *1 Single* *2 Married* *3 Separated* *4 No longer married*	What are the main activities of [name]? *1. Farming/aquaculture* *2. Self-employed trader* *3 Self-employed - other* *4. Agricultural wage labor* *5. Other wage labor* *6. Housework* *7. Student* *8. Other* *9. None* Main	Secondary	Is [name] actively involve in you citrus farming? *1. Yes* *2. No*
A1		A2	A3	A4	A5	A6	A7	A8a	A8b	A9
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										

Note: The household is defined as a group of people who live and eat together most of the time. Each member must live with others at least 6 months of the year.
The head of the household is defined as the member who makes most of the economic decisions.

B. HOUSING AND ASSETS

What is the approximate area of your house in square meters (icl. homegarden)? [ ] B1

[If house owned] What is the approximate value of your house without farmland? (Rp. Million) [ ] B2a

[If house rented] What is the annual rent that you pay for your house (without farmland)? [ ] B2b

What is the main source of drinking water for your household? [ ] B3

1 Indoor tap	5 Collected rainwater
2 Outdoor private tap	6 River, lake, pond, spring
3 Outdoor shared tap	7 Spring water
4 Covered well	8 Water collected in a tank
	9 Bottled water

What is the main type of toilet used by your household? [ ] B4

1 Flush toilet	3 Latrine over canal/pond
2. Latrine with pipe	4 Public toilet
3 Pit latrine	5 Other or none

What is the main type of lighting used by your household? [ ] B5

1 Electric lights	4 Others
2 Oil lamps	5 None
3. Candles	

What type of fuel is used by your household for cooking? [ ] B6

1 Electricity	4 Kerosene
2 LPG	5 Wood
3 Biogas	6 Other

How many of each of the following items do members of your household currently own?

	Number	
a mobile phone/tablet?		B7
internet access (Icl. from Smartphone/tablet) (1. Yes; 0. No)		B8
a bicycle?		B9
a motorbike?		B10
a car?		B11
a PC/laptop		B12
a 3 wheel motor cycle (tossa)		B13
a Gerobak		B14
a truck?		B15
a water pump?		B17
a generator?		B18
a hand/manual sprayer?		B19
a power sprayer?		B20
a tractor/hand tractor?		B21
a storage house?		B22
cattle/buffalo?		B23
goats/sheep?		B24
poultry?		B25

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C. AGRICULTURAL LAND

(1) Draw the house of the farmer; **(2)**Ask and draw all of the plot they managed in lat 12 months**;

(3) Write "C" on the plot planted with citrus; **(4)** Write "1" on the most recently finished plot harvested [If there is more than one plot, write "1" in the largest plot]

	1. Yes ; 2. No		Number of plot	Area	Area Unit			
Have you **sold** farm land over the past 5 years?		If yes, how much total land did you sell and what was the total value?				1. Hectare 2. Bau 3. Bata	4. Tumbak 5. Ru 6. m2	7. Patok 8. Wolon
	C1		C2a	C2u	C2p			

Plot nbr	What is the area of this plot?		What is the land tenure arrangment for this plot?	[If C5=1-2] How was this plot acquired?	[If C6=3, did you buy this land in te last 5 years?	[If C5=1-2] How is the legal status of this plot?	[If C8=2-4], on whose behalf is the land document written?	What is the type of land?	How many minutes will it take from your house to the plot when using a motorcycle?	What is the largest type of vehicle that can access the	What is the largest type of vehicle that can access the
	Area	Unit *1. Bata* *2. Tumbak* *3. Ru* *4. M2* *5. Hectare* *6. Patok* *7. Wolon*	*1. Owned and farmed* *2. Owned and rent it out* *3. Rented from owner* *4. Other*	*1 Inherited* *2 Gift* *3 Purchased* *4 Allocated by government*	*1. Yes* *0. No*	*1. None* *2. Acta (can't be used to access credit from bank)* *3. Certificate* *4. Traditional ownership evidence (girik)*	*1. Husband* *2. Wife* *3. Other*	*1. Technical irrigation* *2. Semi-technical irrigation* *3. Rainfed*	*(minutes)*	*1. Truck* *2. Pick-up (1-2 ton)* *3. Tossa* *4. Motor* 5. None	*1. Truck* *2. Pick-up (1-2 ton)* *3. Tossa* *4. Motor* 5. None
C3	C4a	C4u	C5	C6	C7	C8	C9	C10	C11	C12	C13
1											
2											
3											
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11											
12											

Page 3a

C. AGRICULTURAL LAND (Cont)

Plot nbr	What is the soil type in the plot?	What is the colour of the soil in the plot?	What type of irrigation does this plot have in the RAINY season?	What type of irrigation does this plot have in the DRY season?	[If plot farmed by household, C8=1 or 7-10] What were the main crops grown currently and previous planting period?		When was citrus planted at this plot for the first time	What was the main crop grown	How many times in the last 5 years this plot experience DROUGHT, where you couldn't access the water to watering your plants?	How many times in the las 5 years this plot experience FLOOD, where you couldn't drain within a week?	How many times in the last 5 years this plot experience DESTRUCTIVE WIND, that destruct your plants?
	1. Clay *2. Crumbly* *3. Sandy* *4. Other*	*1. Black* *2. Black-white* *3. Brown* *4. Brown-orange* *5. Other*	*1 None* *2 Gravity/ tech Irrigated* *3 Pumped surface water* *4 Pumped groundwater* *5. Bucket* *6. Piped water*	*1 None* *2 Gravity/ tech Irrigated* *3 Pumped surface water* *4 Pumped groundwater* *5. Bucket* *6. Piped water* *7. Retention basin*	*Now* *crop code*	*Prev* *crop code*	*(year)*	*crop code*	*number*	*number*	*number*
C3	C14	C15	C16	C17	C18	C19	C20	C21	C16	C17	C18
1											
2											
3											
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D. CITRUS PRODUCTION

	Plot	How many citrus plants are in this plot?	Are you renting out the citrus tree in this plot?	How many productive plants are in this plot?	What the dominant variety of the citrus in the plot?	Did you do top working in the plot?	[If D4=1], when did you do top working?	[If D4=1], why did you do top working?					[If D4=1], What was the previous variety?
								Changing variety	Old trees were not productive	Changing unhealthy trees	Increasing quality/ price	Other	
	[ENTER PLOT NUMBERS IN WHICH CITRUS WERE GROWN]	*Number*	*1. Yes* *0. No*	*Number*	*1 Siam* *2 Keprok* *3 Jeruk manis/baby* *4 Pamelo* *5 Lime/lemon* *6 others*	*1. Yes* *0. No*	*(year)*	*1. Yes* *0. No*	*1. Yes* *0. No*	*1. Yes* *0. No*	*1. Yes* *0. No*	*1. Yes* *0. No*	*1 Siam* *2 Keprok* *3 Jeruk manis* *4 Pamelo* *5 Lime/lemon* *6 others*
	C3	D1	D2	D3	D4	D5	D6	D7a	D7b	D7c	D7d	D7e	D8
1													
2													
3													
4													
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11													

D. CITRUS PRODUCTION (Cont.)

	Plot	[If D4=1], where did you get the scion?	If you buy the scion, how much did you pay for each scion?	When did you plant the citrus in this plot for the last time?	How many trees that you need replant in this plot?	Did you use certified seedling in this plot?	What was the reason you choose the type of seedling?							Where did you get the seedling?
							Availability	Cheapest price	Easy to access	Better performan	Follow other farmers	Longer age	Resistance to climate situation	
	[ENTER PLOT NUMBERS IN WHICH CITRUS WERE GROWN]	*1. BPMT* *2. Selection from own orchard* *3. Selection from other farmers orchard*	(Rp/scion)	year	(trees)	1. Yes 2. No	1. Yes 2. No	1. Yes 2. No	1. Yes 2. No	1. Yes 2. No	1. Yes 2. No	1. Yes 2. No	1. Yes 2. No	1. Nursery 2. Seedling big trader 3. Seedling retailer 4. Market 5. Government assistant 6. Research institute 7. Own production 8. Neighbour/ other farmer
	C3	D9	D10	D11	D12	D13	D13a	D13b	D13c	D13d	D13e	D13f	D13g	D14
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D. CITRUS PRODUCTION (Cont.)

	Plot	If you buy the seedling, what was the price?	Do you find citrus in plot attacked by CVPD or degreeining disease or a disease with the symptoms: yellow spot in the leaf, assymmetric fruit shape, ..)	[If D15=1], how many trees?	PERIOD 1				PERIOD 2			
					When the last time you harvest in the plot?	How much revenue from the harvesting	How many kg did you get?	What was the price?	When the last time you harvest in the plot?	How much revenue from the harvesting	How many kg did you get?	What was the price?
	[ENTER PLOT NUMBERS IN WHICH CITRUS WERE GROWN]	*(Rp/tree)*	*1. Yes* *0. No*	*(number)*	1. Jan 2. Feb 3. Mar 4. Apr 5. May 6. Jun 7. Jul 8. Aug 9. Sept 10. Oct 11. Nov 12. Dec	(Rp/plot)	(kg)	(Rp/kg)	1. Jan 2. Feb 3. Mar 4. Apr 5. May 6. Jun 7. Jul 8. Aug 9. Sept 10. Oct 11. Nov 12. Dec	(Rp/plot)	(kg)	(Rp/kg)
	C3	D15	D16	D17	D18a	D18b	D18c	D18d	D19a	D19b	D19c	D19d
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Page 4c

D. CITRUS PRODUCTION (Cont.)

	Plot	PERIOD 3				PERIOD 4				PERIOD 5				PERIOD 6			
		When the last time you harvest in the plot?	How much revenue from the harvesting	How many kg did you get?	What was the price?	When the last time you harvest in the plot?	How much revenue from the harvesting	How many kg did you	What was the price?	When the last time you harvest in the plot?	How much revenue from the harvesting	How many kg did you get?	What was the price?	When the last time you harvest in the	How much revenue from the harvesting	How many kg did you get?	What was the price?
	[ENTER PLOT NUMBERS IN WHICH CITRUS WERE GROWN]	1. Jan 2. Feb 3. Mar 4. Apr 5. May 6. Jun 7. Jul 8. Aug 9. Sept 10. Oct 11. Nov 12. Dec	(Rp/plot)	(kg)	(Rp/kg)	1. Jan 2. Feb 3. Mar 4. Apr 5. May 6. Jun 7. Jul 8. Aug 9. Sept 10. Oct 11. Nov 12. Dec	(Rp/plot)	(kg)	(Rp/kg)	1. Jan 2. Feb 3. Mar 4. Apr 5. May 6. Jun 7. Jul 8. Aug 9. Sept 10. Oct 11. Nov 12. Dec	(Rp/plot)	(kg)	(Rp/kg)	1. Jan 2. Feb 3. Mar 4. Apr 5. May 6. Jun 7. Jul 8. Aug 9. Sept 10. Oct 11. Nov 12. Dec	(Rp/plot)	(kg)	(Rp/kg)
	C3	D20a	D20b	D20c	D20d	D21a	D22b	D22c	D22d	D23a	D23b	D23c	D23d	D24a	D24b	D24c	D24d
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Page 4d

E. INPUT AND HIRED LABOUR USE

Indicate input and hired labour that you use in the plot w hich has the largest number and oldest productive trees

	Type of input	For the LARGEST CITRUS PLOT in last 12 month, did you use [..]?	How much did you buy the input?		Did you use more than one brand of the input?	How many times did you applicate the input?	How much the input for each application (in average)	Where the [inputs] purchased in cash or on credit?
		1. Yes *0. No*	*Unit*	*Rp/Unit*	*1. Yes* *0. No*	*(number)*	*Unit*	*1. Own production* *2. Buying* *3.Provided by other and free* *4,Government assistant* *5.Credit from cooperative/farmers group* *6.Credit from input trader/Supplier*
E1		E2	E3u	E3p	E4	E5	E6	E7
1	Chemical fertiliser							
	a. Urea							
	b. SP 36							
	c. KCl							
	d. ZA							
	d. ZK							
	e. NPK							
	f. NPK Phonska							
	f. Leaves fertiliser							
2	Organic fertiliser							
	a. Manure							
	b. Branded organic fertiliser							
3	Flow ering hormone							
4	Pesticide							
5	Fungicide							
6	Herbicide							
7	Acaricide							
8	Perekat bunga							
9	Yellow trap							
10	Gasoline for w ater pump/generator							
11	Gasoline for pow er sprayer							
12	Irrigation							
13	Land tax							
14	Poles							
15	Others							

Option for E5 and E6u:(1) Kg; (2) Liter; (3) Pack; (4) Bag; (5) Tree; (6) kali; (7) Label; (8) Roll; (9) Ons; (10) Others

E. INPUT AND HIRED LABOUR USE (Cont.)

Did you have hired fix labour for this plot? (1. Yes; 2. No)		E8
[If E8 = 1), how many hired fix labour do you have?		E9
How mony total man days they work in this plot for the last 12 month? (day)		E10
In the last 12 month, how many days did you come to this plot?		E11
In the last 12 month, how many days did your spouse come to this plot?		E12
In the last 12 month, how many days did your other family member (over 18 y.o.) come to this plot?		E13

