Case Study: Risk and Risk Management Strategies for Smallholder Vegetable Growers in Battambang, Cambodia

By

Sean Kiely

THESIS

Submitted in partial satisfaction of the requirements for the degree of

MASTER OF SCIENCE

in

International Agricultural Development

in the

OFFICE OF GRADUATE STUDIES

of the

UNIVERSITY OF CALIFORNIA

DAVIS

Approved:

_____

Cary Trexler, Chair

_____

Kristin Kiesel

_____

Glenn Young

Abstract

Cambodia's vegetable sector is typically poorly managed and susceptible to a multitude of shocks preventing producers from meeting consumer demand. Thus, consumers rely on imported vegetables from Vietnam and Thailand which fail to meet safe production standards, despite a growing demand for domestic vegetables. The government of Cambodia is intent upon capitalizing on this demand for domestic vegetables and has shown support for farmers and marketers making the shift toward the vegetable sector. However, the government must work quickly if it wishes to assist its rowers in capturing this market. Farming is inherently risky as farmers are faced with a multitude of exogenous factors that can alter yields and farm income. This study assesses vegetable grower knowledge and perceptions of risk management strategies which can mitigate the impact of these exogenous shocks. Additionally, an economic assessment through simulations is carried out to determine key output variables such as net-present value, returns to land and returns to family labor of existing baseline vegetable production. Risk management strategies identified to be of great economic value to growers with high probabilities of adoption were then added to the economic baseline in order to determine their impacts. We conclude that the inclusion of crop insurance and contract farming can significantly reduce farm profit loss and risks. We therefore, recommend the government of Cambodia establish crop insurance programs and create a policy environment in which contract farming can thrive.

Table of Contents

Acknowledgements

I would like to extend my sincere gratitude to all those involved in the research and analysis of this project. I want to thank the growers from Thasey and Anlongrun who were willing to participate in this research study. Additionally, I would like to give special thanks to my enumerator Koemseang Vet and Thort Chuong for translation, and transcription, and assistance with LUS design. I would like to thank Karen LeGrand, Kristin Kiesel, and all the faculty and staff at the Royal University of Agriculture and the University of Battambang for their guidance and assistance throughout the project. This project was conducted under the Horticultural Innovation Lab's Building and Scaling Safe-Vegetable Value Chains project with funding provided by the Research and Innovation Fellowship (RIFA) through the James and Rita Seiber Graduate Student Scholarship, Blum Center for Developing Economies, and the Henry A. Jastro Award.

List of Tables

List of Figures

Chapter 1: Perceptions of Risk and Risk Management Strategies: Identifying Alternative Strategies to Promote Smallholder Vegetable Production in Cambodia

1. Introduction

In Cambodia, 20.5% of the rural population live in poverty and are vulnerable to even minor economic shocks. Vulnerability to shocks is of particular concern in the agricultural sector as approximately 65% of the total population is engaged in agricultural production (Asian Development Bank, 2014; FAO, 2014). Exogenous shocks like pest pressure, drought, and access to water particularly affect the livelihoods of Cambodian farmers impact their revenue streams post-harvest. Farmers in Cambodia are also exposed to market risks as they are subject to extreme price volatility for their crops and often lack access to financial services to acquire loans. Financial market linkages are often weak or non-existent, financial literacy among farmers is low, and farmers lack acceptable collateral needed to acquire capital improvement loans (FAO, 2014). It is of paramount importance to facilitate risk mitigation practices in order to lower risk exposure and increase the economic viability of Cambodian farmers.

and generate greater income for rural farmers while concomitantly providing positive nutritional benefits to consumers (Eliste, 2015). However, Cambodia's existing vegetable sector "is underdeveloped, poorly managed, unreliable and affected by seasonal climate variability. Cambodia therefore relies on cheap imports from neighboring countries" (Sophal, 2009). The Cambodian Agricultural Research and Development Institute estimates more than 75% of vegetables sold in the market are currently imported. Most of these imports comes from Vietnam. However, only 8.0-8.5% of Vietnamese vegetables grown meet standards for safe production set by the Vietnamese Ministry of Agriculture and Rural Development (MARD) (Moustier, Bridier & Loc, 2002; VietNam Bridge, 2009; Trexler, 2016).

e safety of imported vegetables, creating an opportunity for locally-grown vegetables to displace foreign vegetable imports (Kula, Turner & Sar, 2015). The University of California, Davis (UC Davis) has been collaborating with Cambodia's Royal University of Agriculture (RUA) since 2010 to help farmers and the produce sector with the development safe-vegetable value chains (SVVCs). The focus of the SVVC has primarily been to improve vegetable production practices, post-harvest practices, and market linkages. Production practices have also been restructured through participatory research (LeGrand et al. 2017; LeGrand et al. 2018). Improvements and practices include innovations such as soil improvement and nutrient management using earthworm compost, chemical-free crop protection from insect pests using nethouses, and improved post-harvest handling practices such as sorting, washing, packaging, cold-storage . Additionally, the program has established new market linkages that successfully connected producers and marketers through a branding campaign that promoted domestic, chemical-free vegetables. This advantageous branding reduced risk for farmers by creating a price premium for the products grown without chemical pesticides or fertilizers and to negotiate contract prices with marketers. he SVVC project has provided numerous "hard" or tangible technologies for growers to implement and has supported these hard technologies, the use of human-mediated "soft" technologies in the Kandal province including shared interest savings groups (LeGrand et al. 2018; Miller et al. 2017). Shared interest savings groups act as a mechanism of risk management because they supported growers in multiple ways. Participants in shared interest savings groups gain basic financial tools for managing community-based savings and loan programs. Also, the shared interest savings group platform builds social structures that serve as vehicles for collective community action to address agricultural problems. While the SVVC program implemented technologies and practices that established for the first time domestic supply chains for safe vegetables in ways that support farmers, it is necessary to expand the use of soft technologies to further support growers and provide additional income generation, financial assistance, and safety net services.

The focus of this research is to examine grower risks and risk management strategies (soft technologies) which can improve grower livelihoods and protect growers from the pitfalls of poverty. Specifically, the purpose of this study is 1) to understand the risks faced by vegetable producing farmers and their risk-taking abilities and 2) to identify human-mediated risk management strategies that simultaneously promote economic viability and exhibit high adoption rates based on risk. High adoption is defined as the implementation and continued use. While some strategies may have high payoffs, risk aversion levels may lessen the likelihood of implementation and continued

use. Therefore, we place an emphasis on strategies that garner high payoffs for growers while also exhibiting high rates of adoption based on grower risk-taking ability. We assess 1) attitudinal levels of risks faced on the farm 2) perceptions of risk taking ability 3) use, awareness, confidence, interest, and perceived benefits and risks of both traditional and alternative risk management strategies and 4) access to risk information and education for 30 smallholder farmers in two villages in Battambang province.

2. Literature Review

In this section, we review the literature regarding the dimensions of agricultural risks and the risk management strategies available to mitigate these risks. Here, we discuss the areas of risk most pertinent to Cambodia's vegetable sector and the strategies, divided into traditional and alternative strategies, most suitable in aiding growers.

2.1 Risk in Agriculture

Risk can be defined as "uncertain consequences, particularly possible exposure to unfavorable consequences" (Hardaker, 2004). Farmers face multiple dimensions of risk in agricultural production. These agricultural risks are associated with negative outcomes stemming from exogenous variables such as fluctuations in climate, natural disasters, and price volatility that are outside of the control of the farmer. To understand appropriate risk management strategies for farmers, it is important to understand the various dimensions of risk faced. While not exhaustive, the following dimensions of risk are the most pertinent to Cambodian agriculture that although not completely preventable can be mitigated at the farmer level.

Price Risk: The volatility of input and output prices is an extremely important source of agricultural risk. In particular, output prices for agricultural commodities can vary significantly. In segmented, local markets an increase in annual production typically decreases output prices, while a decrease in production leads to increased output prices. The instability of output prices makes it difficult for farmers to accurately predict profits, has severe consequences for the household's ability to plan financially.

Production Risk: The high variability of production outcomes in agriculture are due to the myriad of exogenous variables that effect production. These exogenous variables, including extreme weather conditions (i.e. flood, drought, fire, excessive heat and rain), changing input costs, and pests (i.e. insects, diseases), lead to uncertainty in crop yield and quality, which effects farm profits.

Financial Risk: Farmers need to finance business operations and maintain cash flows in order to meet financial obligations and repay debts. Many farming operations hinge on the ability to access and borrow loans. Borrowing money introduces numerous financial risks. The uncertainty of lenders to supply loans in the present and future is one source of risk. Additionally, the ability of farmers to pay back loans due to interest rates and future production and price risks effect farm cash flows (Drollette, 2009).

Marketing Risk: A lack of market information systems makes it challenging for farmers to assess demand for a product, search for and identify buyers. Market access can be limited by poor infrastructure and supply chains, and limited marketing strategies, which further reduces the number of buyers available for farmers.

Personal Risk: The health of the farming family and main farm operator are the primary personal risks faced by a farm business. Illness or death of the main farm operator or other members of the farm family can disrupt the performance of the operation. Labor shortages can be another source of personal risk. Labor shortages often occur during rural to urban migration as well as political and social unrest (Kahan, 2008).

2.2 Risk Management Strategies

Farmers often use a diverse set of strategies to manage the risks they face. Some strategies address a single risk while others can deal with multiple risks. This section defines intangible risk management strategies that are both pertinent to addressing the risks that Cambodian farmers face and potentially feasible to employ in current or near future management systems. We divide the risk management strategies into two groups: traditional risk management strategies and alternative risk management strategies. Traditional strategies are defined as "arrangements made by individuals or households or such groups as communities or villages". Alternative strategies are defined as "market-based activities and publicly provided mechanisms" (World Bank, 2005). While there is some fluidity in these definitions (i.e. the categorization of producer groups), they characterize strategies as those that are traditionally available to farmers and those that are not. When assessing the appropriateness of risk

management strategies, it is important to consider both ex-ante and ex-post forms of risk reactions, i.e. the reactions of an individual once an exogenous shock has occurred in order to better understand how they will likely be employed to mitigate the effects of a shock after it has occurred and the ability of these strategies to reduce the impact of a risk.

2.2.1 Traditional Risk Management Strategies

We evaluate the following traditional risk management strategies. These strategies are typically accessible in any farming community.

Off-farm Work: Off-farm work is a traditional strategy that mitigates the effects of agricultural risks on farm household income by supplementing agricultural income through a more diversified and reliable income stream. Off-farm work can be both an ex-ante or ex-post reaction to risk depending on the time of employment.

Precautionary Savings: Precautionary savings include liquid and semi-liquid assets in the form of cash, livestock, crops, tools and equipment, and other household assets. This traditional strategy is an ex-post shock absorbing mechanism used by smallholder farmers (Ullah, Raza, et al., 2015).

Vegetable Diversification: Vegetable diversification refers to the planting of multiple types of vegetable crops in order to reduce the risks of crop failure due to the exogenous effects of weather and pests as well as to diversify income to mitigate the effects of volatile market prices (Ullah, Raza, et al., 2015). As vegetable production is the mail focus in this study, vegetable diversification is considered a traditional risk management strategy that functions in the same way as crop diversification. Non-vegetable crops, however, are considered under enterprise diversification.

Enterprise Diversification: Enterprise diversification refers to the inclusion of several farming operations such as the production of multiple crops, livestock, aquaculture, etc. The main principle of enterprise diversification is to engage in operations that negatively or weakly positively correlate with each other. Therefore, if there is lower income resulting from one activity, it may be offset by higher income from another activity as the two do not move in lockstep with one another (Gunjal, 2016).

Social Networks: Traditional societies can protect against risk through strong community bonds, often supporting individual families in times of hardship. Social networks can operate as an informal social safety net when idiosyncratic shocks occur. Idiosyncratic shocks are shocks where" one household's experience is typically weakly, if at all, related to neighboring households." These shocks typically occur due to crop yield shocks within microclimates, localized pest or disease outbreaks, or one-off events such as flood or fires. However, social networks particularly in developing countries typically do not ensure against covariate shocks, meaning that "many households in the same locality suffer similar shocks." Covariate shocks occur due to price instability, natural disasters, or financial crises (Bhattamishra & Barrett, 2008). Social networks can also extend lines of credit when formal credit institutions are not accessible.

2.2.2 Alternative Risk Management Strategies

We evaluate the following alternative risk management strategies. These strategies are not always accessible in farming communities, particularly in developing countries but they may provide large benefits once implemented.

ontract Farming: Farming contracts are arrangements made between buyers and producers that set a price and outlet for the good prior to harvest. These contracts secure a buyer and guarantee prices growers receive for commodities, thus minimizing market and price risks. In the context of this study, flat-rate contracts are offered to growers under the condition of producing vegetables in nethouses and eliminating the use of pesticides in the production process. This form of contract is a mix of a marketing contract and a production contract. The contract emulates a marketing contract in that it establishes a buyer and pricing arrangement. The farm operator controls most of the production process and owns the commodity while it is being produced. The production risks are therefore faced mainly by the operator. However, the contract also imitates a producer contract in the sense that the buyer/contractor has some control over the production process by specifying the use of nethouses and compost as well as the nonuse of pesticides. Flat-rate contracts negate future price risks and spread marketing risks while guaranteeing a minimum price. This minimum price provides market price protection for growers when open-market prices are low, but also

means that growers potentially forgo upside market price potential. In cases when open-market prices are high, side-selling on the part of the producer may occur (ERS, 1999). However, we observe contract prices that are typically above mean market prices, largely mitigating the issue of forgone profit opportunities and side-selling. It is worth noting that financial literacy is often low among smallholder farmers, which can pose a legitimate risk to producers as contracts must be clearly defined before entering into agreement.

Inventory Credit Systems: An inventory credit system (ICS) is an agreement between a storage facility operator and a grower who deposits a commodity of a specified quality and quantity in a secured storage environment. The grower is then issued a receipt for the deposit which can be used as collateral to obtain loans or to sell the commodity at a later period when the market price is at a more desirable level. The storage facility or warehouse typically functions either privately, publicly, or as part of a community inventory credit. ICSs can manage price risks by storing commodities when market prices are low and selling commodities when prices are acceptably high. ICSs also manage financial risk by offering growers a way to obtain credit they are often excluded from due to lack of collateral required by lending organizations. ICSs also reduce post-harvest losses by placing commodities in a secure, stable environment. However, several disadvantages exist as well. Lenders face the risk that borrowers will default on their loans. Creating suitable storage systems in rural areas is often prohibitively costly (Gunjal, 2016). In relation to this research study, vegetables require well developed cold storage systems for ICSs to function properly; however, in the study area such a system has only recently been introduced and is in experimental phases.

Crop Insurance: Crop yield insurance is used by growers to mitigate production risks when yield losses occur. Growers typically pay the insurer a fixed premium for protection from uncertain, but potentially large yield losses. When these losses occur, indemnities compensate the grower up to the insured coverage level. Coverage levels are typically between 50 to 80 percent of a grower's annual production history (APH) increasing at five percent increments (i.e. coverage levels of 50%. 55%, 60%, 65%,…,80%). Multiple forms of agricultural insurance schemes exist such as livestock and hail damage insurance. However, of particular interest is multi-peril crop insurance. This type of insurance protects the grower from yield losses that result from the many exogenous factors faced in agricultural production including natural disasters and pest damage. Typically, insurance schemes rely on risk-pooling where risks are not highly correlated among individuals and thus the total portfolio of the insurance company is less risky than the average of the individual policies. However, natural disasters are often correlated across a geographical area; thus pooling risk in this instance can be difficult for private insurers. Therefore, it is often the case that governments will handle multi-peril crop insurance coverage by subsidizing the premiums of the growers to ensure that indemnity payouts exceed the premiums paid by growers and that the operation costs of private insurers are covered (ERS, 1999). Premiums for growers are often subsidized up to 67% of the premium rate, which makes crop yield insurance particularly attractive to growers as a strategy to manage production risks.

Savings Groups: Savings groups are a management tool to mitigate financial risk. These groups are often structured as community-managed microfinance institutions where all fund accumulation is through member savings. Savings groups are often low-cost and easy to manage. They also allow members to build financial capital that can provide access to financial services from more formal institutions. Savings groups throughout the developing world allow members to have access to savings accounts that are not typically available in rural communities. Also, savings groups do not have prohibitive barriers to credit access such as high collateral. These groups also allow members to access small loans which are often used to support agricultural businesses and often include emergency insurance for members (Ksoll, 2016; LeGrand, 2018).

Producer Groups: Producer groups or cooperatives, can be leveraged by growers to manage price and market risks. Producer groups give smallholder producers bargaining power to reduce agricultural input costs such as equipment, fertilizer, and seeds (FAO, 2007). Producer groups also lower marketing risk by creating improved access to markets through storage, delivery, packaging, and branding. Producer groups can also leverage negotiating power for selling goods at contract and market prices. Producer groups also play an important role in information sharing, education, technology, and training opportunities for producers (Feyisa, 2016).

Formal Credit Institutions: Formal credit institutions can assist farmers in managing financial risks. These institutions provide financial services in the form of small loans or insurance that allow smallholder producers to invest in more profitable farm business ventures. However, the use of formal credit institutions can be limited by

high transaction costs, which are all the costs associated with conducting a business transaction such as travel time, financial literacy, and high collateral costs should farmers default on their loans. Collateral for loans is often in the form of land as it is one of the few production assets farmers possess (Agricultural Risk Management and Insurance, 2018).

3. Methodology

In this section, we describe the development of our questionnaire design, testing, and administration in order to accurately assess perceptions of risk and risk management strategies.

3.1 Risk and Risk Management Questionnaire Design and Administration

This study was conducted using a risk and risk management questionnaire collecting 1) demographic information about farm family and property attributes, 2) historical yields and prices for vegetable crops, 3) perceptions of risks in agriculture, 4) perceptions of risk-taking ability, 5) use and attitudinal assessments of eleven risk management strategies, and 6) access to risk management information and education. The questionnaire gathered data on basic demographic information to understand the sample population in the area. The questionnaire captured information on all vegetable crops grown in the last year and recorded up to five of the most recent yields and prices received for each crop. It also asked about crop failures including dates and causes. We needed to collect this information in order to construct a dataset with which to predict future yields and prices. Historical data for vegetable crops in Cambodia is nearly nonexistent.

e followed similar surveys in the existing literature (e.g, Koble et al., 1999; Meuwissen et al., 2001; Martin et al., 1998) when constructing the risk and risk management sections. Questions were contextualized for vegetable production as well as available marketing and financial options in Cambodia. The survey also captured farmer's willingness to take risks. Typically, the literature suggests using a likert scale (1-5). However, to accommodate for cultural perceptions observed when this scale was pre-tested, we determined that a larger scale could create more accurate distributions and tease out risk-taking ability and important risks faced by growers in this region more accurately. Risk-taking in production, marketing, finance and investment as well as general risk-taking ability were assessed on a scale from 0-10 (0=Not Risk Seeking At All and 10=Very Risk Seeking). A similar scale was used by Meuwissen et al. (2001) and Dohmen et al. (2011). The scale used in this study most closely follows Dohmen et al. who study responses toward risks and risk-taking ability on attitudinal scales and compared the outcomes with behavioral experiments to determine the usefulness of attitudinal scales in self assessments of risk. They argue that self-assessments of risk-taking abilities are accurately captured in comparison to behavioral experiments (Dohmen et al. 2011). For consistency, we applied this scale throughout the entire questionnaire.

The questionnaire assessed the importance of 20 sources of risk including an open ended section for growers to include additional risk sources. Use and attitudes toward 11 different risk management strategies as identified in the literature above were also included. In addition, an open ended section was included to capture strategies not listed in the survey. Attitudes toward risk management strategies assessed included 1) awareness of strategy 2) interest in using strategy 3) comfort in using strategy 4) perceived benefit to income of strategy 5) perceived risk to income of strategy. Finally, if growers did not participate in a particular strategy, they were asked to specify why. Pre-coded response options were given to growers, as well as an open ended option allowing them to state alternative reasons why a particular strategy was not being adopted. Participants who engaged in alternative risk management strategies were asked questions that allow us to estimate costs and benefits of employing these strategies. Finally, respondents were also asked to rank 16 sources of risk management information and education on a scale of 0-10. The results of this section will be used in order to determine the appropriate channels in terms of outreach, cost, and accessibility in order deliver information on risk management strategies to growers in the future. The complete survey can be found in Kiely et al. (2019).

We tested the validity of the questionnaire through three forms of content validity. First, the literature review was used to justify the content and design sections relevant to our research objective. A draft questionnaire was then examined by members of the SVVC project in order to determine the appropriateness of questions given the current state of the Cambodian vegetable sector and those who operate within. Finally, we piloted the questionnaire in Kandal Province with 10 vegetable growers and we analyzed the instrument and questionnaire responses for conceptual understanding and feasibility. Adjustment was made to the survey instrument to reflect this. Finally, the questionnaire was administered to five farmers in Battambang Province to assess adjustments to the instrument.

After completion of these initial surveys, it was determined that the questionnaire had obtained sufficient content validity and was used throughout the remainder of the fieldwork. Thirty vegetable growers were selected as respondents for the questionnaire. Fifteen growers were selected from both Tarsey and Anlongrun villages. The questionnaire was filled out during face-to-face interviews with the growers and the primary researcher and an interpreter, near the city of Battambang, Cambodia in the fall of 2017. All respondents had been growing vegetables for sale in local markets for a minimum of one year.

4. Results & Discussion

4.1 Household Demographics

To gain insight into the risk-taking ability and agricultural risks faced by Cambodian growers, as well as the importance of specific risk management strategies in context, we surveyed 30 smallholder farmers in two villages in Battambang province. Household demographics are shown in Table 1. The gender and age distribution as well as the family size between the villages surveyed were similar. Approximately 67% of the respondents were male, 33% were female and the average age of respondents was 43.5 years old. The average family size was 5.1 members. The land size and area under vegetable cultivation differed between villages. Farmers in Tarsey Village owned on average 1.36 hectares of land, while farmers in Anlongrun Village owned on average 2.47 hectares of land. The average area under vegetable cultivation on each farm surveyed in Tarsey Village was 0.25 hectares, while in Anlongrun Village it was 0.41 hectares.

Household Demographics

Variable	Tarsey Village	Anlongrun Village	Mean of total survey respondents (n=30)
Age	43.8	43.2	43.5
Respondent Gender (M%:F%)	67:33	67:33	67/33
# Household Members	5.2	5.1	5.1
# Household Members Working on Farm Full-time	1.9	2.6	2.3
# of Children in Household	2.6	2.7	2.6
Male Head of Household Age	45.9	45.0	45.4
Male Head of Household Education (%)[a]	0/47/47/7/0	13/73/13/0/0	7/60/30/3/0
Female Head of Household Age	44.3	41.5	42.9
Female Head of Household Education (%)[a]	27/27/20/13/7	27/67/7/0/0	27/50/13/7/3
Land area owned (ha)	1.36	2.47	3.4
Area under cultivation (ha)	0.54	1.52	1.03
Area under Vegetable Cultivation (ha)	0.25	0.41	0.48

[a] none/primary/secondary/high school/technical

Table 1.1 Household Demographics. Survey of 15 farming families in Tarsey Village and 15 farming families in Anlongrun Village

Income sources of farm families are displayed in Table 2. Despite the differences in cultivation area as exhibited in Table 1, growers in Tarsey village only generate $621 less per year in vegetable production than growers in Anlongrun. This may be due in part to a focus on leafy green vegetable production in Tarsey which requires few infrastructure inputs compared to vegetables such as cucumbers, grown on stakes and wires, often in Anlongrun. Additionally, leafy green vegetables can be harvested more frequently throughout the year. Growers in Tarsey also benefit due to their close proximity to the main road in the vicinity which may allow buyers to easily find these growers and lower buyer transaction costs. Income from aquaculture and personal business activities also vary between the two villages. Growers in Tarsey village almost solely relied on a water supply from a pond dug on their property which also provides an opportunity for aquaculture. Whereas, those in Anlongrun mainly sourced their water from a canal that meandered along the village, not allowing for the same income opportunity. Personal business activity is also likely a greater source of income for those in Tarsey village due to proximity the main road

as households often had roadside shops selling snacks, household supplies, gasoline, or offering services such as auto repairs.Income sources of farm families are displayed in Table 2. Despite the differences in cultivation area as exhibited in Table 1, growers in Tarsey village only generate $621 less per year in vegetable production than growers in Anlongrun. This may be due in part to a focus on leafy green vegetable production in Tarsey which requires few infrastructure inputs compared to vegetables such as cucumbers, grown on stakes and wires, often in Anlongrun. Additionally, leafy green vegetables can be harvested more frequently throughout the year. Growers in Tarsey also benefit due to their close proximity to the main road in the vicinity which may allow buyers to easily find these growers and lower buyer transaction costs. Income from aquaculture and personal business activities also vary between the two villages. Growers in Tarsey village almost solely relied on a water supply from a pond dug on their property which also provides an opportunity for aquaculture. Whereas, those in Anlongrun mainly sourced their water from a canal that meandered along the village, not allowing for the same income opportunity. Personal business activity is also likely a greater source of income for those in Tarsey village due to proximity the the main road as households often had roadside shops selling snacks, household supplies, gasoline, or offering services such as auto repairs.

