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A study of smallholder farmers in Australia

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Published in:
Outlook on Agriculture

DOI:
[10.1177/0030727019829754](https://doi.org/10.1177/0030727019829754)

Published: 01/03/2019

Document Version
Peer reviewed version

[Link to publication](#)

Citation for published version (APA):

Duong, T. T., Brewer, T. D., Luck, J., & Zander, K. K. (2019). Farmers' assessment of plant biosecurity risk management strategies and influencing factors: A study of smallholder farmers in Australia. *Outlook on Agriculture*, 48(1), 48-57. <https://doi.org/10.1177/0030727019829754>

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Title: Farmers' assessment of plant biosecurity risk management strategies and influencing factors: a study of smallholder farmers in Australia

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Acknowledgements

This paper is part of a PhD project at Charles Darwin University, Australia. Ethics approval for this study was granted by Charles Darwin University, Australia (H15059). The authors would like to extend our sincerest thanks to the Vietnamese farmers, officers, and scientists in the Northern Territory, South Australia, and Western Australia for their participation and contribution to the study. We thank reviewers for their great comments and Jeremy Garnett for his editing this manuscript. We express our gratitude to Plant Biosecurity Cooperative Research Centre Australia and Charles Darwin University, Australia for funding and supporting this project.

Abstract

Plant biosecurity threats such as pest, weeds, and disease occurrences cause substantial economic damage to the agricultural sector, worldwide and in Australia. How smallholder farmers choose biosecurity management strategies remains poorly understood, particularly of smallholder cultural minority groups. In this study, we explore how Vietnamese smallholder farmers in Australia assess their biosecurity risk management strategies and the factors that explain their choice of different strategies. To do so, we conducted a survey of 101 Vietnamese farmers in the Northern Territory, South Australia, and Western Australia. Based on the Protection Motivation Theory, we assessed farmers' perceived self-efficacy, response efficacy, and response costs (all elements of their coping appraisal) using descriptive statistics, factor analysis, and stepwise regression. Information sources related to biosecurity and farmers' trust in public management explain how farmers assess their risk management strategies. Previous experience with biosecurity issues does not influence how farmers appraise their biosecurity risk coping capacity. Farmers use four types of biosecurity risk management strategies: chemical control, plant growth strategies, on-farm strategies, and asset investment strategies. The first two are the most frequently used. We recommend tailoring relevant government policies to better support farmers' adoption of risk management strategies based on their specific needs, more investment into biosecurity information dissemination and into trust building.

Keywords

Biosecurity threats, management strategies, assessment, Vietnamese farmers, influencing factors, Australia, Protection Motivation Theory

1. INTRODUCTION

The risks associated with agricultural enterprises have long been acknowledged as having a heavy dependence on unpredictable factors such as weather, biosecurity threats (pests, weeds, and diseases) and market fluctuation (Hardaker et al., 2015; Lipinska, 2016; Duong et al., 2019). Research conducted to explore farmers' strategies in minimising the impact of agricultural risks, including biosecurity threats (Ritter et al., 2016), found common strategies to be diversification (Jankelova et al., 2017), working off-farm (Jirgi et al., 2015), off-farm investment in mutual funds and bank deposits (Chengappa et al., 2017), and disease monitoring and prevention (Garforth et al., 2013).

Farmers of different socio-economic backgrounds (age, education, religion, farming practices) have different economic behaviours, decision-making, and risk management strategies (Garforth et al., 2013). Further, farmers' risk management strategies have been explained by a range of factors such as education (Joshi et al., 2017; Oo et al., 2017), farming experience (Cooper and Wheeler, 2016), farm size (Abid et al., 2015), and farm annual income (Tudor et al., 2014). Biosecurity risk management strategies, specifically, have been explained by socio-economic factors, credible information, and advice on biosecurity (Garforth et al., 2013; Toma et al., 2013). Little research, however, has been done to explore farmers' assessment of risk management strategies and factors which influence their assessment of biosecurity risk management strategies.

Australia has a highly regarded system for managing biosecurity threats and incursions, thereby providing benefits to the economy, environment, and community (Beale et al., 2008). This system, however, has been challenged by socio-economic and environmental conditions that favour the increased likelihood of biosecurity incursions such as climate change, globalisation, tourism, and growing international trade (Mankad, 2016).