	Type of activities	For the LARGEST CITRUS PLOT in last 12 month, did you do[..]?	Did you use hired labour for the activity?	[If E10=1], how many hired male labour to do the activity?	[If E10=1], how many days hired male labour to do the activity?	[If E10=1], how many hired female labour to do the activity?	[If E10=1], how many days hired female labour to do the activity?	How many intra household children labour involve in the activity?	How many days intrahousehold children labour involve in the activity?
		1. Yes 0. No	*1. Yes 0. No*	*(number)*	*(number)*	*(number)*	*(number)*	*(number)*	*(number)*
E8		E9	E10	E11	E12	E13	E14	E15	E16
1	Prunning								
2	Manual weeding								
3	Herbicide spraying								
4	Organic fertilising								
5	Chemical fertilising								
6	Fungicide application								
7	Hormone application								
8	Pesticide spraying								
9	Fruit thinning								
10	Yellow trap application								
11	Watering in dry season								
12	Drainage maintenance								
13	Life fence maintenance								
14	Harvesting*)								
15	Other								

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F. CITRUS MARKETING

Who is the main buyer of your citrus in the last 12 months? [ ] F1

1. Other farmers
2. Farmers group
3. Collector (small trader)
4. Big trader (pengepul)
5. Cooperative
6. Citrus industry
7. Supermarket/Modern market
8. Consumers
9. Other

Where is the main buyer come from? [ ] F2

1. Same village
2. Different village in the same subdistrict
3. Different subdistrict in the same district
4. Different district in the same province
5. Different province

How was the payment method from the main buyer? [ ] F3

1. Before harvest
2. At delivery
3. 1-7 days later
4. More than week later
5. Multiple payments (across categories)

Please indicate the marketing arrangement that you use in the last 12 months

1. Self-harvested and sold by kilo	1. Yes; 0. No		F4
2. Harvested by trader and sold by kilo	1. Yes; 0. No		F5
3. Tebas	1. Yes; 0. No		F6
4. Kotasan	1. Yes; 0. No		F7
5. No selling in the last 12 month	1. Yes; 0. No		F8

	Indicate the importance of the reason you choose the citrus buyer for each following statement	1. Very important 2. Important 3. Neutral 4. Not important 5. Very not important
F9	The buyer has a commitment to buy my citrus	
F10	The Buyer pays in cash and fast	
F11	The buyer offers the highest price	
F12	I know the buyer very well or I have family relationship with him/her	
F13	The buyer lend me money or input credit	

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G. SOCIAL CAPITAL AND ACCESSIBILITY

In what year you at the first time involve in citrus farming? G1

What is your main reason at the first time to plant citrus? G2

1. Following my parent
2. Following my neighbour/other farmers
3. Recommended by government/extension workers
4. The demand from traders / supermarkets / industries to be a citrus supplier
5. Citrus has a good prospect/profitability
6. Other

How many times you INDIVIDUALLY have a training/field school of citrus farming in the last 5 year? G3

How many times you INDIVIDUALLY have an extension of citrus farming in the last 5 year? G4

How many times have you ever attended a meeting/extension/training/field-school related to climate change and/or its adaptation strategy in the last 10 years? G5

Are you a part of citrus farmers group currently? [1 = Yes; 0= No] G7

If (H2=1) what is your position in the citrus farmers group? G8

1. FG management
2. Member

What are the activities of the farmers group?

1. Actively give citrus technology from government extension workers [1 = Yes; 0= No] G9a
2. Activiely give farmer to farmer extension? [1 = Yes; 0= No] G9b
3. Facilitate government input assistance? [1 = Yes; 0= No] G9c
4. Facilitate post-harvest handling? [1 = Yes; 0= No] G9d
5. Facilitate marketing? [1 = Yes; 0= No] G9e
6. Comparative study [1 = Yes; 0= No] G9f
7. Integrated pest/disease management

Are you a part of cooperative? [1 = Yes; 0= No] G10

If (H5=1), what is the cooperative activities that you use? (check box) [1 = Yes; 0= No]

1. Financial credit? [1 = Yes; 0= No] G10a
2. Money saving [1 = Yes; 0= No] G10b
3. Input credit [1 = Yes; 0= No] G10c
4. Input procurement [1 = Yes; 0= No] G10d
5. Product marketing [1 = Yes; 0= No] G10e
6. Others___________ [1 = Yes; 0= No] G10f

Do you have a direct access to government auhorithy in agriculture to ask for citrus information? (e.g. Dinas, extension workers, resercher, etc) [1 = Yes; 0= No] G11

Do you adopt agricultural insurance for your citrus farming? G12

[1 = Yes; 0= No]

If (H8=2), What is the main reason? G13

1. Insurance is not available
2. Insurance is not important
3. Do not want to pay additional cost
4. No Money
5. Do not understand
6. Religious reason
7. Other

Do you have a formal credit from bank, cooperative, etc that you use for citrus farming? G14

[1 = Yes; 0= No]

If (H10=2), What is the main reason? G15

1. The requerement is complicated
2. Too high interest rate
3. Do not understand
4. Religious reason
6. No need
7. No collateral

H. INFORMATION SOURCES

Source of information		Over the past 5 years, what have been your main sources of information about citrus production methods ?	How would you rate the quality of the information? 1. Good 2. OK 3. Poor	Over the past 5 years, what have been your main sources of information about citrus prices & markets?	How would you rate the quality of the market information? 1. Good 2. OK 3. Poor	Over the past 5 years, what have been your main sources of information about climate or weather ?	How would you rate the quality of the climate/ weather information? 1. Good 2. OK 3. Poor
H1		H2	H3	H4	H5	H6	H7
1	Extension workers						
2	Research institute						
3	Farmer/relative/neighbor						
4	Trader						
5	Processor						
6	Input sellers						
7	Cooperative						
8	Farmer group						
9	TV						
10	Radio						
11	Newspaper/magazine/books						
12	Input companies						
13	Internet (www)						
14	Mobile info service						
15	Other ___________						

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I. CASH INCOME ACTIVITIES

Income activity	CODE	In the past 12 months, have members of your household received income from [activity]? *1. Yes 0. No*	[------ if I2 = yes ------] Who is the source of the income? (spent more time or obtain more money) *1. Husband 2. Wife 3. Sharing 4. Others*	How many months out of the past 12 months did members of this household receive income from [activity]? *Months*	For each of these months that you were involved in [activity], how much total gross revenue did you make from this activity? (in average) *Rp/month*	For each of these months, how much does your household spend in business expenses related to this activity? (in average) *Rp/month*	Over the past 5 years, has this activity become more or less important as a share of your income? *1. More important 2. No change 3. Less important*
	I1	I2	I3a	I4	I5	I6	I7
CITRUS production							
Other agricultural production							
Livestock & animal product sales							
Aquaculture							
Agricultural trading							
Other trading							
Rice milling business							
Food processing business							
Other business							
Agricultural wage labor							
Non-agricultural employment (e.g. PNS)							
Pension fund							
Remittances from family members							
Other assistance programs							
Other							

J. FARM ACTIVITIES RESPONSIBILITY

Ask this module to husband and wife separately

	Activities	In citrus farming, do you involve in the activity? *1. Yes* *0. No*	Between husband and wife, who has a responsibility for each activity? *1. Husband* *2. Wife* *3. Sharing*
J1		J2	J3
1	Land preparation		
2	Buying farm equipment		
3	Buying farm input (seed, fertiliser, pesticide, etc)		
4	Choosing and buying seedling		
5	Planting		
6	Fertilising		
7	Spraying		
8	Weeding		
9	Watering/Irrigation/Drainage		
10	Prunning		
11	Harvesting		
12	Marketing arrangement		
13	Negotiating with buyer/trader		
14	Looking for hired labour		
15	Credit application		
16	Attending agriculture training or extension activities?		

K. CLIMATE CHANGE KNOWLEDGE, PERCEPTION AND ADAPTATION

Ask this module to husband and Wife

Have you ever heard about "climate change" term? (0. No, 1. Yes) K1

What is your first thought when you heard about climate change? K2

1. Global warming (increasing in temperature)
2. Sea level rise
3. Drought
4. Flood
5. Heavy precipitation
6. Disaster
7. Deacreased rainfall
8. Changing rainfall pattern
9. Oozone layer
10. Destructive wind
11. Deforestration
12. Forest fire
13. Pollution
14. New pest and disease
15. Massive pest and disease incidence
16. Other

Please select the response that reflects the level of your agreement regarding the climate change		**Based on my experience/observation, there are [...] over the last 5 - 10 years**	**The [...] negatively impacted my citrus farming**	**In my perception there is likelihood of [...] in the future**
		1. Strongly disagree *2. Disagree* *3. Neutral* *4. Agree* *5. Strongly agree*	*1. Strongly disagree* *2. Disagree* *3. Neutral* *4. Agree* *5. Strongly agree*	*1. Strongly disagree* *2. Disagree* *3. Neutral* *4. Agree* *5. Strongly agree*
K 4	Increasing air temperature			
K 5	Increasing dry season period			
K 6	Increasing rainy season period			
K 7	Increasing heavy rain			
K 8	Increasing flood			
K 9	Increasing destructive wind			

K. CLIMATE CHANGE KNOWLEDGE, PERCEPTION AND ADAPTATION (Cont.)

		Planning
K 10 What farming practices that you use to adapt the climate change		
1. Certified seedling	1. Yes; 0. No	
2. Irrigation/drainage system improvement	1. Yes; 0. No	
3. Increasing anorganic fertiliser dosage	1. Yes; 0. No	
4. Increasing organic fertiliser dosage	1. Yes; 0. No	
5. Intensive plant maintenance (prunning, weeding, sanitation)	1. Yes; 0. No	
6. Investment in agricultural equipments (generator pump, deep well)	1. Yes; 0. No	
7. Changing crops (from citrus to other crops)	1. Yes; 0. No	
8 Multicropping	1. Yes; 0. No	
9. Planting wind breaker	1. Yes; 0. No	
10. Build retention basin	1. Yes; 0. No	
11. Others _______________	1. Yes; 0. No	

K 11 Do you plan to use this farming practices in future?		
1. Certified seedling	1. Yes; 0. No	
2. Irrigation/drainage system improvement	1. Yes; 0. No	
3. Increasing anorganic fertiliser dosage	1. Yes; 0. No	
4. Increasing organic fertiliser dosage	1. Yes; 0. No	
5. Intensive plant maintenance (prunning, weeding, sanitation)	1. Yes; 0. No	
6. Investment in agricultural equipments (generator pump, deep well)	1. Yes; 0. No	
7. Changing crops (from citrus to other crops)	1. Yes; 0. No	
8 Multicropping	1. Yes; 0. No	
9. Planting wind breaker	1. Yes; 0. No	
10. Build retention basin	1. Yes; 0. No	
11. Others _______________	1. Yes; 0. No	

K 12 What is the constraint of climate change adaptation on citrus farming?	______________________________	
1. Lack of climate information	1. Yes; 0. No	
2. Limited knowledge about adaptation technique	1. Yes; 0. No	
3. Limited water source and/or irrigation system	1. Yes; 0. No	
4. Unsupported land characteristics	1. Yes; 0. No	
5. Lack of money	1. Yes; 0. No	
6. Lack of access to input market	1. Yes; 0. No	
7. Lack of input availability	1. Yes; 0. No	
8. Labaor shortage	1. Yes; 0. No	
9. Others______________________	1. Yes; 0. No	

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L. RISK EXPERIMENT

Ask this module to husband and Wife

Note to enumerator: Please read the risk procedure carefully. Make sure that you understand the experiment procedure.

A. Choose the respondent's answer based on experiment procedure A (Risk preferences)

R0	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11

B. How do you see yourself: Are you a person who is generally willing to take risks, or do you try to avoid taking risks?
(Choose the respondent's answer based on procedure B)

0	1	2	3	4	5	6	7	8	9	10

C. Choose the respondent's answer based on experiment procedure C! (Risk preferences)

T0	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11

D. In comparison to others, are you a person who is generally willing to give up something today in order to benefit from that in the future or are you not willing to do so?
(Choose the respondent's answer based on experiment procedure D!)

0	1	2	3	4	5	6	7	8	9	10

E.what you can expect to get from CERTIFIED and UNCERTIFIED SEED in a given year per 100 citrus trees? (Follow the instruction in procedure E.