Income sources of farm families are displayed in Table 2. Despite the differences in cultivation area as exhibited in Table 1, growers in Tarsey village only generate $621 less per year in vegetable production than growers in Anlongrun. This may be due in part to a focus on leafy green vegetable production in Tarsey which requires few infrastructure inputs compared to vegetables such as cucumbers, grown on stakes and wires, often in Anlongrun. Additionally, leafy green vegetables can be harvested more frequently throughout the year. Growers in Tarsey also benefit due to their close proximity to the main road in the vicinity which may allow buyers to easily find these growers and lower buyer transaction costs. Income from aquaculture and personal business activities also vary between the two villages. Growers in Tarsey village almost solely relied on a water supply from a pond dug on their property which also provides an opportunity for aquaculture. Whereas, those in Anlongrun mainly sourced their water from a canal that meandered along the village, not allowing for the same income opportunity. Personal business activity is also likely a greater source of income for those in Tarsey village due to proximity the the main road as households often had roadside shops selling snacks, household supplies, gasoline, or offering services such as auto repairs.

	Household Income		
Income Source (USD)	**Tarsey Village**	**Anlongrun Village**	**Mean income of respondents (n=30)**
Vegetable Production	2,151	2,773	2,462
Non-vegetable Cropping Activities	2,325	1,886	2,106
Perennial plantation crops	267	-	133
Birds	-	10	5
Cattle, Buffalo, Pigs	17	120	68
Aquaculture	131	-	65
Jobs outside HH farm	228	271	250
Personal business activity	480	15	248
Public transfer	34	-	17
Total Household Income	5,641	5,135	5,388

Table 1.2 Household Income Sources. Income sources (USD) of 15 farming families in Tarsey Village and 15 farming families in Anlongrun Village

4.2 Perceptions of Sources of Risk and Risk-Taking Ability

Understanding farmers' perceptions of risk allows us to identify risk-aversion levels and suggest the most appropriate management strategies. Farmers' perceptions of risk-taking ability were categorized by the different facets inherent in agricultural activities: crop production, marketing of crops, and finance and investment, in addition to a category capturing general risk-taking ability. In a series of four questions, respondents were asked to

rate on a scale of 0 to 10 how willing they are to take risks in the aforementioned categories (Fig. 1). All respondent's answers were then averaged to determine the average score of self-perceived risk-taking ability as shown here.

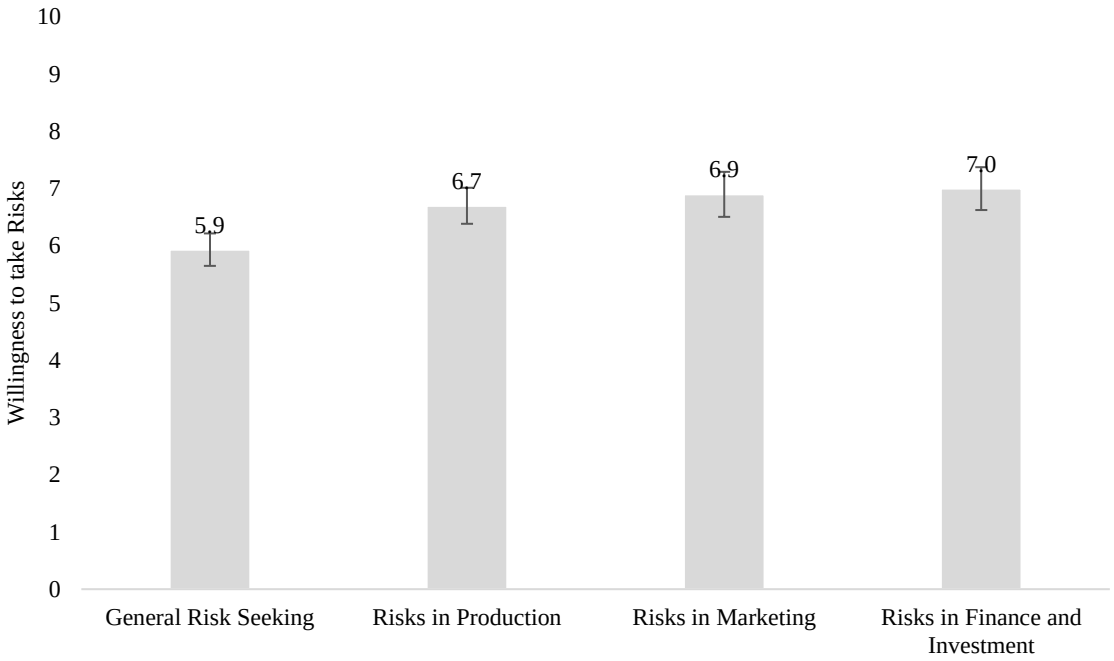

Figure 1.1 Self-Perceived Risk-Taking Ability. Average scored response of vegetable growers pertaining to risk-taking ability in agriculture as determined by four questions ascertaining degrees of risk-taking (where 0=Not Risk-Seeking at All and 10=Very Risk-Seeking).

The highest average score, representing the greatest level of risk-taking ability, was risk-taking in finance and investment. The lowest average score, representing the lowest level of risk-taking ability, was general willingness to take risks. This is interesting since it would be expected that general risk-taking ability would fall somewhere near the average of the three other categories. It is possible the three specific categories scored higher because they are areas in which respondents are well versed and have a good understanding of the relevant risks. This may likely explain why the scores for production and marketing are higher than general risk-seeking. However, since it is generally assumed that financial literacy is low among the rural poor, it might be expected that rural farmers would be most adverse to financial and investment risks. Therefore, it is surprising to see that growers responded to being most open to taking risks in finance and investment as they are likely to have less familiarity and exposure to the associated risks. Furthermore, despite the substantial difference in farm size and income between respondents in the two villages, no notable difference was identified in the perceptions of farmers towards risk. This suggests farmer perceptions towards risk are not dependent on farm size or income. Although the scope of this pilot study is limited, it is interesting to consider the idea that risk perception may be similar among the general population of Cambodian farmers.

Growers in Cambodia face risks on several fronts. Therefore it was important to capture potential risks faced and the degree to which these risks are a concern to growers. Realizing the most critical risk sources will enhance our ability to recommend applicable strategies to mitigate these risks. Assessing discontinuities between areas of risk-taking ability and actual risks faced is another important reason why this information is important to gather. If a misalignment of risk-taking ability and risks exists, then management and training practices will be of even greater importance to bring awareness and action in alleviating these risks. Twenty sources of risk were considered in the questionnaire in order to ascertain the most burdensome risks growers encounter. Respondents were asked to score their perception of these twenty sources of risk on a scale of 0 to 10 in terms of their potential to affect farm income. Scores from all respondents were averaged and reported in categories grouped by related source of risk: price,

production, financial, marketing, and personal risks (Fig. 2).

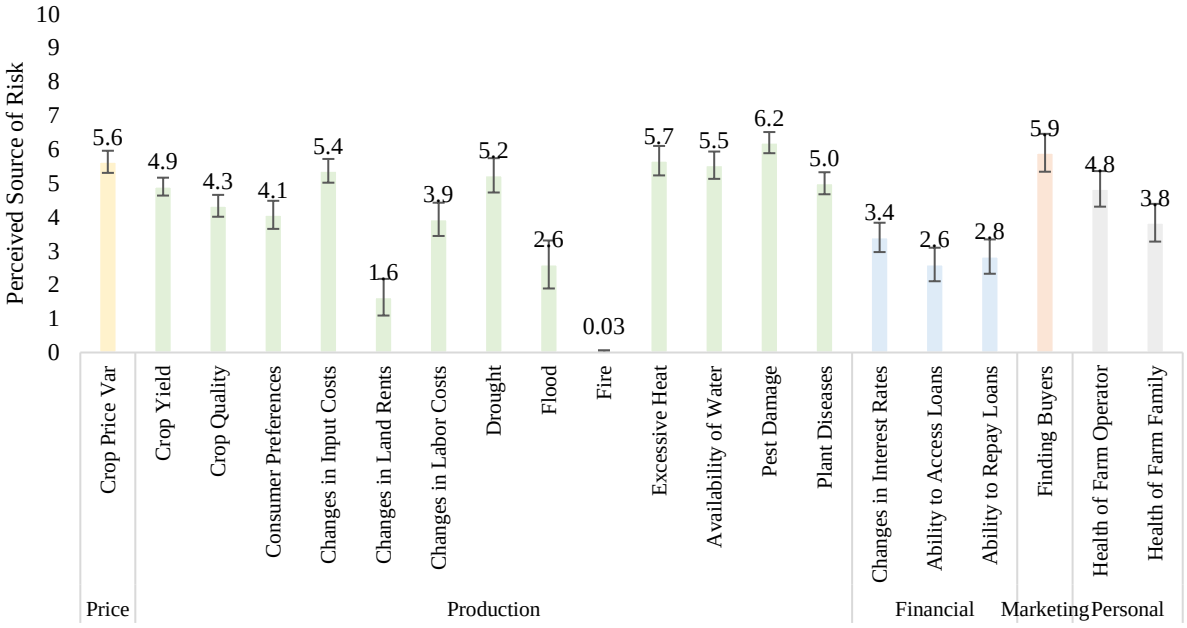

Figure 1.2 Perceived Sources of Risk to Vegetable Farming. Average scored response for perceived sources of risk in agriculture by 30 vegetable growers as determined by the 20 listed sources of risk rated in terms of their potential to affect farm income (where 0=Low Potential Effect on Farm Income and 10=High Potential Effect on Farm Income).

Sources of risk that received an average score of 5 or above with the inclusion of their standard error were considered highly relevant risks and those falling below five were considered irrelevant. Farmers perceived the most relevant sources of risk to be pest damage (score 6.2) and finding a buyer (score 5.9). These results are consistent with findings from other investigations (LeGrand et al. 2018). Other relevant sources of risks included: excessive heat (score 5.7), crop price variability (score 5.6), availability of water (score 5.5), and changes in input costs (score 5.4). These risks mainly pertain to extreme weather events likely to worsen in Cambodia as climate change brings higher temperatures to the area for longer periods of time as well as exogenous prices the growers cannot affect as price-takers. Finally, other relevant sources of risk include: drought (score 5.2), plant diseases (score 5.0), crop yield (score 4.9), and health of farm operator (score 4.8). It is interesting to note that crop yield as a risk source is lower than many of the sources that directly cause crop loss. The remaining 11 risk sources were deemed irrelevant. Interestingly, it seems that financial sources of risk were viewed as irrelevant, potentially due to the inability of producers to access financial resources. Whereas, growers stated they would be most willing to take risks associated with finance and investment. Perhaps growers are more willing to take risks in this area as the available set of financial risks are likely to significantly alter income levels. From these results, it seems that the highest scoring sources of risk center around frequently faced exogenous factors associated with both production and marketing such as weather, pests, price volatility, and transaction costs. Understanding these results will help to inform the appropriate risk management strategies to incorporate.

4.3 Risk Management Strategies

Eleven risk management strategies were evaluated based on their ability to mitigate risk exposure faced by farm families. In the following sections, we analyze these risk management strategies based on their existing usage, growers' awareness and attitudes toward the strategies, and growers' perceived benefits and risks toward farm income through strategy incorporation.

4.3.1 Current Engagement with Risk Management Strategies

This section details the current usage of each risk management strategy. It is important to understand what strategies are currently being leveraged and their availability to growers. Additionally, we seek to identify if growers rely heavily on traditional risk management strategies or if there is local institutional capacity for alternative risk management strategies. Respondents were asked to state whether or not they currently engage in each of 11 risk management strategies. Figure 3 below displays the current use of these strategies.

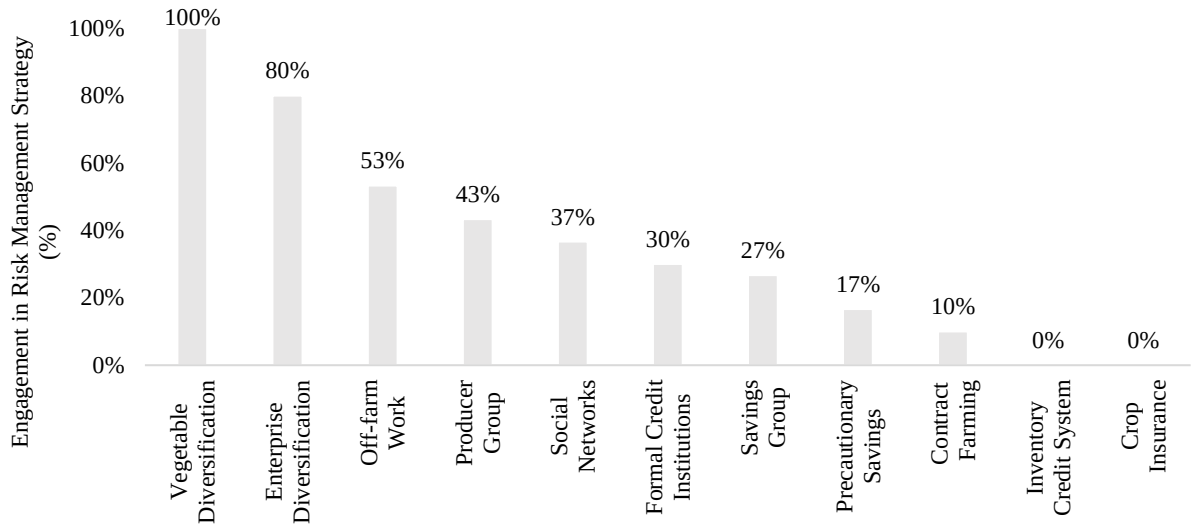

Figure 1.3 Current Engagement of Vegetable Growers with 11 Risk Management Strategies. Percent of vegetable growers currently engaged in each of 11 selected risk management strategies as determined by one yes/no question in questionnaire

All respondents were pre-selected on the basis of vegetable production and therefore it comes as no surprise that 100% of respondents grow a diverse set of vegetables as vegetables can be highly seasonable, forcing growers to plant different varieties to provide year-round income. Enterprise diversification has also been adopted by 80% of respondents. Enterprise diversification mainly came in the form of rice production or the raising of poultry, fish, or ruminants both for income and family consumption. Respondents had moderate engagement with the traditional risk management strategies of off-farm work, and social networks, while having low engagement in precautionary savings. Respondents listed lack of access to savings and capital or an inability to repay loans as the primary reason for not engaging in these strategies. In terms of alternative risk management strategies, respondents had moderate engagement in producer groups and formal credit institutions, and low engagement in savings groups and contract farming. Respondents primarily stated that these alternative strategies were unavailable to them and secondarily stated unawareness of these strategies. The use of inventory credit systems and crop insurance is nonexistent as these risk management tools are currently unavailable to growers. While many of the alternative risk management strategies currently have low engagement rates, attitudinal assessments should be conducted to determine if usage rates would change if these strategies were made available.

4.3.2 Attitudes towards Risk Management Strategies

We seek to understand the attitudinal assessments of risk management strategies by growers to allow insights into their current awareness and receptiveness of these strategies. If levels of awareness are low while interest and comfort in using the strategy are high, farmer trainings can be leveraged in order to facilitate understanding of the strategy. Additionally, it would be evident that those receptive to adoption while displaying low levels of awareness may be more likely to adopt the strategy if it is made aware and available to growers. Respondents' average attitudinal assessments of risk management strategies are displayed below in Figure 4. In terms of awareness of strategies, results are grouped into clusters of high, moderate, and low levels of awareness. The high awareness cluster includes vegetable diversification and enterprise diversification which received average scores of 6.1 and 5.6 respectively. As these strategies had the highest levels of engagement it is not surprising to see this result. The moderate awareness cluster ranged from 3.5-4.5 and includes the traditional risk management strategies of off-farm work, precautionary savings, and social networks. The moderate awareness cluster also included the alternative risk

management strategies of contract farming, savings groups, and producer groups. The low awareness cluster ranged from 1-3 and includes the alternative strategies of formal credit institutions, crop insurance, and inventory credit systems. It is not surprising to see formal credit institutions in the low awareness cluster as its use is rather low and it is viewed as the riskiest strategy. Crop insurance and inventory credit systems likewise are not offered at all which also explains their low awareness. It is surprising to note that savings groups and precautionary savings were in the low awareness cluster. It is likely that survey respondents did not have access to financial tools such as savings accounts and indeed it seems that growers rarely have savings in the first place. However, the idea of setting some money aside for hard times does not appear to be something they actively engage in. Savings groups had a rather low level of use according to survey respondents but it is surprising to see the level of unawareness of this strategy. Several growers responded that they did not belong to a savings group but knew that groups existed nearby.

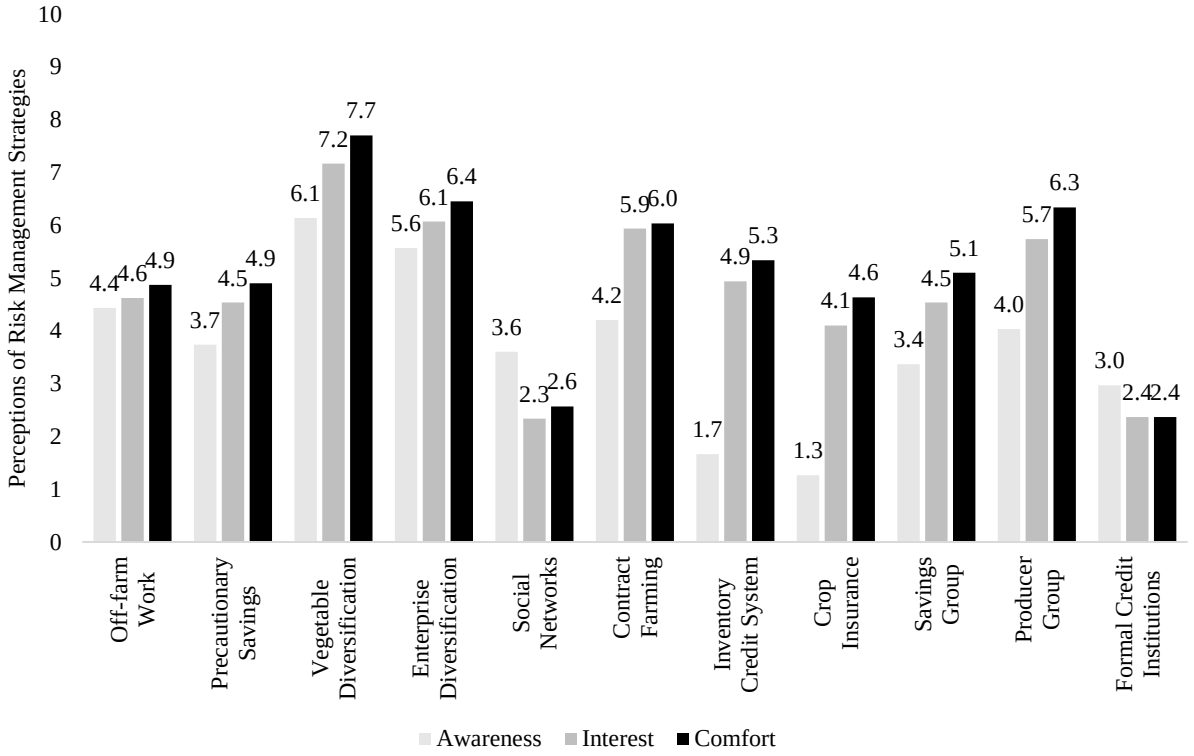

Figure 1.4 Attitudes toward Risk Management Strategies. Awareness, interest, and comfort of engaging in risk management strategies as determined by questionnaire were scored (where 0=Not Aware/Interested/Comfortable At All and 10=Very Aware/Interested/Comfortable) and averaged.

Interest in risk management strategies can again be grouped into high, moderate, and low interest clusters. The high interest cluster ranges from 6.5-7.5 and includes the traditional strategies of vegetable diversification and enterprise diversification as well as the alternative strategies of contract farming and producer groups. High interest levels in contract farming and producer groups are unsurprising as they are actively being implemented in these communities. The moderate interest cluster ranges from 4.0-5.0 including the traditional strategies of off-farm work, precautionary savings and the alternative strategies of inventory credit systems, crop insurance, and savings groups. Inventory credit systems and crop insurance both exhibit the highest difference in awareness and interest (3.2 and 2.8 respectively) suggesting these strategies may have high adoption rates if implemented. Finally, the low interest cluster ranges from 2.0-2.5 and includes social networks and formal credit institutions suggesting to an adverseness to loans and indebtedness.

Perceived comfort follows a very similar pattern with interest in risk management strategies. The high comfort cluster ranges from 6.0-8.0 and includes vegetable diversification, enterprise diversification, producer groups, and contract farming. Vegetable and enterprise diversification have the highest levels of engagement so it is

unsurprising to see that growers are comfortable in using them. Producer groups and contract farming are the two alternative strategies that have been presented to farmers with active implementation. The middle comfort cluster ranges from 3.0-5.5 and includes inventory credit systems, savings groups, off-farm work, precautionary savings, and crop insurance. Again the difference between awareness and comfort in inventory credit systems and crop insurance are larger than any other strategy, suggesting high adoption if these strategies are made available to growers. The low comfort cluster ranges from 2-3 and is made of up of social networks and financial credit institutions, just as in the interest category.

4.3.3 Perceived Benefits and Risks

To shed light on the strategies growers may be likely to adopt, questions were asked about the perceived benefits and risks to income of incorporating these 11 risk management strategies. The average perceived benefits and risks to income of engaging in each of the 11 selected risk management strategies, were rated by respondents from 0 to 10 and averaged (Fig. 5). The average perceived benefit score (light grey bars) was then compared to the average perceived risk score (dark grey bars) to determine whether farmers perceived each risk management strategy as an overall net benefit (green bars) or net risk (red bars).

