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Accounting for diverse risk attitudes in measures of risk perceptions: A case study of climate change risk for small-scale citrus farmers in Indonesia

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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.

1. Introduction

Climate change impacts agriculture predominantly by altering weather-related inputs directly affecting agricultural productivity (Carraro, 2016; Nelson et al., 2014). 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 (Christiaensen et al., 2011; Timmer, 2002). Whilst climate change presents major risks to agriculture in general (Dillon et al., 2015; Godfray et al., 2010; 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 (Berger et al., 2017; Deressa et al., 2009; Fahad and Wang, 2018; Hannah et al., 2017; Mulwa et al., 2017).

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; Khanal et al., 2018; Menapace et al., 2015; Woods et al., 2017). 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.* Cohen, 2015; Gregg and Rolfe, 2017; Kahneman and Tversky, 1979), 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)

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acknowledging that household member choices may be driven in different directions by optimism or pessimism combined with risk aversion or risk loving (Just and Just, 2016; Sidibé et al., 2018; Ward and Singh, 2015). 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., 2012). Like other permanent crops, citrus farmers are particularly susceptible to climate risks due to the relatively long planning timeframes 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 paper 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, we provide evidence about the disadvantage of aggregate level analysis and suggest 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.

The remainder of this paper 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 2). In Section 3, we present the survey method and summary statistics of the data. The methodology is presented in Section 4 including the calculation of the climate risk perception index and the econometric approach. Results are presented in Section 5 and followed by a short discussion in Section 6. Finally, we present the conclusions in Section 7.

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 (Aven and Renn, 2009; Freudenburg, 1988; Sjöberg, 2000; Slovic, 1999; 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.* Abbott-Chapman et al., 2008; Cullen et al., 2018; Duijm, 2015; Frondel et al., 2017; Ogurtsov et al., 2008; Weber et al., 2002). For the construction of

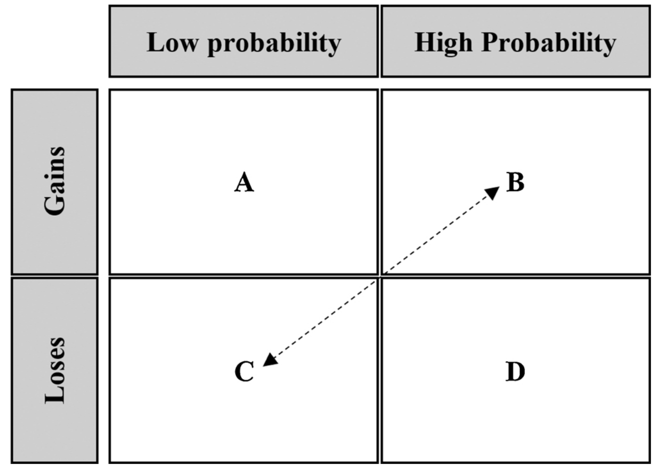

Fig. 1. Fourfold pattern of risk.
(Adapted from Bosch-Domènech and Silvestre (2006); Tversky and Kahneman (1992)).

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[1] (*e.g.* Iqbal et al., 2016; Le Dang et al., 2014; 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 which allows for different perceptions over both outcome (impact) and likelihood (probability) aspects (See Fig. 1).

Considering that the climate change events could have both positive and negative effects on agricultural production (Challinor et al., 2014; Ludwig and Asseng, 2006; Parry et al., 2004), farmers' risk behaviours should be ably explained by the four-fold pattern as shown in Fig. 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.* Iqbal et al., 2016; Le Dang et al., 2014; Sullivan-Wiley and Gianotti, 2017), means that we are only able to identify relations which affect both factors in the same direction – *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

[1] 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).