1. Certified seed

0-2 ton	3-4 ton	5-6 ton	7-8 ton	9-10 ton	11-12 ton	13-14 ton	15-16 ton	17-18 ton

2. Uncertified seed

0-2 ton	3-4 ton	5-6 ton	7-8 ton	9-10 ton	11-12 ton	13-14 ton	15-16 ton	17-18 ton

M. CHILD EDUCATION

The purpose of this section is to record education information and expenditure of all of the respondent's children during the period of July 1, 2016 - June 30, 2017

M1 How many children do you have? [ ]

M2 Who mostly make decision regarding children education expenditure in this household? [ ]
(0. Father, 1. Mother, 2. Grand parents, 3. others)

		Child No.1	Child No.2	Child No.3	Child No.4
M3	Name				
M4	Age				
M5	Gender (0. Male, 1. Female)				
M6	Does the child live in the household? (0. Yes, 1. No)				
M7	Does the child participate in the farmwork? (0.Yes, 1.No)				
M8v	How many times in the period of July 1, 2016 - June 30, 2017 does the child help in farmwork? (number of times)				
M8u	Unit of time (0. Week, 1. Month, 2. Year)				
M9	What is the level of education that the child was attending during the period ** July 1, 2016 - June 30, 2017 **? 1. Play group/kindergarten 2. Primary school 3. Junior high school (SMP) 4. Senior high school (SMA) 5. Academy (D1, D2, D3) 6. University (S1) 7. University (S2) 8. University (S3) 9. Vocational training institute 10. Not in school				
M10	Main reason of stopping school 1. Could not afford to further education 2. Prefer to work (citrus farming) 3. Prefer to work (jobs other than farming) 3. School is too far/No school in the area 4. Helping at home (e.g. caring for younger siblings, housework) 5. Marriage 6. Others				
M11	Is your child studying at ** public school ** in that period? (0.Yes, 1.No)				
M12	Is your child studying at ** boarding school ** in that period? (0.Yes, 1.No)				
M13	Is your child studying at ** religious school ** in that period? (0.Yes, 1.No)				
M14	What is the distance from the house to the school (km)?				
M15v	How many times in the period of ** July 1, 2016 - June 30, 2017 did you pay for ** registration fee **?				
M15u	Unit of time (0. Week, 1. Month, 2. Year)				
M15a	What is the average cost for each payment?				
M16v	How many times during the period of ** July 1, 2016 - June 30, 2017 ** did you pay for SPP, POMG / BP3 /				
M16u	Unit of time (0. Week, 1. Month, 2. Year)				
M16a	What is the average cost for each payment?				
M17v	How many times in the period of ** July 1, 2016 - June 30, 2017 ** did you pay for evaluation / exam fee **?				
M17u	Unit of time (0. Week, 1. Month, 2. Year)				
M17a	What is the average cost for each payment?				
M18v	How many times during the period of ** July 1, 2016 - June 30, 2017 ** did you pay for Books, stationery and				
M18u	Unit of time (0. Week, 1. Month, 2. Year)				
M18a	What is the average cost for each payment?				
M19v	How many times in the period of** July 1, 2016 - June 30, 2017 ** did you pay for school uniform and sport				
M19u	Unit of time (0. Week, 1. Month, 2. Year)				
M19a	What is the average cost for each payment?				
M20v	How many times in the period of** July 1, 2016 - June 30, 2017 did you pay for transportation (including shuttle fee)?				
M20u	Unit of time (0. Week, 1. Month, 2. Year)				
M20a	What is the average cost for each payment?				
M21v	How many times in the period of ** July 1, 2016 - June 30, 2017 ** did you pay for allowance, boarding / room				
M21u	Unit of time (0. Week, 1. Month, 2. Year)				
M21a	What is the average cost for each payment?				
M22v	How many times in the period of ** July 1, 2016 - June 30, 2017 ** did you pay for tutorials?				
M22u	Unit of time (0. Week, 1. Month, 2. Year)				
M22a	What is the average cost for each payment?				
M23v	How many times in the period of ** July 1, 2016 - June 30, 2017** did you pay for fieldtrip?				
M23u	Unit of time (0. Week, 1. Month, 2. Year)				

M. CHILD EDUCATION (Cont.)

		Child No.1	Child No.2	Child No.3	Child No.4
M23a	What is the average cost for each payment?				
M24v	How many times in the period of ** July 1, 2016 - June 30, 2017 ** did you pay for other skill training courses **?				
M24u	Unit of time (0. Week, 1. Month, 2. Year)				
M24a	What is the average cost for each payment?				
M25v	How many times in the period of ** July 1, 2016 - June 30, 2017 did you pay for education cost of any child outside				
M25u	Unit of time (0. Week, 1. Month, 2. Year)				
M25a	What is the average cost for each payment?				
M26	In addition to all other expenses above, what is your total spending on other education expenses in the period of**				
M27v	How many times in the period of ** July 1, 2016 - June 30, 2017 ** did you receive financial aid from GNOTA?				
M27u	Unit of time (0. Week, 1. Month, 2. Year)				
M27a	How much did you receive each time?				
M28v	How many times in the period of ** July 1, 2016 - June 30, 2017 ** did you receive financial aid from ** BSM (Poor				
M28u	Unit of time (0. Week, 1. Month, 2. Year)				
M28a	How much did you receive each time?				
M29v	How many times in the period of ** July 1, 2016 - June 30, 2017 ** did you receive financial aid from Bidik Misi**				
M29u	Unit of time (0. Week, 1. Month, 2. Year)				
M29a	How much did you receive each time?				
M30v	How many times in the period of ** July 1, 2016 - June 30, 2017 ** did you receive financial aid from other types of				
M30u	Unit of time (0. Week, 1. Month, 2. Year)				
M30a	How much did you receive each time?				
M31v	How many times in the period of ** July 1, 2016 - June 30, 2017 ** did you receive financial aid for child education				
M31u	Unit of time (0. Week, 1. Month, 2. Year)				
M31a	How much did you receive each time?				
M32v	How many times in the period of ** July 1, 2016 - June 30, 2017 **did you receive financial aid for education from				
M32u	Unit of time (0. Week, 1. Month, 2. Year)				
M32a	How much did you receive each time?				
M33v	How many times in the period of ** July 1, 2016 - June 30, 2017 ** did you receive financial aid from your child's				
M33u	Unit of time (0. Week, 1. Month, 2. Year)				
M33a	How much did you receive each time?				
M34v	In the period of ** 1 July 2016 - 30 June 2017 ** did you receive assistance from BOS / BKM Fund ?				
M34u	Unit of time (0. Week, 1. Month, 2. Year)				
M34a	How much did you receive each time?				
M35v	How many times in the period of ** July 1, 2016 - June 30, 2017 ** did you receive financial assistance from **				
M35u	Unit of time (0. Week, 1. Month, 2. Year)				
M35a	How much did you receive each time?				

HOUSEHOLD SHOCKS

The purpose of this section is to obtain shocks / extraordinary events occurred in the household over the period ** July 1, 2016 - June 30, 2017 **

M36 Death in the family (0. Yes, 1. No) [ ]

M37 Any sickness causing any family member to be absent from work at least 2 weeks in a row (0.Yes, 1. No) [ ]

M38 Family accidents causing family members to be absent from work at least 2 weeks in a row (0.Yes, 1. No) [ ]

M39 Natural disaster (0.Yes, 1. No) [ ]

M40 Receiving inheritance (0.Yes, 1. No) [ ]

Appendix 3. Experiment procedures for questionnaire Section L

A. Subjective belief of yield eliciting procedures

In this experiment, we will ask you about your expectation about certified and uncertified citrus seedling if planted in your land. The citrus variety is the same variety planted in your land currently.

1. Certified seedling

Please look at the table in front of you (show the respondent poster for certified seedling (Figure A3-1). The table shows different levels of possible yields in ton per 100 citrus trees per year for the certified seedling. You have ten tokens to allocate to the boxes in this table. By considering that you will apply the maximum level of maintenance of citrus trees, such as fertilisers, pesticides, etc., and maximum adaptation to all possibilities of climate situation, we want you to allocate the tokens to each box based on how likely it is that you could get that yield. We do not want you to think about this year only - instead, think in general about what you can expect to get from certified seedling for 100 trees in a given year.

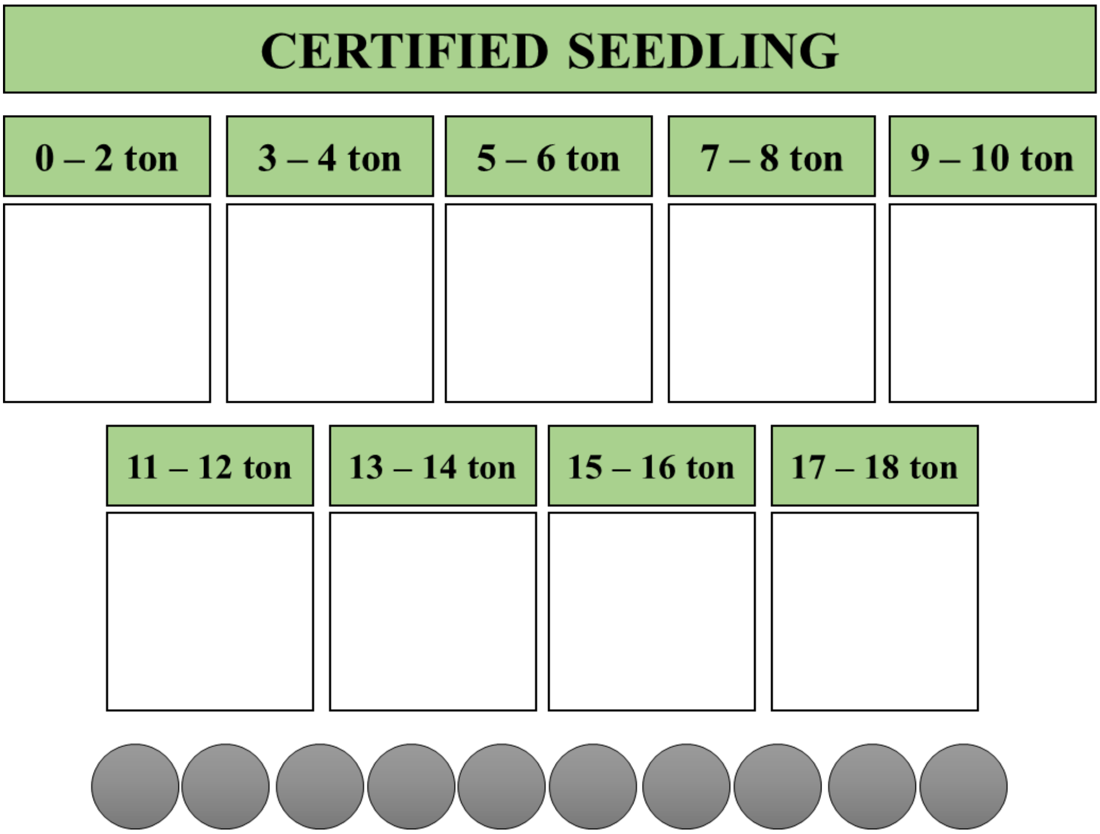

Figure A3-1. Board for certified seedling

If you think there is an equal expectation of yields for certified seedling, for example between 9-10 to 11-12 ton, you should place equal numbers of tokens on each of those boxes to reflect this belief. Alternatively, if you think that the certified seedling has very stable yields, you could place tokens in one or two boxes only which might be the most common yield amounts you think happen for the certified seedling.

2. Uncertified seedling

Please look at the table in front of you (show the respondent poster for uncertified seedling (Figure A3-2). The table shows different levels of possible yields in ton per 100 citrus trees for the uncertified seedling. You have 10 tokens to allocate to the boxes in this table. By considering that you will apply the maximum level of maintenance of citrus trees, such as fertiliser, pesticide, etc., and maximum adaptation to all possibilities of climate situation, we want you to allocate tokens to each box based on how likely it is that you could get that yield from uncertified seedling. We do not want you to think about this year only - rather think in general about what you can expect to get from uncertified seedling for 100 trees in a given year.

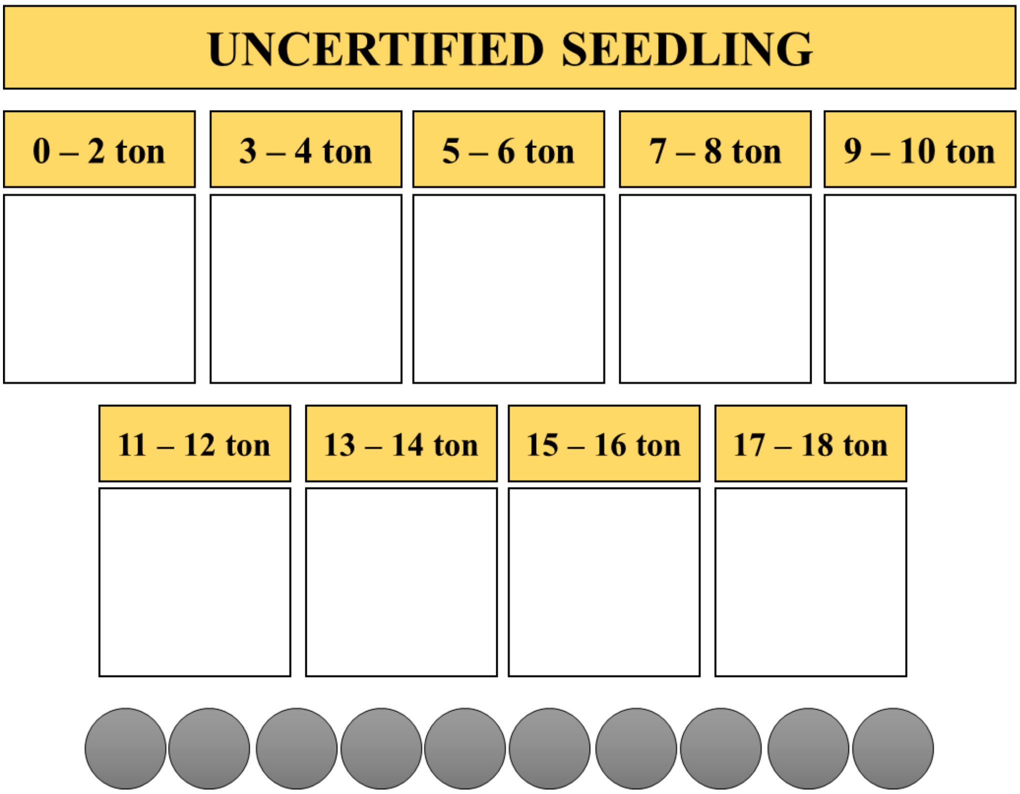

Figure A3-2. Board for uncertified seedling

If you think there is an equal expectation of yields for uncertified seedling, for example between 9-10 to 11-12 ton, you should place equal numbers of tokens on each of those boxes to reflect this belief. Alternatively, if you think uncertified seedling has very stable yields, you could place tokens only in one or two boxes which are the most common yield amounts you think might happen for the uncertified seedling.