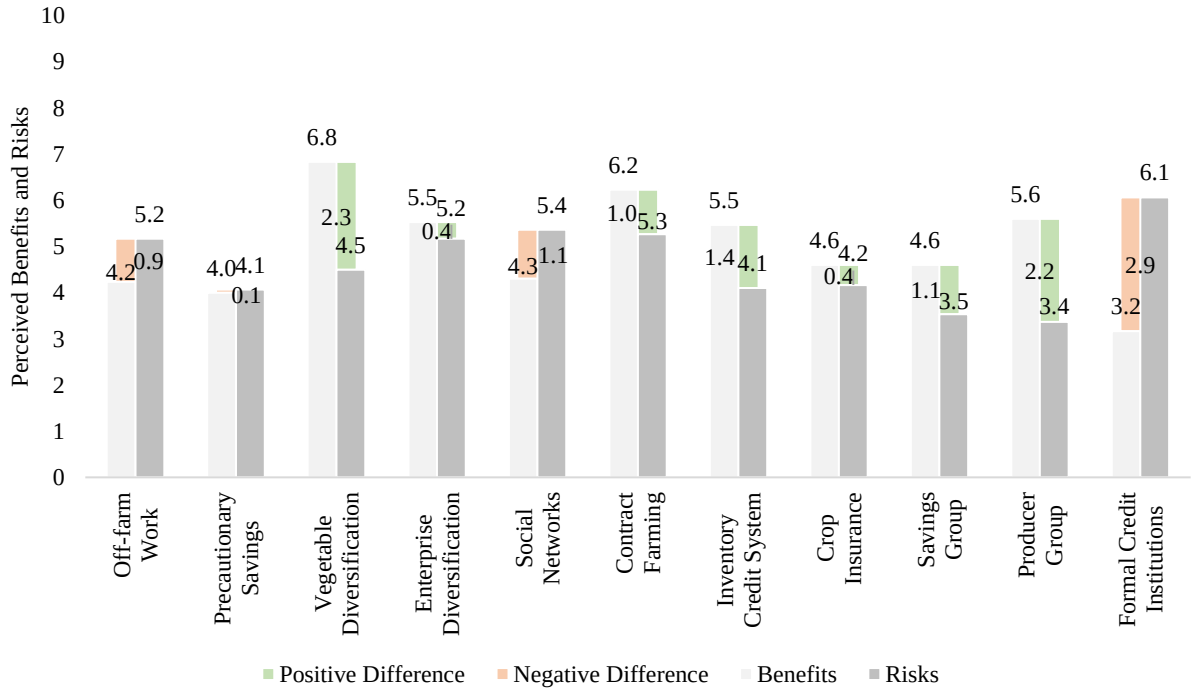

Figure 1.5 Perceived Benefits and Risks of Risk Management Strategies. Average scored response of perceived benefits (light gray) and risks (dark gray) of risk management strategies as determined by two scored responses ranging from 0-10 from questionnaire. A negative difference (red) indicates perceived risk is higher than perceived benefit, while a positive difference (green) indicates perceived benefit is higher than perceived risk (where 0=Not Beneficial or Risky At All and 10=Very Beneficial or Risky).

Three traditional risk management strategies, off-farm work, precautionary savings, and social networks, had average perceived risk scores which outweighed their perceived benefits. Of the strategies where average benefits had higher scores than average risks, the traditional strategies included vegetable diversification (+2.3) and enterprise diversification (+0.4). Vegetable diversification also had the highest positive difference between benefits and risks. All alternative risk management strategies had higher average benefit scores than risk scores with the exception of formal credit institutions. Of the alternative risk management strategies, contract farming received the highest score in terms of perceived benefits to income (6.2) while producer groups had the highest difference between benefits and risks (+2.2) as well as the lowest perceived risks (3.4). It is interesting to note that growers seem more receptive to the alternative strategies. Perhaps through experience growers have realized some traditional strategies do not significantly increase household income and view alternative strategies as unknown

income shifters. The exception of course in vegetable diversification, which is likely due to vegetables being cash crops with low inputs costs. Selection bias is also a likely issue with the high positive difference in vegetable diversification. If these growers did not see the benefits of this strategy, it is likely that they would have stopped growing vegetables and would thus not be included in this survey. The high negative difference between formal credit institutions (-2.9) is misaligned with growers earlier statements that they are willing to take risks in the area of finance and investment. Therefore, it seems that a strategy should be presented to the growers that offers financial assistance without the need for formal institutions.

4.4 Recommendations

These assessments of use, awareness, and attitudes towards traditional and alternative risk management strategies allow us to make determinations as to which alternative strategies to recommend. In order to address the most relevant risks identified by growers, strategies that focus on 1) securing buyers, 2) market prices, 3) addressing costs of inputs and 4) minimizing crop damages due to natural events should be prioritized. The two alternative market strategies available to address securing buyers and market prices are contract farming and inventory credit systems. It is recommended that contract farming be used in favor of inventory credit systems as contract farming continuously secures a buyer whereas an inventory credit system simply lengthens the time available to find a buyer and can increase transaction costs of operation. Contract farming also stabilizes the prices received by growers reducing uncertainty of income and allowing for better future planning and investment. While inventory credit systems can allow growers to capture spikes in market prices that exceed contract prices, the uncertainty of these prices places great risk on the part of the grower and it is possible that growers would find greater utility from stable prices rather than continually attempting to capture high market prices, not obtained with certainty. Perhaps most importantly, contract farming is likely to be a preferred strategy over an inventory credit system when it comes to horticultural products as the latter needs the appropriate cold chain technology in order to function properly as horticultural crops are highly perishable and cannot be stored indefinitely. Currently, cold chain technology in the post-harvest production process is limited in its use and availability in Cambodia. While the current SVVC project is working to introduce cold storage through coolbots, it does not seem like an inventory credit system is the optimal current pathway for growers. Therefore, as contract farming has higher levels of current use, awareness, interest, comfort, and perceived benefits, as well as having the ability to be implemented in the near future, contract farming will be the alternative marketing risk management strategy recommended for implementation.

Finally, growers indicate that the exogenous factors caused by natural events such as extreme weather conditions and pests are some of the biggest risks faced. While this particular study does not focus on tangible agricultural risk management strategies that can negate the yield losses from these events, the introduction of crop insurance is a potentially viable method to introduce to growers. Crop insurance can be an income smoothing strategy when crop losses reach a certain threshold and thus is the main alternative risk management strategy considered in this research to mitigate production risks. Therefore, crop insurance is the recommended intangible risk management strategy recommended to alleviate production risks faced by growers.

4.4.1 Producer Groups and Savings Groups

Changes in the costs of agricultural inputs can be addressed through the formation of producer groups. This alternative risk management strategy can allow a collective of farmers to obtain bargaining power, enabling them to receive bulk pricing discounts on input supplies. Additionally, a producer group can have the added benefit of ensuring that the procured input supplies are of high quality, a major issue growers struggle with in Cambodia. Indeed, the SVVC project has just begun to form a producer group "Tasey Smaki Agricultural Cooperative" (TSAC). This recently formed group no doubt influenced survey results of use of and attitudes toward producer groups. However, as a producer group addresses some of the major risks identified by farmers including input costs and the marketing and labeling of produce, in addition to the benefits of information-sharing, producer groups remain a highly recommended alternative risk management strategy. As TSAC has only recently been formed, it is unclear at this time what growers ultimately want the producer group to achieve. However, it is advised that in addition to bargaining to reduce input costs, the producer group be used to leverage negotiations of contract farming output prices and serve as a platform for technology and information sharing, grower training workshops, and the introduction and development of savings groups.

Savings groups offer an alternative method of financial and capital access to smallholder growers incapable of accessing traditional lending institutions. It is encouraged that growers belonging to TSAC be given the opportunity to opt-in to the savings group with access to a savings account earning an agreed upon interest rate as well as the opportunity to secure small loans which can, for example, be used to purchase expensive inputs such as tillers,

tractors, or irrigation supplies that may otherwise not be accessible. It is suggested that growers consider organizing the savings group as a "shared interest savings group" (SISG). In addition to accessing savings and small loans, a SISG is comprised of members with common interests across the agricultural supply chain. The SISG allows for open dialogue to identify agricultural and supply chain issue, test solutions, and apply early scaling of agricultural technologies (LeGrand, 2018). As the savings group falls under the umbrella of the producer group, the "shared interest" component of the savings group should not be difficult to develop. Membership to the SISG should, however, not be limited to producer group members. Other community members should be encouraged to join and engage in participatory learning and information-sharing to promote food safety practices, technology adoption, market access, and financial access and inclusion.

4.4.2 Contract Farming and Crop Insurance

The results of this study suggest the implementation of contract farming and crop insurance would alleviate some of the greatest risks faced by growers. Additionally, these growers already seem highly receptive to implementing these risk management strategies. Contract farming, through the production of pesticide-free vegetables, as displayed in the Horticultural Innovation Lab model, would alleviate pest damage, the pressure of securing a buyer, and crop price variability, three of the greatest concerns expressed in the questionnaire. While crop insurance cannot directly stabilize crop price variability, pest damage, or excessive heat, it can act as an income-smoothing strategy to mitigate the impacts of production risks and also has the potential to buffer income when market prices fall. Thus this management strategy also mitigates major production risks. Although these strategies may address many production risks, adoption off technologies, techniques, and practices is often difficult to overcome. However, farmers seem to respond favorably to these two risk management strategies presently. As seen in Figure 5, on average, farmers weighed the benefits of contract farming and crop insurance greater than the risks of incorporating these strategies. Additionally, farmers displayed high levels of interest and confidence in utilizing contract farming (Figure 4) while also exhibiting fairly high levels of interest and confidence in employing crop insurance despite having lower levels of awareness of this strategy than any other strategy. Therefore, it appears likely that high demand would exist for these opportunities if offered. However, these two strategies represent two of the three lowest levels of engagement of the risk management strategies surveyed. It seems evident that creating programs focused on the implementation of crop insurance and contract farming is low-hanging fruit for the Cambodian government and development organizations operating in the country.

It is likely that the introduction of crop insurance will have to be implemented by the Cambodian government. At the very least, private companies must be backed by the government in order to make crop insurance successful as the covariate risks associated with farming often make it infeasible for private companies to generate a profit. Additionally, information asymmetries such as adverse selection and moral hazard make it difficult for private insurance companies to exist within agriculture. Therefore, it is suggested that crop insurance be backed by the government and subsidized so as to be affordable for growers. If the government of Cambodia is serious about meeting domestic vegetable demand and alleviating poverty amongst its citizens, the impact of crop insurance cannot be denied.

The implementation of contract farming will lead to increased uptake in recordkeeping of crop yields. This may pave the way for the establishment of long-term, well-structured crop insurance that relies on a history of crop yields in order to effectively determine significant yield losses. Often, the yield history at each farm is used, however, area wide yields can also be used. By collecting extensive data from these farmers, area-wide yields can be determined, thus paving the way for crop insurance. Additionally, as vegetable farmers often produce many vegetable types, insurance programs may find that crop insurance is impractical in its ability to cover all types of vegetables. However, bundling many vegetables grown in this area under "leafy greens" or under the brassicaceae family will help to eliminate this issue. Additionally, using adjusted gross revenue insurance (AGR) would eliminate this impracticality by focusing instead on revenue as opposed to crop-by-crop yields. In order to facilitate greater demand and eventual adoption of these strategies, financial literacy workshops need to be established to familiarize growers with these concepts and display the benefits these tools offer. Based, on the questionnaire results, it seems that growers prefer workshops organized by universities and NGOs which should both be leveraged to accomplish this goal.

4.5 Training and Education Preferences to Implement Risk Management Strategies

Risk management strategies also need a platform in which training and education can be disseminated to growers. To help determine the types of information dissemination strategies with the most potential to meet the needs of

vegetable growers, we asked growers a series of questions to determine their preferences for training and education (Fig. 6).

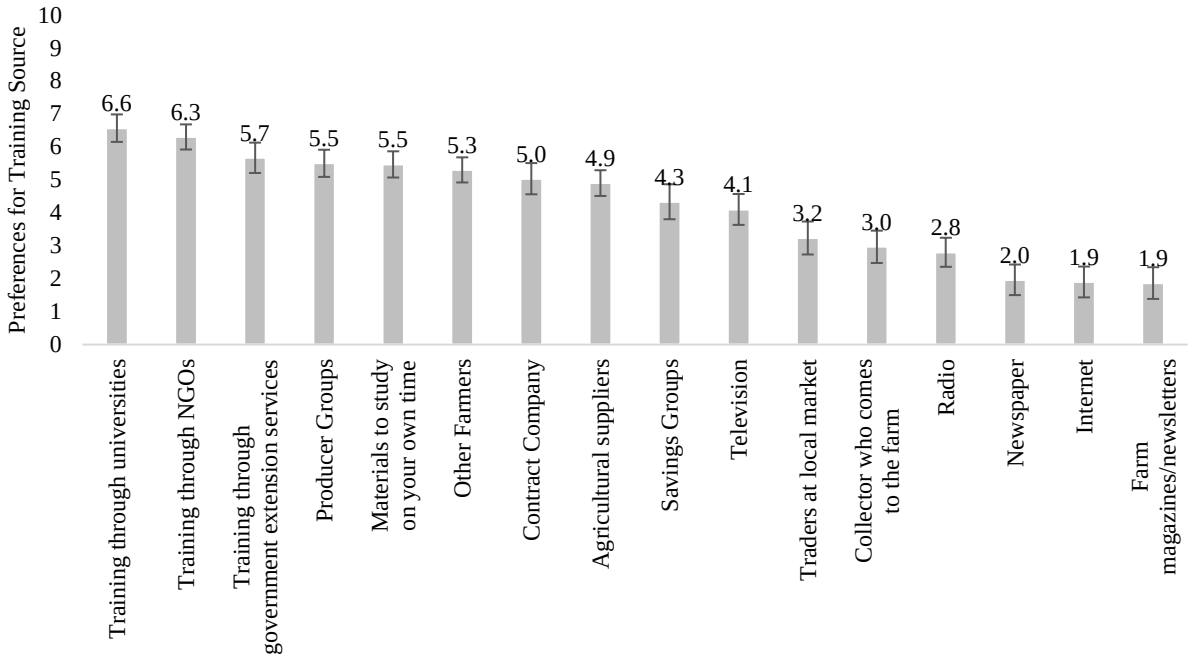

Figure 1.6 Producer Preferences for Training and Education. Average Scored Response for 16 Preferred Sources of Training and Education on Risk Management Strategies as Determined by Scored Responses from the Questionnaire (where 0=Low Preference and 10=High Preference)

Farmers reported the highest preference for training and education would be through universities and NGOs (average scores 6.6 and 6.3, respectively). The moderate preference cluster ranged from 4.0-6.0 and includes training through government extension agencies, producer groups, self-learning, other farmers, contract companies, agricultural suppliers, savings groups, and television. The low preference cluster ranged from 2.0-4.0 and includes local traders, collectors, radio, newspaper, internet, and farm magazine/newsletters. It is advisable that the recommended alternative risk management strategies be delivered through the established producer group by universities or NGOs specializing in educating growers on each of the respective strategies. The SVVC team and TSAC have established a "Safe Agriculture Learning Center" which can raise awareness of alternative risk management strategies that growers are unfamiliar with such as crop insurance. This platform may also raise interest, comfort, and perceived benefits in using these strategies while simultaneously lowering the perceived risks as growers receive more information and become more familiar with the strategies.

Chapter 2: Economic Analysis of Vegetable Production and Alternative Risk Management Strategies through Land Use System Simulations

5. Literature Review

5.1 Expected Utility Theory

The risk ranking procedures used throughout the analysis of this study are established upon the assumptions of expected utility theory (EUT). EUT states that "the decision maker chooses between risky or uncertain prospects by comparing their expected utility values" (Davis et al., 1997). These expected utility values are the subjective value that an individual associates with a gamble. Expected utility is given by the expression:

$$E[u(x)] = \int_{-\infty}^{\infty} u(x)\, f(x)\, dx$$

Where f(x) is the probability density function of the outcome. Expected utility theory is a popular choice in determining decision maker's choices as opposed to expected value which only accounts for the probability of an event and its payout but not the risk associated with the gamble.

5.2 Risk Aversion Coefficients (RACs)

Several measures of risk aversion exist under EUT depending on the utility function used. In this study, both negative exponential utility and power utility functions will be used to evaluate alternative scenarios. As suggested by Anderson and Dillon, the power utility function has a relative risk aversion coefficient (RRAC) ranging from -1-4, as displayed in Table 2, where -1 captures risk loving individuals and 4 captures extremely risk averse individuals (Anderson and Dillon, 1992). Hardaker suggests that the negative exponential utility function display absolute risk aversion coefficients (ARAC) which are the relative risk coefficients divided by the initial wealth of the decision maker (Hardaker, 2007).

	ARAC (Negative Exponential)	RRAC (Power)
Risk-Seeking	-1/W	-1
Risk-Neutral	0	0
Hardly Risk-Averse	0.5/W	0.5
Normal Risk-Aversion	1/W	1
Rather Risk-Averse	2/W	2
Very Risk-Averse	3/W	3
Extremely-Risk Averse	4/W	4

Table 2.1: Risk Aversion Coefficient (RAC) Table for Negative Exponential Utility and Power Utility Functions

5.3 Stochastic Dominance with Respect to a Function (SDRF)

First introduced by Meyer (1977), stochastic dominance with respect to a function (SDRF) ranks risky alternatives for a class of decision makers whose utility function can be defined by a lower risk aversion coefficient (LRAC) and an upper risk aversion coefficient (URAC). In Simetar, the preferred risky alternative is calculated for both the LRAC and the URAC. If the same risky alternative is preferred in both RACs, then it is considered to be in the risk efficient set. If the SDRF ranking is different for the LRAC and URAC then the decision makers are considered to be indifferent between the two alternatives. The benefit of the SDRF is that it can be used to compare two alternatives whose CDFs cross. However, the downside of the tool is that it is a pairwise comparison of alternatives and not a simultaneous ranking of all alternatives. Additionally if the RACs are set too far apart then many of the alternatives may fall in the efficient set. However, setting the RACs too close together is not necessarily useful for decision makers (Richardson, 2008).

5.4 Stochastic Efficiency with Respect to a Function (SERF)

Stochastic efficiency with respect to a function (SERF) evaluates the certainty equivalents at 25 equal intervals across the RACs (as opposed to SDRF, solely evaluating at the extremes). Therefore, using SERF one can observe

the ranking of each of the risky alternatives throughout the range of RACs. Using the SERF chart, one can compare two risky alternatives F(x) and G(x) as defined by Richardson:

1. G(x) is preferred to F(x) over the entire range of RACs where $CE_G > CE_F$.
2. Indifference occurs between G(x) and F(x) when $CE_G = CE_F$, or a break even risk aversion coefficient (BRAC).
3. F(x) is preferred to G(x) over the entire range of RACs where $CE_F > CE_G$.

A positive CE line on the SERF chart is interpreted as rational decision makers preferring the risky alternative to a risk free alternative regardless of risk aversion level. But if the CE line is negative then rational decision makers would choose the risk free alternative to the risky alternative. The vertical distance between the alternative strategies is the confidence premium of the dominant strategy over the other strategies (Richardson, 2008).

5.5 Stoplight Charts

A stoplight chart is the final risk ranking procedure considered in this analysis. The tool is appropriate as it is easy for decision makers to conceptualize without any economic training. By selecting two probability targets, a lower target and a higher target, the stoplight function calculates the probabilities of 1) exceeding the upper target (indicated in green) 2) being less than the lower target (indicated in red) or 3) being between the upper and lower target (indicated in yellow). The results then indicate a favorable, cautionary, and unfavorable probability (green, yellow, and red, respectively) of engaging in the risky scenarios. In this analysis, net present value is the only KOV analyzed using stoplight charts as it is seen as the most pertinent outcome variable for these decision makers.

6. Methodology

6.1 Baseline Land Use System Model

6.1.1 Input Prices

2016 nominal prices were recorded for inputs and hired labor wages across all farms. An inflation rate of 2.89% was then applied to all inputs across all 10 years of the system. The inflation rate was determined by taking the average quarterly inflation rate during the years 2008-2017 (TradingEconomics, 2018). Inputs for vegetable production in Cambodia typically include start-up labor and inputs such as well drilling, small tillers and PVC irrigation systems, and annual labor and inputs including hand weeding, harvesting, cow manure, and urea. A comprehensive list of inputs and outputs captured can be found in Appendix 1.

Wages: In order to value the time of family labor, a minimum wage of 2,733 Riel/hour was applied to all input activities carried out by family labor. The minimum wage in Cambodia is $164/month (TradingEconomics, 2018). This was converted into an appropriate hourly wage for unskilled labor. The 2.89% inflation rate was also applied to family labor wages across all 10 years of the system.

6.1.2 Output Prices

The questionnaire recorded the five most recently received market prices for each vegetable crop grown in the last year under each grower. All market prices were then compiled together in order to simulate stochastic future prices for each crop. For chili, green pepper, luffa, and wax gourd GRKS distributions were used to simulate future prices. A GRKS distribution, developed by Gray, Richardson, Klose, and Schumann, is a distribution based on minimal historic information. Due to a dearth in data collection and recordkeeping of historical prices and yields, limited market prices exist for these crops. Additionally, only a limited number of data points were collected for these crops in the questionnaire. A GRKS distribution uses a minimum, midpoint, and maximum value to generate a distribution of possible outcomes where 50% of the observations are above the midpoint value and 50% of observations are below the midpoint value. Additionally, 2.5% of observations from the distribution fall below the minimum value and 2.5% of observations are above the maximum value to account for possible outliers (Richardson, 2008). The cumulative distribution functions (CDFs) of the GRKS distributions can be seen in Figure 1 below. For all other vegetable crops, empirical distributions were created to simulation future market prices. The empirical distributions were simulated as percent deviations from trend (Richardson, 2008). The CDFs of the empirical distributions can be seen in Figures 2 and 3 below. The market prices were then simulated and multiplied by the inflation rate of 2.89% across all 10 years of the system. The market prices were then multiplied by their respective crop yields throughout the system to assess the economic performance of the system.