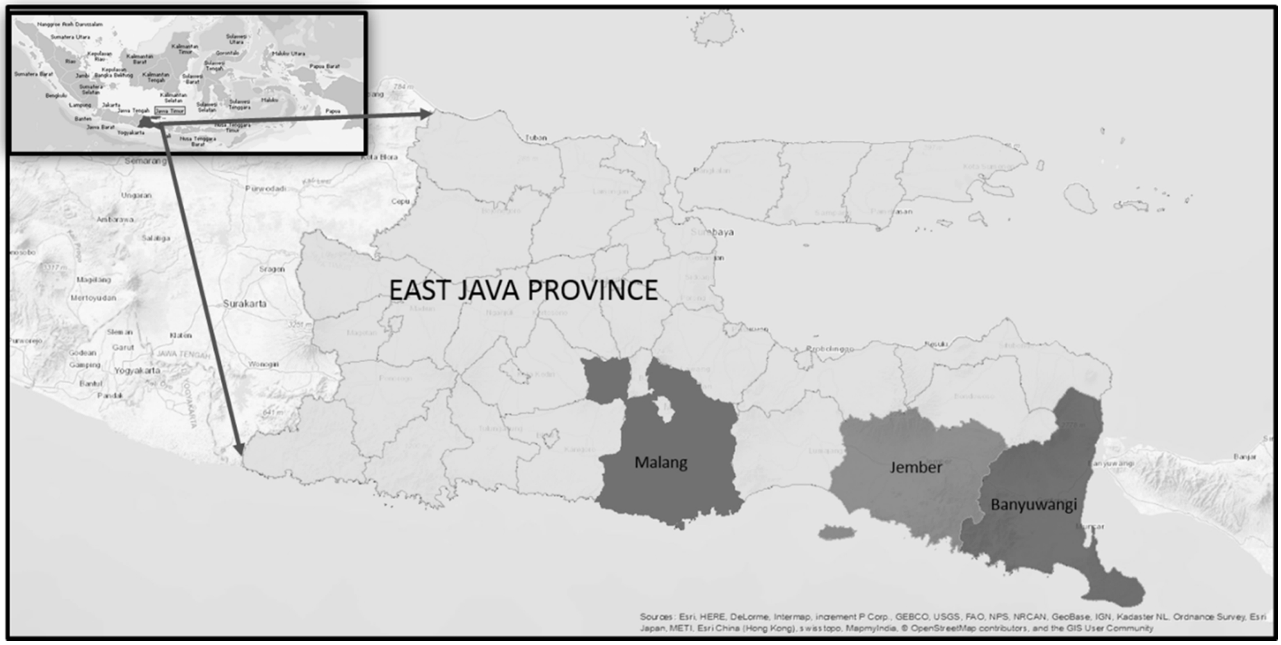

Fig. 2. Survey site.

formulation (Bosch-Domönech 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. We define:

$$RPI = I(x) \times L(x) \quad (1)$$

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.

3. Data

This study uses data obtained from a survey of 500 citrus farming[2] households in East Java, Indonesia, from September – October 2017. We selected the households to be included in the sample using a multistage random sampling process. Three districts: Banyuwangi, Jember and Malang Districts (Fig. 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.

Table 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.

4. Method

4.1. Risk perception index elicitation

As outlined earlier in Eq. (1), we define the RPI as a multiplication function of the perceived likelihood and perceived impact of a certain climate event. We designed a structured questionnaire 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*". We measured the perception for six climate events, 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. We also did a focus group discussion with citrus researchers to obtain broader and deeper understanding of the importance of climate change issues on citrus farming.

[2] 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).

Table 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

Table 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

4.2. 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 we elicited the RPI for 6 types of climate events we sought to incorporate this information 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:

$$y_{ij} = \alpha_j V_i + \beta_j W_i + \gamma_j Z_i + u_{ij} \quad (2)$$

where y_{ij} and u_{ij} represent the outcome variable and white noise 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:

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

Table 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.

Table 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.