Note: After the respondent finish their response for certified seedling, you can put certified and uncertified seedling boards side by side, so they can compare their expectation for certified seedling and uncertified seedling.

B. Risk preferences elicitation experiments

Instruction to enumerators

The elicitation of farmers' risk preferences will use the staircase procedure, consists of sequence choices of hypothetical money experiment. The choices consist of safe and risky options, and it will determine the next question in the sequence. Please emphasise to the respondents that these experiments are not gambling activities, but it is a scientific method to measure farmers' preferences toward risk. So, in this experiment, we will not use real money. To help the respondents remembering the amount of money in each sequence, you can show them the posters and envelopes based on the questions (See Figure A3-3 as an example). *Remember, never show the respondent the poster that will come next. The experiment is started from question number 6. Respondents are instructed as follows:*

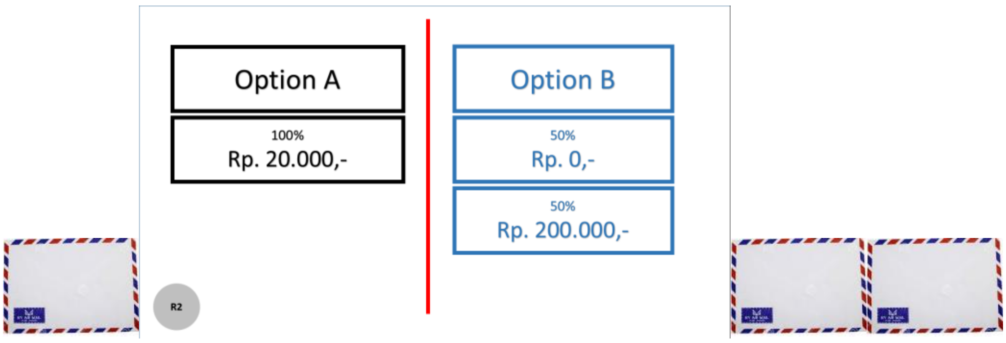

Figure A3-3. Poster for risk preferences question number 2

Please have a look following situation: You can choose between option A and option B. Envelop in option A contains a sure certain amount of hypothetical money as shown in the poster. However, option B consists of two envelops which one of them is empty, and another one contains a sure certain amount of hypothetical money, as shown in the poster. You do not know which envelop that has money so that your possibility to receive money in option B is 50 per cent, or getting nothing. Now, imagine you have to choose between option A and B. We will present you with different situations. Option A will be different in all circumstances, but option B will be similar.

1. Question number 3. Please have a look poster number 6. What would you prefer: Option A which has an envelope with IDR 100,000.- as a sure payment, or option B which has a 50 per cent chance to win IDR 200,000.-, at the same time, there is a 50 per cent chance to receive nothing.
   - If the respondent chooses option A → go to question number 3
   - If the respondent chooses option B → go to question number 9

2. Question number 3. Please have a look poster number 3. What would you prefer: Option A which has an envelope with IDR 40,000.- as a sure payment, or option B which has a 50 per cent chance to win IDR 200,000.-, at the same time, there is a 50 per cent chance to receive nothing.
   - If the respondent chooses option A → go to question number 2
   - If the respondent chooses option B → go to question number 4

3. Question number 9. Please have a look poster number 9. What would you prefer: Option A which has an envelope with IDR 160,000.- as a sure payment, or option B which has a 50 per cent chance to win IDR 200,000.-, at the same time, there is a 50 per cent chance to receive nothing.
   - If the respondent chooses option A → go to question number 8
   - If the respondent chooses option B → go to question number 10

4. Question number 2. Please have a look poster number 2. What would you prefer: Option A which has an envelope with IDR 20,000.- as a sure payment, or option B which has a 50 per cent chance to win IDR 200,000.-, at the same time, there is a 50 per cent chance to receive nothing.
   - If the respondent chooses option A → go to question number 1

- If the respondent chooses option B → STOP, put the respondent answers as STAIRCASE 2

5. Question number 4. Please have a look poster number 4. What would you prefer: Option A which has an envelope with IDR 60,000.- as a sure payment, or option B which has a 50 per cent chance to win IDR 200,000.-, at the same time, there is a 50 per cent chance to receive nothing.
   - If the respondent chooses option A → STOP, put the respondent answers as STAIRCASE 3
   - If the respondent chooses option B → go to question number 5

6. Question number 8. Please have a look poster number 8. What would you prefer: Option A which has an envelope with IDR 140,000.- as a sure payment, or option B which has a 50 per cent chance to win IDR 200,000.-, at the same time, there is a 50 per cent chance to receive nothing.
   - If the respondent chooses option A → go to question number 7
   - If the respondent chooses option B → STOP, put the respondent answers as STAIRCASE 8

7. Question number 10. Please have a look poster number 10. What would you prefer: Option A which has an envelope with IDR 180,000.- as a sure payment, or option B which has a 50 per cent chance to win IDR 200,000.-, at the same time, there is a 50 per cent chance to receive nothing.
   - If the respondent chooses option A → STOP, put the respondent answers as STAIRCASE 9
   - If the respondent chooses option B → go to question number 11

8. Question number 1. Please have a look poster number 1. What would you prefer: Option A which has an envelope with IDR 0.- as a sure payment or option B which has a 50 per cent chance to win IDR 200,000.-, at the same time, there is a 50 per cent
   - If the respondent chooses option A → STOP, put the respondent answers as STAIRCASE 0

- If the respondent chooses option B → STOP, put the respondent answers as STAIRCASE 1

9. Question number 5. Please have a look poster number 5. What would you prefer: Option A which has an envelope with IDR 80,000.- as a sure payment, or option B which has a 50 per cent chance to win IDR 200,000.-, at the same time, there is a 50 per cent chance to receive nothing.
   - If the respondent chooses option A → STOP, put the respondent answers as STAIRCASE 4
   - If the respondent chooses option B → STOP, put the respondent answers as STAIRCASE 5

10. Question number 7. Please have a look poster number 7. What would you prefer: Option A which has an envelope with IDR 120,000.- as a sure payment, or option B which has a 50 per cent chance to win IDR 200,000.-, at the same time, there is a 50 per cent chance to receive nothing.
    - If the respondent chooses option A → STOP, put the respondent answers as STAIRCASE 6
    - If the respondent chooses option B → STOP, put the respondent answers as STAIRCASE 7

11. Question number 11. Please have a look poster number 11. What would you prefer: Option A which has an envelope with IDR 200,000.- as a sure payment, or option B which has a 50 per cent chance to win IDR 200,000.-, at the same time, there is a 50 per cent chance to receive nothing.
    - If the respondent chooses option A → STOP, put the respondent answers as STAIRCASE 10
    - If the respondent chooses option B → STOP, put the respondent answers as STAIRCASE 11

The staircase procedure for risk preferences is illustrated in Figure A3-4.

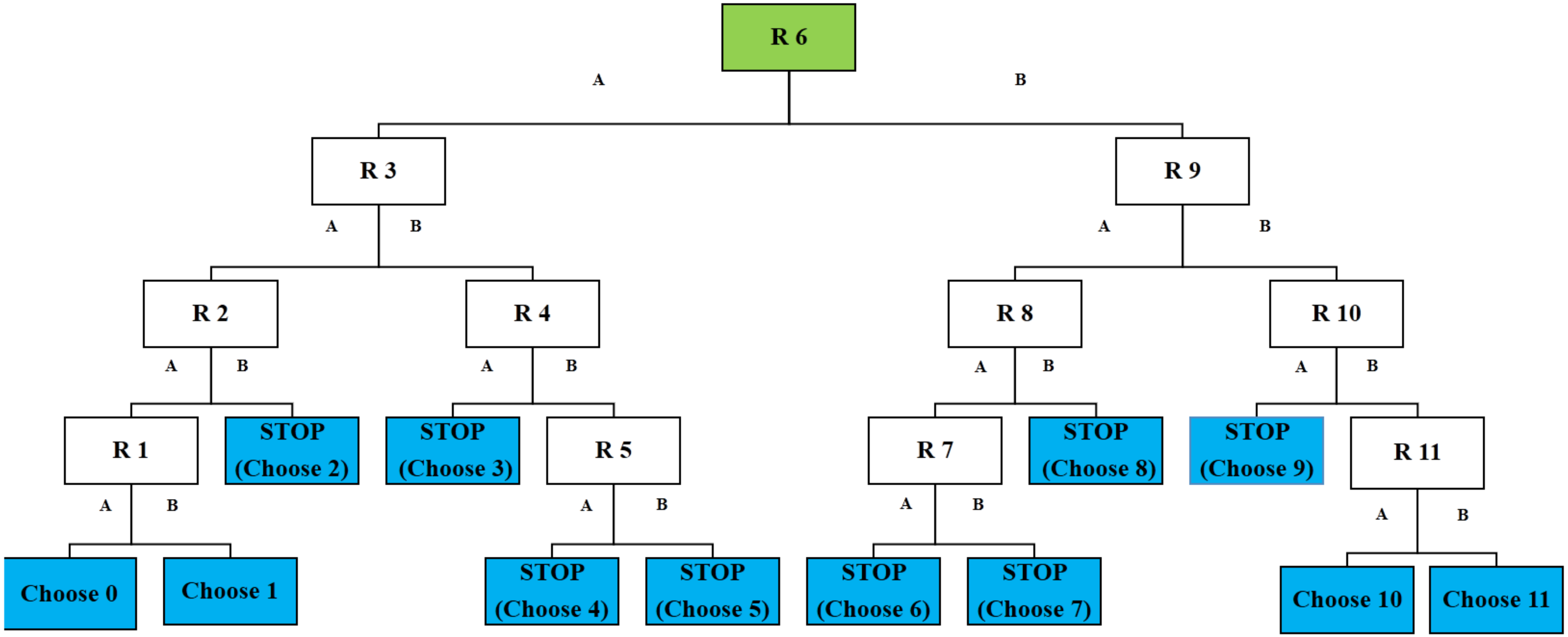

Figure A3-4. Staircase procedure for risk preferences

C. Self-assessment of risk preferences

Please tell me, in general, how willing or unwilling you are to take risks. Please use a scale from 0 to 10. You can see this poster (Figure A3-5) to scale your risk preferences. Scale 0 means you are "completely unwilling to take risks" and a 10 means you are "very willing to take risks". You can also use any numbers between 0 and 10 to indicate where you fall on the scale, like 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9.

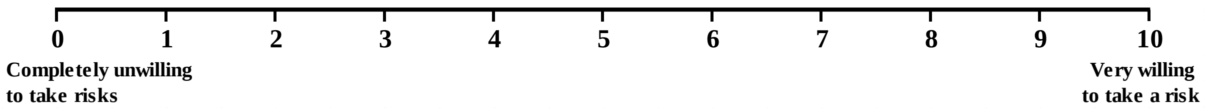

Figure A3-5. Scale for willingness to take a risk

D. Time preferences elicitation procedures

Instruction to enumerators

The elicitation of farmers' time preferences will use staircase procedures, consist of sequence choices of hypothetical money experiment. The choices are receiving certain amount of money for current payment or paid in the next 3 months. Please emphasise to the respondents that these experiments are not gambling activities, but only scientific method to measure farmers' preferences toward risk. To help the respondents remembering the amount of money in each sequence, you can show them the posters based on the questions (See Figure A3-6 as an example). *Remember, never show the respondent the poster that will come next. The experiment is started from question number 6. Respondents are instructed as follows:*

Figure A3-6. Poster for time preferences question number 6

Suppose you were given choices between option A and option B. In option A, you will receive a current payment for a certain amount of money, and option B, you will be paid a certain amount of money in 3 months, as presented in posters. We will now present to you the situations. The payment in option A is the same in each of these situations. But, the payments of option B is different in every case. For each of these situations we would like to know which option you would choose.