Recent incursions highlight the potential social and economic costs of ongoing incursions. In 2013 and 2015, Banana Freckle and Panama Disease TR4 respectively, cost AUD ~26 million to eradicate (Robinson, 2017) across Queensland and the Northern Territory, and threatened to destroy the banana industry, which is worth AUD ~400 million. In 2014, Cucumber Green Mottle Mosaic Virus caused damage and disruption to the AUD ~60 million Northern Territory melon industry (Keane, 2015). Similarly, Red fire ants have been reported to have negative impacts on Australian agriculture, and have been forecast

to cost the country approximately AUD ~1.6 billion if not controlled (Sturmer and Branley, 2016).

Australian agriculture has been increasingly enriched by smallholder farmers of diverse cultural and linguistic backgrounds. Non-English speaking farmers account for 90% of perishable vegetable production in the Sydney basin (Parker, 2007) and Vietnamese vegetable farmers contribute AUD ~40 million per year to the Northern Territory economy (O'Brien, 2017). Research has indicated that the number of overseas-born farmers is highest in the Northern Territory and Western Australia (Collins et al., 2016).

While large-scale farmers' risk perceptions and risk management strategies have received significant attention (Mase et al., 2017), less is known about smallholder farmers risk perceptions and risk management strategies (Young et al., 2017). Yet, in order to support smallholder farmers in managing increasing biosecurity threats, it is crucial to understand how they assess management strategies and the factors that affect their assessment of those strategies.

This paper aims to answer the following questions:

- How do farmers appraise the biosecurity management strategies available to them in terms of self-efficacy, response efficacy, and response costs?; and
- What factors affect their appraisals of biosecurity risk management strategies?

Data were collected from 101 structured interviews of Vietnamese farmers in the Northern Territory, South Australia, and Western Australia. The interviews investigated how farmers assess biosecurity risk management strategies in terms of perceived self-efficacy, perceived response efficacy, perceived response costs, and the factors influencing their assessment of those risk management strategies.

2. FRAMEWORK, HYPOTHESES, CASE STUDIES AND DATA ANALYSIS

2.1. Theoretical framework

Protection Motivation Theory (PMT) is used to understand human attitudes and behaviours (Rogers, 1975). Initially PMT aimed to explore people's health protection behaviours, but its application has diversified, and it is now being used to understand farmers' behaviours in the context of drought risk (Keshavarz and Karami, 2016), flooding (Bubeck et al., 2013), natural conservation (Josefsson et al., 2017), and animal biosecurity (Cui et al., 2016). There are two main processes incorporated in PMT: the threat-appraisal process and the coping-appraisal process (Figure 1). The first process involves people's assessment of the threat, including perceived vulnerability (probability) and perceived severity (consequence) (Bubeck et al., 2013). This study focuses on the second process, coping appraisal, to explore how farmers assess their biosecurity risk management strategies based on the three parts of the coping-appraisal process: response efficacy, self-efficacy, and the response costs associated with each management strategy option.

Response efficacy represents whether a person thinks a risk management strategy is likely to be effective. Self-efficacy represents whether a person is equipped to use a strategy. Response cost represents to the financial, time, and emotional costs incurred when one person decides to employ a specific strategy (Bubeck et al., 2013). Few studies (Cui et al., 2016) have used PMT to examine farmers' capacity to cope with biosecurity threats in the animal industry.

It is understood that this is the first study to apply Protection Motivation Theory to smallholder farmers' assessment of biosecurity risk management strategies in the context of multicultural developed countries, such as Australia.