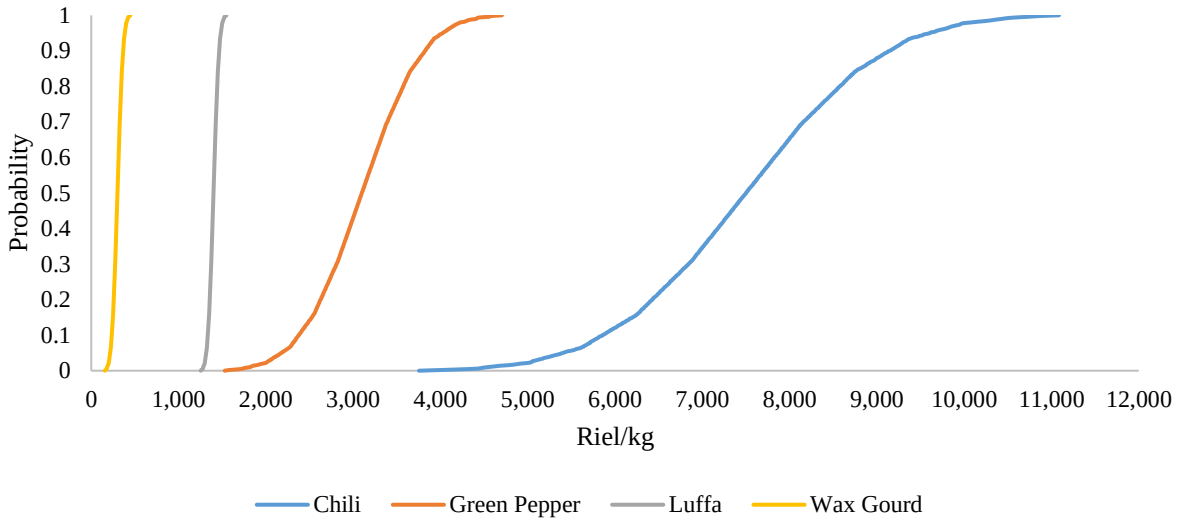

Figure 2.1: CDFs for GRKS Distributions of Vegetable Market Prices (Riel)

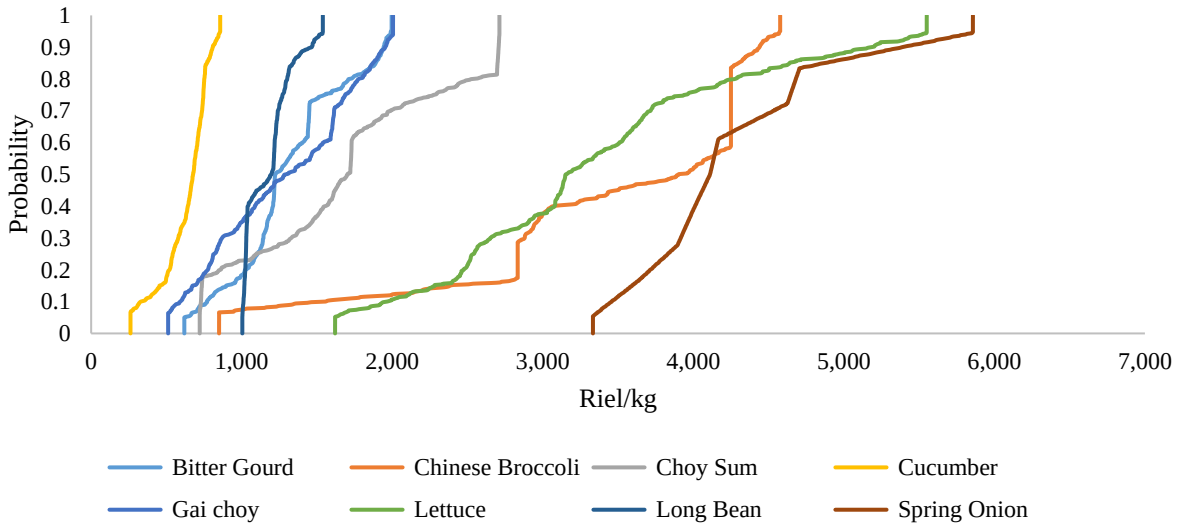

Figure 2.2: CDFs for Empirical Distributions of Vegetable Market Prices (Riel)

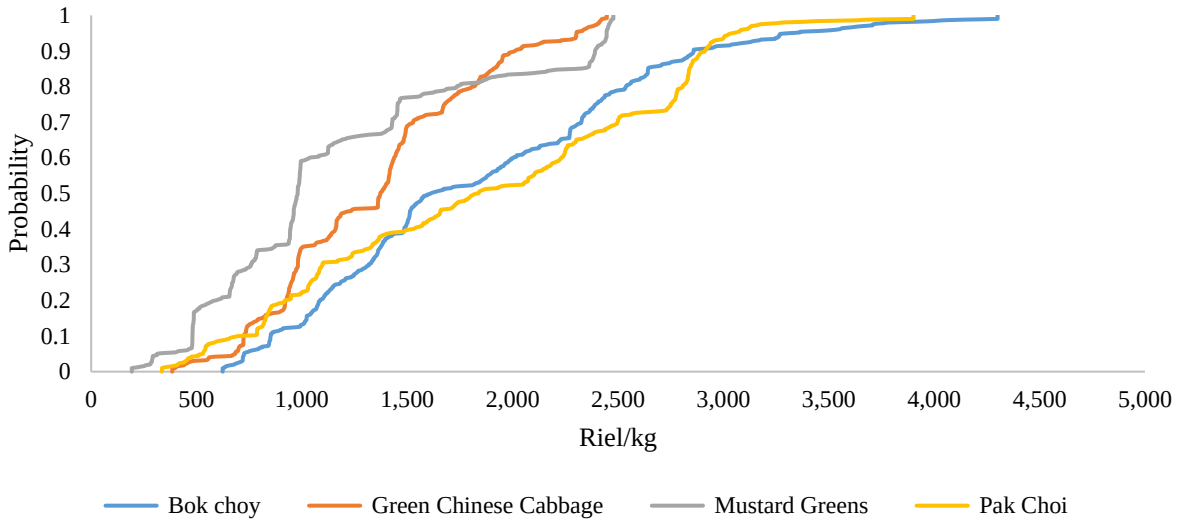

Figure 2.3: CDFs for Empirical Distributions of Vegetable Market Prices (Riel)

6.1.3 Yields

The five most recent yields were recorded for each vegetable crop grown in the last year under each grower. Crop yields from all growers were then compiled together on a kg/m^2 yield basis. For chili, green pepper, luffa, and wax gourd a GRKS distribution was again used to simulate future yields. It was determined through the questionnaire that total crop failure occurs 4.43% of the time over all crops. Therefore, the GRKS distributions were modified to include this crop failure rate for all yields modeled under this distribution. For all other vegetable crops, empirical distributions were created to simulation future yields. The empirical distributions were simulated as percent deviations from yield means (Richardson, 2008). Empirical yield distributions were also modified to include a total crop failure rate of 4.43%. The crop kg/m^2 yield simulations were then multiplied by the size each respective vegetable plot on each farm.

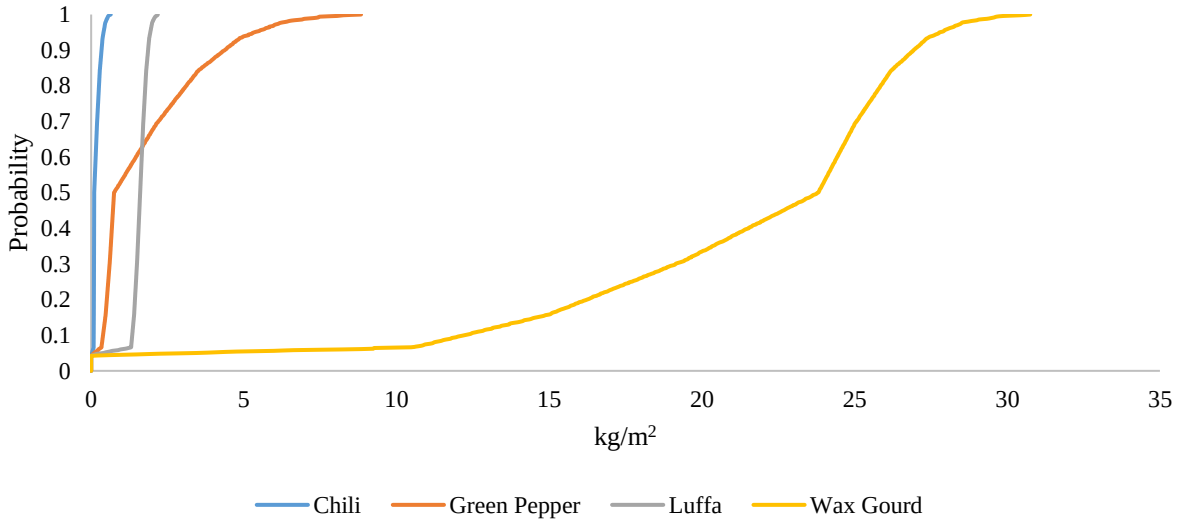

Figure 2.4: CDFs for GRKS Distributions of Vegetable Yields (kg/m^2)

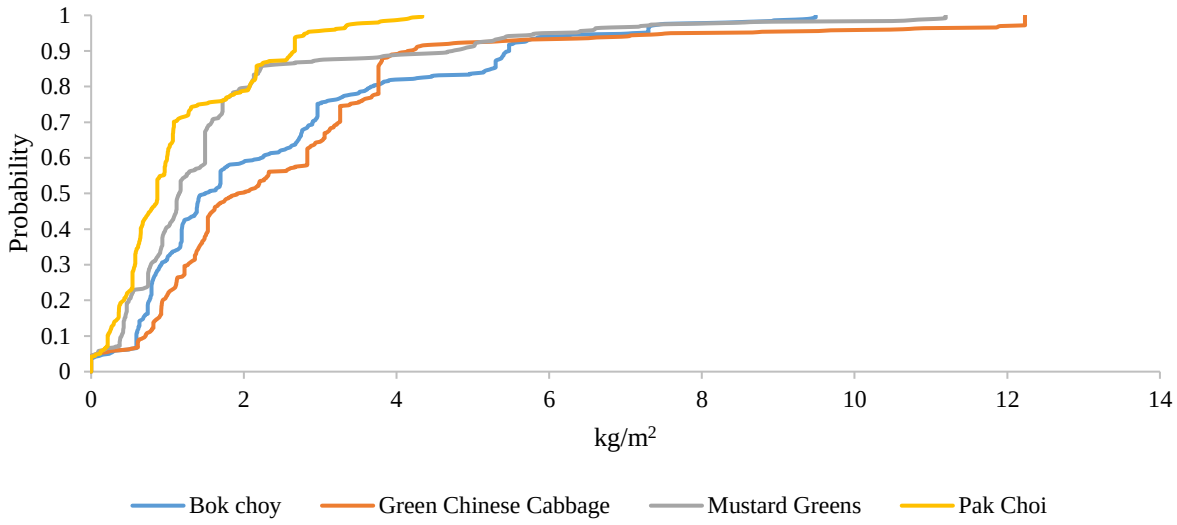

Figure 2.5: CDFs for Empirical Distributions of Vegetable Yields (kg/m^2)

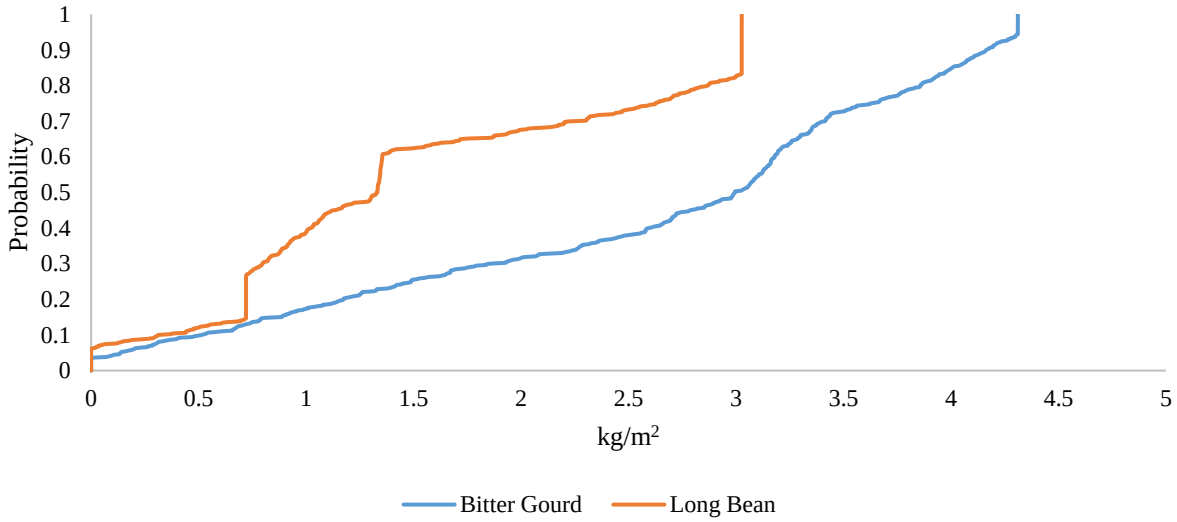

Figure 2.6: CDFs for Empirical Distributions of Vegetable Yields (kg/m^2)

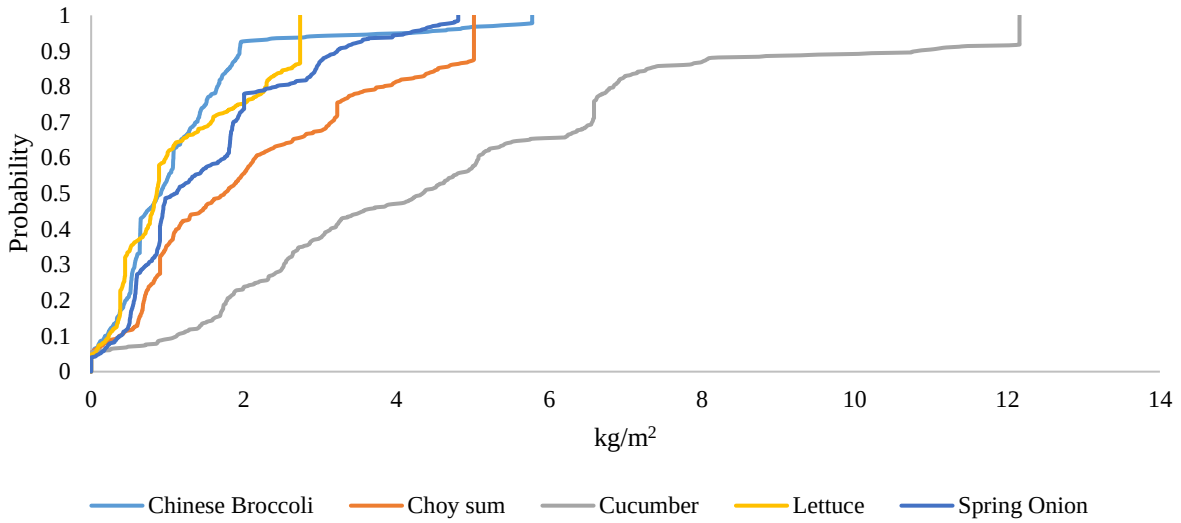

Figure 2.7: CDFs for Empirical Distributions of Vegetable Yields (kg/m^2)

6.1.4 Discount Rate

The discount rate is used to determine the present value of future cash flows. A sensitivity analysis was conducted using discount rates of 18%, 20%, 25%, and 30% to assess distributions of KOV scenarios. The discount rates were determined using microfinance interest rates as a proxy. Typical microfinance interest rates in Cambodia range from 20-30% per annum (Xinhua, 2017). However, in March of 2017 the ruling party put a maximum interest cap on microcredit loans at 18%. It is unclear if this cap will remain long term, as many speculate this move was to increase populist support of the party prior to elections (Phnom Penh Post, 2017). Due to this new law, it was also deemed necessary to include 18% as a discount rate scenario. The results of the sensitivity analyses can be seen in Appendix 3. After assessing these results it was determined to continue with a discount rate of 25% as it is an approximate mean value.

6.1.5 Economic Analysis

In order to determine the economic performance of each farms' vegetable production area, a land use system model was conducted at each farm site. The economic analysis captured the inputs and outputs of vegetable production on a farm. These are 1) the start-up and annual costs of production, broken down into labor and inputs with their per unit prices, and 2) the annual revenues of production. These revenues and costs will give an economic analysis of the farm which can be carried out over a 10 year period of time. 10 years was chosen as the end period of the land-use system because at this point it would require nethouse owners to replace the nethouse structure for a second time as the typical wooden structure nethouse is replaced approximately once every 5 years. Additionally, this is the time a grower would typically invest in a new tiller requiring substantial capital to afford these new purchases. Yields are prices of the baseline year were recorded and entered into the model. Future yields and market prices are the stochastic components to the model and are simulated using the Excel plug-in "Simulation for Applied Risk Management" (Simetar) developed by Professor James W. Richardson at Texas A&M University. The parameters for these simulations will be described in in further detail throughout this section. Using the key output variables (KOVs) net present value, average annual returns to land, and returns to family labor, we can assess the economic benefits of vegetable production over time. The net present value (NPV) of each vegetable system was calculated as:

$$NPV = \sum_{i=0}^{n} \frac{R_t - C_t}{(1+i)^t}$$

Where i is the discount rate, n is the number of years of the production system, t is the current year of the production system, R_t is the annual total revenue generated in year t, and C_t is the annual total cost of the system. The next KOV is average annual returns to land (RtL) which was calculated as:

$$RtL = \frac{(\frac{NPV}{S})}{n}$$

Where *S* is the size of the vegetable production area in hectares, and *n* is the number of years of the system. The RtL can be compared to the land rental rate in order to determine the feasibility of the current use of the land. The final KOV is the average returns to family labor (RtFL) which was calculated as:

$$RtFL = \frac{NPV_f}{L}$$

Where NPV_f is an NPV determined by setting the hourly wages given to the family members for their labor to 0, *L* is the total number of family labor (hours) throughout the system. The RtFL are used to understand the labor opportunity cost to the growers in each system. This can be compared to the market wage rate in order to determine the continued labor feasibility of the system. The average market wage rate over the lifespan of the system is 3118 Riel/hour. This was calculated by adding inflation to the market wage rate of 2733 Riel/hour in the base year, 2016 to each year and finding the resulting average wage (TradingEconomics, 2018). These KOV calculations were done for each farm's vegetable production area and then the results were aggregated into averages of all the production areas to establish a working model. This model established a baseline vegetable production land-use system for the two villages. The baseline model will then incorporate the quantifiable risk management strategies of contract farming and crop insurance to determine their effects on the KOVs. This will serve in determining the inclusion of these tools as part of an integrated set of risk management strategies growers in the region should adopt and policymakers should prioritize access to.

6.2 Contract Farming

6.2.1 Input Prices

Nethouses: In order to determine a working model for nethouses, size and costs of seventeen existing nethouses were recorded in Kandal and Battambang Provinces. The average nethouse size was used as a maximum model nethouse size. This maximum nethouse size was applied to vegetable production areas where a contract crop met or exceeded the maximum nethouse size. A smaller nethouse size was established for the vegetable production area equal to the maximum growing area for any contract vegetable crop that did not reach the maximum nethouse model size. This working nethouse model can be displayed as follows:

$$NH = \begin{cases} 543 \; if \; GA \geq \bar{X} \\ GA \; if \; GA < \bar{X} \end{cases}$$

Where *NH* is nethouse size (m^2), *GA* is the largest growing area of a contract crop on the grower's plot, and $\bar{X}$ is the maximum model nethouse size. The input costs of the model nethouses were determined by dividing the average cost by the average size of the existing nethouses which establishes a cost/m^2 for the model nethouses. The resulting cost is 11,071.57 Riel/m^2 which was multiplied by the nethouse size on each farm. Nethouses are generally assumed to have a lifespan of five years. Therefore, the costs of the nethouses were applied in years 1 and 5 of the LUS (2016 and 2021, respectively.) The maximum nethouse cost applied to any farm model was 12,052,804 Riel (maximum cost in year 1 = 6,015,475 Riel and maximum cost in year 5 = 6,037,328 Riel). Twenty four of the thirty survey respondents grew crops suitable for nethouses, therefore the nethouse model was applied to these farms but not the remaining six which did not grow crops suitable for nethouses. Construction of model nethouses is assumed to be constructed by non-family labor so as not to effect the family labor hours in the model.

Pesticides: The use of nethouses reduces 1) the amount of pesticide inputs purchased and 2) the number of labor hours spent applying pesticides. In the farming contract models, pesticide inputs and labor hour of pesticide applications were reduced proportionally to the harvest areas under nethouse production over the total harvest area. This reduction ranged from 3%-100% with a mean reduction of 47.25%.

6.2.2 Output Prices

Contract Prices: The incorporation of contract farming as a risk management system is one alternate scenario. Contract prices are possible for crops grown under a pest-exclusion net or "nethouse" that can then be sold in markets with a "safe" label, indicating that the produce is free of microbiological and chemical hazards. The Natural Agricultural Village Market, a safe-vegetable shop, is a marketer contracting with growers to producer safe-vegetables. The same company will be opening a new shop in Siem Reap under the name "Remix" and will source safe-vegetables from growers in the villages from this study. Therefore, the contract prices for safe-vegetables grown under pest-exclusion nets are reproduced in this scenario. Contract prices are not extended to all vegetables types as some crops are not conducive to being grown under pest-exclusion nets. Contract prices are offered for the following crops: Bok Choy, Pak Choi, Green Chinese Cabbage, Choy Sum, Chinese Broccoli, and Mustard Greens.

Please see contract price table in Appendix 3 for full breakdown of prices. The contract prices are first applied in Year 2 of the land-use system (2017).

6.2.3 Contract Yields

Contract crops harvested under nethouses are assumed to have the same yield distributions as non-nethouse produced crops. This assumption is made because there is little data on yield differences between nethouse and non-nethouse production. Therefore the main consideration for using the nethouse is derived from the contract prices growers receive. It is also necessary to determine the number of harvests growers could feasibly expect while producing under the nethouse. All contract crops have growing periods lasting between 35-45 days while the growing season is approximately 270 days. The contract crops at each farm were analyzed by individual crop growing days, time of year grown, and allotted growing areas to determine the number of feasible harvests expected at each farm. The number of harvests under contract ranged from 1-15 while the mean harvests per farm was 6.25. If the growing area of a contract crop exceeded the nethouse area, the crop was divided into a growing area under the nethouse and in the field. The nethouse yield received contract prices while the non-nethouse yield received market prices.

6.3 Crop Insurance

6.3.1 Input Prices

Insurance Premiums: Actual Production History (APH) crop insurance was modeled on the APH vegetable crop insurance scheme offered by the United States Department of Agriculture (USDA). Insurance premiums were calculated for all vegetable crops at coverage levels of 50%, 60%, 70%, and 80%. First, the mean yield (kg/m^2) was determined. A stochastic deviate was determined based on the empirical deviations from the mean. Then a stochastic yield was calculated as:

$$Stochastic\ Yield = \ Mean * (1 + Stochastic\ Deviate)$$

An insured yield was then calculated for each insurance coverage level as:

$$Insured\ Yield = Mean * \%\ Insured\ Coverage$$

The lost yield was calculated as:

$$Lost\ Yield = \begin{cases} Insured\ Yield - Stochastic\ Yield & if\ Stochastic\ Yield < Insured\ Yield \\ 0 & if\ Stochastic\ Yield \geq Insured\ Yield \end{cases}$$

The resulting lost yields were then multiplied by the expected market price of the crop in each year from 2017-2025 which results in the indemnities received at each coverage level for each year of the LUS. These stochastic values were then simulated in Simetar and the resulting means were the fair premiums of the crops for each year. In order to model the vegetable crop insurance scheme used by the USDA, a 10% risk premium was then added to the fair premium price. Additionally, the USDA subsidizes vegetable crops at the following rate:

Item	Percent					
Coverage Level	50	55	60	65	70	75
Premium Subsidy	67	64	64	59	59	55
Grower Premium Share	33	36	36	41	41	45

Table 2.2: USDA Vegetable Crop Coverage Levels and Premium Subsidies (Risk Management Agency-USDA, 2011).

Premiums for vegetable crops were subsidized at the same rates. The premium at the 80% coverage level was also subsidized at 55%. The subsidized premium ($Riel/m^2$) was then multiplied by the growing area of the crop (m^2) to obtain the yearly premium per crop. Yearly premiums were then added to the total annual cost starting in year 2 of the system (2017).

6.3.2 Output Prices

Insurance Indemnities: Indemnities were calculated for each harvest in each year as follows:

$$Indemnity = Lost\ Yield * Expected\ Market\ Price$$

Where,

$$Lost\ Yield = \begin{cases} Insured\ Yield - Stochastic\ Yield & if\ Stochastic\ Yield < Insured\ Yield \\ 0 & if\ Stochastic\ Yield \geq Insured\ Yield \end{cases}$$

Yearly indemnities received were then added to the total annual revenue of each farm starting in year 2 of the system (2017).

7. Results & Discussion

7.1 Statistical Analysis and Econometric Simulation

The results from the econometric simulations of the KOVs are displayed in Figures 14-18 below and Table 3 in Appendix 3 provides summary statistics for each of the KOVs and risk management scenarios. Four risky alternative scenarios are considered in these simulations: 1) baseline practices 2) contract farming 3) crop insurance with 80% coverage and 4) contract farming and crop insurance with 80% coverage. A 25% discount rate was applied to each scenario throughout all simulations.

Figure 14 displays the CDF of the average NPV for vegetable farmers under each of the four risky scenarios. All four scenarios were positive throughout their entire distributions. However, the current baseline scenario ranked the lowest in NPV while the contract farming and crop insurance scenarios had NPVs almost 2.5x greater and the joint contract farming and crop insurance scenario was approximately 3.5x greater as well. Although the contract farming CDF is greater than the crop insurance CDF throughout almost the entire distribution, there is overlap at the lower tails and when overlap occurs the comparison of CDFs do not necessarily establish clear rankings. Instead, it will be necessary to rank these two strategies based on expected utility through SDRF and SERF (see Figures 19 & 20).