1. Question number 6. Please have a look poster number 6. What would you prefer: Option A which you will receive IDR 275,000.- immediately, or option B which you will receive IDR 387,500.- in 3 months.
    - If the respondent chooses option A → go to question number 3
    - If the respondent chooses option B → go to question number 9

2. Question number 3. Please have a look poster number 3. What would you prefer: Option A which you will receive IDR 275,000.- immediately, or option B which you will receive IDR 455,000.- in 3 months.
    - If the respondent chooses option A → go to question number 2
    - If the respondent chooses option B → go to question number 4

3. Question number 9. Please have a look poster number 9. What would you prefer: Option A which you will receive IDR 275,000.- immediately, or option B which you will receive IDR 320,000.- in 3 months.
    - If the respondent chooses option A → go to question number 8
    - If the respondent chooses option B → go to question number 10

4. Question number 2. Please have a look poster number 2. What would you prefer: Option A which you will receive IDR 275,000.- immediately, or option B which you will receive IDR 477,500.- in 3 months.
    - If the respondent chooses option A → go to question number 1
    - If the respondent chooses option B → STOP, put the respondent answers as STAIRCASE 2

5. Question number 4. Please have a look poster number 4. What would you prefer: Option A which you will receive IDR 275,000.- immediately, or option B which you will receive IDR 432,500.- in 3 months.
    - If the respondent chooses option A → STOP, put the respondent answers as STAIRCASE 3
    - If the respondent chooses option B → go to question number 5

6. Question number 8. Please have a look poster number 8. What would you prefer: Option A which you will receive IDR 275,000.- immediately, or option B which you will receive IDR 342,500.- in 3 months.
    - If the respondent chooses option A → go to question number 7
    - If the respondent chooses option B → STOP, put the respondent answers as STAIRCASE 8

7. Question number 10. Please have a look poster number 10. What would you prefer: Option A which you will receive IDR 275,000.- immediately, or option B which you will receive IDR 297,500.- in 3 months.
    - If the respondent chooses option A → STOP, put the respondent answers as STAIRCASE 9
    - If the respondent chooses option B → go to question number 11

8. Question number 1. Please have a look poster number 1. What would you prefer: Option A which you will receive IDR 275,000.- immediately, or option B which you will receive IDR 500,000.- in 3 months.
    - If the respondent chooses option A → STOP, put the respondent answers as STAIRCASE 0
    - If the respondent chooses option B → STOP, put the respondent answers as STAIRCASE 1

9. Question number 5. Please have a look poster number 5. What would you prefer: Option A which you will receive IDR 275,000.- immediately, or option B which you will receive IDR 410,000.- in 3 months.

- If the respondent chooses option A → STOP, put the respondent answers as STAIRCASE 4
- If the respondent chooses option B → STOP, put the respondent answers as STAIRCASE 5

10. Question number 7. Please have a look poster number 7. What would you prefer: Option A which you will receive IDR 275,000.- immediately, or option B which you will receive IDR 365,000.- in 3 months.
    - If the respondent chooses option A → STOP, put the respondent answers as STAIRCASE 6
    - If the respondent chooses option B → STOP, put the respondent answers as STAIRCASE 7

11. Question number 11. Please have a look poster number 11. What would you prefer: Option A which you will receive IDR 275,000.- immediately, or option B which you will receive IDR 275,000.- in 3 months.
    - If the respondent chooses option A → STOP, put the respondent answers as STAIRCASE 10
    - If the respondent chooses option B → STOP, put the respondent answers as STAIRCASE 11

    The staircase procedure for time preferences is illustrated in Figure A3-7.

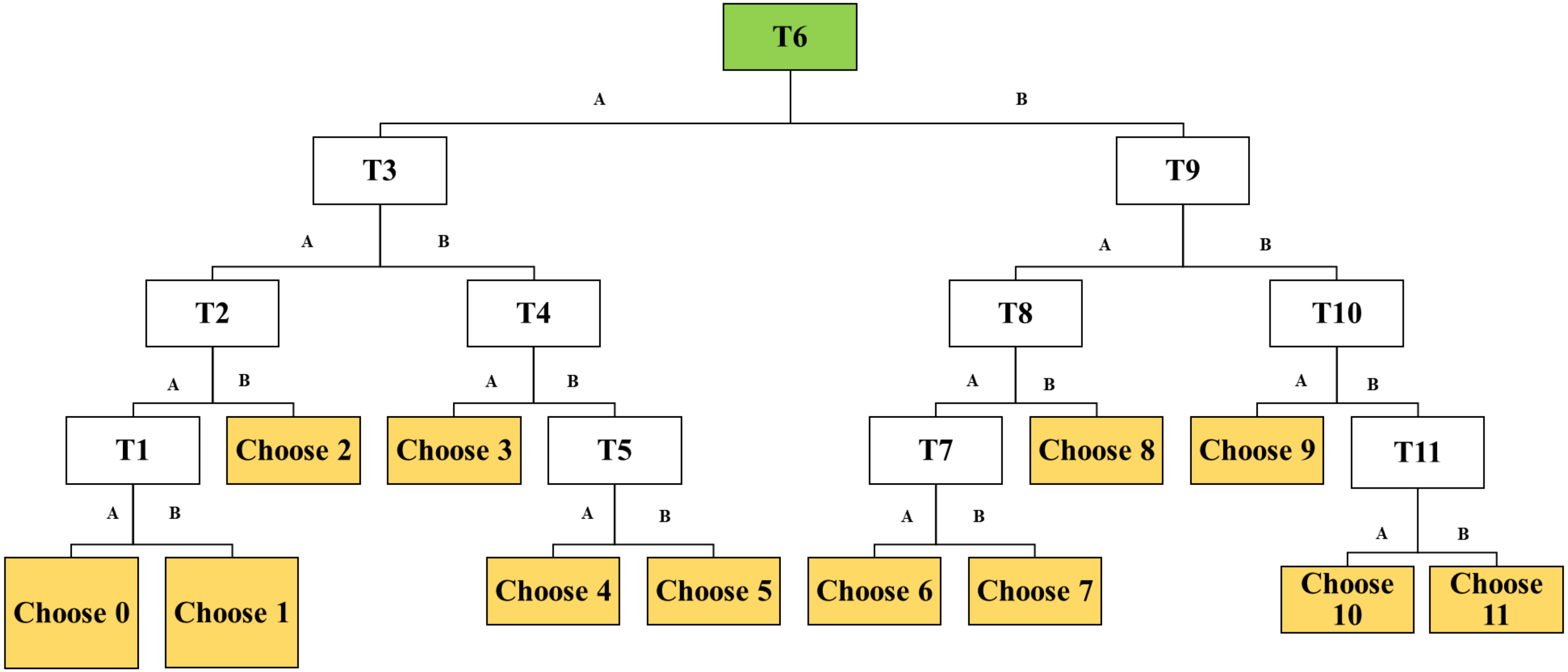

Figure A3-7. Staircase procedure for time preferences elicitation

D. Time preferences self-assessment

Please tell me, in comparison to others, are you a person who is generally willing to give up something today in order to benefit from that in the future or are you not willing to do so? Please use a scale from 0 to 10. You can see this poster (Figure A3-8) to scale your willingness. Scale 0 means you are "completely unwilling to give up something today" and a 10 means you are "very willing to give up something today". You can also use values in-between where you fall on the scale, like 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10.

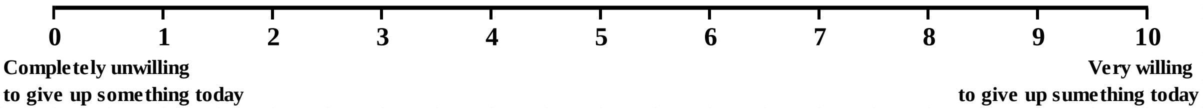

Figure A3-8. Scale for willingness to give up something today

Appendix 4. Selected districts, sub-districts and villages

Districts	Subdistricts	Villages
Banyuwangi	Bangorejo	Bangorejo
		Temurejo
	Purwoharjo	Purwoharjo
		Sidorejo
	Tegaldlimo	Purwoasri
		Kedungasri
	Cluring	Tamanagung
		Plampangrejo
	Pesanggaran	Sumbermulyo
		Sarongan
	Siliragung	Barurejo
	Gambiran	Jajag
	Tegalsari	Tegalrejo
	Muncar	Kedungringin
Jember	Umbulsari	Paleran
		Gunungsari
		Sidorejo
		Umbulrejo
	Semboro	Sidomekar
		Pondok Dalem
		Pondok Joyo
		Sidomulyo
	Sumberbaru	Yosorati
		Pringgowirawan
		Rowo Tengah
	Jombang	Keting
		Jombang
		Padomasan
Malang	Dau	Selorejo
		Kucur
		Petungsewu
		Sumbersekar
		Gadingkulon
		Tegalweru
		Kerangwedoro
	Poncokusumo	Wringin Anom
		Ngadireso
		Ngebrug
		Sumber Rejo
		Jambe Sari
		Karang Nongko
		Karanganyar

Appendix 5. Appendices for Chapter 4

Table A4-1. Seemingly unrelated regression and ordered logit model estimation for risk perception index, perceived likelihood and perceived impact of increasing air temperature

Variables	RPI	Perceived Likelihood	Perceived Impact
(Intercept)	5.829 ***	-	-
	(1.512)	-	-
District dummy (1 if Banyuwangi)	-0.112	-0.001	0.152
	(0.388)	(0.240)	(0.246)
District dummy (1 if Jember)	-0.316	-0.081	-0.019
	(0.421)	(0.261)	(0.267)
Gender (1 if male)	-1.227	0.116	-1.184 **
	(0.899)	(0.593)	(0.576)
Age (year)	-0.010	-0.004	-0.005
	(0.015)	(0.009)	(0.009)
Citrus farming experience (year)	-0.017	-0.002	-0.014
	(0.016)	(0.010)	(0.010)
Experience the increasing air temperature in the last 10 years (1 if yes)	2.078 ***	1.208 ***	1.117 ***
	(0.295)	(0.201)	(0.207)
Education (year)	0.163 ***	0.083 ***	0.098 ***
	(0.044)	(0.028)	(0.029)
Ethnicity (1 if Javanese)	-0.580	-0.304	-0.172
	(0.670)	(0.431)	(0.448)
HH size (person)	0.152	0.121 *	0.054
	(0.108)	(0.065)	(0.069)
Citrus income (IDR million)	0.003	-0.003	0.003
	(0.005)	(0.003)	(0.003)
Non-agricultural income (IDR million)	-0.004	-0.003	-0.003
	(0.004)	(0.002)	(0.002)
Water pump (unit)	0.451*	0.091	0.258
	(0.262)	(0.162)	(0.175)
Generator (unit)	-1.075 **	-0.523 *	-0.386
	(0.478)	(0.294)	(0.311)
Cattle (unit)	0.022	0.010	-0.020
	(0.108)	(0.060)	(0.069)
Goat (unit)	0.007	-0.007	-0.002
	(0.034)	(0.022)	(0.022)
Land (hectare)	-0.087	0.027	-0.066
	(0.066)	(0.045)	(0.044)
Citrus tree (number)	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)
Mobile phone (unit)	-0.327 **	-0.301 ***	-0.063
	(0.157)	(0.097)	(0.102)
Internet access (1 if yes)	0.707 *	0.708 ***	-0.103
	(0.369)	(0.229)	(0.238)
Citrus training (number)	-0.042	-0.073	0.040
	(0.093)	(0.059)	(0.058)
Citrus extension (number)	0.004	0.002	-0.003
	(0.019)	(0.010)	(0.012)
Climate extension (number)	-0.099 *	-0.028	-0.078 **
	(0.058)	(0.031)	(0.038)
Farmers group membership (1 if yes)	-0.149	-0.077	0.024
	(0.456)	(0.283)	(0.286)
Cooperative membership (1 if yes)	-0.623	0.409	-0.948 **
	(0.685)	(0.447)	(0.441)
Direct access to gov authority (1 if yes)	0.258	0.037	0.219
	(0.356)	(0.224)	(0.231)
Citrus credit (1 if yes)	0.651*	0.394 *	0.150
	(0.332)	(0.212)	(0.213)
Citrus technology information source (1 if other farmers)	-0.108	-0.447 **	0.364 *
	(0.344)	(0.215)	(0.219)
Climate information source (1 if none)	-0.651 **	-0.624 ***	-0.086
	(0.301)	(0.191)	(0.193)
y>=1	-	5.946 ***	5.549 ***
	-	(1.377)	(1.135)
y>=2	-	0.798	1.543
	-	(0.955)	(0.985)
y>=3	-	-0.887	0.741
	-	(0.956)	(0.983)
y>=4	-	-4.835 ***	-2.540 **
	-	(1.003)	(0.988)
No. Observations	500	500	500
R-squared/LR chi2	0.209	104.76	82.33
P-value	<0.0001	<0.0001	<0.0001