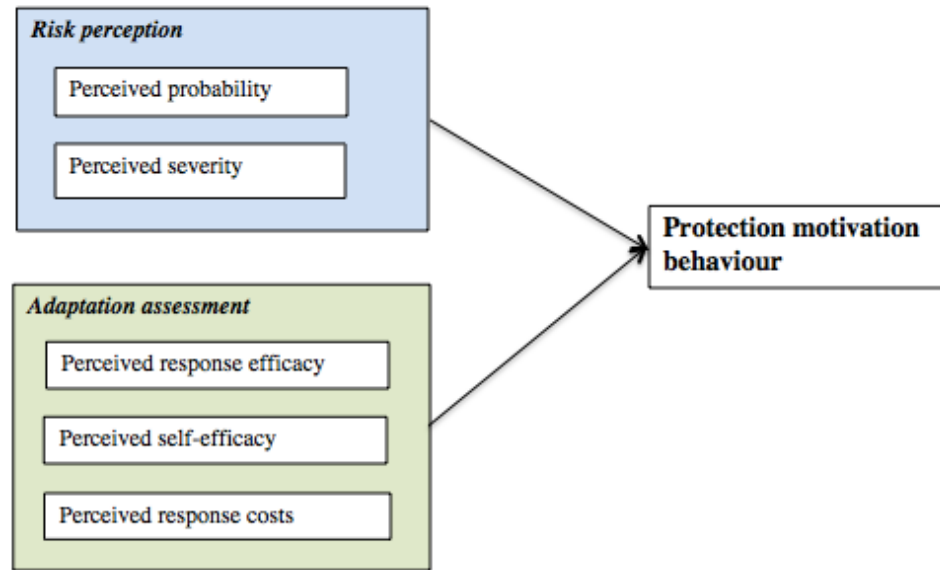


Figure 1: Conceptual model of the Protection Motivation Theory adapted from Keshavarz and Karami (2016).

2.2. Hypotheses

This paper tests two hypotheses, based on the current literature and under the conceptual framework of the Protection Motivation Theory.

Firstly, it is expected that the more information on biosecurity threats and management strategies are available, the better farmers' cope with threats and minimise future risks. Previous research has confirmed the positive relationship between the receipt of information and farmers' decision-making in management strategies, in the context of organic agriculture (Tzouramani et al., 2013) and climate change (Dang et al., 2014). This study aims to empirically test the relationship between biosecurity information and biosecurity risk-coping appraisal:

H1: Information on biosecurity risk management strategies is positively related to biosecurity-risk coping strategies (higher response efficacy, higher self-efficacy, and lower response costs).

Secondly, Kellens et al. (2011) reported the positive relationship between previous risk perception and coping appraisal of a flood in Belgium. Here it was assumed that farmers with previous experience of biosecurity threats tended to have a higher appraisal of how to cope with the threats than farmers who had no experience:

H2: High level of experience with biosecurity threats is positively correlated with biosecurity risk-coping appraisal (higher response efficacy, higher self-efficacy, and lower response costs).

2.3. Case studies

Communities of Vietnamese farmers live and farm in some states and territories in Australia, especially in regional areas of the Northern Territory (NT), South Australia (SA), and Western Australia (WA) (Figure 2), where this research was undertaken. The majority of interviewed farmers across all jurisdictions immigrated to Australia after 1975. Of the three selected jurisdictions, Vietnamese farmers in the Northern Territory had recently been affected by Green Cucumber Mottle Mosaic Virus when the research was conducted in 2015.



Figure 2: Map of research areas. Map source: <http://nationalmap.gov.au/>

About 120 Vietnamese farmers predominantly grow fruit and vegetables near Darwin, in the Northern Territory, with the most active period of production being the Dry season (May to October). They are one of the key suppliers of Asian vegetables, mangoes, and tropical fruits for Darwin and the surrounding regions. The majority of their produce, however, is exported interstate (primarily to the cities of Melbourne and Sydney) and internationally (primarily mangoes). In 2003, there were about 60 Asian vegetable growers (93% Vietnamese growers) (Morgan, 2003) and the number is now on the rise. Their industry association was established in 2013 as a result of farmers' active and increasing contribution to the Northern Territory agriculture sector.

South Australia has been acknowledged as the largest hub of Vietnamese farmers, with approximately 200 to 300 farmers growing fruit and vegetables in greenhouses and glasshouses. The majority of Vietnamese farmers in the region arrived in the 1980s and gradually acquired land on the Northern Adelaide Plain. The fertile soil, Mediterranean climate, and availability of water allow farmers to intensively grow fruit and vegetables including capsicums, cucumbers, eggplants, and a wide range of tomatoes. In recent years younger farmers have attempted to install and operate high-end hydroponics systems. Two established industry associations unite and support Vietnamese farmers in the region. Their produce is supplied both intrastate and interstate (mainly exporting to Melbourne and Sydney).

The agricultural region in Western Australia has a broad geographic spread, diversity of production environment, and climate variability. WA farmers produce vegetables, tomatoes, cucumbers, eggplants, and strawberries, grown in either open fields or polytunnels. The vegetables are mainly consumed intrastate while the strawberries are exported both interstate and internationally. More than 220 Vietnamese farmers live and work in three central locations: north of Perth (Wanneroo, Joondalup), Geraldton, and Carnarvon. The farmers predominantly came to Western Australia as refugees from Vietnam in the 1980s and 1990s. They have received regular visits from an agricultural extension officer for several years.