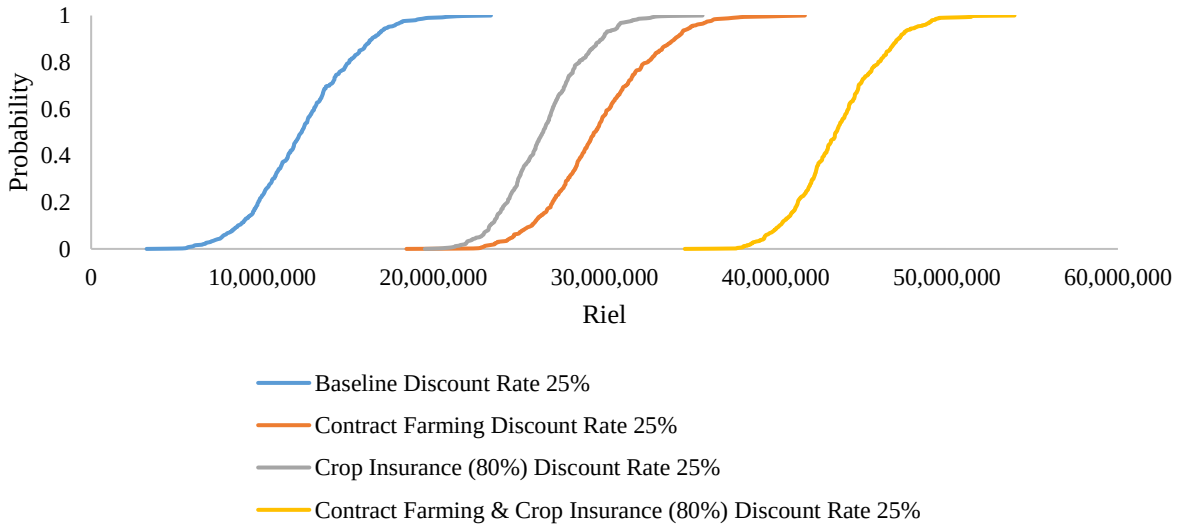

Figure 2.8: CDFs of net-present value for baseline and alternative management scenarios.

The returns to land CDFs are displayed in Figure 9. The baseline scenario is negative throughout the entire distribution which suggests that the land would be more profitable to the landowners simply through renting it. Additionally, this suggests that the inputs in the production process are costly or inefficiently used. This is most evident in the large amounts of labor used for weeding and harvesting as it is solely accomplished by hand. The crop insurance scenario is positive throughout the entire distribution except at the lower tail in the 0-2.5% range. Still the mean returns to land for crop insurance is $1,182 USD higher than the mean RtL under the baseline scenario. The contract Farming and crop insurance and contract farming scenarios are positive throughout each of their distributions and have mean RtLs that are $2207.64 and $3,445.19 USD higher than the baseline scenario.

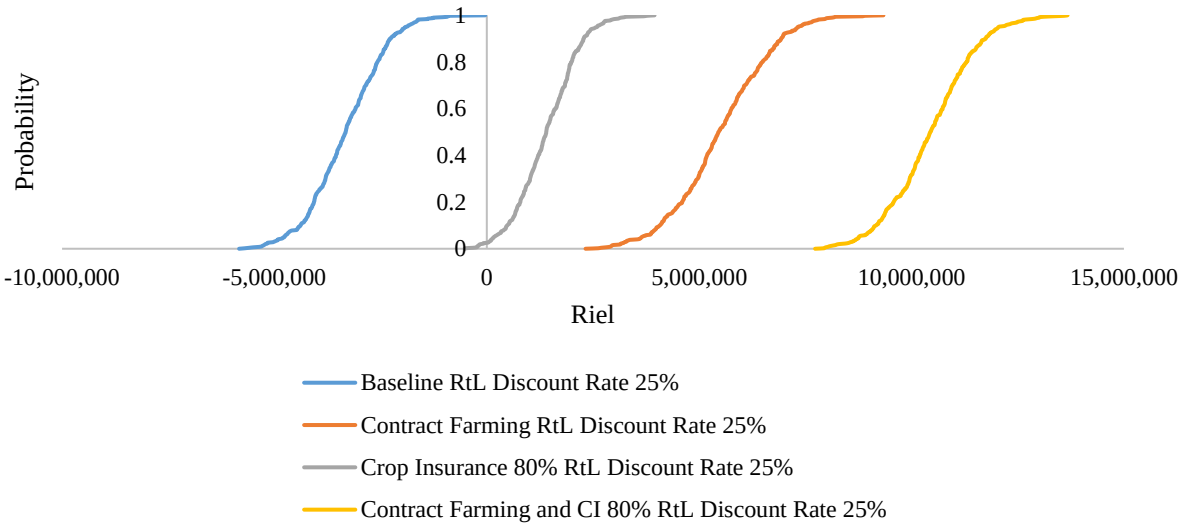

Figure 2.9: CDFs of returns to land for baseline and alternative management scenarios.

The ratio of the RtL and the rental rate are compared in Figure 16. Again, we see that the baseline scenario is negative and landowners would be better off renting their land. Under the crop insurance scenario, even though returns are mainly positive, the ratio is below 1 and therefore the landowner would still be better off renting. The contract farming scenario, obtains a ratio greater than or equal to one with a 38.6% probability, while the combination of contract farming and crop insurance obtains a ratio greater than or equal to one throughout the entire distribution.

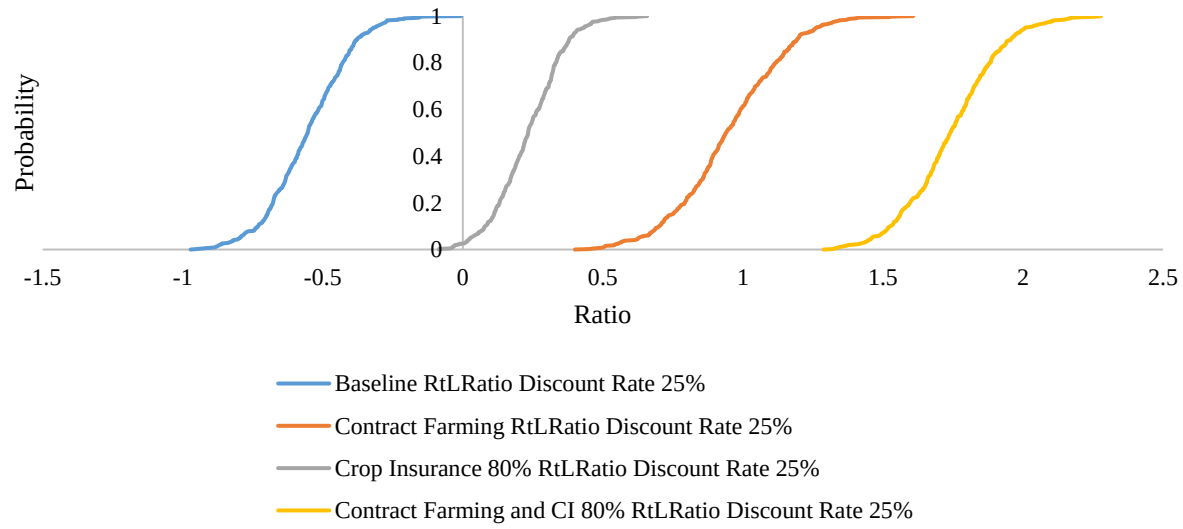

Figure 2.10: CDFs of returns to land to rental rate ratio for baseline and alternative management scenarios.

Figure 11 displays the simulation results for the average returns to family labor under each of the four scenarios. All returns in this KOV were positive with mean values of $1.42/hour in the baseline scenario, $1.88/hour under the contract farming scenario, $1.96/hour under the crop insurance scenario, and $2.49/hour under the contract farming and crop insurance scenario. Figure 12 displays the ratio of these wages to the market wage rate in Cambodia ($0.78/hour). All scenarios show large benefits to the family in terms of hourly wage through vegetable production. The baseline scenario alone is on average 1.82 times greater than the market rate. The alternative scenarios are 2.58, 2.41, and 3.18 times greater on average than the market wage rate for contract farming, crop insurance, and their

combination respectively. These results display clear benefits to horticultural production and the inclusion of these risk management to safeguard the producers.

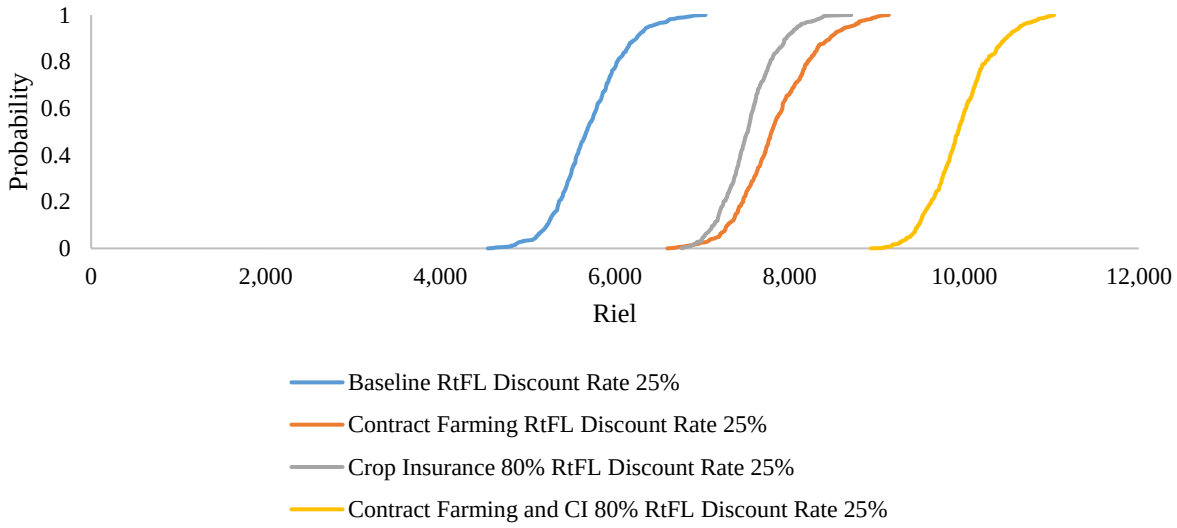

Figure 2.11: CDFs of returns to family labor for baseline and alternative management scenarios.

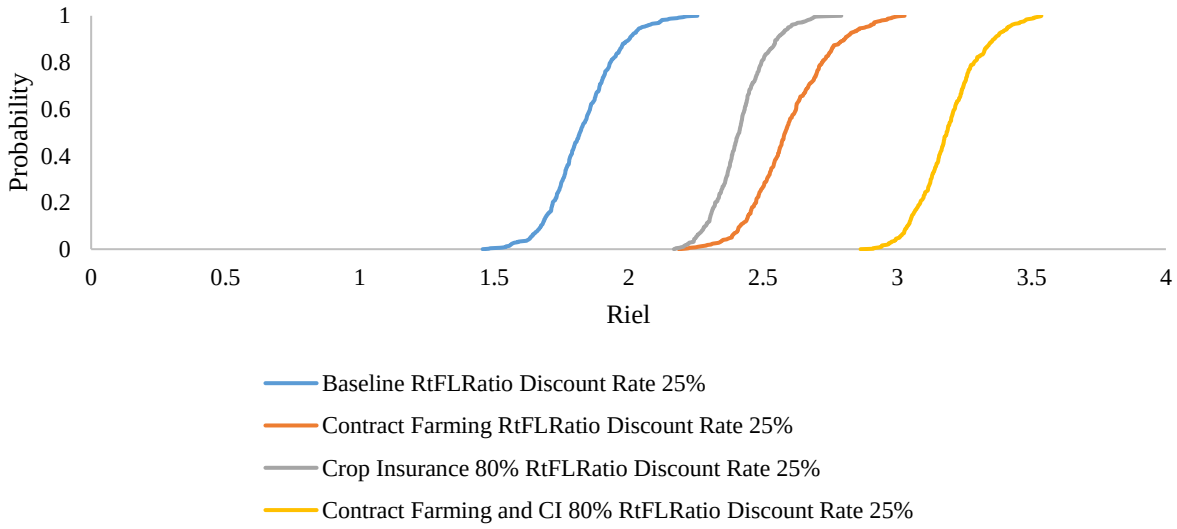

Figure 2.12: CDFs of average returns to family labor ratio to market wage rate for baseline and alternative management scenarios.

The results of the SDRF analysis is displayed in Figure 19. The lower risk aversion coefficient (RAC) was set at -1 to capture any possible observations of risk-loving farmers while the upper RAC was set at 4 which covers the extremely risk averse farmers, thus the entire set of risk-aversion will be covered between these RACs. The combination of contract farming and crop insurance is the most preferred strategy at both the lower and upper RACs while the baseline strategy is the least preferred across both the upper and lower RACs. The contract farming and crop insurance scenarios alternate between the 2nd and 3rd most preferred scenarios between the lower and upper RACs. In order to assess the RACs where the efficient set changes, it is necessary to perform a SERF analysis of these strategies as well.

Analysis of Stochastic Dominance with Respect to a Function (SDRF)

© 2016

Efficient Set Based on SDRF at

Lower RAC	-1
Name	Level of Preference
1 Contract Farming & Crop Insurance (80%) Discount Rate 25%	Most Preferred
2 Contract Farming Discount Rate 25%	2nd Most Preferred
3 Crop Insurance (80%) Discount Rate 25%	3rd Most Preferred
4 Baseline Discount Rate 25%	Least Preferred

Efficient Set Based on SDRF at

Upper RAC	4
Name	Level of Preference
1 Contract Farming & Crop Insurance (80%) I	Most Preferred
2 Crop Insurance (80%) Discount Rate 25%	2nd Most Preferred
3 Contract Farming Discount Rate 25%	3rd Most Preferred
4 Baseline Discount Rate 25%	Least Preferred

*The efficient sets are not the same for both RAC values. This result suggests that the efficient set changes between the two RACs. Use SERF analysis to determine the RAC(s) where the efficient set changes.

Figure 2.13: Stochastic dominance with respect to a function output for baseline and three alternative management scenarios.

A SERF analysis is displayed in Figure 20 below. A power utility function was used in order to incorporate relative risk aversion coefficients (RRAC) due to changes in wealth. Here the RRAC ranges from 0-4. Again, the combination of contract farming and crop insurance have the highest certainty equivalents throughout. The baseline scenario also has the lowest certainty equivalents throughout. Contract farming as higher certainty equivalents than crop insurance in the RRAC range of 0-0.167 while crop insurance has greater certainty equivalents in the RRAC range from 0.167-4. This suggests that crop insurance is likely to be the more preferred risk management strategy as it covers a larger range of risk aversion coefficients particularly for risk-averse agents, which smallholder farmers are typically assumed to be.

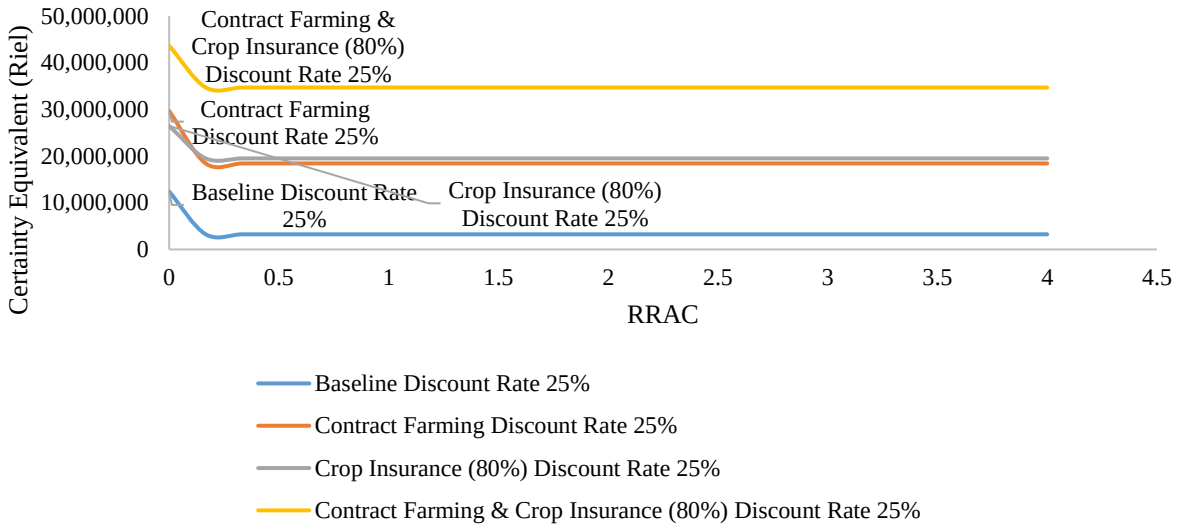

Figure 2.14: Stochastic efficiency with respect to a function under a power utility function, output for baseline and three alternative management scenarios.

A stoplight chart of the likelihood of outcomes is displayed in Figure 21. The baseline scenario has a 17% probability of a favorable outcome, 71% probability of a cautionary outcome, and 12% probability of a favorable outcome. All of the alternative scenarios have 100% probability of a favorable outcome. These results clearly demonstrate how powerful the incorporation of these risk management strategies can be in improving the livelihoods of smallholder farmers.

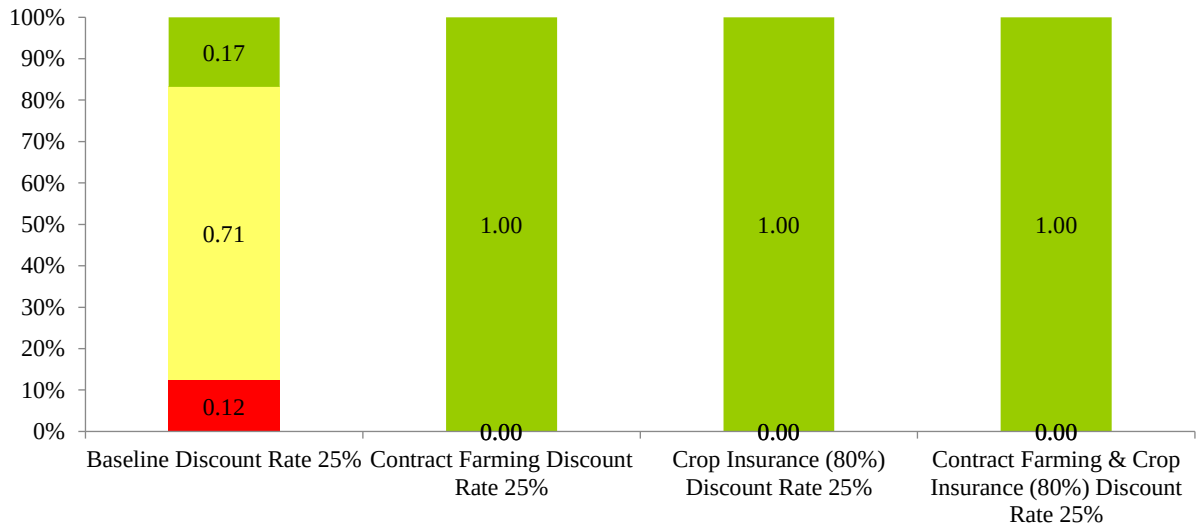

Figure 2.15: Stoplight Chart for unfavorable (red), cautionary (yellow), and favorable (green) outcomes for baseline and three alternative management scenarios (red less than 9,000,000 and green greater than 15,500,000 riel).

The results of the questionnaire suggest that the implementation of contract farming and crop insurance would alleviate some of the greatest risks faced by growers. Additionally, these growers already seem highly receptive to implementing these risk management strategies. Contract farming, through the production of pesticide-free vegetables, as displayed in the Horticultural Innovation Lab model, would alleviate pest damage, the pressure of securing a buyer, and crop price variability, three of the greatest concerns expressed by farmers. While crop insurance cannot directly stabilize crop price variability, pest damage, or excessive heat, it can act as an income-smoothing strategy to mitigate the impacts of production risks and also has the potential to buffer income when market prices fall thus this management strategy can alleviate some of the biggest risks faced by producers. Although these strategies may address many of the risks these farmers face, it is often difficult for adoption of technologies, techniques, and practices to take place. However, farmers seem to respond favorably to these two risk management strategies presently. As seen in Figure 12, on average, farmers weighed the benefits of contract farming and crop insurance greater than the risks of incorporating these strategies. Additionally, farmers displayed high levels of interest and confidence in utilizing contract farming (Figure 10) while also exhibiting fairly high levels of interest and confidence in employing crop insurance despite having lower levels of awareness of this strategy than any other strategy. Therefore, it appears likely that high demand would exist for these opportunities if offered. However, these two strategies represent two of the three lowest levels of engagement of the risk management strategies surveyed. It seems evident that creating programs focused on the implementation of crop insurance and contract farming is low-hanging fruit for the Cambodian government and development organizations operating in the country.

The economic assessment of vegetable production and simulation of four alternative scenarios reveals the drastic benefits these risk management strategies have on KOVs. On average, crop insurance produced a net-present value 2.13x greater than baseline production, contract farming's NPV was 2.39x greater than baseline production, and the combination of the two strategies produced an NPV 3.52x greater than baseline production. Clearly, these strategies can greatly improve the livelihood of vegetable growers. Additionally, the use of SDRF and SERF using a power utility function combined the scenario NPVs with risk aversion levels of growers to assess potential determinants of adoption rates. The results of these measurements conclude the baseline production as the least preferred practice and the combination of crop insurance and contract farming as the most preferred. Contract farming and crop insurance scenarios are weakly preferred to each other along the efficient set with contract farming being preferred in the 0-0.167 range of the RRAC and crop insurance being preferred across the remainder of the RRAC which suggests that only risk neutral agents prefer contract farming to crop insurance despite higher KOVs for contract farming. Thus, based upon the benefits demonstrated above, it is recommended that both contract farming and crop insurance be made viable risk management tools in which farmers have the ability to access in Cambodia.

It is likely that the introduction of crop insurance will have to be implemented by the Cambodian government. At the very least, private companies must be backed by the government in order to make crop insurance successful as the covariate risks associated with farming often make it infeasible for private company to generate a profit. Additionally, information asymmetries such as adverse selection and moral hazard make it difficult for private insurance companies to exist within agriculture. Therefore, it is likely that crop insurance must be backed by the government and subsidized so as to be affordable for growers. But, if the government of Cambodia is serious about meeting domestic vegetable demand and alleviating poverty amongst its citizens, the impact of crop insurance cannot be denied.

The implementation of contract farming will lead to increased uptake in recordkeeping of crop yields. This may pave the way for the establishment of long-term, well-structured crop insurance that relies on a history of crop yields in order to effectively determine significant yield losses. Often, the yield history at each farm is used, however, area wide yields can also be used. By collecting extensive data from these farmers, area-wide yields can be determined, thus paving the way for crop insurance. Additionally, as vegetable farmers often produce many vegetable types, insurance programs may find that crop insurance is impractical in its ability to cover all types of vegetables. However, bundling many vegetables grown in this area under "leafy greens" or under the brassicaceae family will help to eliminate this issue. Additionally, using adjusted gross revenue insurance (AGR) would eliminate this impracticality by focusing instead on revenue as opposed to crop-by-crop yields. In order to facilitate greater demand and eventual adoption of these strategies, financial literacy workshops need to be established to familiarize growers with these concepts and display the benefits these tools offer. Based, on the questionnaire results, it seems that growers prefer workshops organized by universities and NGOs which should both be leveraged to accomplish this goal.