Note: Standard error in parentheses. '*', '**', '***' significant at 10%, 5%, and 1% levels, respectively

Table A4-2. Seemingly unrelated regression and ordered logit model estimation for risk perception index, perceived likelihood and perceived impact of increasing dry season period

Variables	RPI	Perceived Likelihood	Perceived Impact
(Intercept)	**4.690 *****	-	-
	(1.450)	-	-
District dummy (1 if Banyuwangi)	-0.153	-0.227	0.284
	(0.375)	(0.234)	(0.250)
District dummy (1 if Jember)	-0.231	0.117	-0.254
	(0.411)	(0.256)	(0.272)
Gender (1 if male)	-0.227	0.227	-0.594
	(0.876)	(0.568)	(0.562)
Age (year)	-0.003	-0.011	-0.002
	(0.014)	(0.009)	(0.009)
Citrus farming experience (year)	-0.004	0.006	-0.008
	(0.016)	(0.010)	(0.010)
Experience the increasing dry season period in the last 10 years (1 if yes)	**1.253 *****	**1.232** ***	**0.522** ***
	(0.255)	**(0.188)**	**(0.194)**
Education (year)	**0.128 *****	**0.062 ****	**0.067** **
	(0.043)	**(0.027)**	**(0.029)**
Ethnicity (1 if Javanese)	-0.271	-0.103	-0.063
	(0.653)	(0.419)	(0.438)
HH size (person)	-0.089	-0.070	-0.109
	(0.105)	(0.068)	(0.071)
Citrus income (IDR million)	0.000	-0.003	0.004
	(0.005)	(0.003)	(0.003)
Non-agricultural income (IDR million)	-0.001	0.000	-0.001
	(0.004)	(0.002)	(0.002)
Water pump (unit)	0.268	0.203	0.083
	(0.255)	(0.159)	(0.174)
Generator (unit)	-0.268	-0.247	-0.223
	(0.466)	(0.296)	(0.305)
Cattle (unit)	0.056	0.062	-0.031
	(0.106)	(0.060)	(0.068)
Goat (unit)	0.049	**0.037 ***	0.012
	(0.033)	**(0.020)**	(0.022)
Land (hectare)	0.030	0.016	0.023
	(0.065)	(0.040)	(0.042)
Citrus tree (number)	0.001	0.000	0.000
	(0.000)	(0.000)	(0.000)
Mobile phone (unit)	-0.184	**-0.202** **	0.040
	(0.153)	**(0.096)**	(0.103)
Internet access (1 if yes)	0.560	**0.629** ***	-0.027
	(0.360)	**(0.230)**	(0.244)
Citrus training (number)	-0.126	-0.051	-0.067
	(0.090)	(0.056)	(0.064)
Citrus extension (number)	-0.024	-0.007	**-0.029 ****
	(0.018)	(0.012)	**(0.013)**
Climate extension (number)	0.053	0.012	0.104
	(0.056)	(0.031)	(0.071)
Farmers group membership (1 if yes)	0.054	0.112	0.021
	(0.446)	(0.279)	(0.296)
Cooperative membership (1 if yes)	-0.195	0.199	-0.242
	(0.665)	(0.428)	(0.481)
Direct access to gov authority (1 if yes)	0.204	-0.058	0.320
	(0.347)	(0.218)	(0.231)
Citrus credit (1 if yes)	0.111	-0.021	-0.039
	(0.323)	(0.201)	(0.215)
Citrus technology information source (1 if other farmers)	0.030	0.046	0.138
	(0.336)	(0.213)	(0.223)
Climate information source (1 if none)	-0.059	0.120	-0.086
	(0.293)	(0.185)	(0.197)
y>=1	-	**4.799 *****	**6.736 *****
	-	**(1.074)**	**(1.386)**
y>=2	-	0.293	**1.794 ***
	-	(0.912)	**(0.956)**
y>=3	-	-1.460	1.206
	-	(0.914)	(0.954)
y>=4	-	**-4.944 *****	**-2.152 ****
		(0.974)	**(0.960)**
No. Observations	500	500	500
R-squared/LR chi2	0.133	85.820	51.530
P-value	<0.0001	<0.0001	0.004

Note: Standard error in parentheses. '*', '**', '***' significant at 10%, 5%, and 1% levels, respectively

Table A4-3. Seemingly unrelated regression and ordered logit model estimation for risk perception index, perceived likelihood and perceived impact of increasing rainy season period

Variables	RPI	Perceived Likelihood	Perceived Impact
(Intercept)	5.263 ***	-	-
	(1.354)	-	-
District dummy (1 if Banyuwangi)	1.202 ***	0.321	1.055 ***
	(0.349)	(0.246)	(0.287)
District dummy (1 if Jember)	0.711 *	0.172	0.458
	(0.378)	(0.260)	(0.298)
Gender (1 if male)	-0.046	-0.535	0.108
	(0.808)	(0.587)	(0.670)
Age (year)	-0.002	-0.009	0.005
	(0.013)	(0.009)	(0.010)
Citrus farming experience (year)	-0.010	-0.017 *	0.010
	(0.014)	(0.010)	(0.011)
Experience the increasing rainy season period in the last 10 years (1 if yes)	1.327 ***	1.198 ***	0.602 ***
	(0.272)	(0.202)	(0.226)
Education (year)	0.059	-0.012	0.106 ***
	(0.039)	(0.027)	(0.032)
Ethnicity (1 if Javanese)	-1.234 **	-0.547	-0.677
	(0.603)	(0.426)	(0.481)
HH size (person)	0.049	-0.001	0.106
	(0.097)	(0.067)	(0.076)
Citrus income (IDR million)	-0.002	-0.003	0.003
	(0.004)	(0.003)	(0.003)
Non-agricultural income (IDR million)	0.005	0.003	0.001
	(0.003)	(0.002)	(0.003)
Water pump (unit)	0.126	0.177	-0.037
	(0.235)	(0.164)	(0.187)
Generator (unit)	-0.121	-0.177	-0.015
	(0.429)	(0.286)	(0.338)
Cattle (unit)	0.032	0.005	0.025
	(0.097)	(0.062)	(0.075)
Goat (unit)	0.023	0.017	-0.001
	(0.031)	(0.023)	(0.025)
Land (hectare)	-0.028	-0.026	-0.003
	(0.060)	(0.046)	(0.048)
Citrus tree (number)	0.001 **	0.001 **	0.000
	(0.000)	(0.000)	(0.000)
Mobile phone (unit)	-0.387 ***	-0.172 *	-0.260 **
	(0.141)	(0.097)	(0.110)
Internet access (1 if yes)	1.044 ***	0.381 *	0.729 ***
	(0.332)	(0.231)	(0.266)
Citrus training (number)	-0.094	-0.052	-0.070
	(0.083)	(0.059)	(0.061)
Citrus extension (number)	-0.023	-0.018	-0.015
	(0.017)	(0.012)	(0.013)
Climate extension (number)	-0.001	-0.013	0.004
	(0.052)	(0.032)	(0.041)
Farmers group membership (1 if yes)	-0.060	0.066	-0.287
	(0.409)	(0.276)	(0.319)
Cooperative membership (1 if yes)	0.569	0.409	0.610
	(0.612)	(0.441)	(0.502)
Direct access to gov authority (1 if yes)	-0.922 ***	-0.458 **	-0.576 **
	(0.320)	(0.221)	(0.249)
Citrus credit (1 if yes)	0.249	0.223	0.076
	(0.299)	(0.206)	(0.234)
Citrus technology information source (1 if other farmers)	0.344	0.489 **	-0.160
	(0.309)	(0.210)	(0.242)
Climate information source (1 if none)	-0.387	-0.380 **	0.080
	(0.270)	(0.189)	(0.214)
y>=1	-	7.138 ***	4.781 ***
	-	(1.382)	(1.475)
y>=2	-	2.108 **	0.416
	-	(0.958)	(1.094)
y>=3	-	0.022	-0.267
	-	(0.955)	(1.092)
y>=4	-	-4.584 ***	-4.406 ***
	-	(1.070)	(1.118)
No. Observations	500	500	500
R-squared/LR chi2	0.181	87.920	75.040
P-value	<0.0001	<0.0001	<0.0001

Note: Standard error in parentheses. '*', '**', '***' significant at 10%, 5%, and 1% levels, respectively

Table A4-4. Seemingly unrelated regression and ordered logit model estimation for risk perception index, perceived likelihood and perceived impact of increasing excessive rainfall

Variables	RPI	Perceived Likelihood	Perceived Impact
(Intercept)	**5.266** ***	-	-
	(1.433)	-	-
District dummy (1 if Banyuwangi)	0.192	-0.098	0.329
	(0.371)	**(0.242)**	(0.248)
District dummy (1 if Jember)	-0.208	**-0.443** *	-0.095
	(0.401)	(0.259)	(0.269)
Gender (1 if male)	-0.410	0.290	-0.838
	(0.854)	(0.578)	(0.576)
Age (year)	-0.011	-0.008	-0.012
	(0.014)	(0.009)	(0.009)
Citrus farming experience (year)	0.016	0.005	**0.017** *
	(0.015)	(0.010)	**(0.010)**
Experience the increasing excessive rainfall in the last 10 years (1 if yes)	**1.080** ***	**0.717** ***	**0.791** ***
	(0.274)	**(0.195)**	**(0.199)**
Education (year)	**0.076** *	0.036	0.031
	(0.042)	(0.027)	(0.029)
Ethnicity (1 if Javanese)	**-1.122** *	-0.606	-0.686
	(0.635)	(0.413)	(0.452)
HH size (person)	-0.033	-0.061	-0.002
	(0.102)	(0.067)	(0.069)
Citrus income (IDR million)	**-0.008** *	**-0.006** **	-0.001
	(0.005)	**(0.003)**	(0.003)
Non-agricultural income (IDR million)	-0.001	-0.001	0.000
	(0.004)	(0.002)	(0.003)
Water pump (unit)	0.219	0.183	0.070
	(0.248)	(0.161)	(0.163)
Generator (unit)	-0.464	-0.245	-0.224
	(0.453)	(0.284)	(0.303)
Cattle (unit)	0.052	-0.002	0.046
	(0.103)	(0.061)	(0.067)
Goat (unit)	0.039	**0.053** **	-0.001
	(0.032)	**(0.023)**	(0.022)
Land (hectare)	0.052	0.058	-0.004
	(0.063)	(0.049)	(0.040)
Citrus tree (number)	**0.001** *	0.000	0.000
	(0.000)	(0.000)	(0.000)
Mobile phone (unit)	-0.022	0.007	-0.013
	(0.149)	(0.097)	(0.100)
Internet access (1 if yes)	0.265	0.159	0.096
	(0.350)	(0.228)	(0.234)
Citrus training (number)	-0.130	**-0.105** *	-0.064
	(0.088)	**(0.059)**	(0.061)
Citrus extension (number)	**-0.034** *	**-0.032** **	-0.015
	(0.018)	(0.014)	(0.013)
Climate extension (number)	-0.068	-0.017	-0.041
	(0.055)	(0.031)	(0.038)
Farmers group membership (1 if yes)	**0.845** *	**0.592** **	0.243
	(0.432)	**(0.292)**	(0.289)
Cooperative membership (1 if yes)	0.365	0.359	0.558
	(0.646)	(0.448)	(0.456)
Direct access to gov authority (1 if yes)	0.003	-0.126	0.098
	(0.338)	(0.220)	(0.228)
Citrus credit (1 if yes)	-0.049	0.240	-0.164
	(0.314)	(0.205)	(0.213)
Citrus technology information source (1 if other farmers)	0.330	0.230	0.031
	(0.326)	(0.210)	(0.218)
Climate information source (1 if none)	-0.088	0.016	0.006
	(0.285)	(0.187)	(0.193)
y>=1	-	0.000	**7.275** ***
	-	(0.000)	**(1.397)**
y>=2	-	1.143	**1.880** *
	-	(0.932)	**(0.977)**
y>=3	-	-0.750	1.328
	-	(0.931)	(0.976)
y>=4	-	**-5.663** ***	**-2.208** **
		(1.106)	**(0.980)**
No. Observations	500	500	500
R-squared/LR chi2	0.126	61.730	47.900
P-value	<0.0001	0.0002	0.011

Note: Standard error in parentheses. '*', '**', '***' significant at 10%, 5%, and 1% levels, respectively

Table A4-5. Seemingly unrelated regression and ordered logit model estimation for risk perception index, perceived likelihood and perceived impact of increasing flood