2.4. Data collection and analysis

2.4.1. Data collection procedure

The data were obtained through in-person interviews with farmers between September 2015 and September 2016. Nine preliminary in-depth interviews (with four farmers and five biosecurity officers) were conducted, followed by the main empirical survey. Based on the in-depth interview outcome, a set of questionnaires was developed, refined, and piloted with six Vietnamese farmers. The majority of the questions were close-ended and ordinal, using a five-point Likert scale.

This paper used data from a more extensive questionnaire which consisted of the following elements: farmers' biosecurity risk experience, farmers' belief in biosecurity, farmers' assessment of biosecurity risk management strategies (response efficacy, self efficacy, and response costs), support resources to biosecurity management, information sources on biosecurity, and farm characteristics and their demographic features. Farmers were asked to rank, based on a five-point Likert scale, the effectiveness of each strategy (perceived response efficacy), their capacity to employ the strategy (perceived self-efficacy), and the

perceived financial, time, and emotional costs associated with the strategy (perceived response costs). The first and second dependent variables were ranked from 1 (*extremely ineffective*) to 5 (*extremely effective*) while the third dependent variable was rated from 1 (*not costly at all*) to 5 (*extremely costly*).

Participating in the survey were 101 farmers, comprised of 40 farmers from the Northern Territory, 30 from South Australia, and 31 from Western Australia who spent, in general, approximately one and a half hours answering the questions. Eleven farmers refused to participate in the research due to inadequate time or a lack of interest, possibly due to a lack of a prior relationship between the researchers and the respondents. Snowball sampling was subsequently successfully employed to conduct interviews (Handcock and Gile, 2011), as in this study, it proved to be more convenient for the farmers when prior interviewees introduced the researchers to the other farmers.

2.4.2. Data analysis and variables

The data were analysed using SPSS 25 software. Firstly, descriptive statistics summarised variables in the study. Secondly, stepwise regressions were adopted to determine the most appropriate regression model based on the criteria of the probability of F-to-enter. Using the Protection Motivation framework for predicting, explanatory variables (X) are information sources on biosecurity, socio-economic features (age, gender, marital status, farming experience, land under production, and total land held), risk experience, trust in public management, and support resources from the government (Table 1). Farmers' assessment of risk management strategies is measured based on three dependent variables (Y): perceived response efficacy, perceived self-efficacy, and perceived response risks, calculated as follows: *Farmers assessment of biosecurity risk management strategies* (perceived response efficacy, perceived self-efficacy, and perceived response risks) = f (information on biosecurity, support resources, trust in public management, and socio-economic features).

Factor analysis was used to determine which biosecurity risk management strategies tended to cluster across respondents. This technique has been used widely in agriculture to categorise the clusters of risk management strategies that farmers employed (Tzouramani et al., 2013, Tudor et al., 2014).

Table 1: Variables in the study (N=101).

<i>No.</i>	<i>Variables</i>	<i>Descriptions</i>	<i>Number of questions</i>	<i>Cronbach's alpha coefficient</i>
1	Gender	Gender of the respondents (dummy variable): 1 = male; 0 = female	1	
2	Age	Age of respondents (years)	1	
3	Farming experience	Number of years farm household has been doing farm work (years)	1	
4	Land under production	Agricultural land used for current farming activities (acres)	1	
5	Total land held	Total agricultural land that farmers owned or rented (acres)	1	
6	Marital status	Marital status of respondents (dummy variable): 1 = married, 0 = others	1	
7	Risk experience	These variables represent risk experience (dummy variable): 1 = respondents experienced the biosecurity risk at their farm; 0 = respondents did not experience biosecurity risk at their farm	4	
8	Biosecurity information sources	This variable represents respondents' information sources on biosecurity. Farmers were asked to what extents they agreed with five statements based on a five-point Likert scale from 1-totally useless to 5-extremely useful.	7	0.49
9	Resource support	This variable represents respondents' possible resource support offered in the locality. They were asked to what extents they are affected by the possible five resource support based on a five-point Likert scale from 1 (Not useful at all) to 5 (extremely useful).	6	0.75
10	Trust in public management	This variable represents respondents' trust in current public management of biosecurity. They were asked to what extents they agreed with six statements based on a five-point Likert scale from 1 (strongly disagree) to 5 (strongly agree).	6	8.23
11	Biosecurity management strategies	This variable represents respondents' risk strategies of biosecurity. They were asked if they implemented those strategies or not at their farming properties (Yes or No).	12	0.63
12	Self-efficacy	This variable represents whether farmers are equipped to use a strategy. They were asked to what extents they agreed with twelve statements based on a five-point Likert scale from 1 (Not effective) to 5 (extremely effective).	12	0.85
13	Response efficacy	This variable represents whether farmers think a risk management strategy is likely to be effective. They were asked to what extents they agreed with twelve statements based on a five-point Likert scale from 1 (Not effective) to 5 (extremely effective).	12	0.88
14	Response costs	This variable refers to the financial, time and emotional costs incurred when one farmer decides to employ a specific strategy. They were asked to what extents they agreed with twelve statements based on a five-point Likert scale from 1 (Not costly) to 5 (extremely costly).	12	0.82