A few limitations exist that may impact the final results of this analysis. First, due to funding and time constraints, only thirty farmers were surveyed in this study. A larger sample size would make these findings more robust. Second, behavioral games could have been played to elicit risk aversion levels. The results from these behavioral games may reveal different information about growers' risk preferences as stated and revealed preferences are known to differ. Third, risk was modeled using the expected utility theorem, however, using the prospect theory model may more accurately reflect real-world behavior as losses are "felt" more than gains, thus potentially further limiting adoption of risk management strategies, particularly those with high start-up costs due to present bias. Finally, very limited data exists on vegetable crop yields and market prices throughout Cambodia. Simulating yields and prices would lead to more accurate representations of real-world outcomes if proper databases on this information existed.

8. Conclusion

The existing vegetable sector in Cambodia is poorly managed, prone to systemic shocks, and fails to meet consumer demand. In spite of this, consumer demand for domestic vegetables is increasing as foreign vegetables, typically imported by Vietnam are perceived as not as safe as domestic vegetables despite similar production methods. The Cambodian government is concerned with assisting growers in capturing this market, believing the window of opportunity to capitalize on this market to be small as production standards in neighboring countries improve and production costs decrease. Cambodian vegetable growers are exposed to exogenous production, market, and personal shocks that can greatly impact the yields, prices, and incomes of these smallholder operations. Thus it is necessary to examine current and potential risk management strategies to properly safeguard vegetable growers.

This study examined the use, understanding, and attitudes of eleven traditional and alternative risk management strategies in order to determine which practice/s are under-utilized, have the potential for high rates of adoption, can increase grower income, and can induce farmers into transitioning into vegetables production in order to meet the growing domestic demand. We find the implementation of contract farming and crop insurance are low-hanging fruit in that they are currently infrequently used as there exists few channels for farmers to assess these risk management strategies. An economic assessment of currently vegetable production was carried out to establish the viability production. Costs and benefits of crop insurance and contract farming were then quantified and added to the baseline to determine their impact. Simulations were run to determine key output variables including net-present value, returns to land, and returns to family labor for four scenarios: baseline production, inclusion of contract farming, inclusion of crop insurance, inclusion of both contract farming and crop insurance. On average, crop insurance produced a net-present value 2.13x greater than baseline production, contract farming's NPV was 2.39x greater than baseline production, and the combination of the two strategies produced an NPV 3.52x greater than baseline production. These four scenarios were also assessed using stochastic dominance with respect to a function

and stochastic efficiency with respect to a function using a power utility function in order to include risk aversion levels of growers which likely impact adoption rates. The results of these measurements conclude the baseline production as the least preferred practice and the combination of crop insurance and contract farming as the most preferred. Contract farming and crop insurance scenarios are weakly preferred to each other along the efficient set with contract farming being preferred in the 0-0.167 range of the RRAC and crop insurance being preferred across the remainder of the RRAC which suggests that only risk neutral agents prefer contract farming to crop insurance despite higher KOVs for contract farming.

Based off of the results of this study it is recommended that the government of Cambodia develop a crop insurance program that subsidizes insurance for growers, making insurance affordable and alleviating risks faced by growers. Additionally, it is necessary to establish an environment that promotes business opportunities where producers and marketers can coordinate and streamline production of safe-vegetables. This will pave the way for the establishment of contract farming, positively impacting social welfare. Accomplishing these goals will create positive economic impacts for vegetable growers, inducing farmers to convert to vegetable production. In this way, the Cambodian government can achieve its goal of meeting domestic vegetable demand while concomitantly increasing grower incomes and reducing poverty.

9. Future Research

A plethora of future research can be conducted as a follow-up to this study. Expansion of the existing questionnaire and economic assessment could determine the accuracy of prices and yields captured in this study and give further clarification of the knowledge, attitudes, and benefits of traditional and alternative risk management strategies. Conducting behavioral "games to elicit risk aversion and using the loss aversion framework under prospect theory developed by Kahneman and Tversky could more accurately assess decision-making under uncertainty. Another research question that could be addressed is the implementation of alternative types of crop insurance schemes than the ones examined in this study. The use of index-based crop insurance is appealing in its ability to eliminate moral hazard and adverse selection. Crop insurance policies based on revenue rather than yields is also an appealing area of future research as it may reduce transaction costs for insurance companies particularly when assessing vegetables as they have shorter growing periods than other crops. Finally, once the implementation and use of the cold storage facility is in place, the opportunity may arise where the producer group in Battambang may want to pilot an inventory credit system. To the author's knowledge, there has been no attempt to link inventory credit systems to vegetables. However, it may be a viable alternative to growers who are not engaged in contract farming in order to mitigate yield losses or wait out low market prices.

10.0 References

Asian Development Bank (2014). Cambodia: Country Poverty Analysis 2014. Manila, Philippines.

ILOSTAT (2018). The statistics division of ILO.

Southeast Asia Globe. (10 Sept., 2009). In search of fertile ground. Accessed online 30 Sept, 2010 at: http://www.sea-globe.com/cambodia/89-economy/291-in-search-of-fertileground?tmpl=component&print=1&page=

Sophal, (2009). Interview with Huong Sophal, dean of the faculty of agronomy at the Royal University of Agriculture. Accessed online 30 Sept, 2010 at: http://www.sea-globe.com/cambodia/89-economy/291-insearch-of-fertile-ground?tmpl=component&print=1&page=

MARD, (2009). Safe vegetable production in Vietnam. Accessed 5 June, 2010 at: http://www.agroviet.gov.vn/

Eliste, Paavo; Zorya, Sergiy. 2015. *Cambodian agriculture in transition : opportunities and risks (English)*. Washington, D.C. : World Bank Group.

TradingEconomics, (2018). Cambodia Inflation Rate-Forecast. Accessed 19 July, 2018 at: https://tradingeconomics.com/cambodia/inflation-cpi/forecast

TradingEconomics, (2018). Cambodia Minimum Wages. Accessed 19 July, 2018 at: https://tradingeconomics.com/cambodia/minimum-wages

Richardson, J. W. (2008). *Simulation for Applied Risk Management with an Introduction to Simetar*.

Meta, Kong, et al. (2017). "MFI Loan Interest Capped." *Phnom Penh Post*, Accessed at: www.phnompenhpost.com/national/mfi-loan-interest-capped

Xinhua, (2017). "Cambodia caps interest rates on microfinance institution loans". Asia & Pacific Edition 13 March, 2017. Accessed at: http://www.xinhuanet.com/english/2017-03/13/c_136125874.htm

Martin, S., and F. Mcleay. "The Diversity of Farmers' Risk Management Strategies in a Deregulated New Zealand Environment." *Journal of Agricultural Economics*, vol. 49, no. 2, 1998, pp. 218–233., doi:10.1111/j.1477-9552.1998.tb01265.x.

Meuwissen, M.p.m., et al. "Sharing Risks in Agriculture; Principles and Empirical Results." *NJAS - Wageningen Journal of Life Sciences*, vol. 49, no. 4, 2001, pp. 343–356., doi:10.1016/s1573-5214(01)80022-1.

Coble, K.H., et al. (1999) "Crop Producer Risk Management Survey: A Preliminary Summary of Selected Data." Presentations, Working Papers, and Gray Literature: Agricultural Economics. University of Nebraska-Lincoln.

Dohmen, Thomas, et al. "Individual Risk Attitudes: Measurement, Determinants, And Behavioral Consequences." *Journal of the European Economic Association*, vol. 9, no. 3, 2011, pp. 522–550., doi:10.1111/j.1542-4774.2011.01015.x.

Hardaker, J. Brian, et al. *Coping with Risk in Agriculture*. CABI, 2007.

Managing Agricultural Production Risk. The International Bank for Reconstruction and Development / The World Bank, 2005, *Managing Agricultural Production Risk*.

Drollette, Sarah A. *Managing Financial Risk in Agriculture*. Department of Applied Economics, 2009, *Managing Financial Risk in Agriculture*.

Kahan, Davis. *Managing Risk in Farming*. FAO, 2008, p. 8, *Managing Risk in Farming*.

Gunjal, Kisan. *Agricultural Risk Management Tools*. PARM, 2016.

Ullah, Raza, et al. “Managing Catastrophic Risks in Agriculture: Simultaneous Adoption of Diversification and Precautionary Savings.” *International Journal of Disaster Risk Reduction*, vol. 12, June 2015, pp. 268–277., doi:10.1016/j.ijdrr.2015.02.001.

Bhattamishra, Ruchira, and Christopher B. Barrett. “Community-Based Risk Management Arrangements: An Overview and Implications for Social Fund Program Design.” *SSRN Electronic Journal*, 2008, doi:10.2139/ssrn.1141878.

Economic Research Service, United States Department of Agriculture. “Managing Risk in Farming: Concepts, Research, and Analysis”. USDS, 1999.

FAO (2007). Approaches to linking producers to markets, Rome, FAO.

Feyisa, Ashenafi Duguma. “The Role of Agricultural Cooperatives in Risk Management and Impact on Farm Income: *Evidence from Southern Ethiopia*.” *International Journal of Economic Behavior and Organization*, vol. 4, no. 4, 2016, p. 28., doi:10.11648/j.ijebo.20160404.11.

Ksoll, Christopher, et al. “Impact of Village Savings and Loan Associations: Evidence from a Cluster Randomized Trial.” *Journal of Development Economics*, vol. 120, 2016, pp. 70–85., doi:10.1016/j.jdeveco.2015.12.003.

“Agricultural Risk Management and Insurance.” *Agricultural Finance and Opportunities for Investment and Expansion Advances in Finance, Accounting, and Economics*, pp. 221–234., doi:10.4018/978-1-5225-3059-6.ch012.

Davis, J.B., Hands, D.W., & Maki, U. (1997). *The handbook of economic methodology*. Cheltenham, UK: Edward Elgar.

J.R. Anderson, J.L. Dillon, *Risk Analysis in Dryland Farming Systems*.

FAO, Rome (1992), pp. 16-35

Appendix 1: Risk and Risk Management Questionnaire

UC Davis researchers, in partnership with The Royal University of Agriculture and The University of Battambang, are interested in assessing awareness and use of risk management strategies among Kandal and Battambang vegetable farmers as they relate risk mitigation and welfare improvement. The end goals of this project are to increase awareness and use of specific risk management strategies and their combinations to promote farmer welfare and protect the health of farmers and the environment.

As a participant in the Safe Vegetable Value Chains project, we would appreciate your participation in this survey to help us achieve these goals. Please answer each of these questions honestly and to the best of your ability. You should know that your responses will be treated confidentially. Please feel free to ask any questions or express any concerns you may have along the way. The responses you provide will be anonymized, and will not be shared with anyone outside the project. Thank you for your assistance, your responses are important to us, and to the success of our project.

Risk Management Survey for Vegetable Farmers in Battambang, Cambodia

A. Demographics

General Information

Date (mm/dd/yyyy)	
Country	Cambodia
Province	Battambang
District	
Commune	
Village	
Name of Household Head	
Name of Respondent	
Age of Respondent	
Respondent Phone Number	
Gender of Respondent	
ID #	

Household Information

A.1 Total Family Members in Household	
A.2 Total Family Members Working on Farm	
A.3 Total Number of Children in Household	
A.4 Male Head of Household Age	
A.5 Male Head of Household Education* (none=1, primary=2, secondary=3, high school=4, technical=5, university=6)	
A.6 Female Head of Household Age	
A.7 Female Head of Household Education*	

Farm Information

A.8 Total land area owned (including house)	m^2
A.9 Total cultivated area (commercial and home garden)	m^2
A.10 Total vegetable production area	m^2
A.11 Total (ideal) nethouse area	m^2
A.12 Crops grown (ideal) in nethouse	

A.13 Do you have employees working for you on the farm?

- ☐ 1 Yes
- ☐ 2 No (*if no, skip to question A.15*)

A.14 No. of full-time male employees _____ No. of part-time male employees _____

No. of full-time female employees_____ No. of part-time female employees _____

Household Income

Activity	Engage in Activity (1=yes, 0=no)	Household Income
A.15 Vegetable Production		
A.16 Non-vegetable Cropping activities		
A.17 Perennial plantation crops		
A.18 Birds		
A.19 Cattle, Buffalo, Pig		
A.20 Aquaculture		
A.21 Jobs outside the household farm		
A.22 Personal business activity		
A.23 Public transfer		
A.24 Private Transfer		
A.25 Forest dependent activities		
A.26		TOTAL

B. Historical Crop Production

Historical Yields and Prices

Please complete the following table with the yields and received prices for the five most recent harvests of each of your vegetable crops.

Vegetable	Date	Yield (kgs)	Price (Riel)
Vegetable 1:			
B.1 Harvest #1 (Most Recent)			
B.2 Harvest #2			
B.3 Harvest #3			
B.4 Harvest #4			
B.5 Harvest #5			
Vegetable 2:			
B.6 Harvest #1 (Most Recent)			
B.7 Harvest #2			
B.8 Harvest #3			
B.9 Harvest #4			
B.10 Harvest #5			
Vegetable 3:			
B.11 Harvest #1 (Most Recent)			
B.12 Harvest #2			
B.13 Harvest #3			
B.14 Harvest #4			
B.15 Harvest #5			
Vegetable 4:			
B.16 Harvest #1 (Most Recent)			
B.17 Harvest #2			
B.18 Harvest #3			
B.19 Harvest #4			
B.20 Harvest #5			
Vegetable 5:			
B.21 Harvest #1 (Most Recent)			
B.22 Harvest #2			
B.23 Harvest #3			
B.24 Harvest #4			
B.25 Harvest #5			
Vegetable 6:			
B.26 Harvest #1 (Most Recent)			
B.27 Harvest #2			
B.28 Harvest #3			
B.29 Harvest #4			
B.30 Harvest #5			

B.31 In the last five years, how many times have you lost 25% or more of your total vegetable harvest due to weather or pest damage? _____ (*if none, skip to question B.33*)

B.32 Please list the five most recent times you lost 25% or more of your total vegetable harvest.

Year of Harvest Loss	Percent of Total Harvest Lost (select either 25%, 35%, 50%, 100%)	Cause of Loss	Expected Lost Yield (kgs)	Expected Lost Income (Riel)

B.33 In the last five years, how many times have you *not* harvested a crop due to low market prices? _____ (*if none, skip to question C.1*)

B.34 Please list the times you did not harvest crops due to low market prices.

Year of Lost Crop	Crop Type	Expected Yield (Kgs)	Expected Lost Income (Riel)	Price Offered in Market (Riel)

C. Risks and Risk Aversion

C.1 How do you see yourself: Are you generally a risk seeking person or do you try to avoid risks? Please indicate on the following scale:

Not Risk Seeking at All										Very Risk Seeking
0	1	2	3	4	5	6	7	8	9	10

C.2 Are you willing to take risks when it comes to farm production or do you try to avoid risks? Please indicate on the following scale:

Not Risk Seeking at All										Very Risk Seeking
0	1	2	3	4	5	6	7	8	9	10

C.3 Are you willing to take risks when it comes to marketing your crops or do you try to avoid risks? Please indicate on the following scale:

Not Risk Seeking at All										Very Risk Seeking
0	1	2	3	4	5	6	7	8	9	10

C.4 Are you willing to take risks when it comes to investment and finance or do you try to avoid risks? Please indicate on the following scale:

Not Risk Seeking at All										Very Risk Seeking
0	1	2	3	4	5	6	7	8	9	10

In terms of their potential to affect your farm income, how would you rate the following sources of risk? (Check each appropriate box)

Risk Source	**Potential Effect on Farm Income** **Low.....High**										
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Price risks											
C.5 Crop Price Variability											
Production risks											
C.6 Crop Yield Variability											
C.7 Crop Quality											
C.8 Consumer Preferences											
C.9 Changes in Input costs											
C.10 Changes in Land Rents											
C.11 Changes in Labor costs											
C.12 Drought											
C.13 Flood											
C.14 Fire											
C.15 Excessive Heat											
C.16 Availability of Water											
C.17 Pest Damage											
C.18 Plant Diseases											
Financial risks											
C.19 Changes in Interest Rates											
C.20 Ability to Access Loans											
C.21 Ability to Repay Loans											
Marketing risks											
C.22 Finding Buyer											
Personal risks											
C.23 Health of Farm Operator											
C.24 Health of Farm Family											

Risk Management Strategies

D. Off-Farm Employment

D.1 Does anyone in your household engage in off-farm work?

- ☐ 1 Yes
- ☐ 2 No

D.2 On a scale of 0-10, how aware are you of off-farm employment?

Not Aware at All										Very Aware
0	1	2	3	4	5	6	7	8	9	10

D.3 On a scale of 0-10, how interested are you in engaging in off-farm employment?

Not Interested at All										Very Interested
0	1	2	3	4	5	6	7	8	9	10

D.4 On a scale of 0-10, how comfortable are you in engaging in off-farm employment?

Not Comfortable at All										Very Comfortable
0	1	2	3	4	5	6	7	8	9	10

D.5 On a scale of 0-10, how effective do you believe off-farm employment is in increasing income?

Not Effective at All										Very Effective
0	1	2	3	4	5	6	7	8	9	10

D.6 On a scale of 0-10, how risky do you believe it is for you to engage in off-farm employment?

Not Risk Seeking at All										Very Risk Seeking
0	1	2	3	4	5	6	7	8	9	10

D.7 Why does your family *not* engage in off-farm work? (*select all that apply*)

- ☐ 1 Not Aware
- ☐ 2 Not Available
- ☐ 3 No Additional Income Needed
- ☐ 4 Time Commitment
- ☐ 5 No Start-up Capital for New Business
- ☐ 6 Distance
- ☐ 99 Other (Specify)_____

E. Precautionary Savings

E.1 Do you keep extra savings for emergencies?

- ☐ 1 Yes
- ☐ 2 No

E.2 On a scale of 0-10, how aware are you of keeping extra savings for emergencies?

Not Aware at All										Very Aware
0	1	2	3	4	5	6	7	8	9	10

E.3 On a scale of 0-10, how interested are you in keeping extra savings for emergencies?

Not Interested at All										Very Interested
0	1	2	3	4	5	6	7	8	9	10

E.4 On a scale of 0-10, how comfortable are you in keeping extra savings for emergencies?

Not Comfortable at All										Very Comfortable
0	1	2	3	4	5	6	7	8	9	10

E.5 On a scale of 0-10, how effective do you believe keeping extra savings for emergencies is in increasing income?

Not Effective at All										Very Effective
0	1	2	3	4	5	6	7	8	9	10

E.6 On a scale of 0-10, how risky do you believe it is for you to keep extra savings for emergencies?

Not Risk Seeking at All										Very Risk Seeking
0	1	2	3	4	5	6	7	8	9	10

E.7 Why do you *not* keep extra savings for emergencies? (*select all that apply*)

- ☐ 1 Not aware
- ☐ 2 Do not have extra savings
- ☐ 3 Not Needed
- ☐ 4 Distrust of Banks
- ☐ 99 Other (Specify)_____

F. Crop Diversification

F.1 Do you produce multiple vegetable crops?

- ☐ 1 Yes
- ☐ 2 No

F.2 On a scale of 0-10, how aware are you of producing multiple types of vegetable crops?

Not Aware at All										Very Aware
0	1	2	3	4	5	6	7	8	9	10

F.3 On a scale of 0-10, how interested are you in producing multiple types of vegetable crops?

Not Interested at All										Very Interested
0	1	2	3	4	5	6	7	8	9	10

F.4 On a scale of 0-10, how comfortable are you in producing multiple types of vegetable crops?

Not Comfortable at All										Very Comfortable
0	1	2	3	4	5	6	7	8	9	10

F.5 On a scale of 0-10, how effective do you believe producing multiple vegetable types is in increasing income?

Not Effective at All										Very Effective
0	1	2	3	4	5	6	7	8	9	10

F.6 On a scale of 0-10, how risky do you believe it is for you to producing multiple vegetable types?

Not Risk Seeking at All										Very Risk Seeking
0	1	2	3	4	5	6	7	8	9	10

F.7 Why do you choose to produce/not produce multiple types of vegetables?

G. Enterprise Diversification

G.1 Do you engage in non-vegetable farm production?

- ☐ 1 Yes
- ☐ 2 No

G.2 On a scale of 0-10, how aware are you of non-vegetable farm production?

Not Aware at All										Very Aware
0	1	2	3	4	5	6	7	8	9	10

G.3 On a scale of 0-10, how interested are you in engaging in non-vegetable farm production?

Not Interested at All										Very Interested
0	1	2	3	4	5	6	7	8	9	10

G.4 On a scale of 0-10, how comfortable are you in engaging in non-vegetable farm production?

Not Comfortable at All										Very Comfortable
0	1	2	3	4	5	6	7	8	9	10

G.5 On a scale of 0-10, how effective do you believe engaging in non-vegetable farm production is in increasing income?

Not Effective at All										Very Effective
0	1	2	3	4	5	6	7	8	9	10

G.6 On a scale of 0-10, how risky do you believe it is for you to engage in non-vegetable farm production?

Not Risk Seeking at All										Very Risk Seeking
0	1	2	3	4	5	6	7	8	9	10

G.7 Why does your family *not* engage in non-vegetable farm production? (*select all that apply*)

- ☐ 1 Not aware
- ☐ 2 Not enough capital available
- ☐ 3 No Additional Income Needed
- ☐ 4 No Market Available
- ☐ 99 Other (Specify)_____

H. Strong Social Networks

H.1 Do you borrow money from community members/organizations?

- ☐ 1 Yes
- ☐ 2 No

H.2 On a scale of 0-10, how aware are you of using social networks as a source of credit?

Not Aware at All										Very Aware
0	1	2	3	4	5	6	7	8	9	10

H.3 On a scale of 0-10, how interested are you in using social networks as a source of credit?

Not Interested at All										Very Interested
0	1	2	3	4	5	6	7	8	9	10

H.4 On a scale of 0-10, how comfortable are you in using social networks as a source of credit?

Not Comfortable at All										Very Comfortable
0	1	2	3	4	5	6	7	8	9	10

H.5 On a scale of 0-10, how effective do you believe using social networks as a source of credit is in increasing income?

Not Effective at All										Very Effective
0	1	2	3	4	5	6	7	8	9	10

H.6 On a scale of 0-10, how risky do you believe it is for you to use social networks as a source of credit?

Not Risk Seeking at All										Very Risk Seeking
0	1	2	3	4	5	6	7	8	9	10

H.7 Why does your family *not* using social networks to access credit? (*select all that apply*)

- ☐ 1 Not aware
- ☐ 2 Not available
- ☐ 3 No Additional Income Needed
- ☐ 4 Social Stigma
- ☐ 5 Distance
- ☐ 6 Distrust
- ☐ 7 Difficult to Repay Loan
- ☐ 99 Other (Specify)_____

H.8 What other benefits do you receive from having strong social networks?

I. Contract Farming

I.1 Do you engage in contract farming for any type of farm production?

- ☐ 1 Yes
- ☐ 2 No

I.2 On a scale of 0-10, how aware are you of contract farming?

Not Aware at All										Very Aware
0	1	2	3	4	5	6	7	8	9	10

I.3 On a scale of 0-10, how interested are you in engaging in contract farming?

Not Interested at All										Very Interested
0	1	2	3	4	5	6	7	8	9	10

I.4 On a scale of 0-10, how comfortable are you in engaging in contract farming?

Not Comfortable at All										Very Comfortable
0	1	2	3	4	5	6	7	8	9	10

I.5 On a scale of 0-10, how effective do you believe engaging in contract farming is in increasing income?

Not Effective at All										Very Effective
0	1	2	3	4	5	6	7	8	9	10

I.6 On a scale of 0-10, how risky do you believe it is for you to engage in contract farming?

Not Risk Seeking at All										Very Risk Seeking
0	1	2	3	4	5	6	7	8	9	10

If no to question I.1, skip to question I.12

I.7 Does your contractor provide you with input supplies?