Variables	RPI	Perceived Likelihood	Perceived Impact
(Intercept)	4.528 ***	-	-
	(1.076)	-	-
District dummy (1 if Banyuwangi)	0.476 *	0.275	0.778 ***
	(0.279)	(0.266)	(0.253)
District dummy (1 if Jember)	0.385	-0.271	0.843 ***
	(0.307)	(0.299)	(0.276)
Gender (1 if male)	-0.230	0.354	-0.767
	(0.650)	(0.610)	(0.564)
Age (year)	-0.014	0.001	-0.008
	(0.011)	(0.010)	(0.010)
Citrus farming experience (year)	0.004	0.003	-0.008
	(0.012)	(0.011)	(0.010)
Experience the increasing flood in the last 10 years (1 if yes)	3.335 ***	3.058 ***	0.558 **
	(0.283)	(0.311)	(0.284)
Education (year)	0.017	-0.029	0.081 ***
	(0.032)	(0.030)	(0.029)
Ethnicity (1 if Javanese)	-0.757	-0.513	-0.348
	(0.485)	(0.479)	(0.455)
HH size (person)	-0.124	-0.205 ***	0.043
	(0.078)	(0.077)	(0.071)
Citrus income (IDR million)	0.009 **	0.007 **	0.004
	(0.003)	(0.003)	(0.003)
Non-agricultural income (IDR million)	0.000	0.001	-0.002
	(0.003)	(0.003)	(0.003)
Water pump (unit)	0.017	-0.189	0.338 *
	(0.189)	(0.185)	(0.174)
Generator (unit)	-0.185	-0.365	0.114
	(0.347)	(0.337)	(0.317)
Cattle (unit)	0.078	0.070	0.007
	(0.079)	(0.064)	(0.068)
Goat (unit)	-0.026	-0.019	-0.033
	(0.025)	(0.024)	(0.022)
Land (hectare)	-0.092 *	-0.084 *	-0.069
	(0.048)	(0.048)	(0.043)
Citrus tree (number)	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)
Mobile phone (unit)	-0.010	-0.023	0.052
	(0.113)	(0.109)	(0.102)
Internet access (1 if yes)	0.563 **	0.691 ***	-0.225
	(0.267)	(0.262)	(0.245)
Citrus training (number)	0.016	0.002	0.002
	(0.067)	(0.064)	(0.062)
Citrus extension (number)	0.004	0.008	-0.004
	(0.014)	(0.013)	(0.012)
Climate extension (number)	-0.062	-0.134 **	0.101 *
	(0.042)	(0.073)	(0.053)
Farmers group membership (1 if yes)	-0.209	0.126	-0.400
	(0.330)	(0.314)	(0.285)
Cooperative membership (1 if yes)	-0.173	-0.427	0.303
	(0.494)	(0.508)	(0.468)
Direct access to gov authority (1 if yes)	-0.999 ***	-0.781 ***	-0.757 ***
	(0.259)	(0.259)	(0.240)
Citrus credit (1 if yes)	-0.148	-0.039	-0.007
	(0.240)	(0.230)	(0.218)
Citrus technology information source (1 if other farmers)	0.359	0.297	0.259
	(0.249)	(0.244)	(0.221)
Climate information source (1 if none)	0.034	-0.226	0.429 **
	(0.218)	(0.208)	(0.200)
y>=1		3.738 ***	5.881 ***
	-	(1.045)0	(1.194)
y>=2	-	-0.541	1.548
	-	(1.020)	(0.967)
y>=3	-	-2.265 **	0.999
	-	(1.031)	(0.966)
y>=4	-	-6.265 ***	-2.419 **
	-	(1.249)	(0.971)
No. Observations	500	500	500
R-squared/LR chi2	0.328	163.160	85.850
P-value	<0.0001	<0.0001	<0.0001

Note: Standard error in parentheses. '*', '**', '***' significant at 10%, 5%, and 1% levels, respectively

Table A4-6. Seemingly unrelated regression and ordered logit model estimation for risk perception index, perceived likelihood and perceived impact of increasing destructive wind

Variables	RPI	Perceived Likelihood	Perceived Impact
(Intercept)	**4.538** ***	-	-
	(1.157)	-	-
District dummy (1 if Banyuwangi)	-0.123	-0.322	**0.457** *
	(0.301)	(0.251)	**(0.248)**
District dummy (1 if Jember)	-0.087	-0.324	0.365
	(0.327)	(0.273)	(0.270)
Gender (1 if male)	0.129	0.286	-0.421
	(0.697)	(0.552)	(0.559)
Age (year)	-0.014	-0.007	-0.010
	(0.011)	(0.010)	(0.009)
Citrus farming experience (year)	0.009	0.008	0.003
	(0.012)	(0.010)	(0.010)
Experience the increasing destructive wind event in the last 10 years (1 if yes)	**2.885** ***	**2.452** ***	**1.126** ***
	(0.321)	**(0.310)**	**(0.292)**
Education (year)	0.003	-0.025	**0.069** **
	(0.034)	(0.029)	**(0.029)**
Ethnicity (1 if Javanese)	-0.208	-0.204	-0.229
	(0.520)	(0.439)	(0.452)
HH size (person)	-0.107	-0.100	-0.006
	(0.084)	(0.070)	(0.069)
Citrus income (IDR million)	0.006	0.004	0.004
	(0.004)	(0.003)	(0.003)
Non-agricultural income (IDR million)	**0.006** *	**0.006** **	0.001
	(0.003)	**(0.002)**	(0.003)
Water pump (unit)	-0.220	-0.231	0.012
	(0.203)	(0.175)	(0.168)
Generator (unit)	-0.139	-0.271	0.005
	(0.371)	(0.312)	(0.303)
Cattle (unit)	0.071	**0.107** *	-0.038
	(0.084)	**(0.063)**	(0.067)
Goat (unit)	0.004	0.007	-0.022
	(0.026)	(0.022)	(0.021)
Land (hectare)	0.069	0.005	**0.071** *
	(0.051)	(0.042)	**(0.042)**
Citrus tree (number)	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)
Mobile phone (unit)	-0.054	0.045	-0.127
	(0.122)	(0.101)	(0.102)
Internet access (1 if yes)	0.138	0.349	**-0.427** *
	(0.286)	(0.238)	**(0.237)**
Citrus training (number)	-0.040	-0.033	-0.052
	(0.072)	(0.056)	(0.059)
Citrus extension (number)	-0.005	-0.001	-0.007
	(0.015)	(0.012)	(0.012)
Climate extension (number)	**-0.077** *	**-0.112** *	0.055
	(0.045)	**(0.061)**	(0.038)
Farmers group membership (1 if yes)	0.249	0.447	-0.312
	(0.354)	(0.289)	(0.292)
Cooperative membership (1 if yes)	-0.093	-0.190	0.556
	(0.529)	(0.455)	(0.462)
Direct access to gov authority (1 if yes)	**-0.824** ***	**-0.517** **	**-0.942** ***
	(0.277)	**(0.236)**	**(0.236)**
Citrus credit (1 if yes)	-0.215	-0.156	-0.026
	(0.257)	(0.214)	(0.213)
Citrus technology information source (1 if other farmers)	0.284	0.279	0.049
	(0.267)	(0.225)	(0.219)
Climate information source (1 if none)	-0.116	-0.184	0.148
	(0.233)	(0.194)	(0.196)
y>=1	-	**3.395** ***	**6.532** ***
	-	**(0.963)**	**(1.182)**
y>=2	-	-0.136	**2.322** **
	-	(0.942)	**(0.951)**
y>=3	-	**-2.395** **	**1.581** *
	-	**(0.954)**	**(0.948)**
y>=4	-	-	**-1.626** *
	-	-	**(0.949)**
No. Observations	500	500	500
R-squared/LR chi2	0.211	108.600	72.150
P-value	<0.0001	<0.0001	<0.0001

Note: Standard error in parentheses. ‘*’, ‘**’, ‘***’ significant at 10%, 5%, and 1% levels, respectively

Appendix 6. Appendices for Chapter 5

Table A5-1. Estimation result of multinomial logit model (without interaction)

Variables	CU	UC	UU
(Intercept)	**4.412*** **	**3.904*** **	**3.045** **
	(1.680)	**(1.426)**	**(1.363)**
Age (year)	-0.032	**-0.043** **	-0.023
	(0.021)	**(0.017)**	(0.016)
Citrus farming experience (year)	**0.046** **	**0.069*** **	**0.080*** **
	(0.023)	**(0.019)**	**(0.019)**
Education (year)	-0.097	0.011	-0.035
	(0.062)	(0.051)	(0.049)
HH size (person)	**-0.242***	**-0.291** **	**-0.222** **
	(0.130)	**(0.121)**	**(0.109)**
Citrus income (IDR million)	-0.002	0.002	-0.002
	(0.006)	(0.005)	(0.005)
Non-agricultural income (IDR million)	0.002	0.000	0.002
	(0.006)	(0.005)	(0.004)
Land (hectare)	0.056	0.059	0.088
	(0.122)	(0.109)	(0.105)
Citrus tree (number)	0.000	-0.001	-0.000
	(0.001)	(0.001)	(0.000)
Generator (unit)	-0.848	-0.703	**-0.835***
	(0.658)	(0.486)	**(0.467)**
Mobile phone (unit)	**-0.554** **	0.108	-0.112
	(0.234)	(0.181)	(0.172)
Internet access (1 if yes)	0.833	-0.249	-0.072
	(0.529)	(0.442)	(0.421)
Citrus training (1 if yes)	-1.270	-0.479	**-1.975** **
	(0.812)	(0.679)	**(0.774)**
Citrus extension (1 if yes)	0.387	-0.375	-0.026
	(0.601)	(0.524)	(0.493)
Climate extension (1 if yes)	0.551	0.673	-1.142
	(0.763)	(0.650)	(0.823)
Farmers group membership (1 if yes)	-0.645	**-0.943***	**-0.942***
	(0.620)	**(0.530)**	**(0.504)**
Cooperative membership (1 if yes)	-0.584	-0.628	-0.830
	(0.976)	(0.720)	(0.732)
Citrus credit (1 if yes)	0.603	0.437	**0.719***
	(0.494)	(0.411)	**(0.396)**
Direct access to gov authority (1 if yes)	0.166	0.439	0.537
	(0.520)	(0.422)	(0.409)
Citrus technology information source (1 if other farmers)	0.074	**0.745***	**0.697***
	(0.452)	**(0.405)**	**(0.380)**
Climate information source (1 if none)	0.521	-0.037	**0.655***
	(0.443)	(0.352)	**(0.339)**
Risk perception index of increasing air temperature	-0.021	-0.076	-0.028
	(0.069)	(0.055)	(0.054)
Risk perception index of increasing dry season period	0.053	-0.056	-0.028
	(0.073)	(0.056)	(0.055)
Risk perception index of increasing rainy season period	**-0.150** **	0.069	0.024
	(0.074)	(0.059)	(0.057)
Mean expected yield of certified seedling (ton/100 trees/yr)	-0.131	0.046	**-0.160** **
	(0.104)	(0.074)	**(0.076)**
Mean expected yield of uncertified seedling (ton/100 trees/yr)	0.049	-0.044	0.120
	(0.109)	(0.082)	(0.082)
Variance expected yield of certified seedling	0.186	-0.041	-0.098
	(0.218)	(0.200)	(0.194)
Variance expected yield of uncertified seedling	-0.324	-0.101	-0.040
	(0.263)	(0.205)	(0.201)
Risk preferences	0.010	-0.043	0.035
	(0.095)	(0.079)	(0.074)
Time preferences	-0.112	-0.102	-0.106
	(0.092)	(0.069)	(0.066)

Note: Certified – certified (CC) is the comparison group. The standard error in parentheses. *', '**', '***' significant at 10%, 5%, and 1% probability level.