3. RESULTS

3.1. Farmers' profiles characteristics

Survey respondents exhibited variations in their social and demographic characteristics. The majority of respondents (73.3%, 74) were male, while 26.7% (27) were female. The median age was 49 years old, of a range between 22 and 76 years old. Most farmers (90%) were married, and 92% of the households had less than five members. About 77% of farmers had no or low command of English. About 33% of farmers reported some on-farm biosecurity regulations for workers (verbal and written forms) and visitors. Almost 90% of farmers owned or rented less than 50 acres of land for production.

3.2. Farmers' biosecurity risk management strategies

The factor analysis of management strategies resulted in four components explaining 57.3% of the total variance (Table 2). The factor model had a Kaiser Mayer Olkin measure of 0.608, suggesting that the data were suitable for factor analysis. The Bartlett's Test of Sphericity was significant ($p < 0.001$). In this model, the factor loadings which were greater than 0.5 were considered significant. The first component included five management strategies: "destroy/burn off all weeds and old plants," "offer foot baths and tools cleaning," "discourage workers from working on other farms (at the same time)," "use suitable clothing on the farm," and "install biosecurity signs." We refer to this group of strategies as "on-farm strategies." The second component comprised: "use farm inputs (seeds, fertilisers) from trusted sources," "diversify plant varieties," "adjust planting schedule," and "divide farm into separate growing zones," which we refer to, collectively, as "plant growth strategies." The third component consisted of two biosecurity risk management strategies "use separate cars on and off farms" and "build farm fences," which we refer to, collectively, as "asset investment strategies." The fourth component comprised only one risk management strategy, "chemical spray," which we refer to as "chemical control".

Table 2: A factor analysis of biosecurity management strategies used by farmers (N=101) (Varimax rotated, Coefficient values ≥ 0.5 in bold).

<i>No.</i>	<i>Strategies</i>	<i>On-farm strategies</i>	<i>Plant growth strategies</i>	<i>Asset investment strategies</i>	<i>Chemical control</i>
1	Destroy/burn off all weeds and old plants	0.531	-0.169	-0.0325	-0.063
2	Offer foot baths and tools cleaning	0.795	0.168	0.106	0.110
3	Discourage workers from working on other farms*	0.754	-0.043	0.285	-0.122
4	Use suitable clothing on farm	0.590	0.168	0.028	0.271
5	Install biosecurity signs	0.717	0.096	-0.105	-0.116
6	Use farm inputs (seeds, fertilisers) from trusted sources	-0.089	0.742	0.027	-0.094
7	Diversify plant varieties	0.108	0.597	-0.006	0.143
8	Adjust planting schedule	0.115	0.725	0.205	0.081
9	Divide farm into separate growing zones	0.081	0.707	-0.058	-0.161
10	Use separate cars on and off farms	0.073	0.027	0.827	0.168
11	Build farm fence	-0.009	0.049	0.630	-0.281
12	Chemical spray	-0.011	-0.039	-0.052	0.909

Note: * *Farmers may ask workers not to work for other farms concurrently to prevent disease from possible spreading from farms to farms at the same time.*

The plant biosecurity risk management strategies used by farmers were subsequently ranked based on the frequency of usage. Farmers in all three jurisdictions (NT, SA, WA) varied in their use of risk management strategies. Farmers regarded “chemical spray” (98%), “use farm inputs (seeds, fertilisers) from trusted sources” (85%), and “build farm fences” (77%) as their primary strategies of managing biosecurity threats. Strategies such as “offer foot bath and tools cleaning,” “discourage workers to work on other farms,” and “install biosecurity signs” were not frequently used by farmers, and these resulted in percentages of 32%, 23%, and 21% respectively (Table 3).

Table 3: Per cent of farmers using biosecurity management strategies (N=101).