- ☐ 1 Yes
- ☐ 2 No

I.8 Supplies provided by contractor:

Type of Supply	Quantity	Frequency Received	Per Unit Cost (Riel)

I.9 Are any of the contract conditions difficult to meet?

- ☐ 1 Yes
- ☐ 2 No (*if no, skip to question I.11*)

I.10 What contract condition/s do you find difficult to meet?

I.11 List of the five most recent crops harvested under a farming contract:

Crop	Price (Riel/kg)	Yield	Total Revenue

I.12 Why do you *not* engage in contract farming? (*select all that apply*)

- ☐ 1 Not aware
- ☐ 2 Not available
- ☐ 3 Quantity produced is too low
- ☐ 4 Quality produced is too low
- ☐ 5 Contract price is too low
- ☐ 6 Distrust
- ☐ 99 Other (Specify)_____

J. Inventory Credit System

J.1 Do you use an inventory credit system (warehouse receipt system)?

- ☐ 1 Yes
- ☐ 2 No

J.2 On a scale of 0-10, how aware are you of inventory credit systems?

Not Aware at All										Very Aware
0	1	2	3	4	5	6	7	8	9	10

J.3 On a scale of 0-10, how interested are you in using inventory credit systems?

Not Interested at All										Very Interested
0	1	2	3	4	5	6	7	8	9	10

J.4 On a scale of 0-10, how comfortable are you in using inventory credit systems?

Not Comfortable at All										Very Comfortable
0	1	2	3	4	5	6	7	8	9	10

J.5 On a scale of 0-10, how effective do you believe using an inventory credit system is in increasing income?

Not Effective at All										Very Effective
0	1	2	3	4	5	6	7	8	9	10

J.6 On a scale of 0-10, how risky do you believe it is for you to use an inventory credit system?

Not Risk Seeking at All										Very Risk Seeking
0	1	2	3	4	5	6	7	8	9	10

If no to question J.1, skip to question J.9.

J.7 List of five most recent deposits in an inventory credit system:

Date of Deposit	Crop	Loan Size Received	Initial Market Price	Date of Withdrawal	Final Market Price

J.8 What is the loan used for?

- ☐ 1 Invest in vegetable production
- ☐ 2 Health
- ☐ 3 Set up new business
- ☐ 4 Personal uses
- ☐ 99 Other (Specify) _____

J.9 Why do you *not* use an inventory credit system? (*select all that apply*)

- ☐ 1 Not aware
- ☐ 2 Not offered
- ☐ 3 Distance
- ☐ 4 Distrust
- ☐ 5 Confusing process
- ☐ 6 Difficult to repay loan
- ☐ 99 Other (Specify) _____

K. Crop Insurances

K.1 Do you have crop insurance?

- ☐ 1 Yes
- ☐ 2 No

K.2 On a scale of 0-10, how aware are you of crop insurance?

Not Aware at All										Very Aware
0	1	2	3	4	5	6	7	8	9	10

K.3 On a scale of 0-10, how interested are you in using crop insurance?

Not Interested at All										Very Interested
0	1	2	3	4	5	6	7	8	9	10

K.4 On a scale of 0-10, how comfortable are you in using crop insurance?

Not Comfortable at All										Very Comfortable
0	1	2	3	4	5	6	7	8	9	10

K.5 On a scale of 0-10, how effective do you believe using crop insurance is in increasing income?

Not Effective at All										Very Effective
0	1	2	3	4	5	6	7	8	9	10

K.6 On a scale of 0-10, how risky do you believe it is for you to use crop insurance5?

Not Risk Seeking at All										Very Risk Seeking
0	1	2	3	4	5	6	7	8	9	10

If no to question K.1, skip to question K.15

K.7 How much do you pay in premiums per month? _____

K.8 Are these premiums subsidized?

- ☐ 1 Yes
- ☐ 2 No

K.9 In the last five years, how many times have you received a payout for crop insurance?

- ☐ 1 One
- ☐ 2 Two
- ☐ 3 Three
- ☐ 4 Four
- ☐ 5 Five
- ☐ 6 Six or more

K.10 What was the average amount of these payouts? _____

K.11 What organization provides you with crop insurance? _____

K.12 What kind of crop insurance do you have?

- ☐ 1 Indemnity
- ☐ 2 Index

K.13 What incidents does the insurance cover? (*select all that apply*)

- ☐ 1 Fire
- ☐ 2 Flood
- ☐ 3 Drought
- ☐ 4 Extreme Temperatures
- ☐ 99 Other(Specify)_____

K.14 For which crops do you have crop insurance?

K.15 What other kinds of insurance do you have? (*select all that apply*)

- ☐ 1 House
- ☐ 2 Car
- ☐ 3 Life
- ☐ 4 Livestock
- ☐ 5 None
- ☐ 99 Other (Specify) _____

K.16 Why do you *not* have crop insurance? (*select all that apply*)

- ☐ 1 Not aware
- ☐ 2 Not offered
- ☐ 3 Too expensive
- ☐ 4 Confusing process
- ☐ 99 Other (Specify) _____

L. Savings Groups

L.1 Do you belong to a savings group?

- ☐ 1 Yes
- ☐ 2 No

L.2 On a scale of 0-10, how aware are you of savings groups?

Not Aware at All										Very Aware
0	1	2	3	4	5	6	7	8	9	10

L.3 On a scale of 0-10, how interested are you in belonging to a savings group in order to access credit?

Not Interested at All										Very Interested
0	1	2	3	4	5	6	7	8	9	10

L.4 On a scale of 0-10, how comfortable are you in using a savings group to access credit?

Not Comfortable at All										Very Comfortable
0	1	2	3	4	5	6	7	8	9	10

L.5 On a scale of 0-10, how effective do you believe using a savings group to access credit is in increasing income?

Not Effective at All										Very Effective
0	1	2	3	4	5	6	7	8	9	10

L.6 On a scale of 0-10, how risky do you believe it is for you to belong to a savings group to access credit?

Not Risk Seeking at All										Very Risk Seeking
0	1	2	3	4	5	6	7	8	9	10

If no to question L.1, skip to question L.16

L.7 What is the interest rate? _____

L.8 How much do you typically borrow? _____

L.9 How frequently do you need to make repayments on the loan? _____

L.10 What is the length of the loan? _____

L.11 What is the loan used for?

- ☐ 1 Invest in vegetable production
- ☐ 2 Health
- ☐ 3 Set up new business
- ☐ 4 Personal uses
- ☐ 5 School
- ☐ 99 Other (Specify)_____

L.12 How difficult do you find it to repay the loan?

- ☐ 1 Very difficult
- ☐ 2 Difficult
- ☐ 3 Neither difficult nor easy
- ☐ 4 Easy
- ☐ 5 Very easy

L.13 How frequently do you borrow from the savings group? _____

L.14 How much money do you deposit each meeting (in Riel)? _____

L.15 How frequent are the meetings?

- ☐ 1 Weekly
- ☐ 2 Bi-weekly
- ☐ 3 Monthly
- ☐ 4 Bi-monthly
- ☐ 99 Other (Specify) _____

L.16 Why do you *not* belong to a savings group? (*select all that apply*)

- ☐ 1 Not aware
- ☐ 2 Not formed
- ☐ 3 Too far away
- ☐ 4 Lack of organization
- ☐ 5 Not Interested
- ☐ 6 Time commitment
- ☐ 7 Difficult to Repay Loan
- ☐ 8 No need for additional credit
- ☐ 99 Other (Specify)_____

M. Producer Groups

M.1 Do you belong to a producer group?

- ☐ 1 Yes
- ☐ 2 No

M.2 On a scale of 0-10, how aware are you of producer groups?

Not Aware at All										Very Aware
0	1	2	3	4	5	6	7	8	9	10

M.3 On a scale of 0-10, how interested are you in belonging to a producer group?

Not Interested at All										Very Interested
0	1	2	3	4	5	6	7	8	9	10

M.4 On a scale of 0-10, how comfortable are you in belonging to a producer group?

Not Comfortable at All										Very Comfortable
0	1	2	3	4	5	6	7	8	9	10

M.5 On a scale of 0-10, how effective do you believe belonging to a producer group is in increasing income?

Not Effective at All										Very Effective
0	1	2	3	4	5	6	7	8	9	10

M.6 On a scale of 0-10, how risky do you believe it is for you to belong to a producer group?

Not Risk Seeking at All										Very Risk Seeking
0	1	2	3	4	5	6	7	8	9	10

If no to question M.1, skip to question M.10

M.7 Do you receive reduced prices for inputs from your producer group?

- ☐ 1 Yes
- ☐ 2 No

M.8 List the inputs for which you receive reduced prices:

Input Type	Total Savings

M.9 What other benefits do you receive from belonging to a producer group?

M.10 Why do you *not* belong to a producer group? (*select all that apply*)

- ☐ 1 Not aware
- ☐ 2 Not available
- ☐ 3 Too far away
- ☐ 4 Lack of organization
- ☐ 5 Not Interested
- ☐ 6 Time commitment
- ☐ 99 Other (Specify)_____

N. Access to Formal Credit Institutions

N.1 In the past five years, have you taken out a loan from a bank or microfinance institution?

- ☐ 1 Yes
- ☐ 2 No

N.2 On a scale of 0-10, how aware are you of using banks and microfinance institutions to access credit?

Not Aware at All										Very Aware
0	1	2	3	4	5	6	7	8	9	10

N.3 On a scale of 0-10, how interested are you in using banks and microfinance institutions to access credit?

Not Interested at All										Very Interested
0	1	2	3	4	5	6	7	8	9	10

N.4 On a scale of 0-10, how comfortable are you in using banks and microfinance institutions to access credit?

Not Comfortable at All										Very Comfortable
0	1	2	3	4	5	6	7	8	9	10

N.5 On a scale of 0-10, how effective do you believe using banks and microfinance institutions to access credit is in increasing income?

Not Effective at All										Very Effective
0	1	2	3	4	5	6	7	8	9	10

N.6 On a scale of 0-10, how risky do you believe using banks and microfinance to access credit is for you?

Not Risk Seeking at All										Very Risk Seeking
0	1	2	3	4	5	6	7	8	9	10

N.7 Why do you *not* apply for loans from formal credit institutions? (*select all that apply*)

- ☐ 1 Not aware
- ☐ 2 Not available
- ☐ 3 Too far away
- ☐ 4 High collateral
- ☐ 5 Too much bureaucracy
- ☐ 6 Time commitment
- ☐ 7 Difficult to repay
- ☐ 8 No need for additional credit
- ☐ 99 Other (Specify)_____

O. Other Risk Management Strategies

O.1 List any other risk management strategies you engage in:

Type of Risk Management Strategy	Define	Financial Benefits Received (Riel)

P. Access to Risk Management Information and Education

How do you prefer to learn about risk management strategies? (Check each appropriate box)

Learning Methods	**Low Preference……..High Preference**										
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
P.14 Training through universities											
P.15 Training through NGOs											
P.16 Training through government extension services											
P.17 Materials to study on your own time											
P.18 Contract Company											
P.19 Collector who comes to the farm											
P.20 Agricultural Suppliers											
P.21 Traders at local market											
P.22 Other Farmers											
P.23 Savings Groups											
P.24 Producer Groups											
P.25 Television											
P.26 Radio											
P.27 Newspaper											
P.28 Farm magazines/newsletters											
P.29 Internet											
P.30 Other (Specify)											

P.31 In the last five years have you or a family member attended any workshops on risk management?

- ☐ 1 Yes
- ☐ 2 No

P.32 Who provided the workshops? (*select all that apply*)

- ☐ 1 University
- ☐ 2 NGO
- ☐ 3 Government extension service
- ☐ 4 Community Organization
- ☐ 99 Other (Specify)_____

P.33 What risk management strategies did the workshops cover? (*select all that apply*)

- ☐ 1 Off-farm employment
- ☐ 2 Precautionary Savings
- ☐ 3 Crop Diversification
- ☐ 4 Enterprise Diversification
- ☐ 5 Strong Social Networks
- ☐ 6 Contract Farming
- ☐ 7 Inventory Credit Systems
- ☐ 8 Crop Insurance
- ☐ 9 Index-based Crop Insurance
- ☐ 10 Savings Groups
- ☐ 11 Producer Groups
- ☐ 12 Access to Formal Credit Institutions
- ☐ 99 Other (Specify):_____

P.34 Did you use what you learned from these workshops? Please describe.

Appendix 2: Land Use System Template

Vegetable Production, Battambang, Cambodia												
Inputs/Outputs (I/O), by Year												
		Year										
	Units	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	Total
LUS Inputs												
Start-up Labor												
Drilling well (Skilled Labor)	hours											
Installing irrigation (Labor)	hours											
Installing shade structure (Labor)	hours											
Net-house installment												
Structure installation (Skilled Labor)	hours											
Net installment (Skilled Labor)	hours											
Additional Start-up Labor												
Shade Structure	hours											
Annual Labor												
Land Preparation												
Tilling Field-Skilled Labor	hours											
Tilling Field-Unskilled Labor	hours											
Tilling Field-Family Labor	hours											
Bed Preparation												
Unskilled Labor	hours											
Family Labor	hours											
Compost basal application (Family Labor)	hours											
Rice straw on-bed application (Family Labor)	hours											
Installing plastic bed cover	hours											
Installing stakes and wire	hours											
Composting												
Making compost (Family Labor)	hours											
Planting and Crop Management												
Seed broadcasting (Family Labor)	hours											
Organic Forage fertilizer application (Family Labor)	hours											
1st Round of Hand Weeding												
Unskilled Labor	hours											
Family Labor	hours											
Irrigation												
Family Labor	hours											
Unskilled Labor	hours											
2nd Round of Weeding and Thinning												
Unskilled Labor	hours											
Family Labor	hours											
Pest Control												
Insecticide Application (Labor)	hours											
Herbicide Application (Labor)	hours											
Fungicide Application (Labor)	hours											
Harvesting and Packaging												
Unskilled Labor	hours											
Family Labor	hours											

Start-up Inputs												
Nethouse Installment												
Net-house structure	units											
Anti-Insect net	sq meters											
Metal wire	kgs											
Shade Structure												
General Equipment												
Rake	units											
Hoe	units											
Knife	units											
Tiller	units											
Machete	units											
Irrigation												
Pumping motor	units											
Electric wire	meters											
Hose	meters											
PVC pipe	meters											
PVC pipe	meters											
Sprinkler	units											
Drip Tape	meters											
Watering Can	units											
Pest Control												
Liquid Pesticide Spreader	units											
Water container (40Liter)	units											
Fertilizer/Soil Amendment Equipment												
Liquid fertilizer speader	units											
Water container (40Liter)	units											
Transportation												
Vehicle	units											
Vehicle Attachment	units											
Annual Inputs												
Land (Rent)	ac/mo											
Land Preparation												
Tractor Rental (Tilling field)	hours											
Gas for Tiller	liters											
Bed Preparation												
Cow manure (small truck =250kg)	kgs											
Straw	kgs											
Compost (basal application)	kgs											
Plastic bed cover	units											
Stakes	units											
Wire	meters											
Urea	kgs											
Seed	kgs											
Seed	kgs											
Seed	kgs											
Seed	kgs											
Seed	kgs											
Seed	kgs											
Irrigation												
Electricity	kwt											
Gas	liters											
Fertilizers/Soil Amendments												
Fruit for making forage fertilizer	kgs											
Bat guano	kgs											
Molasses	kgs											
EM (effective Microorganism)	liters											
Organic Fertilizer (1 Bag= 30 kg)	bags											
Snails	kgs											
Pest Control												
Insecticide	kgs											
Herbicide	kgs											
Fungicide	kgs											
Harvesting and Packaging												
Boxes	units											
Scotch tape	units											
Transportation												
Fuel	liters											
Vehicle Maintenance	units											
Horticultural Outputs												
	kgs											
	kgs											
	kgs											
	kgs											
	kgs											
	kgs											

Vegetable Production, Battambang, Cambodia											
Price, by Year											
		Year									
	Units	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
LUS Inputs											
Start-up Labor											
Drilling well (Skilled Labor)	Riel/hour										
Installing irrigation (Labor)	Riel/hour										
Installing shade structure (Labor)	Riel/hour										
Net-house installment											
Structure installation (Skilled Labor)	Riel/hour										
Net installment (Skilled Labor)	Riel/hour										
Additional Start-up Labor											
Shade Structure	Riel/hour										
Annual Labor											
Land Preparation											
Tilling Field-Skilled Labor	Riel/hour										
Tilling Field-Unskilled Labor	Riel/hour										
Tilling Field-Family Labor	Riel/hour										
Bed Preparation											
Unskilled Labor	Riel/hour										
Family Labor	Riel/hour										
Compost basal application (Family Labor)	Riel/hour										
Rice straw on-bed application (Family Labor)	Riel/hour										
Installing plastic bed cover	Riel/hour										
Installing stakes and wire	Riel/hour										
Composting											
Making compost (Family Labor)	Riel/hour										
Planting and Crop Management											
Seed broadcasting (Family Labor)	Riel/hour										
Organic Forage fertilizer application (Family Labor)	Riel/hour										
1st Round of Hand Weeding											
Unskilled Labor	Riel/hour										
Family Labor	Riel/hour										
Irrigation											
Family Labor	Riel/hour										
Unskilled Labor	Riel/hour										
2nd Round of Weeding and Thinning											
Unskilled Labor	Riel/hour										
Family Labor	Riel/hour										
Pest Control											
Insecticide Application (Labor)	Riel/hour										
Herbicide Application (Labor)	Riel/hour										
Fungicide Application (Labor)	Riel/hour										
Harvesting and Packaging											
Unskilled Labor	Riel/hour										
Family Labor	Riel/hour										

Start-up Inputs												
Nethouse Installment												
Net-house structure	Riel/unit											
Anti-Insect net	iel/sq meter											
Metal wire	Riel/kg											
Shade Structure												
General Equipment												
Rake	Riel/unit											
Hoe	Riel/unit											
Knife	Riel/unit											
Tiller	Riel/unit											
Machete	Riel/unit											
Irrigation												
Pumping motor	Riel/unit											
Electric wire	Riel/meter											
Hose	Riel/meter											
PVC pipe	Riel/meter											
PVC pipe	Riel/meter											
Sprinkler	Riel/unit											
Drip Tape	Riel/meter											
Watering Can	Riel/unit											
Pest Control												
Liquid Pesticide Spreader	Riel/unit											
Water container (40Liter)	Riel/unit											
Fertilizer/Soil Amendment Equipment												
Liquid fertilizer speader	Riel/unit											
Water container (40Liter)	Riel/unit											
Transportation												
Vehicle	Riel/unit											
Vehicle Attachment	Riel/unit											
Annual Inputs												
Land (Rent)	Riel/ac/mo											
Land Preparation												
Tractor Rental (Tilling field)	Riel/hour											
Gas for Tiller	Riel/liter											
Bed Preparation												
Cow manure (small truck =250kg)	Riel/kg											
Straw	Riel/kg											
Compost (basal application)	Riel/kg											
Plastic bed cover	Riel/unit											
Stakes	Riel/unit											
Wire	Riel/meter											
Urea	Riel/kg											
Seed	Riel/kg											
Seed	Riel/kg											
Seed	Riel/kg											
Seed	Riel/kg											
Seed	Riel/kg											
Seed	Riel/kg											
Irrigation												
Electricity	Riel/kwt											
Gas	Riel/liter											
Fertilizers/Soil Amendments												
Fruit for making forage fertilizer	Riel/kg											
Bat guano	Riel/kg											
Molasses	Riel/kg											
EM (effective Microorganism)	Riel/liter											
Organic Fertilizer (1 Bag= 30 kg)	Riel/bag											
Snails												
Pest Control												
Insecticide	Riel/kg											
Herbicide	Riel/kg											
Fungicide	Riel/kg											
Harvesting and Packaging												
Boxes	Riel/unit											
Scotch tape	Riel/roll											
Transportation												
Fuel	Riel/liter											
Vehicle Maintenance	Riel/unit											
Horticultural Outputs												
	Riel/kg											
	Riel/kg											
	Riel/kg											
	Riel/kg											
	Riel/kg											
	Riel/kg											

Vegetable Production, Battambang, Cambodia												
LUS Performance												
		Year										
	Units	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	Total
LUS Inputs												
Start-up Labor												
Drilling well (Skilled Labor)	Riel											
Installing irrigation (Labor)	Riel											
Installing shade structure (Labor)	Riel											
Net-house installment												
Structure installation (Skilled Labor)	Riel											
Net installment (Skilled Labor)	Riel											
Additional Start-up Labor												
Shade Structure	Riel											
Annual Labor												
Land Preparation												
Tilling Field-Skilled Labor	Riel											
Tilling Field-Unskilled Labor	Riel											
Tilling Field-Family Labor	Riel											
Bed Preparation												
Unskilled Labor	Riel											
Family Labor	Riel											
Compost basal application (Family Labor)	Riel											
Rice straw on-bed application (Family Labor)	Riel											
Installing plastic bed cover	Riel											
Installing stakes and wire	Riel											
Composting												
Making compost (Family Labor)	Riel											
Planting and Crop Management												
Seed broadcasting (Family Labor)	Riel											
Organic Forage fertilizer application (Family Labor)	Riel											
1st Round of Hand Weeding												
Unskilled Labor	Riel											
Family Labor	Riel											
Irrigation												
Family Labor	Riel											
Unskilled Labor	Riel											
2nd Round of Weeding and Thinning												
Unskilled Labor	Riel											
Family Labor	Riel											
Pest Control												
Insecticide Application (Labor)	Riel											
Herbicide Application (Labor)	Riel											
Fungicide Application (Labor)	Riel											
Harvesting and Packaging												
Unskilled Labor	Riel											
Family Labor	Riel											

Start-up Inputs												
Nethouse Installment												
Net-house structure	Riel											
Anti-Insect net	Riel											
Metal wire	Riel											
Shade Structure												
	Riel											
	Riel											
	Riel											
General Equipment												
Rake	Riel											
Hoe	Riel											
Knife	Riel											
Tiller	Riel											
Machete	Riel											
Irrigation												
Pumping motor	Riel											
Electric wire	Riel											
Hose	Riel											
PVC pipe	Riel											
PVC pipe	Riel											
Sprinkler	Riel											
Drip Tape	Riel											
Watering Can	Riel											
Pest Control												
Liquid Pesticide Spreader	Riel											
Water container (40Liter)	Riel											
Fertilizer/Soil Amendment Equipment												
Liquid fertilizer speader	Riel											
Water container (40Liter)	Riel											
Transportation												
Vehicle	Riel											
Vehicle Attachment	Riel											
Annual Inputs												
Land (Rent)	Riel											
Land Preparation												
Tractor Rental (Tilling field)	Riel											
Gas for Tiller	Riel											
Bed Preparation												
Cow manure (small truck =250kg)	Riel											
Straw	Riel											
Compost (basal application)	Riel											
Plastic bed cover	Riel											
Stakes	Riel											
Wire	Riel											
Urea	Riel											
Seed	Riel											
Seed	Riel											
Seed	Riel											
Seed	Riel											
Seed	Riel											
Seed	Riel											
Irrigation												
Electricity	Riel											
Gas	Riel											
Fertilizers/Soil Amendments												
Fruit for making forage fertilizer	Riel											
Bat guano	Riel											
Molasses	Riel											
EM (effective Microorganism)	Riel											
Organic Fertilizer (1 Bag= 30 kg)	Riel											
Snails	Riel											
Pest Control												
Insecticide	Riel											
Herbicide	Riel											
Fungicide	Riel											
Harvesting and Packaging												
Boxes	Riel											
Scotch tape	Riel											
Transportation												
Fuel	Riel											
Vehicle Maintenance	Riel											
Horticultural Outputs												
	Riel											
	Riel											
	Riel											
	Riel											
	Riel											
	Riel											
Total Annual Costs	Riel											
Total Annual Revenue	Riel											
Annual Net Revenue	Riel											
Annual Discounted Net Benefit (20%)	Riel											
Accumulative Net Present Value	Riel											
										Net Present Value (2016, Riel)		
										Average Annual Returns to Lan		
										Ratio of Rental Rate		
										Average Returns to Family Labo		
										Ratio of Average Return of Fam		
Annual Discounted Net Benefit (25%)	Riel											
										Net Present Value (2016, Riel)		
										Average Annual Returns To lan		
										Ratio of Rental Rate		
										Average Returns to Family Labo		
										Ratio of Average Return of Fam		
Annual Discounted Net Benefit (30%)	Riel											
										Net Present Value (2016, Riel)		
										Average Annual Returns To lan		
										Ratio of Rental Rate		
										Average Returns to Family Labo		
										Ratio of Average Return of Fam		