Appendix 7. Appendices for Chapter 6

Table A6-1. Estimation result of production and risk function using Quadratic (Hicks-neutral) specification

	Profit	Profit variability
(Intercept)	-36.524	**7.184*** **
	(22.793)	**(2.481)**
Certified seedling (1 if yes)	1.215	0.573
	(1.372)	(0.540)
Citrus age	**2.369*** **	**-0.479*** **
	(0.393)	**(0.159)**
Citrus age squared	**-0.084*** **	**0.018** **
	(0.019)	**(0.008)**
Rented plot (1 if yes)	-2.147	0.962
	(1.571)	(0.633)
Number citrus tree in the plot	0.003	**-0.003** **
	(0.003)	**(0.001)**
Irrigated plot (1 if yes)	**3.478*** **	**-1.269** **
	(1.230)	**(0.497)**
Insecticides	**2.175* **	**0.308* **
	(1.288)	**(0.168)**
Fungicides	**1.417** **	-0.011
	(0.638)	(0.050)
Herbicides	0.554	**0.099* **
	(0.935)	**(0.055)**
Fertiliser	-1.799	-0.266
	(1.558)	(0.209)
Other Inputs	6.171	-0.115
	(5.399)	(0.207)
Hired Labours	0.593	0.027
	(0.735)	(0.043)
Generator (number)	**20.555*** **	**-5.440*** **
	(5.424)	**(0.609)**
Insecticides2	**-0.344** **	-
	(0.171)	-
Fungicides2	**-0.304** **	-
	(0.139)	-
Herbicides2	-0.171	-
	(0.239)	-
Fertiliser2	0.289	-
	(0.202)	-
Other Inputs2	-0.657	-
	(0.618)	-
Hired Labours2	-0.162	-
	(0.152)	-
Generator2	**-30.692*** **	-
	(9.431)	-
R^2	0.221	0.251
Adj. R^2	0.173	0.221
Num. obs.	346	346
RMSE	8.660	3.535

Note: Standard errors are in parenthesis; '***', '**', and '*' significant at 0.01, 0.05 and 0.1 levels, respectively

Table A6-2. Moran's I statistic and spatial dependence diagnostic test

	Insecticides	Fungicides	Herbicides	Fertilisers
Moran I-statistics	0.163***	0.192***	0.107***	0.067***
	(8.560)	(9.877)	(5.519)	(3.499)

Note: Standard deviations are in parenthesis; '***', '**', and '*' significant at 0.01, 0.05 and 0.1 levels, respectively

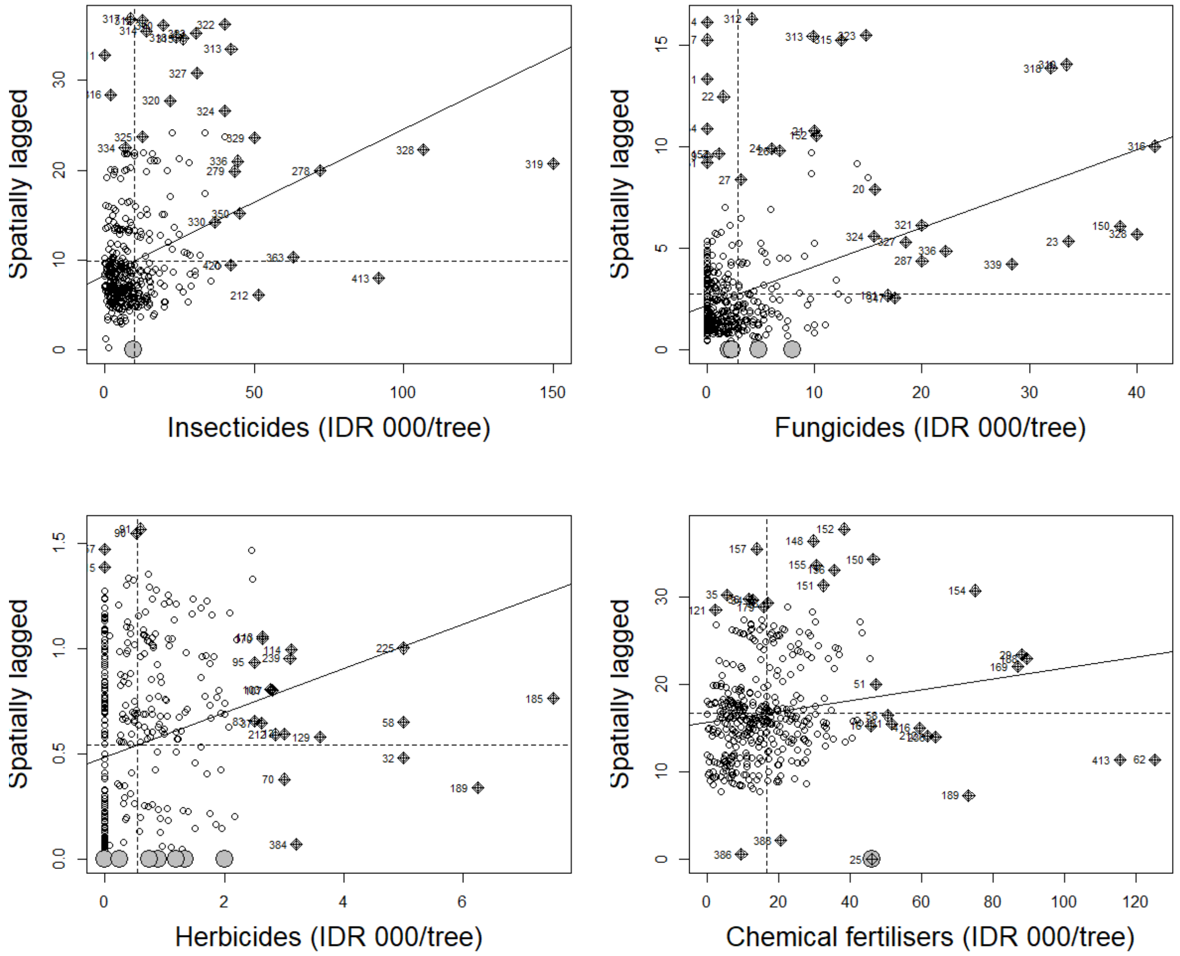

Figure A6-1. Spatial lag of chemical inputs use

Table A6-3. Estimation results of the use of chemical inputs (IDR 000/tree) (Intra-household dynamics was predicted using CFA)

	Insecticides	**Fungicides**	**Herbicides**	**Fertilisers**
(Intercept)	6.539	0.763	**0.781****	**24.667*****
	(5.347)	(2.116)	**(0.392)**	**(7.061)**
Age of wife (year)	0.128	0.057	0.006	**0.259***
	(0.128)	(0.054)	(0.009)	**(0.138)**
Education of wife (year)	-0.236	-0.070	-0.007	0.176
	(0.237)	(0.099)	(0.016)	(0.255)
Age of husband (year)	-0.128	-0.045	-0.005	**-0.274****
	(0.121)	(0.051)	(0.008)	**(0.129)**
Education of husband (year)	-0.236	0.072	0.017	-0.237
	(0.205)	(0.085)	(0.014)	(0.217)
Household size	0.089	0.031	-0.007	0.650
	(0.399)	(0.167)	(0.027)	(0.432)
Citrus age (year)	**0.754*****	0.095	0.005	0.229
	(0.179)	(0.072)	(0.013)	(0.199)
Certified seedling (1 if yes)	**3.348****	**1.233***	0.105	-1.248
	(1.571)	**(0.639)**	(0.116)	(1.808)
Irrigated plot (1 if yes)	**-3.759*****	-0.377	-0.007	0.348
	(1.437)	(0.558)	(0.117)	(1.786)
Total citrus tree in the plot	**-0.015*****	**-0.004****	**-0.000***	**-0.025*****
	(0.004)	**(0.002)**	**(0.000)**	**(0.004)**
Rented in (1 if yes)	**6.231*****	0.589	**-0.281****	**5.813*****
	(1.982)	(0.831)	**(0.137)**	**(2.156)**
Cooperative (1 if yes)	2.250	0.368	-0.026	**6.032****
	(2.693)	(1.130)	(0.184)	**(2.897)**
Citrus credit (1 if yes)	1.096	0.164	0.087	**3.999*****
	(1.356)	(0.569)	(0.093)	**(1.475)**
Citrus extension (1 if yes)	0.456	0.364	0.160	**3.697****
	(1.626)	(0.666)	(0.115)	**(1.801)**
Citrus training (1 if yes)	**-4.973***	**-1.923***	-0.111	**-8.394*****
	(2.727)	**(1.136)**	(0.190)	**(2.989)**
Climate extension (1 if yes)	**7.109*****	**3.449*****	-0.103	3.374
	(2.686)	**(1.128)**	(0.187)	(2.931)
Citrus income (million IDR)	**0.060*****	**0.030*****	-0.001	**0.120*****
	(0.019)	**(0.008)**	(0.001)	**(0.021)**
Non-agricultural income (million IDR)	-0.013	-0.010	**0.003*****	0.007
	(0.015)	(0.006)	**(0.001)**	(0.017)
Risk preferences of husband	**0.758*****	0.045	0.021	0.071
	(0.260)	(0.109)	(0.018)	(0.282)
Risk preferences of wife	**0.513***	-0.022	-0.007	0.174
	(0.289)	(0.121)	(0.020)	(0.315)
Wife-wife leadership	-1.903	**-2.262****	0.215	-0.419
	(2.217)	**(0.928)**	(0.155)	(2.441)
Disagreement	3.250	**2.032****	-0.213	0.635
	(2.195)	**(0.919)**	(0.153)	(2.403)
Hired labour	0.019	0.039	**0.018*****	0.143
	(0.086)	(0.036)	**(0.006)**	(0.096)
Rho (spatial lag)	**0.296***	**0.521*****	**-0.814*****	**-0.536****
	(0.166)	**(0.135)**	**(0.200)**	**(0.253)**
Lambda (Spatial error)	0.005	-0.166	**0.724*****	**0.584*****
	(0.242)	(0.285)	**(0.059)**	**(0.107)**

Note: Standard errors are in parenthesis; '***', '**', and '*' significant at 0.01, 0.05 and 0.1 levels, respectively

Table A6-4. CFA results for intra-household dynamics

	Estimate	Std. Err.	z	p
WWL				
WWL_land preparation	1.00	0.01	125.47	.000
WWL_buying farm equipment	0.95	0.04	21.22	.000
WWL_buying farm inputs	0.93	0.02	37.60	.000
WWL_choosing and buying seedling	0.94	0.04	22.64	.000
WWL_planting	0.98	0.02	44.77	.000
WWL_fertilisers application	0.96	0.02	49.48	.000
WWL_pesticides application	1.00	0.01	69.60	.000
WWL_weeding	0.85	0.05	17.30	.000
WWL_watering - irrigation/drainage maintenance	0.99	0.03	37.59	.000
WWL_prunning	0.97	0.04	25.28	.000
WWL_harvesting	0.92	0.06	14.78	.000
WWL_ deciding the marketing method	0.66	0.08	8.08	.000
WWL_negotiating with buyer/trader	0.60	0.08	7.07	.000
WWL_looking for hired labour	0.79	0.08	10.44	.000
DIS_NEG				
DIS.NEG_land preparation	0.36	0.18	1.98	.047
DIS.NEG_buying farm equipments	0.37	0.20	1.82	.068
DIS.NEG_buying farm inputs	0.32	0.17	1.90	.058
DIS.NEG_choosing and buying seedling	0.26	0.14	1.85	.065
DIS.NEG_planting	0.27	0.14	1.97	.048
DIS.NEG_fertilisers application	0.33	0.17	1.96	.050
DIS.NEG_weeding	0.23	0.12	1.99	.047
DIS.NEG_watering - irrigation/drainage maintenance	0.38	0.20	1.92	.055
DIS.NEG_prunning	0.28	0.15	1.91	.057
DIS.NEG_harvesting	0.21	0.11	1.87	.061
DIS.NEG_ deciding the marketing method	0.15	0.08	1.86	.063
DIS.NEG_negotiating with buyer/trader	0.10	0.06	1.52	.128
DIS.NEG_looking for hired labour	0.16	0.10	1.69	.092
DIS.NEG_attending training or extension	0.46	0.27	1.71	.087
DIS_POS				
DIS.POS_land preparation	0.74	0.08	8.79	.000
DIS.POS_buying farm equipment	0.74	0.07	10.86	.000
DIS.POS_buying farm inputs	0.69	0.06	11.03	.000
DIS.POS_choosing and buying seedling	0.68	0.07	10.39	.000
DIS.POS_planting	0.71	0.07	10.61	.000
DIS.POS_fertilisers application	0.72	0.07	10.69	.000
DIS.POS_pesticides application	0.78	0.07	11.42	.000
DIS.POS_weeding	0.62	0.06	10.09	.000
DIS.POS_watering - irrigation/drainage maintenance	0.63	0.07	9.57	.000
DIS.POS_prunning	0.64	0.07	9.67	.000
DIS.POS_harvesting	0.56	0.06	9.23	.000
DIS.POS_ deciding the marketing method	0.48	0.06	8.02	.000
DIS.POS_negotiating with buyer/trader	0.46	0.06	7.65	.000
DIS.POS_looking for hired labour	0.55	0.06	9.25	.000
DIS.POS_attending training or extension	0.73	0.09	8.08	.000
DIS				
DIS.NEG	1.66	1.20	1.39	.165
DIS.POS	0.72	0.19	3.79	.000

Table A6-5. Goodness of fit indices for CFA intra-household dynamics

Criteria	Target	Value
χ^2	-	1819.99
Degree of freedom (df)	-	889
χ^2/df (SCM)	< 3	2.04
CFI	> 0.9	0.98
TLI	> 0.9	0.98
RMSEA	< 0.05	0.05
SRMR	< 0.07	0.18

Table A6-6. Variance inflation factor (VIF) of variables used in the spatial model

Variables	**VIF**
Age of wife (year)	5.307
Education of wife (year)	2.177
Age of husband (year)	5.513
Education of husband (year)	2.062
Household size	1.079
Citrus age (year)	1.167
Certified seedling (1 if yes)	1.199
Irrigated plot (1 if yes)	1.197
Total citrus tree in the plot	1.165
Rented in (1 if yes)	1.102
Cooperative (1 if yes)	1.176
Citrus credit (1 if yes)	1.128
Citrus extension (1 if yes)	1.358
Citrus training (1 if yes)	1.350
Climate extension (1 if yes)	1.168
Citrus income (million IDR)	1.244
Non-agricultural income (million IDR)	1.228
Risk preferences of husband	1.110
Risk preferences of wife	1.090
Wife-wife leadership	7.071
Disagreement	7.033
Hired labour	1.093