<i>Group strategies</i>	<i>Strategies</i>	<i>Farmers used (%)</i>	<i>Overall rank</i>	<i>NT</i>	<i>SA</i>	<i>WA</i>
On-farm strategies	1. Destroy/burn off all weeds and old plants	65	5	2	2	7
	2. Use suitable clothing on farm	37	9	7	8	6
	3. Offer foots bath and tools cleaning	32	10	8	7	8
	4. Discourage workers from working on other farms	23	11	9	9	9
	5. Install biosecurity signs	21	12	10	9	8
Plant growth strategies	6. Use farm inputs from trusted sources	85	2	4	1	1
	7. Divide farm into separate growing zones	67	4	5	3	3
	8. Adjust planting schedule	58	6	6	5	4
	9. Diversify plant varieties	55	7	7	6	3
Asset investment strategies	10. Build farm fence	77	3	3	4	2
	11. Use separate cars on and off farms	45	8	4	10	5
Chemical control	12. Chemical spray	98	1	1	1	1

Farmers were asked about the availability of support resources where they lived. Eighty-three per cent of farmers reported that they were not aware of available low-interest loans or low-interest subsidies offered by the government in their jurisdiction when they need capital for expansion or relief support. Farmers did not receive information translated into Vietnamese (67%), extension services (54%), and testing for diseases and pests (34%) (Figure 3).

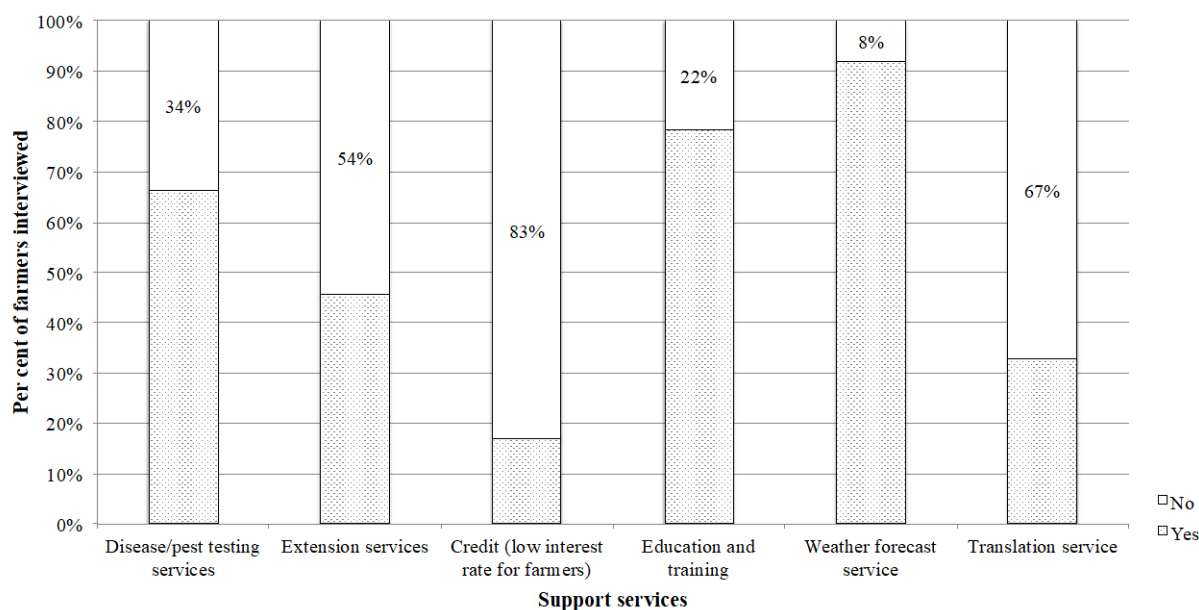


Figure 3: Available support resources for biosecurity management perceived by farmers (N=101).

3.3. Factors affecting farmers' assessment

Response efficacy was explained by information on biosecurity ($p = 0.025$) (Table 4). The more farmers referred to information on plant biosecurity, the better they assessed on-farm strategies against pests and diseases threats to be useful in protecting their farms. The sources of information included fellow farmers, relatives, neighbours, independent experts, industry associations, and agriculture departments. Self-efficacy; whether farmers were able to implement biosecurity management strategies, was also explained by information on biosecurity matters ($p = 0.008$). The more farmers engaged with information sources on biosecurity matters, the higher capacity they believed they had in order to adapt and handle biosecurity risk strategies at their farms. Farmers' levels of trust explained response costs (costs of time, financial resources, and farmers' effort when employing the response strategies) to public management. Specifically, farmers who had a low level of trust in biosecurity management perceived the costs of biosecurity strategies to be higher ($p = 0.015$).