Table 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 (1 if yes)	−0.149	0.000	0.012	0.007	−0.018	−0.001	0.000	−0.004	−0.002	0.004	0.002
	(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 if yes)	−0.623	0.000	−0.055	−0.046	0.094	0.007	0.006	0.175 *	0.048 ***	−0.187 **	−0.042 ***
	(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 authority (1 if yes)	0.258	0.000	−0.006	−0.004	0.009	0.001	−0.001	−0.031	−0.016	0.034	0.015
	(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 if other farmers)	−0.108	0.001	0.063 **	0.047 *	−0.103 **	−0.008	−0.002	−0.057	−0.025 *	0.062	0.021 *
	(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 (1 if none)	−0.651 **	0.001	0.091 ***	0.063 ***	−0.144 ***	−0.010 **	0.000	0.013	0.006	−0.014	−0.005
	(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 (1 if yes)	0.054	0.000	−0.022	−0.001	0.022	0.001	0.000	−0.003	−0.001	0.003	0.002
	(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 if yes)	−0.195	−0.001	−0.038	−0.004	0.040	0.003	0.000	0.037	0.013	−0.034	−0.017
	(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 authority (1 if yes)	0.204	0.000	0.012	0.000	−0.011	−0.001	0.000	−0.044	−0.018	0.036	0.026
	(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 if other farmers)	0.030	0.000	−0.009	0.000	0.009	0.001	0.000	−0.020	−0.008	0.018	0.010
	(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 (1 if none)	−0.059	−0.001	−0.024	0.000	0.023	0.002	0.000	0.012	0.005	−0.011	−0.007
	(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)

(*continued on next page*)

Table 5 (*continued*)

	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
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 (1 if yes)	−0.060	0.000	−0.009	−0.006	0.015	0.000	0.000	0.027	0.017	−0.028	−0.017
	(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 if yes)	0.569	0.000	−0.052	−0.046	0.096	0.003	−0.001	−0.043	−0.031	**0.025** ***	0.049
	(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 authority (1 if yes)	**−0.922** ***	0.001	**0.071** *	**0.030** **	**−0.100** **	−0.002	0.001	**0.057** **	**0.035** **	**−0.061** *	**−0.032** **
	(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 if other farmers)	0.344	−0.001	**−0.076** **	**−0.033** ***	**0.107** **	0.003	0.000	0.014	0.009	−0.012	−0.011
	(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 (1 if none)	−0.387	0.001	**0.053** **	**0.036** *	**−0.087** **	−0.002	0.000	−0.007	−0.005	0.007	0.005
	(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.

Eq. (3) can be expressed in matrix notation as:

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

Given our 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:

$$y_{ij}^{*} = \delta_j V_i + \theta_j W_i + \tau_j Z_i + \varepsilon_j \tag{5}$$

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.

5. Results

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 2). Based on t-test, the RPI of increasing rainy season period is significantly higher than other events. 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 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.

5.2. Econometric estimation

The estimated cross-equation correlations from the regression equations for the aggregate RPI are presented in Table 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[3] .

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. 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.

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.

[3] We provide the estimation regression result for all six climate events, both for RPI and elements in the Appendix (See Table A1–A6).

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.

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 (Tables 4 and 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.

6. Discussion

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 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 2) which could be associated with the variation in socio-demographic and external factors (See Table A1–A6). 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 (Dixon, 2012; Sutherst et al., 2011). 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.

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.

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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Appendix

Table A1
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 A2
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)	

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Table A2 (*continued*)

Variables	RPI		Perceived Likelihood		Perceived Impact	
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 A3
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)**	

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Table A3 (*continued*)

Variables	RPI		Perceived Likelihood		Perceived Impact	
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
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)	

(*continued on next page*)

Table A4 (*continued*)

Variables	RPI		Perceived Likelihood		Perceived Impact	
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 A5
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)	

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Table A5 (*continued*)

Variables	RPI		Perceived Likelihood		Perceived Impact	
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)**		**(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 A6
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)**	

(*continued on next page*)

Table A6 (*continued*)

Variables	RPI		Perceived Likelihood		Perceived Impact	
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.

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