Appendix 3: Supplementary Figures

KOV		Baseline	Contract Farming	Crop Insurance 80%	Contract Farming and CI 80%
NPV	Mean	12,396,620	29,665,152	26,447,690	43,643,243
	StDev	3,063,196	3,259,281	2,504,585	2,712,736
	Min	3,240,328	18,426,095	19,499,512	34,688,412
	Max	23,361,615	41,707,176	35,727,387	53,957,123
RtL	Mean	(3,324,579)	5,505,991	1,404,796	10,456,186
	StDev	883,762	1,134,587	730,109	1,018,631
	Min	(5,832,020)	2,324,976	(515,719)	7,729,480
	Max	(37,456)	9,337,557	3,948,907	13,672,458
RtLRatiotoRR	Mean	(0.55)	0.95	0.23	1.74
	StDev	0.15	0.20	0.12	0.17
	Min	(0.97)	0.40	(0.09)	1.29
	Max	(0.01)	1.61	0.66	2.28
RtFL	Mean	5,703	7,840	7,529	9,952
	StDev	411	457	325	384
	Min	4,543	6,600	6,763	8,929
	Max	7,035	9,135	8,705	11,027
RtFLRatiotoMWR	Mean	1.83	2.60	2.41	3.19
	StDev	0.13	0.15	0.10	0.12
	Min	1.46	2.19	2.17	2.86
	Max	2.26	3.03	2.79	3.54

Table 1A: Summary Statistics of Key Output Variables

Crop	Price (Riel/kg)
Bok Choy	3000
Pak Choi	3000
Green Chinese Cabbage	3000
Choy sum	3000
Chinese Broccoli	5500
Mustard Greens	2500

Table 2A: Contract Prices for "Safe-Vegetable" Crops

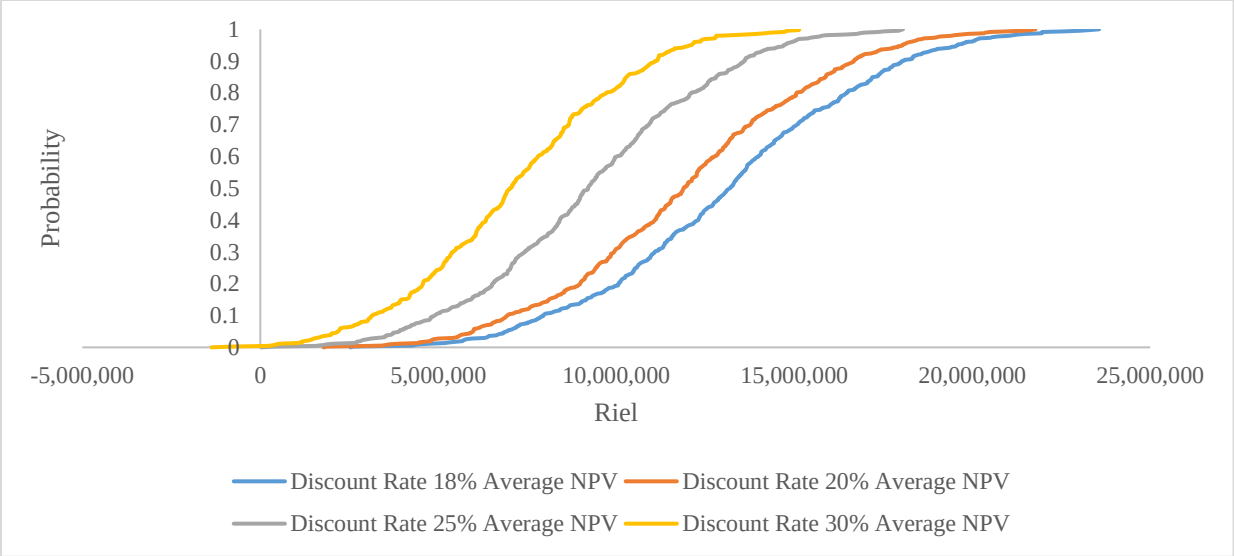

Figure 1A: CDF for Average Baseline Net-Present Values (Riel)

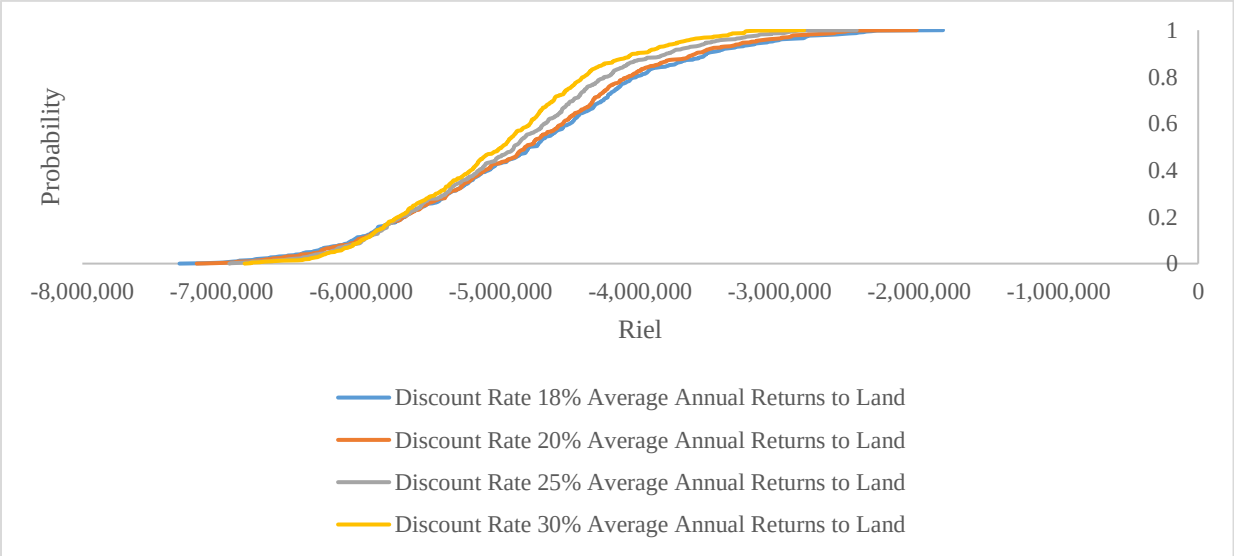

Figure 2A: CDF for Average Baseline Returns to Land (Riel)

Figure 3A: Baseline CDF for Average Annual RtL to Rental Rate

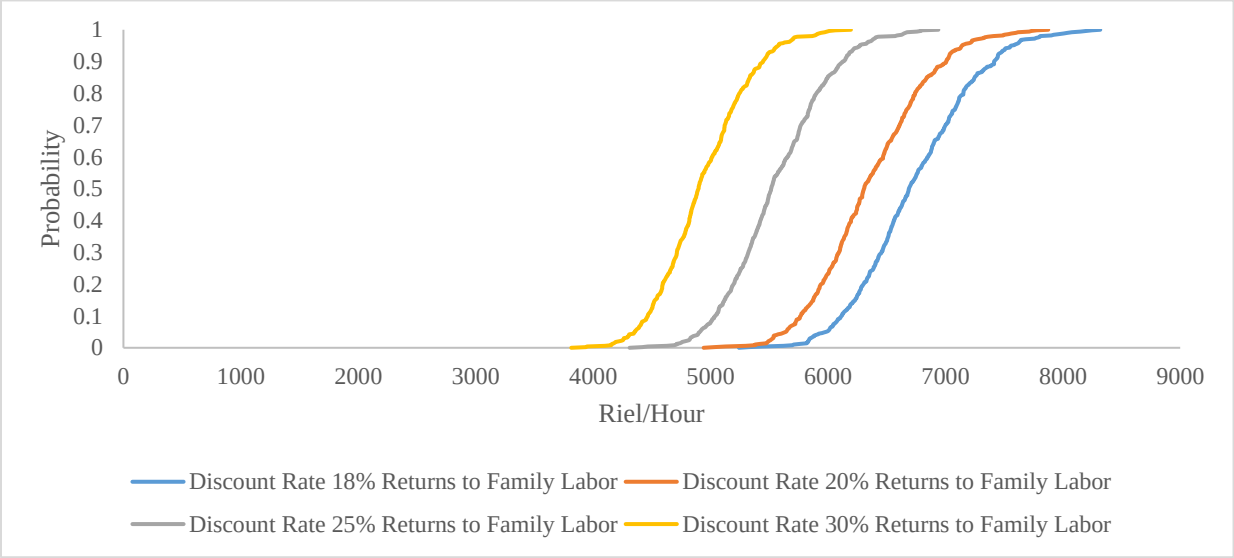

Figure 4A: CDF for Average Baseline Returns to Family Labor (Riel/Hour)

Figure 5A: Ratio of Average RtFL to Market Wage Rate Baseline CDF

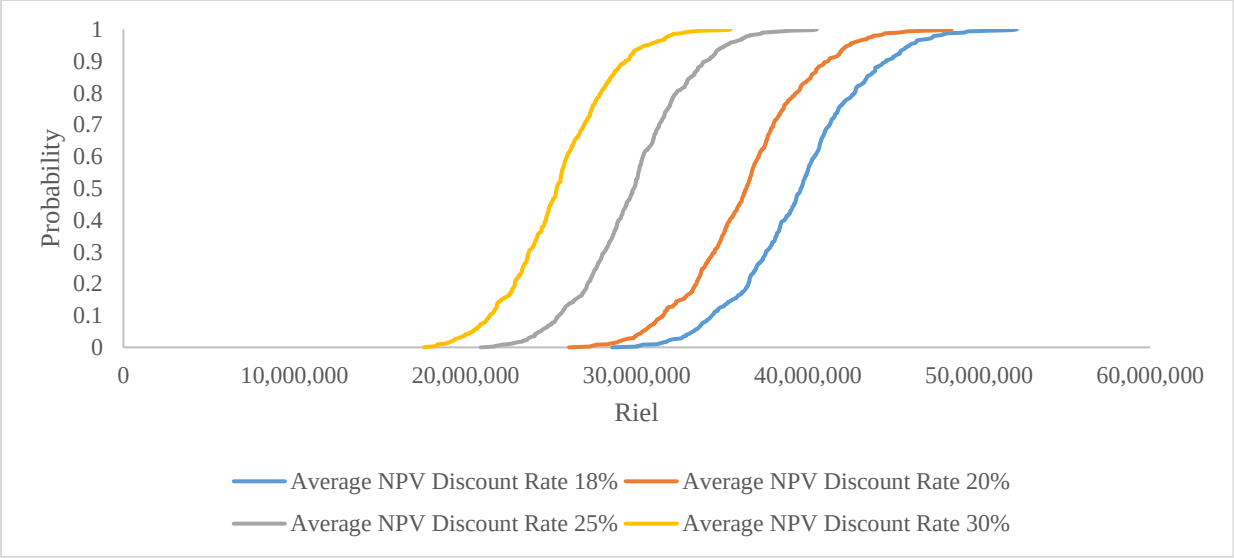

Figure 6A: CDF for Average Contract Farming Net-Present Values (Riel)

Figure 7A: CDF for Average Contract Farming Returns to Land (Riel)

Figure 8A: CDF for Average Contract Farming Ratio Average Annual Returns to Land to Rental Rate

Figure 9A: CDF for Average Contract Farming Returns to Family Labor (Riel/Hour)

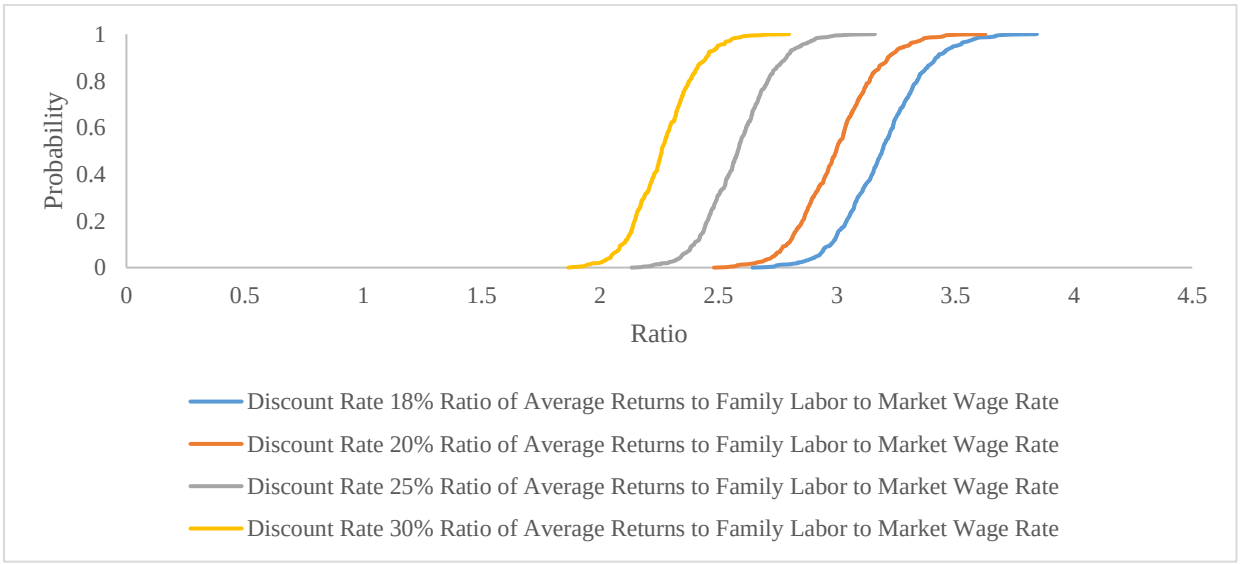

Figure 10A: CDF for Average Contract Farming Ratio Returns to Family Labor to Market Wage Rate

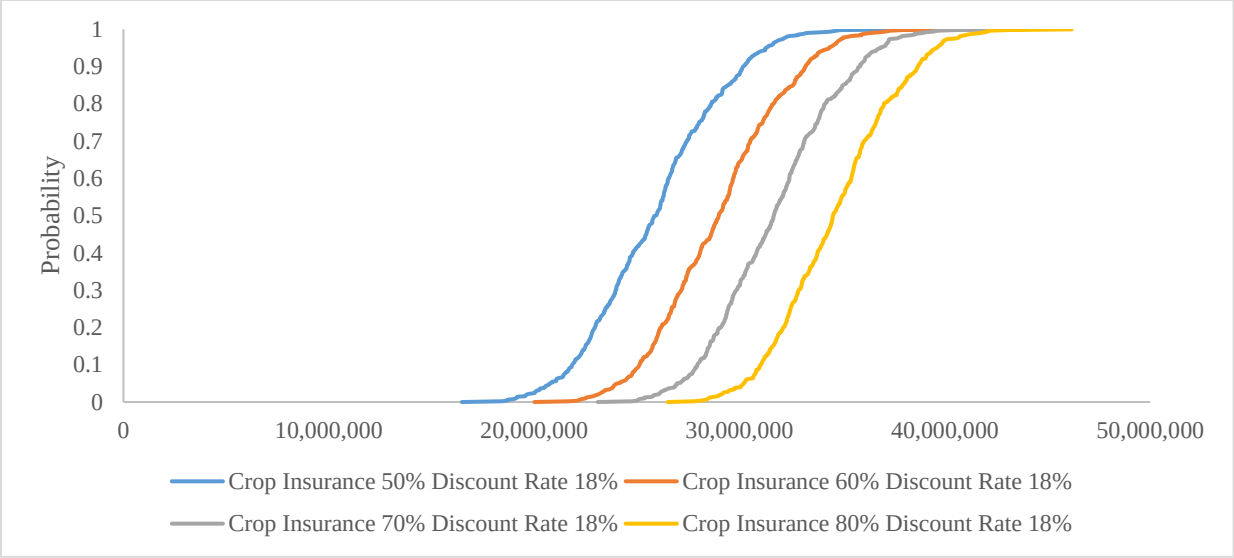

Figure 11A: NPVs under 4 Coverage Levels of Crop Insurance at 18% Discount Rate CDF

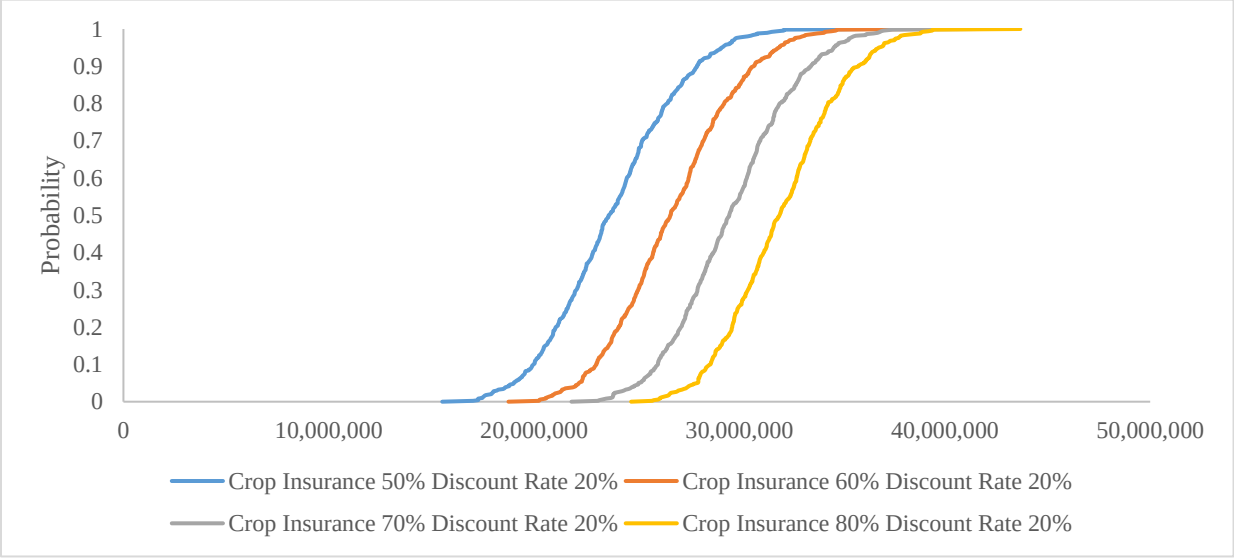

Figure 12A: NPVs under 4 Coverage Levels of Crop Insurance at 20% Discount Rate CDF

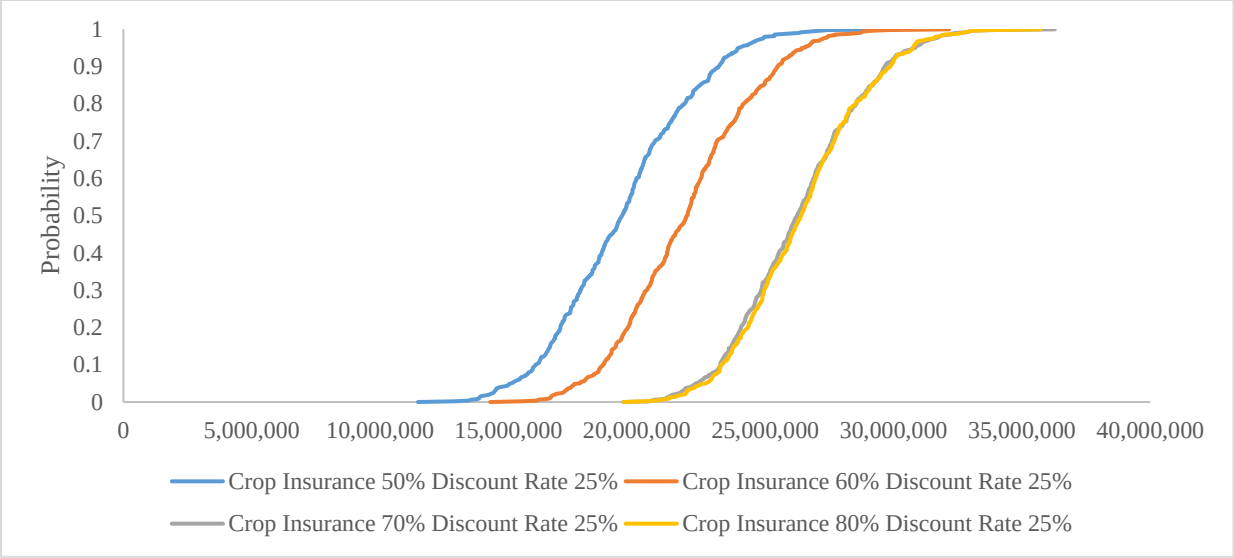

Figure 13A: NPVs under 4 Coverage Levels of Crop Insurance at 25% Discount Rate CDF

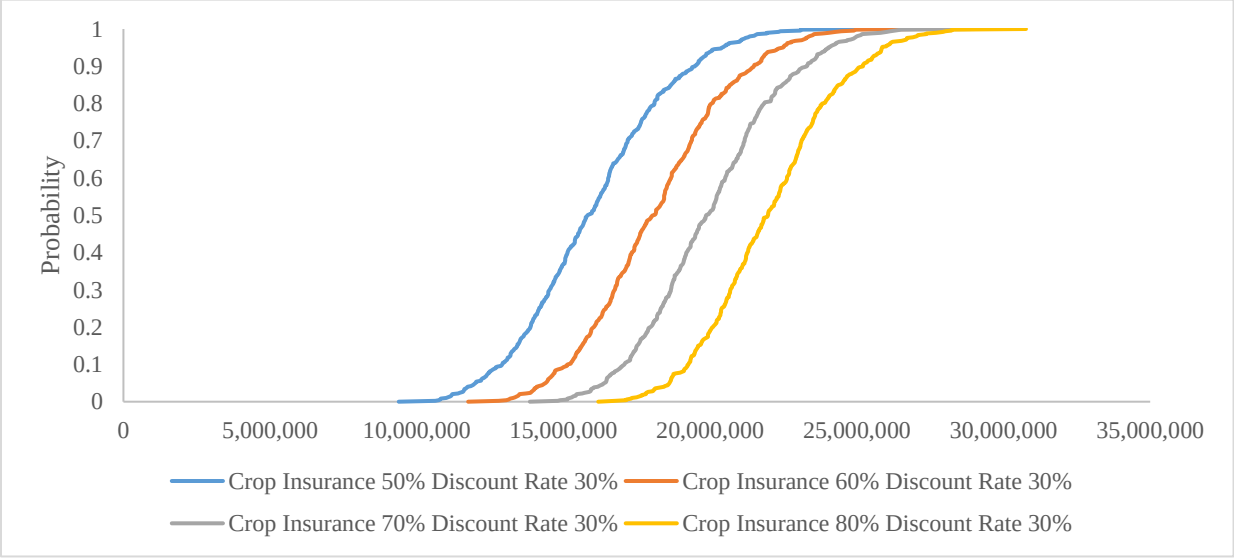

Figure 14A: NPVs under 4 Coverage Levels of Crop Insurance at 30% Discount Rate CDF