Table 4: Regression models of response efficacy, self-efficacy and response costs (N=101).

<i>Dependent variables</i>	<i>Explanatory variables</i>	<i>Standardised Coefficients</i>	<i>t-value</i>	<i>Sig.</i>	<i>R²</i>	<i>Adj R²</i>	<i>F test, p-value</i>
1. Self efficacy	Information	0.26	2.7	0.008	0.069	0.059	0.08
2. Response efficacy	Information	0.22	2.27	0.025	0.049	0.040	0.025
3. Response cost	Trust in public management	-0.24	-2.47	0.015	0.058	0.048	0.015

Farmers' were asked to assess the usefulness of information sources on biosecurity. About 55% referred to the people surrounding them (friends, relative, neighbours) as a beneficial source of information, followed by the chemical stores and independent experts, with 38% and 26% respectively. The Internet (17%) and agricultural departments (12%) were not considered useful sources of information.

4. DISCUSSION

4.1. Farmers' coping appraisal and influencing factors

This study applied the PMT framework to explore how smallholder farmers assess the coping strategies of plant biosecurity threats on their farms, in Australia. Information of biosecurity matters and available management strategies has, as expected (Hypothesis 1), a positive influence on farmers' self-efficacy and response efficacy while trust in public management had a negative impact on farmers' perceived response costs.

We confirm our first hypothesis that reliable information on biosecurity supplied by authorities helps farmers in their coping appraisal, with the scope of our research. Information has been confirmed as one of the critical factors influencing farmers' assessment of risk management strategies (Zulfiqar et al., 2016). With valid information, farmers are likely to partake in an informed decision-making process (Roco et al., 2014) before undertaking strategies that are most suitable for their farm and circumstances. Specifically, with more information on plant biosecurity available through appropriate pathways, farmers can be more confident in using risk management strategies at the farm level. Farmers predominantly acquire information from the people around them (friends, relatives, fellow farmers) which influences their assessment of biosecurity risk management strategies and is in line with the findings of a study of Vietnamese farmers in Vietnam (Dang et al., 2014).

Our finding that farmers who trust the public management of biosecurity perceive the response costs to be lower than those without trust was not surprising. Studies indicate that mutual levels of trust between landholders and agencies influence the effectiveness of risk communication in biosecurity management as a consultative process among stakeholders, which is vital in clearing barriers and building trust (Gilmour et al., 2011). Successful biosecurity risk management strategies implementation is reliant on shared responsibility and trust between farmers and the relevant stakeholders, including the government (Hernandez-Jover et al., 2012).

Our results do not support a relationship between farmers' biosecurity experience and their assessment of biosecurity risk management strategies, and so we reject our second hypothesis. Previous studies had shown a positive relationship (Kellens et al., 2011) so this was a surprising result. In risk communication, by understanding the biosecurity experience of targeted farmers, their rate of adoption of risk management strategies could be improved (Garforth et al., 2013).

Larger farm size has previously been shown to be positively associated with farmers' employment of risk management strategies (Pennings et al., 2008). In Nepal, farmers' land size was found to positively influence their adoption of strategies against climate change as the more land farmers have, the greater the probability of adopting risk management strategies (Joshi et al., 2017). However, this study found farm size to have no effect on whether farmers would be more, or less, willing to implement on-farm measures against biosecurity threats.

4.2. Farmers' use of biosecurity risk management strategies

The four main groups of management strategies identified in this study were on-farm strategies, plant growth strategies, asset investment strategies, and chemical control strategies. The finding of the factor analysis suggests that though some biosecurity risk management strategies were implemented ("chemical spray," "build farm fences"), other strategies such as "foot bath" and "install biosecurity signs" were infrequently undertaken or not conducted at all. Even though those strategies had been strongly recommended by the biosecurity manual (Farm Biosecurity, 2010), which offers advice on biosecurity strategies at the farm level, farmers showed hesitation towards undertaking unfamiliar strategies.

Results from other research suggested extension services increase farmers' uptake of risk-reduction strategies (Oo et al., 2017). This study identified that the introduction of extension activities should place more emphasis on the groups of risk management strategies which were yet popular among Vietnamese farmers such as on-farm strategies. In addition, the farmers considered the information from friends, relatives, and fellow farmers as regular and effective information sources of biosecurity. Thus, extension programs in other jurisdictions may consider the adoption of the industry champion as used in the Northern Territory for sharing information among farmers in the community. This strategy was well regarded by farmers and officers alike.

Local government can play an important role in offering farmers a favourable environment for farming practices including adequate infrastructure, resources, and information support (Abid et al., 2016). In this study, however, farmers reported the low availability of support resources for biosecurity risk management in their vicinity. For example, recognising farmers' income loss as a result of biosecurity incursions, the Northern Territory government offered financial incentive which was intended for temporary relief for farmers to start new cropping season (Scott, 2015). However, results showed that farmers were unaware of this financial initiative, which had been made available in 2015.

Poor communication between farmers and government signals the need for improved methods of information dissemination. Information on biosecurity incursions, information on alternative crops during incursions, and some translated information in Vietnamese have been made available online on the agricultural departments' websites. However, farmers generally prefer obtaining information via their informal connections of known people. As the majority of farmers had a low command of English, we recommend that the training materials or biosecurity information are translated into Vietnamese. On the one hand, more farm visits would be a better target than posting information online for Vietnamese farmers, which are then inaccessible to most Vietnamese farmers residing in regional areas. On the other hand, Internet connectivity and farmers' Internet literacy need to be better resourced.

Vietnamese farmers use of chemical control is a common and important biosecurity risk management strategy. However, using chemical substances (pesticide, fungicide, herbicide, and bactericide) to control pests and diseases means farmers inadvertently risk their health (Jallow et al., 2017), and potentially reduce produce value. Improved access to education and alternative management strategies could reduce the need for extensive use of chemical management in the future.

5. CONCLUSION, POLICY IMPLICATIONS, AND RESEARCH OUTLOOK

This paper presented the results of a survey of 101 Vietnamese farmers across three regions of Australia, the Northern Territory, South Australia, and Western Australia, concerning their assessment of biosecurity risk management strategies. Their assessment of biosecurity risk management strategies and the factors influencing their decisions were explored and analysed under the framework of the Protection Motivation Theory.

Based on factor analysis, farmers tend to use biosecurity management strategies in four groups with a higher frequency of employment of chemical control and plant growth strategies. Their management strategies were assessed based on response efficacy, self-efficacy, and response costs. Factors affecting three dimensions of risk management strategies were also explored. Information on biosecurity is found to influence farmers' appraisal of risk management strategies (as suggested by Hypothesis 1) and farmers' trust of public management is revealed to be significant in farmers' assessment of biosecurity strategies. The result does not support Hypothesis 2, in that previous experience with biosecurity issues did not positively correlated with risk coping appraisal.

These findings provide policymakers, researchers, biosecurity officers, and industry associations, in Australia, with insight into how farmers assess risk management strategies and associated factors affecting their decision-making process.

Recommendations for possible changes in current communication practices to enhance farmers' biosecurity coping appraisal are proposed to increase farmers' rate of adoption of on-farm biosecurity risk management strategies.

Specifically, the recommendations from this study are:

- More direct communication is required, with the reintroduction and investment in extension activities. Programs should be better designed with a particular focus on information sources, clear communication channels, and adequate investment in extension services. More emphasis on support, such as extension services, in delivering biosecurity information is needed, including on-farm biosecurity risk management strategies for farmers.
- Trust building and nurturing relationships between the government and farmers are crucial to increasing farmers' engagement and commitment to the standards of the industry. When farmers' level of trust in biosecurity management is high, they will be more likely to be confident in assessing biosecurity risk strategies and increase the

rate of adoption of those strategies to protect their farms against biosecurity incursions. This suggests there are opportunities for the government and industry organisations to collaborate with Vietnamese horticultural associations across the three study regions.

- In addition, as farmers commonly favour chemical spray, education programs should focus on safe and effective spray application. In particular, newcomers to the industry need support on how to handle chemicals appropriately to manage biosecurity threats, protect their health, maintain the reputation of the industry, and contribute to the long-term sustainability of the industry.

Potential topics for future research include the comparison of farmers' coping appraisal across the different scales of production and culture. To ensure good on-farm biosecurity practices, the benefits of risk management strategies perceived by farmers and the barriers that farmers encounter when adopting strategies are worth exploring. Moreover, chemical control has been widely used by farmers in this study, but not necessarily in a sustainable manner. More research is needed to explore how farmers' perceive the benefits and costs of chemical control and whether they consider the harmful effect on farmers, consumers, and environmental health in the context of minorities farming groups.

Conflict of interests

There are no competing interests of the authors.

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